# PGMcpp: PRIMED Grid Modelling (in C++)

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# Chapter 1

# Hierarchical Index

## 1.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

# Chapter 2

# Class Index

## 2.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

# Chapter 3

# File Index

## 3.1 File List

Here is a list of all files with brief descriptions:

# Chapter 4

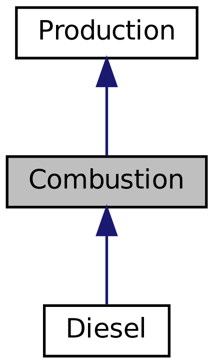
# Class Documentation

## 4.1 Combustion Class Reference

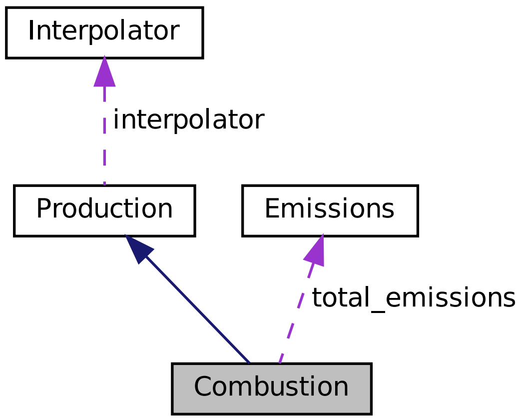
The root of the Combustion branch of the Production hierarchy. This branch contains derived classes which model the production of energy by way of combustibles.

```
#include <Combustion.h>
```

Inheritance diagram for Combustion:



Collaboration diagram for Combustion:




## Public Member Functions

- Combustion (void)

  *Constructor (dummy) for the Combustion class.*
- Combustion (int, double, CombustionInputs, std::vector< double > ∗)

  *Constructor (intended) for the Combustion class.*
- virtual void handleReplacement (int)

  *Method to handle asset replacement and capital cost incursion, if applicable.*
- void computeFuelAndEmissions (void)

  *Helper method to compute the total fuel consumption and emissions over the Model run.*
- void computeEconomics (std::vector< double > ∗)

  *Helper method to compute key economic metrics for the Model run.*
- virtual double requestProductionkW (int, double, double)
- virtual double commit (int, double, double, double)

  *Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.*
- double getFuelConsumptionL (double, double)

  *Method which takes in production and returns volume of fuel burned over the given interval of time.*
- Emissions getEmissionskg (double)

  *Method which takes in volume of fuel consumed and returns mass spectrum of resulting emissions.*
- void writeResults (std::string, std::vector< double > ∗, int, int=-1)

  *Method which writes Combustion results to an output directory.*
- virtual ∼Combustion (void)

  *Destructor for the Combustion class.*

## Public Attributes

- CombustionType type
  *The type (CombustionType) of the asset.*
- FuelMode fuel_mode
  *The fuel mode to use in modelling fuel consumption.*
- Emissions total_emissions
  *An Emissions structure for holding total emissions [kg].*
- double fuel_cost_L
  *The cost of fuel [1/L] (undefined currency).*
- double nominal_fuel_escalation_annual
  *The nominal, annual fuel escalation rate to use in computing model economics.*
- double real_fuel_escalation_annual
  *The real, annual fuel escalation rate used in computing model economics. Is computed from the given nominal inflation and discount rates.*
- double linear_fuel_slope_LkWh
  *The slope [L/kWh] to use in computing linearized fuel consumption. This is fuel consumption per unit energy produced.*
- double linear_fuel_intercept_LkWh
  *The intercept [L/kWh] to use in computing linearized fuel consumption. This is fuel consumption per unit energy produced.*
- double cycle_charging_setpoint
  *The cycle charging set point (the load ratio at which to produce when running in cycle charging mode).*
- double CO2_emissions_intensity_kgL
  *Carbon dioxide (CO2) emissions intensity [kg/L].*
- double CO_emissions_intensity_kgL
  *Carbon monoxide (CO) emissions intensity [kg/L].*
- double NOx_emissions_intensity_kgL
  *Nitrogen oxide (NOx) emissions intensity [kg/L].*
- double SOx_emissions_intensity_kgL
  *Sulfur oxide (SOx) emissions intensity [kg/L].*
- double CH4_emissions_intensity_kgL
  *Methane (CH4) emissions intensity [kg/L].*
- double PM_emissions_intensity_kgL
  *Particulate Matter (PM) emissions intensity [kg/L].*
- double total_fuel_consumed_L
  *The total fuel consumed [L] over a model run.*
- std::string fuel_mode_str
  *A string describing the fuel mode of the asset.*
- std::vector< double > fuel_consumption_vec_L
  *A vector of fuel consumed [L] over each modelling time step.*
- std::vector< double > fuel_cost_vec
  *A vector of fuel costs (undefined currency) incurred over each modelling time step. These costs are not discounted (i.e., these are actual costs).*
- std::vector< double > CO2_emissions_vec_kg
  *A vector of carbon dioxide (CO2) emitted [kg] over each modelling time step.*
- std::vector< double > CO_emissions_vec_kg
  *A vector of carbon monoxide (CO) emitted [kg] over each modelling time step.*
- std::vector< double > NOx_emissions_vec_kg
  *A vector of nitrogen oxide (NOx) emitted [kg] over each modelling time step.*
- std::vector< double > SOx_emissions_vec_kg
  *A vector of sulfur oxide (SOx) emitted [kg] over each modelling time step.*
- std::vector< double > CH4_emissions_vec_kg
  *A vector of methane (CH4) emitted [kg] over each modelling time step.*
- std::vector< double > PM_emissions_vec_kg
  *A vector of particulate matter (PM) emitted [kg] over each modelling time step.*

## Private Member Functions

- void __checkInputs (CombustionInputs)

    *Helper method to check inputs to the Combustion constructor.*
- virtual void __writeSummary (std::string)
- virtual void __writeTimeSeries (std::string, std::vector< double > ∗, int=-1)

### 4.1.1 Detailed Description

The root of the Combustion branch of the Production hierarchy. This branch contains derived classes which model the production of energy by way of combustibles.

### 4.1.2 Constructor & Destructor Documentation

#### 4.1.2.1 Combustion() [1/2]

```
Combustion::Combustion (
            void )
```

Constructor (dummy) for the Combustion class.

```
{
    return;
}   /* Combustion() */
```

#### 4.1.2.2 Combustion() [2/2]

```
Combustion::Combustion (
            int n_points,
            double n_years,
            CombustionInputs combustion_inputs,
            std::vector< double > * time_vec_hrs_ptr )
```

Constructor (intended) for the Combustion class.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *n_years* | The number of years being modelled. |
| *combustion_inputs* | A structure of Combustion constructor inputs. |
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
  :
Production(
    n_points,
    n_years,
    combustion_inputs.production_inputs,
    time_vec_hrs_ptr
)
```

```
{
    //  1. check inputs
    this->__checkInputs(combustion_inputs);

    //  2. set attributes
    this->fuel_mode = combustion_inputs.fuel_mode;

    switch (this->fuel_mode) {
        case (FuelMode :: FUEL_MODE_LINEAR): {
            this->fuel_mode_str = "FUEL_MODE_LINEAR";

            break;
        }

        case (FuelMode :: FUEL_MODE_LOOKUP): {
            this->fuel_mode_str = "FUEL_MODE_LOOKUP";

            this->interpolator.addData1D(
                0,
                combustion_inputs.path_2_fuel_interp_data
            );

            break;
        }

        default: {
            std::string error_str = "ERROR:  Combustion():  ";
            error_str += "fuel mode ";
            error_str += std::to_string(this->fuel_mode);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    this->fuel_cost_L = 0;
    this->nominal_fuel_escalation_annual =
        combustion_inputs.nominal_fuel_escalation_annual;

    this->real_fuel_escalation_annual = this->computeRealDiscountAnnual(
        combustion_inputs.nominal_fuel_escalation_annual,
        combustion_inputs.production_inputs.nominal_discount_annual
    );

    this->linear_fuel_slope_LkWh = 0;
    this->linear_fuel_intercept_LkWh = 0;

    this->cycle_charging_setpoint = combustion_inputs.cycle_charging_setpoint;

    this->CO2_emissions_intensity_kgL = 0;
    this->CO_emissions_intensity_kgL = 0;
    this->NOx_emissions_intensity_kgL = 0;
    this->SOx_emissions_intensity_kgL = 0;
    this->CH4_emissions_intensity_kgL = 0;
    this->PM_emissions_intensity_kgL = 0;

    this->total_fuel_consumed_L = 0;

    this->fuel_consumption_vec_L.resize(this->n_points, 0);
    this->fuel_cost_vec.resize(this->n_points, 0);

    this->CO2_emissions_vec_kg.resize(this->n_points, 0);
    this->CO_emissions_vec_kg.resize(this->n_points, 0);
    this->NOx_emissions_vec_kg.resize(this->n_points, 0);
    this->SOx_emissions_vec_kg.resize(this->n_points, 0);
    this->CH4_emissions_vec_kg.resize(this->n_points, 0);
    this->PM_emissions_vec_kg.resize(this->n_points, 0);

    //  3. construction print
    if (this->print_flag) {
        std::cout « "Combustion object constructed at " « this « std::endl;
    }

    return;
}   /* Combustion() */
```

#### 4.1.2.3 ∼Combustion()

```
Combustion::∼Combustion (
            void ) [virtual]
```

Destructor for the Combustion class.

```
{
    // 1. destruction print
    if (this->print_flag) {
        std::cout « "Combustion object at " « this « " destroyed" « std::endl;
    }

    return;
}   /* ~Combustion() */
```

### 4.1.3 Member Function Documentation

#### 4.1.3.1 __checkInputs()

```
void Combustion::__checkInputs (
            CombustionInputs combustion_inputs ) [private]
```

Helper method to check inputs to the Combustion constructor.

**Parameters**

| | |
|---|---|
| *combustion_inputs* | A structure of Combustion constructor inputs. |

```
{
    // 1. if FUEL_MODE_LOOKUP, check that path is given
    if (
        combustion_inputs.fuel_mode == FuelMode :: FUEL_MODE_LOOKUP and
        combustion_inputs.path_2_fuel_interp_data.empty()
    ) {
        std::string error_str = "ERROR:  Combustion()  fuel mode was set to ";
        error_str += "FuelMode::FUEL_MODE_LOOKUP, but no path to fuel interpolation ";
        error_str += "data was given";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    // 2. cycle charging setpoint
    if (
        combustion_inputs.cycle_charging_setpoint < 0 or
        combustion_inputs.cycle_charging_setpoint > 1
    ) {
        std::string error_str = "ERROR:  Combustion()  cycle charging set point ";
        error_str += "must be in the closed interval [0, 1].";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkInputs() */
```

#### 4.1.3.2 __writeSummary()

```
virtual void Combustion::__writeSummary (
              std::string  )  [inline], [private], [virtual]
```

Reimplemented in Diesel.

```
{return;}
```

#### 4.1.3.3 __writeTimeSeries()

```
virtual void Combustion::__writeTimeSeries (
              std::string ,
              std::vector< double > * ,
              int  = -1 )  [inline], [private], [virtual]
```

Reimplemented in Diesel.

```
          {return;}
```

#### 4.1.3.4 commit()

```
double Combustion::commit (
              int timestep,
              double dt_hrs,
              double production_kW,
              double load_kW )  [virtual]
```

Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *production_kW* | The production [kW] of the asset in this timestep. |
| *load_kW* | The load [kW] passed to the asset in this timestep. |

**Returns**

The load [kW] remaining after the dispatch is deducted from it.

Reimplemented from Production.

Reimplemented in Diesel.

```
{
    //  1. invoke base class method
    load_kW = Production :: commit(
        timestep,
        dt_hrs,
        production_kW,
        load_kW
```

```
    );


    if (this->is_running) {
        //  2. compute and record fuel consumption
        double fuel_consumed_L = this->getFuelConsumptionL(dt_hrs, production_kW);
        this->fuel_consumption_vec_L[timestep] = fuel_consumed_L;

        //  3. compute and record emissions
        Emissions emissions = this->getEmissionskg(fuel_consumed_L);
        this->CO2_emissions_vec_kg[timestep] = emissions.CO2_kg;
        this->CO_emissions_vec_kg[timestep] = emissions.CO_kg;
        this->NOx_emissions_vec_kg[timestep] = emissions.NOx_kg;
        this->SOx_emissions_vec_kg[timestep] = emissions.SOx_kg;
        this->CH4_emissions_vec_kg[timestep] = emissions.CH4_kg;
        this->PM_emissions_vec_kg[timestep] = emissions.PM_kg;

        //  4. incur fuel costs
        this->fuel_cost_vec[timestep] = fuel_consumed_L * this->fuel_cost_L;
    }

    return load_kW;
}   /* commit() */
```

#### 4.1.3.5 computeEconomics()

```
void Combustion::computeEconomics (
            std::vector< double > * time_vec_hrs_ptr )  [virtual]
```

Helper method to compute key economic metrics for the Model run.

Ref: HOMER [2023b]

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |

Reimplemented from Production.

```
{
    //  1. account for fuel costs in net present cost
    double t_hrs = 0;
    double real_fuel_escalation_scalar = 0;

    for (int i = 0; i < this->n_points; i++) {
        t_hrs = time_vec_hrs_ptr->at(i);

        real_fuel_escalation_scalar = 1.0 / pow(
            1 + this->real_fuel_escalation_annual,
            t_hrs / 8760
        );

        this->net_present_cost += real_fuel_escalation_scalar * this->fuel_cost_vec[i];
    }

    //  2. invoke base class method
    Production :: computeEconomics(time_vec_hrs_ptr);

    return;
}   /* computeEconomics() */
```

#### 4.1.3.6 computeFuelAndEmissions()

```
void Combustion::computeFuelAndEmissions (
            void  )
```

Helper method to compute the total fuel consumption and emissions over the Model run.

```
{
    for (int i = 0; i < n_points; i++) {
        this->total_fuel_consumed_L += this->fuel_consumption_vec_L[i];

        this->total_emissions.CO2_kg += this->CO2_emissions_vec_kg[i];
        this->total_emissions.CO_kg += this->CO_emissions_vec_kg[i];
        this->total_emissions.NOx_kg += this->NOx_emissions_vec_kg[i];
        this->total_emissions.SOx_kg += this->SOx_emissions_vec_kg[i];
        this->total_emissions.CH4_kg += this->CH4_emissions_vec_kg[i];
        this->total_emissions.PM_kg += this->PM_emissions_vec_kg[i];
    }

    return;
}   /* computeFuelAndEmissions() */
```

#### 4.1.3.7 getEmissionskg()

```
Emissions Combustion::getEmissionskg (
            double fuel_consumed_L )
```

Method which takes in volume of fuel consumed and returns mass spectrum of resulting emissions.

**Parameters**

| | |
|---|---|
| *fuel_consumed↩_L* | The volume of fuel consumed [L]. |

**Returns**

A structure containing the mass spectrum of resulting emissions.

```
                                                        {
    Emissions emissions;

    emissions.CO2_kg = this->CO2_emissions_intensity_kgL * fuel_consumed_L;
    emissions.CO_kg = this->CO_emissions_intensity_kgL * fuel_consumed_L;
    emissions.NOx_kg = this->NOx_emissions_intensity_kgL * fuel_consumed_L;
    emissions.SOx_kg = this->SOx_emissions_intensity_kgL * fuel_consumed_L;
    emissions.CH4_kg = this->CH4_emissions_intensity_kgL * fuel_consumed_L;
    emissions.PM_kg = this->PM_emissions_intensity_kgL * fuel_consumed_L;

    return emissions;
}   /* getEmissionskg() */
```

#### 4.1.3.8 getFuelConsumptionL()

```
double Combustion::getFuelConsumptionL (
            double dt_hrs,
            double production_kW )
```

Method which takes in production and returns volume of fuel burned over the given interval of time.

**Parameters**

| | |
|---|---|
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *production_kW* | The production [kW] of the asset in this timestep. |

**Returns**

The volume of fuel consumed [L].

```
{
    double fuel_consumed_L = 0;

    switch (this->fuel_mode) {
        case (FuelMode :: FUEL_MODE_LINEAR): {
            fuel_consumed_L = (
                this->linear_fuel_slope_LkWh * production_kW +
                this->linear_fuel_intercept_LkWh * this->capacity_kW
            ) * dt_hrs;

            break;
        }

        case (FuelMode :: FUEL_MODE_LOOKUP): {
            double load_ratio = production_kW / this->capacity_kW;

            fuel_consumed_L = this->interpolator.interp1D(0, load_ratio) * dt_hrs;

            break;
        }

        default: {
            std::string error_str = "ERROR:  Combustion::getFuelConsumptionL():  ";
            error_str += "fuel mode ";
            error_str += std::to_string(this->fuel_mode);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    return fuel_consumed_L;
} /* getFuelConsumptionL() */
```

#### 4.1.3.9 handleReplacement()

```
void Combustion::handleReplacement (
              int timestep )  [virtual]
```

Method to handle asset replacement and capital cost incursion, if applicable.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |

Reimplemented from Production.

Reimplemented in Diesel.

```
{
    //  1. reset attributes
    //...

    //  2. invoke base class method
    Production :: handleReplacement(timestep);

    return;
}   /* __handleReplacement() */
```

#### 4.1.3.10 requestProductionkW()

```
virtual double Combustion::requestProductionkW (
            int ,
            double ,
            double ) [inline], [virtual]
```

Reimplemented in Diesel.

```
{return 0;}
```

#### 4.1.3.11 writeResults()

```
void Combustion::writeResults (
            std::string write_path,
            std::vector< double > * time_vec_hrs_ptr,
            int combustion_index,
            int max_lines = -1 )
```

Method which writes Combustion results to an output directory.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |
| *combustion_index* | An integer which corresponds to the index of the Combustion asset in the Model. |
| *max_lines* | The maximum number of lines of output to write. If <0, then all available lines are written. If =0, then only summary results are written. |

```
{
    //  1. handle sentinel
    if (max_lines < 0) {
        max_lines = this->n_points;
    }

    //  2. create subdirectories
    write_path += "Production/";
    if (not std::filesystem::is_directory(write_path)) {
        std::filesystem::create_directory(write_path);
    }

    write_path += "Combustion/";
    if (not std::filesystem::is_directory(write_path)) {
        std::filesystem::create_directory(write_path);
    }

    write_path += this->type_str;
    write_path += "_";
    write_path += std::to_string(int(ceil(this->capacity_kW)));
    write_path += "kW_idx";
    write_path += std::to_string(combustion_index);
    write_path += "/";
    std::filesystem::create_directory(write_path);

    //  3. write summary
    this->__writeSummary(write_path);

    //  4. write time series
    if (max_lines > this->n_points) {
        max_lines = this->n_points;
    }

    if (max_lines > 0) {
        this->__writeTimeSeries(write_path, time_vec_hrs_ptr, max_lines);
    }
```

```
    return;
} /* writeResults() */
```

## 4.1.4 Member Data Documentation

### 4.1.4.1 CH4_emissions_intensity_kgL

`double Combustion::CH4_emissions_intensity_kgL`

Methane (CH4) emissions intensity [kg/L].

### 4.1.4.2 CH4_emissions_vec_kg

`std::vector<double> Combustion::CH4_emissions_vec_kg`

A vector of methane (CH4) emitted [kg] over each modelling time step.

### 4.1.4.3 CO2_emissions_intensity_kgL

`double Combustion::CO2_emissions_intensity_kgL`

Carbon dioxide (CO2) emissions intensity [kg/L].

### 4.1.4.4 CO2_emissions_vec_kg

`std::vector<double> Combustion::CO2_emissions_vec_kg`

A vector of carbon dioxide (CO2) emitted [kg] over each modelling time step.

### 4.1.4.5 CO_emissions_intensity_kgL

`double Combustion::CO_emissions_intensity_kgL`

Carbon monoxide (CO) emissions intensity [kg/L].

#### 4.1.4.6 CO_emissions_vec_kg

```
std::vector<double> Combustion::CO_emissions_vec_kg
```

A vector of carbon monoxide (CO) emitted [kg] over each modelling time step.

#### 4.1.4.7 cycle_charging_setpoint

```
double Combustion::cycle_charging_setpoint
```

The cycle charging set point (the load ratio at which to produce when running in cycle charging mode).

#### 4.1.4.8 fuel_consumption_vec_L

```
std::vector<double> Combustion::fuel_consumption_vec_L
```

A vector of fuel consumed [L] over each modelling time step.

#### 4.1.4.9 fuel_cost_L

```
double Combustion::fuel_cost_L
```

The cost of fuel [1/L] (undefined currency).

#### 4.1.4.10 fuel_cost_vec

```
std::vector<double> Combustion::fuel_cost_vec
```

A vector of fuel costs (undefined currency) incurred over each modelling time step. These costs are not discounted (i.e., these are actual costs).

#### 4.1.4.11 fuel_mode

```
FuelMode Combustion::fuel_mode
```

The fuel mode to use in modelling fuel consumption.

#### 4.1.4.12 fuel_mode_str

`std::string Combustion::fuel_mode_str`

A string describing the fuel mode of the asset.

#### 4.1.4.13 linear_fuel_intercept_LkWh

`double Combustion::linear_fuel_intercept_LkWh`

The intercept [L/kWh] to use in computing linearized fuel consumption. This is fuel consumption per unit energy produced.

#### 4.1.4.14 linear_fuel_slope_LkWh

`double Combustion::linear_fuel_slope_LkWh`

The slope [L/kWh] to use in computing linearized fuel consumption. This is fuel consumption per unit energy produced.

#### 4.1.4.15 nominal_fuel_escalation_annual

`double Combustion::nominal_fuel_escalation_annual`

The nominal, annual fuel escalation rate to use in computing model economics.

#### 4.1.4.16 NOx_emissions_intensity_kgL

`double Combustion::NOx_emissions_intensity_kgL`

Nitrogen oxide (NOx) emissions intensity [kg/L].

#### 4.1.4.17 NOx_emissions_vec_kg

`std::vector<double> Combustion::NOx_emissions_vec_kg`

A vector of nitrogen oxide (NOx) emitted [kg] over each modelling time step.

#### 4.1.4.18 PM_emissions_intensity_kgL

`double Combustion::PM_emissions_intensity_kgL`

Particulate Matter (PM) emissions intensity [kg/L].

#### 4.1.4.19 PM_emissions_vec_kg

`std::vector<double> Combustion::PM_emissions_vec_kg`

A vector of particulate matter (PM) emitted [kg] over each modelling time step.

#### 4.1.4.20 real_fuel_escalation_annual

`double Combustion::real_fuel_escalation_annual`

The real, annual fuel escalation rate used in computing model economics. Is computed from the given nominal inflation and discount rates.

#### 4.1.4.21 SOx_emissions_intensity_kgL

`double Combustion::SOx_emissions_intensity_kgL`

Sulfur oxide (SOx) emissions intensity [kg/L].

#### 4.1.4.22 SOx_emissions_vec_kg

`std::vector<double> Combustion::SOx_emissions_vec_kg`

A vector of sulfur oxide (SOx) emitted [kg] over each modelling time step.

#### 4.1.4.23 total_emissions

`Emissions Combustion::total_emissions`

An Emissions structure for holding total emissions [kg].

#### 4.1.4.24 total_fuel_consumed_L

```
double Combustion::total_fuel_consumed_L
```

The total fuel consumed [L] over a model run.

#### 4.1.4.25 type

```
CombustionType Combustion::type
```

The type (CombustionType) of the asset.

The documentation for this class was generated from the following files:

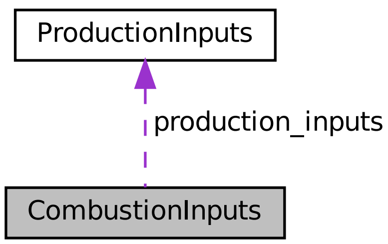
- header/Production/Combustion/Combustion.h
- source/Production/Combustion/Combustion.cpp

## 4.2 CombustionInputs Struct Reference

A structure which bundles the necessary inputs for the Combustion constructor. Provides default values for every necessary input. Note that this structure encapsulates ProductionInputs.

```
#include <Combustion.h>
```

Collaboration diagram for CombustionInputs:




### Public Attributes

- ProductionInputs production_inputs

    *An encapsulated ProductionInputs instance.*
- FuelMode fuel_mode = FuelMode :: FUEL_MODE_LINEAR

    *The fuel mode to use in modelling fuel consumption.*
- double nominal_fuel_escalation_annual = 0.05

    *The nominal, annual fuel escalation rate to use in computing model economics.*
- double cycle_charging_setpoint = 0.85

    *The cycle charging set point (the load ratio at which to produce when running in cycle charging mode).*
- std::string path_2_fuel_interp_data = ""

    *A path (either relative or absolute) to a set of fuel consumption data.*

### 4.2.1 Detailed Description

A structure which bundles the necessary inputs for the Combustion constructor. Provides default values for every necessary input. Note that this structure encapsulates ProductionInputs.

### 4.2.2 Member Data Documentation

#### 4.2.2.1 cycle_charging_setpoint

```
double CombustionInputs::cycle_charging_setpoint = 0.85
```

The cycle charging set point (the load ratio at which to produce when running in cycle charging mode).

#### 4.2.2.2 fuel_mode

```
FuelMode CombustionInputs::fuel_mode = FuelMode ::  FUEL_MODE_LINEAR
```

The fuel mode to use in modelling fuel consumption.

#### 4.2.2.3 nominal_fuel_escalation_annual

```
double CombustionInputs::nominal_fuel_escalation_annual = 0.05
```

The nominal, annual fuel escalation rate to use in computing model economics.

#### 4.2.2.4 path_2_fuel_interp_data

```
std::string CombustionInputs::path_2_fuel_interp_data = ""
```

A path (either relative or absolute) to a set of fuel consumption data.

#### 4.2.2.5 production_inputs

```
ProductionInputs CombustionInputs::production_inputs
```

An encapsulated ProductionInputs instance.

The documentation for this struct was generated from the following file:

- header/Production/Combustion/Combustion.h

## 4.3 Controller Class Reference

A class which contains a various dispatch control logic. Intended to serve as a component class of Model.

```
#include <Controller.h>
```

### Public Member Functions

- Controller (void)

    *Constructor for the Controller class.*
- void setControlMode (ControlMode)

    *Method to set control mode of Controller.*
- void setLoadOperatingReserveFactor (double)

    *Method to set Controller load_operating_reserve_factor attribute.*
- void setMaxOperatingReserveFactor (double)

    *Method to set Controller max_operating_reserve_factor attribute.*
- void init (ElectricalLoad ∗, std::vector< Renewable ∗ > ∗, Resources ∗, std::vector< Combustion ∗ > ∗)

    *Method to initialize the Controller component of the Model.*
- void applyDispatchControl (ElectricalLoad ∗, Resources ∗, std::vector< Combustion ∗ > ∗, std::vector< Noncombustion ∗ > ∗, std::vector< Renewable ∗ > ∗, std::vector< Storage ∗ > ∗)

    *Method to apply dispatch control at every point in the modelling time series.*
- void clear (void)

    *Method to clear all attributes of the Controller object.*
- ∼Controller (void)

    *Destructor for the Controller class.*

### Public Attributes

- ControlMode control_mode

    *The ControlMode that is active in the Model.*
- std::string control_string

    *A string describing the active ControlMode.*
- double load_operating_reserve_factor

    *An operating reserve factor [0, 1] to cover random fluctuations in load.*
- double max_operating_reserve_factor

    *A maximum reserve factor [0, 1] that limits the required overall operating reserve to, at most, factor ∗ load_kW.*
- double required_operating_reserve_kW

    *A required operating reserve [kW], to absorb load and Renewable production fluctuations.*
- std::vector< bool > storage_discharge_bool_vec

    *A boolean vector attribute to track which Storage assets have been discharged in each time step.*
- std::vector< double > net_load_vec_kW

    *A vector of net load values [kW] at each point in the modelling time series. Net load is defined as load minus all available Renewable production.*
- std::vector< double > missed_load_vec_kW

    *A vector of missed load values [kW] at each point in the modelling time series.*
- std::map< double, std::vector< bool > > combustion_map

    *A map of all possible combustion states, for use in determining optimal dispatch.*

## Private Member Functions

- void __computeRenewableProduction (ElectricalLoad *, std::vector< Renewable * > *, Resources *)

  *Helper method to compute and record Renewable production, net load.*
- void __constructCombustionMap (std::vector< Combustion * > *)

  *Helper method to construct a Combustion map, for use in determining.*
- double __getRenewableProduction (int, double, Renewable *, Resources *)

  *Helper method to compute the production from the given Renewable asset at the given point in time.*
- double __handleStorageDischarging (int, double, double, std::vector< Storage * > *)

  *Helper method to handle the discharging of available Storage assets.*
- double __handleNoncombustionDispatch (int, double, double, std::vector< Noncombustion * > *, Resources *)
- double __handleCombustionDispatch (int, double, double, double, double, double, std::vector< Combustion * > *, bool)

  *Helper method to handle the dispatch of Combustion assets. Accounts for load operating reserve and Renewable production reserve (firmness), as per conversation with BC Hydro (April 2024).*
- double __handleRenewableDispatch (int, double, double, std::vector< Renewable * > *)
- void __handleStorageCharging (int, double, std::vector< Storage * > *, std::vector< Combustion * > *, std::vector< Noncombustion * > *, std::vector< Renewable * > *)

  *Helper method to handle the charging of available Storage assets.*

### 4.3.1 Detailed Description

A class which contains a various dispatch control logic. Intended to serve as a component class of Model.

### 4.3.2 Constructor & Destructor Documentation

#### 4.3.2.1 Controller()

```
Controller::Controller (
            void )
```

Constructor for the Controller class.

```
{
    return;
}   /* Controller() */
```

#### 4.3.2.2 ~Controller()

```
Controller::~Controller (
            void )
```

Destructor for the Controller class.

```
{
    this->clear();

    return;
}   /* ~Controller() */
```

### 4.3.3 Member Function Documentation

#### 4.3.3.1 __computeRenewableProduction()

```
void Controller::__computeRenewableProduction (
            ElectricalLoad * electrical_load_ptr,
            std::vector< Renewable * > * renewable_ptr_vec_ptr,
            Resources * resources_ptr ) [private]
```

Helper method to compute and record Renewable production, net load.

The net load at a given point in time is defined as the load at that point in time, minus the sum of all Renewable production at that point in time. Therefore, a negative net load indicates a surplus of Renewable production, and a positive net load indicates a deficit of Renewable production.

**Parameters**

| | |
|---|---|
| *electrical_load_ptr* | A pointer to the ElectricalLoad component of the Model. |
| *renewable_ptr_vec_ptr* | A pointer to the Renewable pointer vector of the Model. |
| *resources_ptr* | A pointer to the Resources component of the Model. |

```
{
    double dt_hrs = 0;
    double load_kW = 0;
    double net_load_kW = 0;
    double production_kW = 0;

    Renewable* renewable_ptr;

    for (int timestep = 0; timestep < electrical_load_ptr->n_points; timestep++) {
        dt_hrs = electrical_load_ptr->dt_vec_hrs[timestep];
        load_kW = electrical_load_ptr->load_vec_kW[timestep];
        net_load_kW = load_kW;

        for (size_t asset = 0; asset < renewable_ptr_vec_ptr->size(); asset++) {
            renewable_ptr = renewable_ptr_vec_ptr->at(asset);

            production_kW = this->__getRenewableProduction(
                timestep,
                 dt_hrs,
                 renewable_ptr,
                 resources_ptr
             );

             renewable_ptr->production_vec_kW[timestep] = production_kW;

             net_load_kW -= production_kW;
         }

         this->net_load_vec_kW[timestep] = net_load_kW;
     }

     return;
 }   /* __computeRenewableProduction() */
```

#### 4.3.3.2 __constructCombustionMap()

```
void Controller::__constructCombustionMap (
            std::vector< Combustion * > * combustion_ptr_vec_ptr ) [private]
```

Helper method to construct a Combustion map, for use in determining.

#### Parameters

| | |
|---|---|
| *combustion_ptr_vec_ptr* | A pointer to the Combustion pointer vector of the Model. |

```
{
    std::string print_str = "Controller :: __constructCombustionMap()  ";
    print_str += "constructing combustion map (dispatch)  ";

    //  1. get state table dimensions
    unsigned int n_cols = combustion_ptr_vec_ptr->size();
    unsigned long int n_rows = pow(2, n_cols);

    //  2. walk through all possible operating states (on/off) and populate combustion
    //     map, keeping only states with minimum number of assets running.
    for (unsigned long int row = 0; row < n_rows; row++) {
        std::vector<bool> state_vec(n_cols, false);

        unsigned int asset_count = 0;
        unsigned long int x = row;
        double total_capacity_kW = 0;

        for (unsigned int i = 0; i < n_cols; i++) {
            if (x <= 0) {
                break;
            }

            if (x % 2 != 0) {
                state_vec[i] = true;
                total_capacity_kW += combustion_ptr_vec_ptr->at(i)->capacity_kW;
                asset_count++;
            }

            x /= 2;
        }

        if (this->combustion_map.count(total_capacity_kW) == 0) {
            this->combustion_map[total_capacity_kW] = state_vec;
        }

        else {
            unsigned int incumbent_asset_count = 0;

            for (unsigned int i = 0; i < n_cols; i++) {
                if (this->combustion_map[total_capacity_kW][i]) {
                    incumbent_asset_count++;
                }
            }

            if (asset_count < incumbent_asset_count) {
                this->combustion_map[total_capacity_kW] = state_vec;
            }
        }

        if (n_cols >= 14) {
            std::cout « print_str « row + 1 « " / " « n_rows « "\r";
        }
    }

    if (n_cols >= 14) {
        std::cout « print_str « n_rows « " / " « n_rows « "  DONE" « std::endl;
    }

    //  3. sort combustion map by key value (ascending order)
    /*
     *  Not necessary, since std::map is automatically sorted by key value on insertion.
     *  See https://en.cppreference.com/w/cpp/container/map, namely "std::map is a
     *  sorted associative container that contains key-value pairs with unique keys.
     *  Keys are sorted by using the comparison function Compare."
     */

    /*
    // ==== TEST PRINT ==== //
    std::cout « std::endl « std::endl;

    std::cout « "\t\t";
    for (size_t i = 0; i < combustion_ptr_vec_ptr->size(); i++) {
        std::cout « combustion_ptr_vec_ptr->at(i)->capacity_kW « "\t";
    }
    std::cout « std::endl;

    std::map<double, std::vector<bool»::iterator iter;
    for (
        iter = this->combustion_map.begin();
        iter != this->combustion_map.end();
        iter++
    ) {
```

```
        std::cout « iter->first « ":\t{\t";

        for (size_t i = 0; i < iter->second.size(); i++) {
            std::cout « iter->second[i] « "\t";
        }
        std::cout « "}" « std::endl;
    }


    // ==== END TEST PRINT ==== //
    */

    return;
}   /* __constructCombustionTable() */
```

#### 4.3.3.3 __getRenewableProduction()

```
double Controller::__getRenewableProduction (
              int timestep,
              double dt_hrs,
              Renewable * renewable_ptr,
              Resources * resources_ptr )  [private]
```

Helper method to compute the production from the given Renewable asset at the given point in time.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *renewable_ptr* | A pointer to the Renewable asset. |
| *resources_ptr* | A pointer to the Resources component of the Model. |

**Returns**

The production [kW] of the Renewable asset.

```
{
    double production_kW = 0;

    switch (renewable_ptr->type) {
        case (RenewableType :: SOLAR): {
            double resource_value = 0;

            if (not renewable_ptr->normalized_production_series_given) {
                resource_value =
                    resources_ptr->resource_map_1D[renewable_ptr->resource_key][timestep];
            }

            production_kW = renewable_ptr->computeProductionkW(
                timestep,
                dt_hrs,
                resource_value
            );

            break;
        }

        case (RenewableType :: TIDAL): {
            double resource_value = 0;

            if (not renewable_ptr->normalized_production_series_given) {
                resource_value =
                    resources_ptr->resource_map_1D[renewable_ptr->resource_key][timestep];
            }

            production_kW = renewable_ptr->computeProductionkW(
                timestep,
                dt_hrs,
```

```
                resource_value
            );

            break;
        }

        case (RenewableType :: WAVE): {
            double significant_wave_height_m = 0;
            double energy_period_s = 0;

            if (not renewable_ptr->normalized_production_series_given) {
                significant_wave_height_m =
                    resources_ptr->resource_map_2D[renewable_ptr->resource_key][timestep][0];

                energy_period_s =
                    resources_ptr->resource_map_2D[renewable_ptr->resource_key][timestep][1];
            }

            production_kW = renewable_ptr->computeProductionkW(
                timestep,
                dt_hrs,
                significant_wave_height_m,
                energy_period_s
            );

            break;
        }

        case (RenewableType :: WIND): {
            double resource_value = 0;

            if (not renewable_ptr->normalized_production_series_given) {
                resource_value =
                    resources_ptr->resource_map_1D[renewable_ptr->resource_key][timestep];
            }

            production_kW = renewable_ptr->computeProductionkW(
                timestep,
                dt_hrs,
                resource_value
            );

            break;
        }

        default: {
            std::string error_str = "ERROR:  Controller::__getRenewableProduction():  ";
            error_str += "renewable type ";
            error_str += std::to_string(renewable_ptr->type);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    return production_kW;
}   /* __getRenewableProduction() */
```

#### 4.3.3.4 __handleCombustionDispatch()

```
double Controller::__handleCombustionDispatch (
            int timestep,
            double dt_hrs,
            double load_kW,
            double remaining_load_kW,
            double total_renewable_production_kW,
            double firm_renewable_production_kW,
            std::vector< Combustion * > * combustion_ptr_vec_ptr,
            bool is_cycle_charging )   [private]
```

Helper method to handle the dispatch of Combustion assets. Accounts for load operating reserve and Renewable production reserve (firmness), as per conversation with BC Hydro (April 2024).

#### Parameters

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *load_kW* | The load [kW] for this timestep. |
| *remaining_load_kW* | The load remaining [kW] before dispatch. |
| *total_renewable_production_kW* | The total production [kW] from all Renewable assets. |
| *firm_renewable_production_kW* | The firm production [kW] from all Renewable assets. |
| *combustion_ptr_vec_ptr* | A pointer to the Combustion pointer vector of the Model. |
| *is_cycle_charging* | A flag which indicates whether the Combustion assets are running in cycle charging mode (true) or load following mode (false). |

#### Returns

The load [kW] remaining after the dispatch is deducted from it.

```
{
    //  1. set target dispatch
    bool operating_reserve_flag = false;
    double target_dispatch_kW = remaining_load_kW;

    if (target_dispatch_kW < this->required_operating_reserve_kW) {
        target_dispatch_kW = this->required_operating_reserve_kW;
        operating_reserve_flag = true;
    }

    if (target_dispatch_kW < 0) {
        target_dispatch_kW = 0;
    }

    //  2. allocate Combustion assets
    double allocated_capacity_kW = 0;

    std::map<double, std::vector<bool»::iterator iter = this->combustion_map.begin();

    while (iter != std::prev(this->combustion_map.end(), 1)) {
        if (target_dispatch_kW <= allocated_capacity_kW) {
            break;
        }

        iter++;
        allocated_capacity_kW = iter->first;
    }

    //  3. dispatch Combustion assets
    //     sharing load proportionally to individual rated capacities
    Combustion* combustion_ptr;

    double production_kW = 0;
    double request_kW = 0;
    double target_production_kW = target_dispatch_kW;

    for (
        size_t asset = 0;
        asset < this->combustion_map[allocated_capacity_kW].size();
        asset++
    ) {
        combustion_ptr = combustion_ptr_vec_ptr->at(asset);

        if (allocated_capacity_kW > 0) {
            request_kW =
                int(this->combustion_map[allocated_capacity_kW][asset]) *
                target_production_kW *
                (combustion_ptr->capacity_kW / allocated_capacity_kW);
        }

        else {
            request_kW = 0;
        }

        if (is_cycle_charging and request_kW > 0) {
            if (request_kW < combustion_ptr->cycle_charging_setpoint * combustion_ptr->capacity_kW) {
                request_kW = combustion_ptr->cycle_charging_setpoint * combustion_ptr->capacity_kW;
            }
        }

```

```
        production_kW = combustion_ptr->requestProductionkW(
            timestep,
            dt_hrs,
            request_kW
        );

        target_dispatch_kW = combustion_ptr->commit(
            timestep,
            dt_hrs,
            production_kW,
            target_dispatch_kW
        );
    }

    //  4. log impact of dispatch
    if (operating_reserve_flag) {
        remaining_load_kW -= this->required_operating_reserve_kW - target_dispatch_kW;
        this->required_operating_reserve_kW = target_dispatch_kW;
    }

    else {
        this->required_operating_reserve_kW -= remaining_load_kW - target_dispatch_kW;
        remaining_load_kW = target_dispatch_kW;
    }

    return remaining_load_kW;
}   /* __handleCombustionDispatch() */
```

#### 4.3.3.5 __handleNoncombustionDispatch()

```
double Controller::__handleNoncombustionDispatch (
            int timestep,
            double dt_hrs,
            double remaining_load_kW,
            std::vector< Noncombustion * > * noncombustion_ptr_vec_ptr,
            Resources * resources_ptr )  [private]
```

```
{
    //  1. set target dispatch
    bool operating_reserve_flag = false;
    double target_dispatch_kW = remaining_load_kW;

    if (target_dispatch_kW < this->required_operating_reserve_kW) {
        target_dispatch_kW = this->required_operating_reserve_kW;
        operating_reserve_flag = true;
    }

    if (target_dispatch_kW < 0) {
        target_dispatch_kW = 0;
    }

    //  2. dispatch Noncombustion assets
    Noncombustion* noncombustion_ptr;
    double production_kW = 0;

    for (size_t asset = 0; asset < noncombustion_ptr_vec_ptr->size(); asset++) {
       noncombustion_ptr = noncombustion_ptr_vec_ptr->at(asset);

        switch (noncombustion_ptr->type) {
            case (NoncombustionType :: HYDRO): {
                double resource_value = 0;

                if (not noncombustion_ptr->normalized_production_series_given) {
                    resource_value =
                        resources_ptr->resource_map_1D[noncombustion_ptr->resource_key][timestep];
                }

                production_kW = noncombustion_ptr->requestProductionkW(
                    timestep,
                    dt_hrs,
                    target_dispatch_kW,
                    resource_value
                );

                target_dispatch_kW = noncombustion_ptr->commit(
                    timestep,
                    dt_hrs,
                    production_kW,
```

```
                    target_dispatch_kW,
                    resource_value
                );

                break;
            }

            default: {
                production_kW = noncombustion_ptr->requestProductionkW(
                    timestep,
                    dt_hrs,
                    target_dispatch_kW
                );

                target_dispatch_kW = noncombustion_ptr->commit(
                    timestep,
                    dt_hrs,
                    production_kW,
                    target_dispatch_kW
                );

                break;
            }
        }
    }

    //  3. log impact of dispatch
    if (operating_reserve_flag) {
        remaining_load_kW -= this->required_operating_reserve_kW - target_dispatch_kW;
        this->required_operating_reserve_kW = target_dispatch_kW;
    }

    else {
        this->required_operating_reserve_kW -= remaining_load_kW - target_dispatch_kW;
        remaining_load_kW = target_dispatch_kW;
    }

    return remaining_load_kW;
}   /* __handleNoncombustionDispatch() */
```

#### 4.3.3.6 __handleRenewableDispatch()

double Controller::__handleRenewableDispatch (
    int *timestep*,
    double *dt_hrs*,
    double *remaining_load_kW*,
    std::vector< Renewable * > * *renewable_ptr_vec_ptr* ) [private]

```
{
    //  1. set target dispatch
    double target_dispatch_kW = remaining_load_kW;

    if (target_dispatch_kW < 0) {
        target_dispatch_kW = 0;
    }

    //  2. dispatch Renewable assets
    Renewable* renewable_ptr;
    double production_kW = 0;

    for (size_t asset = 0; asset < renewable_ptr_vec_ptr->size(); asset++) {
        renewable_ptr = renewable_ptr_vec_ptr->at(asset);

        production_kW = renewable_ptr->production_vec_kW[timestep];

        target_dispatch_kW = renewable_ptr->commit(
            timestep,
            dt_hrs,
            production_kW,
            target_dispatch_kW
        );
    }

    //  3. log impact of dispatch
    remaining_load_kW = target_dispatch_kW;

    return remaining_load_kW;
}   /* __handleRenewableDispatch() */
```

#### 4.3.3.7 __handleStorageCharging()

```
void Controller::__handleStorageCharging (
            int timestep,
            double dt_hrs,
            std::vector< Storage * > * storage_ptr_vec_ptr,
            std::vector< Combustion * > * combustion_ptr_vec_ptr,
            std::vector< Noncombustion * > * noncombustion_ptr_vec_ptr,
            std::vector< Renewable * > * renewable_ptr_vec_ptr ) [private]
```

Helper method to handle the charging of available Storage assets.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *storage_ptr_vec_ptr* | A pointer to a vector of pointers to the Storage assets that are to be charged. |
| *combustion_ptr_vec_ptr* | A pointer to the Combustion pointer vector of the Model. |
| *noncombustion_ptr_vec_ptr* | A pointer to the Noncombustion pointer vector of the Model. |
| *renewable_ptr_vec_ptr* | A pointer to the Renewable pointer vector of the Model. |

```
{
    double acceptable_kW = 0;
    double curtailment_kW = 0;

    Storage* storage_ptr;
    Combustion* combustion_ptr;
    Noncombustion* noncombustion_ptr;
    Renewable* renewable_ptr;

    for (
        size_t storage_asset = 0;
        storage_asset < storage_ptr_vec_ptr->size();
        storage_asset++
    ) {
        //  1. if already discharged, continue
        if (this->storage_discharge_bool_vec[storage_asset]) {
            continue;
        }

        //  2.  get pointer to asset
        storage_ptr = storage_ptr_vec_ptr->at(storage_asset);

        //  3. attempt to charge from Combustion curtailment first
        for (size_t asset = 0; asset < combustion_ptr_vec_ptr->size(); asset++) {
            combustion_ptr = combustion_ptr_vec_ptr->at(asset);
            curtailment_kW = combustion_ptr->curtailment_vec_kW[timestep];

            if (curtailment_kW <= 0) {
                continue;
            }

            acceptable_kW = storage_ptr->getAcceptablekW(dt_hrs);

            if (acceptable_kW > curtailment_kW) {
                acceptable_kW = curtailment_kW;
            }

            combustion_ptr->curtailment_vec_kW[timestep] -= acceptable_kW;
            combustion_ptr->storage_vec_kW[timestep] += acceptable_kW;
            storage_ptr->power_kW += acceptable_kW;
        }

        //  4. attempt to charge from Noncombustion curtailment second
        for (size_t asset = 0; asset < noncombustion_ptr_vec_ptr->size(); asset++) {
            noncombustion_ptr = noncombustion_ptr_vec_ptr->at(asset);
            curtailment_kW = noncombustion_ptr->curtailment_vec_kW[timestep];

            if (curtailment_kW <= 0) {
                continue;
            }

            acceptable_kW = storage_ptr->getAcceptablekW(dt_hrs);

```

```
            if (acceptable_kW > curtailment_kW) {
                acceptable_kW = curtailment_kW;
            }

            noncombustion_ptr->curtailment_vec_kW[timestep] -= acceptable_kW;
            noncombustion_ptr->storage_vec_kW[timestep] += acceptable_kW;
            storage_ptr->power_kW += acceptable_kW;
        }

        //  5. attempt to charge from Renewable curtailment third
        for (size_t asset = 0; asset < renewable_ptr_vec_ptr->size(); asset++) {
            renewable_ptr = renewable_ptr_vec_ptr->at(asset);
            curtailment_kW = renewable_ptr->curtailment_vec_kW[timestep];

            if (curtailment_kW <= 0) {
                continue;
            }

            acceptable_kW = storage_ptr->getAcceptablekW(dt_hrs);

            if (acceptable_kW > curtailment_kW) {
                acceptable_kW = curtailment_kW;
            }

            renewable_ptr->curtailment_vec_kW[timestep] -= acceptable_kW;
            renewable_ptr->storage_vec_kW[timestep] += acceptable_kW;
            storage_ptr->power_kW += acceptable_kW;
        }

        //  6. commit charge
        storage_ptr->commitCharge(
            timestep,
            dt_hrs,
            storage_ptr->power_kW
        );
    }

    return;
}   /* __handleStorageCharging() */
```

#### 4.3.3.8 __handleStorageDischarging()

```
double Controller::__handleStorageDischarging (
              int timestep,
              double dt_hrs,
              double net_load_kW,
              std::vector< Storage * > * storage_ptr_vec_ptr )  [private]
```

Helper method to handle the discharging of available Storage assets.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *remaining_load_kW* | The load remaining [kW] before discharging. |
| *storage_ptr_vec_ptr* | A pointer to a vector of pointers to the Storage assets. |

**Returns**

The load [kW] remaining after the discharge is deducted from it.

```
{
    //  1. set target discharge
    bool operating_reserve_flag = false;
    double target_discharge_kW = remaining_load_kW;

    if (target_discharge_kW < this->required_operating_reserve_kW) {
        target_discharge_kW = this->required_operating_reserve_kW;
```

```
            operating_reserve_flag = true;
        }

        //  2. immediately return on target_discharge_kW <= 0
        if (target_discharge_kW <= 0) {
            return remaining_load_kW;
        }

        //  3. discharge available Storage assets
        double discharging_kW = 0;

        Storage* storage_ptr;

        for (size_t asset = 0; asset < storage_ptr_vec_ptr->size(); asset++) {
            //  3.1. break on vanishing target_discharge_kW
            if (target_discharge_kW <= 0) {
                break;
            }

            //  3.2. get pointer to asset
            storage_ptr = storage_ptr_vec_ptr->at(asset);

            //  3.3. continue if depleted
            if (storage_ptr->is_depleted) {
                continue;
            }

            //  3.4. get available discharging power
            discharging_kW = storage_ptr->getAvailablekW(dt_hrs);

            if (discharging_kW > target_discharge_kW) {
                discharging_kW = target_discharge_kW;
            }

            //  3.5. commit discharging, log
            target_discharge_kW = storage_ptr->commitDischarge(
                timestep,
                dt_hrs,
                discharging_kW,
                target_discharge_kW
            );

            this->storage_discharge_bool_vec[asset] = true;
        }

        //  4. log impact of discharge
        if (operating_reserve_flag) {
            remaining_load_kW -= this->required_operating_reserve_kW - target_discharge_kW;
            this->required_operating_reserve_kW = target_discharge_kW;
        }

        else {
            this->required_operating_reserve_kW -= remaining_load_kW - target_discharge_kW;
            remaining_load_kW = target_discharge_kW;
        }

        return remaining_load_kW;
}   /* __handleStorageDischarging() */
```

#### 4.3.3.9 applyDispatchControl()

```
void Controller::applyDispatchControl (
        ElectricalLoad * electrical_load_ptr,
        Resources * resources_ptr,
        std::vector< Combustion * > * combustion_ptr_vec_ptr,
        std::vector< Noncombustion * > * noncombustion_ptr_vec_ptr,
        std::vector< Renewable * > * renewable_ptr_vec_ptr,
        std::vector< Storage * > * storage_ptr_vec_ptr )
```

Method to apply dispatch control at every point in the modelling time series.

**Parameters**

| | |
|---|---|
| *electrical_load_ptr* | A pointer to the ElectricalLoad component of the Model. |

**Parameters**

| | |
|---|---|
| *resources_ptr* | A pointer to the Resources component of the Model. |
| *combustion_ptr_vec_ptr* | A pointer to the Combustion pointer vector of the Model. |
| *noncombustion_ptr_vec_ptr* | A pointer to the Noncombustion pointer vector of the Model. |
| *renewable_ptr_vec_ptr* | A pointer to the Renewable pointer vector of the Model. |
| *storage_ptr_vec_ptr* | A pointer to the Storage pointer vector of the Model. |

```
{
    double dt_hrs = 0;
    double load_kW = 0;
    double total_renewable_production_kW = 0;
    double firm_renewable_production_kW = 0;
    double remaining_load_kW = 0;
    /*
    double required_operating_reserve_before_kW = 0;
    double rem_load_test_0 = 0;
    double rem_load_test_1 = 0;
    double rem_load_test_2 = 0;
    double rem_load_test_3 = 0;
    double rem_load_test_4 = 0;
    */
    this->required_operating_reserve_kW = 0;
    this->storage_discharge_bool_vec.clear();
    this->storage_discharge_bool_vec.resize(storage_ptr_vec_ptr->size(), false);

    Renewable* renewable_ptr;

    for (int timestep = 0; timestep < electrical_load_ptr->n_points; timestep++) {
        //  1. get dt_hrs and load
        dt_hrs = electrical_load_ptr->dt_vec_hrs[timestep];
        load_kW = electrical_load_ptr->load_vec_kW[timestep];

        //  2. compute firm and total Renewable productions
        total_renewable_production_kW = 0;
        firm_renewable_production_kW = 0;

        for (size_t asset = 0; asset < renewable_ptr_vec_ptr->size(); asset++) {
            renewable_ptr = renewable_ptr_vec_ptr->at(asset);

            total_renewable_production_kW += renewable_ptr->production_vec_kW[timestep];

            firm_renewable_production_kW +=
                renewable_ptr->firmness_factor * renewable_ptr->production_vec_kW[timestep];
        }

        //  3. compute required operating reserve (load + Renewable), enforce max
        this->required_operating_reserve_kW =
            this->load_operating_reserve_factor * load_kW +
            total_renewable_production_kW - firm_renewable_production_kW;

        if (
            this->required_operating_reserve_kW >
            this->max_operating_reserve_factor * load_kW
        ) {
            this->required_operating_reserve_kW =
                this->max_operating_reserve_factor * load_kW;
        }

        //required_operating_reserve_before_kW = this->required_operating_reserve_kW;

        //  4. init remaining_load_kW
        remaining_load_kW = load_kW - total_renewable_production_kW;

        //rem_load_test_0 = remaining_load_kW;

        //  5. handle Storage discharging
        remaining_load_kW = this->__handleStorageDischarging(
            timestep,
            dt_hrs,
            remaining_load_kW,
            storage_ptr_vec_ptr
        );

        //rem_load_test_1 = remaining_load_kW;

        //  6. handle Noncombustion dispatch
        remaining_load_kW = this->__handleNoncombustionDispatch(
            timestep,
            dt_hrs,
            remaining_load_kW,
            noncombustion_ptr_vec_ptr,
```

```
        resources_ptr
    );

    //rem_load_test_2 = remaining_load_kW;

    //  7. handle Combustion dispatch
    switch(control_mode) {
        case (ControlMode :: LOAD_FOLLOWING): {
            remaining_load_kW = this->__handleCombustionDispatch(
                timestep,
                dt_hrs,
                load_kW,
                remaining_load_kW,
                total_renewable_production_kW,
                firm_renewable_production_kW,
                combustion_ptr_vec_ptr,
                false
            );

            break;
        }

        case (ControlMode :: CYCLE_CHARGING): {
            bool is_cycle_charging = false;

            for (size_t asset = 0; asset < storage_ptr_vec_ptr->size(); asset++) {
                if (not this->storage_discharge_bool_vec[asset]) {
                    is_cycle_charging = true;
                    break;
                }
            }

            remaining_load_kW = this->__handleCombustionDispatch(
                timestep,
                dt_hrs,
                load_kW,
                remaining_load_kW,
                total_renewable_production_kW,
                firm_renewable_production_kW,
                combustion_ptr_vec_ptr,
                is_cycle_charging
            );

            break;
        }

        default: {
            std::string error_str = "ERROR:  Controller :: setControlMode():  ";
                error_str += "control mode ";
                error_str += std::to_string(control_mode);
                error_str += " not recognized";

                #ifdef _WIN32
                    std::cout « error_str « std::endl;
                #endif

                throw std::runtime_error(error_str);

            break;
        }
    }

    //rem_load_test_3 = remaining_load_kW;

    //  8. handle Renewable dispatch
    remaining_load_kW += total_renewable_production_kW;

    //rem_load_test_4 = remaining_load_kW;

    remaining_load_kW = this->__handleRenewableDispatch(
        timestep,
        dt_hrs,
        remaining_load_kW,
        renewable_ptr_vec_ptr
    );

    //  9. handle Storage charging
    this->__handleStorageCharging(
        timestep,
        dt_hrs,
        storage_ptr_vec_ptr,
        combustion_ptr_vec_ptr,
        noncombustion_ptr_vec_ptr,
        renewable_ptr_vec_ptr
    );

    //  10. log missed load, if any
```

```
        if (remaining_load_kW > 1e-6) {
            this->missed_load_vec_kW[timestep] = remaining_load_kW;
        }

        //  11. reset storage_discharge_bool_vec
        for (size_t asset = 0; asset < storage_ptr_vec_ptr->size(); asset++) {
            this->storage_discharge_bool_vec[asset] = false;
        }

        //  12. test print
        /*
        if (required_operating_reserve_before_kW < load_kW) {
            std::cout « "Timestep: " « timestep « std::endl;
            std::cout « "Load: " « load_kW « std::endl;
            std::cout « "Req Op Reserve: " « required_operating_reserve_before_kW « std::endl;
            std::cout « "Rem Load (before Storage): " « rem_load_test_0 « std::endl;
            std::cout « "Rem Load (after Storage): " « rem_load_test_1 « std::endl;
            std::cout « "Rem Load (after Noncombustion): " « rem_load_test_2 « std::endl;
            std::cout « "Rem Load (after Combustion): " « rem_load_test_3 « std::endl;
            std::cout « "Rem Load (before Renewable): " « rem_load_test_4 « std::endl;
            std::cout « "Rem Load: " « remaining_load_kW « std::endl;
            std::cout « std::endl;
        }
        */
    }

    return;
}   /* applyDispatchControl() */
```

#### 4.3.3.10 clear()

```
void Controller::clear (
            void   )
```

Method to clear all attributes of the Controller object.

```
{
    this->net_load_vec_kW.clear();
    this->missed_load_vec_kW.clear();
    this->combustion_map.clear();

    return;
}   /* clear() */
```

#### 4.3.3.11 init()

```
void Controller::init (
            ElectricalLoad * electrical_load_ptr,
            std::vector< Renewable * > * renewable_ptr_vec_ptr,
            Resources * resources_ptr,
            std::vector< Combustion * > * combustion_ptr_vec_ptr )
```

Method to initialize the Controller component of the Model.

**Parameters**

| | |
|---|---|
| *electrical_load_ptr* | A pointer to the ElectricalLoad component of the Model. |
| *renewable_ptr_vec_ptr* | A pointer to the Renewable pointer vector of the Model. |
| *resources_ptr* | A pointer to the Resources component of the Model. |
| *combustion_ptr_vec_ptr* | A pointer to the Combustion pointer vector of the Model. |

```
{
```

```
    //  1. init vector attributes
    this->net_load_vec_kW.resize(electrical_load_ptr->n_points, 0);
    this->missed_load_vec_kW.resize(electrical_load_ptr->n_points, 0);

    //  2. compute Renewable production
    this->__computeRenewableProduction(
        electrical_load_ptr,
        renewable_ptr_vec_ptr,
        resources_ptr
    );

    //  3. construct Combustion table
    this->__constructCombustionMap(combustion_ptr_vec_ptr);

    return;
}   /* init() */
```

#### 4.3.3.12 setControlMode()

```
void Controller::setControlMode (
            ControlMode control_mode )
```

Method to set control mode of Controller.

**Parameters**

| | |
|---|---|
| *control_mode* | The ControlMode which is to be active in the Controller. |

```
{
    this->control_mode = control_mode;

    switch(control_mode) {
        case (ControlMode :: LOAD_FOLLOWING): {
            this->control_string = "LOAD_FOLLOWING";

            break;
        }

        case (ControlMode :: CYCLE_CHARGING): {
            this->control_string = "CYCLE_CHARGING";

            break;
        }

        default: {
            std::string error_str = "ERROR:  Controller :: setControlMode():  ";
                error_str += "control mode ";
                error_str += std::to_string(control_mode);
                error_str += " not recognized";

                #ifdef _WIN32
                    std::cout « error_str « std::endl;
                #endif

                throw std::runtime_error(error_str);

            break;
        }
    }

    return;
}   /* setControlMode() */
```

#### 4.3.3.13 setLoadOperatingReserveFactor()

```
void Controller::setLoadOperatingReserveFactor (
            double load_operating_reserve_factor )
```

Method to set Controller load_operating_reserve_factor attribute.

**Parameters**

| | |
|---|---|
| *load_operating_reserve_factor* | An operating reserve factor [0, 1] to cover random fluctuations in load. |

```
{
    this->load_operating_reserve_factor = load_operating_reserve_factor;

    return;
}   /* setLoadOperatingReserveFactor() */
```

#### 4.3.3.14 setMaxOperatingReserveFactor()

```
void Controller::setMaxOperatingReserveFactor (
            double max_operating_reserve_factor )
```

Method to set Controller max_operating_reserve_factor attribute.

**Parameters**

| | |
|---|---|
| *max_operating_reserve_factor* | An operating reserve factor [0, 1] that limits the required overall operating reserve to, at most, factor ∗ load_kW. |

```
{
    this->max_operating_reserve_factor = max_operating_reserve_factor;

    return;
}   /* setMaxOperatingReserveFactor() */
```

### 4.3.4 Member Data Documentation

#### 4.3.4.1 combustion_map

```
std::map<double, std::vector<bool> > Controller::combustion_map
```

A map of all possible combustion states, for use in determining optimal dispatch.

#### 4.3.4.2 control_mode

```
ControlMode Controller::control_mode
```

The ControlMode that is active in the Model.

#### 4.3.4.3 control_string

```
std::string Controller::control_string
```

A string describing the active ControlMode.

#### 4.3.4.4 load_operating_reserve_factor

```
double Controller::load_operating_reserve_factor
```

An operating reserve factor [0, 1] to cover random fluctuations in load.

#### 4.3.4.5 max_operating_reserve_factor

```
double Controller::max_operating_reserve_factor
```

A maximum reserve factor [0, 1] that limits the required overall operating reserve to, at most, factor $*$ load_kW.

#### 4.3.4.6 missed_load_vec_kW

```
std::vector<double> Controller::missed_load_vec_kW
```

A vector of missed load values [kW] at each point in the modelling time series.

#### 4.3.4.7 net_load_vec_kW

```
std::vector<double> Controller::net_load_vec_kW
```

A vector of net load values [kW] at each point in the modelling time series. Net load is defined as load minus all available Renewable production.

#### 4.3.4.8 required_operating_reserve_kW

```
double Controller::required_operating_reserve_kW
```

A required operating reserve [kW], to absorb load and Renewable production fluctuations.

#### 4.3.4.9 storage_discharge_bool_vec

```
std::vector<bool> Controller::storage_discharge_bool_vec
```

A boolean vector attribute to track which Storage assets have been discharged in each time step.

The documentation for this class was generated from the following files:

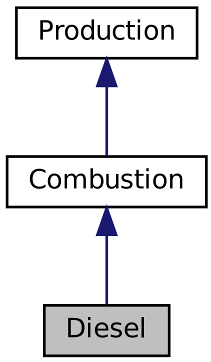
- header/Controller.h
- source/Controller.cpp

## 4.4 Diesel Class Reference

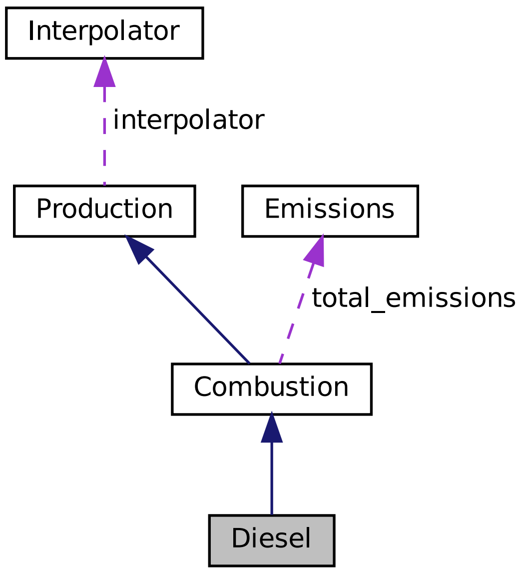
A derived class of the Combustion branch of Production which models production using a diesel generator.

```
#include <Diesel.h>
```

Inheritance diagram for Diesel:



Collaboration diagram for Diesel:




## Public Member Functions

- Diesel (void)

  *Constructor (dummy) for the Diesel class.*
- Diesel (int, double, DieselInputs, std::vector< double > ∗)

  *Constructor (intended) for the Diesel class.*
- void handleReplacement (int)

  *Method to handle asset replacement and capital cost incursion, if applicable.*
- double requestProductionkW (int, double, double)

  *Method which takes in production request, and then returns what the asset can deliver (subject to operating constraints, etc.).*
- double commit (int, double, double, double)

  *Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.*
- ∼Diesel (void)

  *Destructor for the Diesel class.*

## Public Attributes

- double minimum_load_ratio

  *The minimum load ratio of the asset. That is, when the asset is producing, it must produce at least this ratio of its rated capacity.*
- double minimum_runtime_hrs

  *The minimum runtime [hrs] of the asset. This is the minimum time that must elapse between successive starts and stops.*
- double time_since_last_start_hrs

  *The time that has elapsed [hrs] since the last start of the asset.*

## Private Member Functions

- void __checkInputs (DieselInputs)

  *Helper method to check inputs to the Diesel constructor.*
- void __handleStartStop (int, double, double)

  *Helper method (private) to handle the starting/stopping of the diesel generator. The minimum runtime constraint is enforced in this method.*
- double __getGenericFuelSlope (void)

  *Helper method to generate a generic, linearized fuel consumption slope for a diesel generator.*
- double __getGenericFuelIntercept (void)

  *Helper method to generate a generic, linearized fuel consumption intercept for a diesel generator.*
- double __getGenericCapitalCost (void)

  *Helper method to generate a generic diesel generator capital cost.*
- double __getGenericOpMaintCost (void)

  *Helper method (private) to generate a generic diesel generator operation and maintenance cost. This is a cost incurred per unit energy produced.*
- void __writeSummary (std::string)

  *Helper method to write summary results for Diesel.*
- void __writeTimeSeries (std::string, std::vector< double > *, int=-1)

  *Helper method to write time series results for Diesel.*

### 4.4.1 Detailed Description

A derived class of the Combustion branch of Production which models production using a diesel generator.

### 4.4.2 Constructor & Destructor Documentation

#### 4.4.2.1 Diesel() [1/2]

```
Diesel::Diesel (
            void )
```

Constructor (dummy) for the Diesel class.

```
632 {
633     return;
634 }   /* Diesel() */
```

#### 4.4.2.2 Diesel() [2/2]

```
Diesel::Diesel (
            int n_points,
            double n_years,
            DieselInputs diesel_inputs,
            std::vector< double > * time_vec_hrs_ptr )
```

Constructor (intended) for the Diesel class.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *n_years* | The number of years being modelled. |
| *diesel_inputs* | A structure of Diesel constructor inputs. |
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
  :
Combustion(
    n_points,
    n_years,
    diesel_inputs.combustion_inputs,
    time_vec_hrs_ptr
)
{
    //  1. check inputs
    this->__checkInputs(diesel_inputs);

    //  2. set attributes
    this->type = CombustionType :: DIESEL;
    this->type_str = "DIESEL";

    this->replace_running_hrs = diesel_inputs.replace_running_hrs;

    this->fuel_cost_L = diesel_inputs.fuel_cost_L;

    this->minimum_load_ratio = diesel_inputs.minimum_load_ratio;
    this->minimum_runtime_hrs = diesel_inputs.minimum_runtime_hrs;
    this->time_since_last_start_hrs = 0;

    this->CO2_emissions_intensity_kgL = diesel_inputs.CO2_emissions_intensity_kgL;
    this->CO_emissions_intensity_kgL = diesel_inputs.CO_emissions_intensity_kgL;
    this->NOx_emissions_intensity_kgL = diesel_inputs.NOx_emissions_intensity_kgL;
    this->SOx_emissions_intensity_kgL = diesel_inputs.SOx_emissions_intensity_kgL;
    this->CH4_emissions_intensity_kgL = diesel_inputs.CH4_emissions_intensity_kgL;
    this->PM_emissions_intensity_kgL = diesel_inputs.PM_emissions_intensity_kgL;

    if (diesel_inputs.linear_fuel_slope_LkWh < 0) {
        this->linear_fuel_slope_LkWh = this->__getGenericFuelSlope();
    }
    else {
        this->linear_fuel_slope_LkWh = diesel_inputs.linear_fuel_slope_LkWh;
    }

    if (diesel_inputs.linear_fuel_intercept_LkWh < 0) {
        this->linear_fuel_intercept_LkWh = this->__getGenericFuelIntercept();
    }
    else {
        this->linear_fuel_intercept_LkWh = diesel_inputs.linear_fuel_intercept_LkWh;
    }

    if (diesel_inputs.capital_cost < 0) {
        this->capital_cost = this->__getGenericCapitalCost();
    }
    else {
        this->capital_cost = diesel_inputs.capital_cost;
    }

    if (diesel_inputs.operation_maintenance_cost_kWh < 0) {
        this->operation_maintenance_cost_kWh = this->__getGenericOpMaintCost();
    }
    else {
        this->operation_maintenance_cost_kWh =
            diesel_inputs.operation_maintenance_cost_kWh;
    }

    if (not this->is_sunk) {
        this->capital_cost_vec[0] = this->capital_cost;
    }

    //  3. construction print
    if (this->print_flag) {
        std::cout « "Diesel object constructed at " « this « std::endl;
    }

    return;
}   /* Diesel() */
```

#### 4.4.2.3 ∼Diesel()

```
Diesel::∼Diesel (
            void )
```

Destructor for the Diesel class.

```
{
    //  1. destruction print
    if (this->print_flag) {
        std::cout « "Diesel object at " « this « " destroyed" « std::endl;
    }

    return;
}   /* ~Diesel() */
```

### 4.4.3 Member Function Documentation

#### 4.4.3.1 __checkInputs()

```
void Diesel::__checkInputs (
            DieselInputs diesel_inputs ) [private]
```

Helper method to check inputs to the Diesel constructor.

**Parameters**

| | |
|---|---|
| *diesel_inputs* | A structure of Diesel constructor inputs. |

```
{
    //  1. check fuel_cost_L
    if (diesel_inputs.fuel_cost_L < 0) {
        std::string error_str = "ERROR:  Diesel():  ";
        error_str += "DieselInputs::fuel_cost_L must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  2. check CO2_emissions_intensity_kgL
    if (diesel_inputs.CO2_emissions_intensity_kgL < 0) {
        std::string error_str = "ERROR:  Diesel():  ";
        error_str += "DieselInputs::CO2_emissions_intensity_kgL must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  3. check CO_emissions_intensity_kgL
        if (diesel_inputs.CO_emissions_intensity_kgL < 0) {
        std::string error_str = "ERROR:  Diesel():  ";
        error_str += "DieselInputs::CO_emissions_intensity_kgL must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

     //  4. check NOx_emissions_intensity_kgL
     if (diesel_inputs.NOx_emissions_intensity_kgL < 0) {
```

```
        std::string error_str = "ERROR:  Diesel():  ";
        error_str += "DieselInputs::NOx_emissions_intensity_kgL must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  5. check SOx_emissions_intensity_kgL
    if (diesel_inputs.SOx_emissions_intensity_kgL < 0) {
        std::string error_str = "ERROR:  Diesel():  ";
        error_str += "DieselInputs::SOx_emissions_intensity_kgL must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  6. check CH4_emissions_intensity_kgL
    if (diesel_inputs.CH4_emissions_intensity_kgL < 0) {
        std::string error_str = "ERROR:  Diesel():  ";
        error_str += "DieselInputs::CH4_emissions_intensity_kgL must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  7. check PM_emissions_intensity_kgL
    if (diesel_inputs.PM_emissions_intensity_kgL < 0) {
        std::string error_str = "ERROR:  Diesel():  ";
        error_str += "DieselInputs::PM_emissions_intensity_kgL must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  8. check minimum_load_ratio
    if (diesel_inputs.minimum_load_ratio < 0) {
        std::string error_str = "ERROR:  Diesel():  ";
        error_str += "DieselInputs::minimum_load_ratio must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  9. check minimum_runtime_hrs
    if (diesel_inputs.minimum_runtime_hrs < 0) {
        std::string error_str = "ERROR:  Diesel():  ";
        error_str += "DieselInputs::minimum_runtime_hrs must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  10. check replace_running_hrs
    if (diesel_inputs.replace_running_hrs <= 0) {
        std::string error_str = "ERROR:  Diesel():  ";
        error_str += "DieselInputs::replace_running_hrs must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkInputs() */
```

#### 4.4.3.2 __getGenericCapitalCost()

```
double Diesel::__getGenericCapitalCost (
            void ) [private]
```

Helper method to generate a generic diesel generator capital cost.

This model was obtained by way of surveying an assortment of published diesel generator costs, and then constructing a best fit model. Note that this model expresses cost in terms of Canadian dollars [CAD].

**Returns**

A generic capital cost for the diesel generator [CAD].

```
{
    double capital_cost_per_kW = 1000 * pow(this->capacity_kW, -0.425) + 800;

    return capital_cost_per_kW * this->capacity_kW;
}   /* __getGenericCapitalCost() */
```

#### 4.4.3.3 __getGenericFuelIntercept()

```
double Diesel::__getGenericFuelIntercept (
            void ) [private]
```

Helper method to generate a generic, linearized fuel consumption intercept for a diesel generator.

This model was obtained by way of surveying an assortment of published diesel generator fuel consumption data, and then constructing a best fit model.

Ref: HOMER [2023c]
Ref: HOMER [2023d]

**Returns**

A generic fuel intercept coefficient for the diesel generator [L/kWh].

```
{
    double linear_fuel_intercept_LkWh = 0.0940 * pow(this->capacity_kW, -0.2735);

    return linear_fuel_intercept_LkWh;
}   /* __getGenericFuelIntercept() */
```

#### 4.4.3.4 __getGenericFuelSlope()

```
double Diesel::__getGenericFuelSlope (
            void ) [private]
```

Helper method to generate a generic, linearized fuel consumption slope for a diesel generator.

This model was obtained by way of surveying an assortment of published diesel generator fuel consumption data, and then constructing a best fit model.

Ref: HOMER [2023c]
Ref: HOMER [2023e]

**Returns**

A generic fuel slope for the diesel generator [L/kWh].

```
{
    double linear_fuel_slope_LkWh = 0.4234 * pow(this->capacity_kW, -0.1012);

    return linear_fuel_slope_LkWh;
}   /* __getGenericFuelSlope() */
```

#### 4.4.3.5 __getGenericOpMaintCost()

```
double Diesel::__getGenericOpMaintCost (
            void ) [private]
```

Helper method (private) to generate a generic diesel generator operation and maintenance cost. This is a cost incurred per unit energy produced.

This model was obtained by way of surveying an assortment of published diesel generator costs, and then constructing a best fit model. Note that this model expresses cost in terms of Canadian dollars per kiloWatt-hour production [CAD/kWh].

**Returns**

A generic operation and maintenance cost, per unit energy produced, for the diesel generator [CAD/kWh].

```
{
    double operation_maintenance_cost_kWh = 0.05 * pow(this->capacity_kW, -0.2) + 0.05;

    return operation_maintenance_cost_kWh;
}   /* __getGenericOpMaintCost() */
```

#### 4.4.3.6 __handleStartStop()

```
void Diesel::__handleStartStop (
            int timestep,
            double dt_hrs,
            double production_kW ) [private]
```

Helper method (private) to handle the starting/stopping of the diesel generator. The minimum runtime constraint is enforced in this method.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *production_kW* | The current rate of production [kW] of the generator. |

```
{
    /*
     *  Helper method (private) to handle the starting/stopping of the diesel
     *  generator. The minimum runtime constraint is enforced in this method.
     */

    if (this->is_running) {
        // handle stopping
        if (
            production_kW <= 0 and
            this->time_since_last_start_hrs >= this->minimum_runtime_hrs
        ) {
            this->is_running = false;
        }
    }

    else {
        // handle starting
        if (production_kW > 0) {
            this->is_running = true;
            this->n_starts++;
            this->time_since_last_start_hrs = 0;
        }
    }

```

```
    return;
} /* __handleStartStop() */
```

#### 4.4.3.7 __writeSummary()

```
void Diesel::__writeSummary (
            std::string write_path )  [private], [virtual]
```

Helper method to write summary results for Diesel.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |

Reimplemented from Combustion.

```
{
    //  1. create filestream
    write_path += "summary_results.md";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  2. write to summary results (markdown)
    ofs « "# ";
    ofs « std::to_string(int(ceil(this->capacity_kW)));
    ofs « " kW DIESEL Summary Results\n";
    ofs « "\n--------\n\n";

    //  2.1. Production attributes
    ofs « "## Production Attributes\n";
    ofs « "\n";

    ofs « "Capacity: " « this->capacity_kW « " kW  \n";
    ofs « "\n";

    ofs « "Production Override: (N = 0 / Y = 1): "
        « this->normalized_production_series_given « "  \n";
    if (this->normalized_production_series_given) {
        ofs « "Path to Normalized Production Time Series: "
            « this->path_2_normalized_production_time_series « "  \n";
    }
    ofs « "\n";

    ofs « "Sunk Cost (N = 0 / Y = 1): " « this->is_sunk « "  \n";
    ofs « "Capital Cost: " « this->capital_cost « "  \n";
    ofs « "Operation and Maintenance Cost: " « this->operation_maintenance_cost_kWh
        « " per kWh produced  \n";
    ofs « "Nominal Inflation Rate (annual): " « this->nominal_inflation_annual
        « "  \n";
    ofs « "Nominal Discount Rate (annual): " « this->nominal_discount_annual
        « "  \n";
    ofs « "Real Discount Rate (annual): " « this->real_discount_annual « "  \n";
    ofs « "\n";

    ofs « "Replacement Running Hours: " « this->replace_running_hrs « "  \n";
    ofs « "\n--------\n\n";

    //  2.2. Combustion attributes
    ofs « "## Combustion Attributes\n";
    ofs « "\n";

    ofs « "Cycle Charging Setpoint: " « this->cycle_charging_setpoint « "\n";
    ofs « "\n";

    ofs « "Fuel Cost: " « this->fuel_cost_L « " per L  \n";
    ofs « "Nominal Fuel Escalation Rate (annual): "
        « this->nominal_fuel_escalation_annual « "  \n";
    ofs « "Real Fuel Escalation Rate (annual): "
        « this->real_fuel_escalation_annual « "  \n";
    ofs « "\n";

    ofs « "Fuel Mode: " « this->fuel_mode_str « "  \n";
```

```
    switch (this->fuel_mode) {
        case (FuelMode :: FUEL_MODE_LINEAR): {
            ofs « "Linear Fuel Slope: " « this->linear_fuel_slope_LkWh
                « " L/kWh  \n";
            ofs « "Linear Fuel Intercept Coefficient: "
                « this->linear_fuel_intercept_LkWh « " L/kWh  \n";
            ofs « "\n";

            break;
        }

        case (FuelMode :: FUEL_MODE_LOOKUP): {
            ofs « "Fuel Consumption Data: " « this->interpolator.path_map_1D[0]
                « "  \n";

            break;
        }

        default: {
            // write nothing!

            break;
        }
    }

    ofs « "Carbon Dioxide (CO2) Emissions Intensity: "
        « this->CO2_emissions_intensity_kgL « " kg/L  \n";

    ofs « "Carbon Monoxide (CO) Emissions Intensity: "
        « this->CO_emissions_intensity_kgL « " kg/L  \n";

    ofs « "Nitrogen Oxides (NOx) Emissions Intensity: "
        « this->NOx_emissions_intensity_kgL « " kg/L  \n";

    ofs « "Sulfur Oxides (SOx) Emissions Intensity: "
        « this->SOx_emissions_intensity_kgL « " kg/L  \n";

    ofs « "Methane (CH4) Emissions Intensity: "
        « this->CH4_emissions_intensity_kgL « " kg/L  \n";

    ofs « "Particulate Matter (PM) Emissions Intensity: "
        « this->PM_emissions_intensity_kgL « " kg/L  \n";

    ofs « "\n--------\n\n";

    //  2.3. Diesel attributes
    ofs « "## Diesel Attributes\n";
    ofs « "\n";

    ofs « "Minimum Load Ratio: " « this->minimum_load_ratio « "  \n";
    ofs « "Minimum Runtime: " « this->minimum_runtime_hrs « " hrs  \n";

    ofs « "\n--------\n\n";

    //  2.4. Diesel Results
    ofs « "## Results\n";
    ofs « "\n";

    ofs « "Net Present Cost: " « this->net_present_cost « "  \n";
    ofs « "\n";

    ofs « "Total Dispatch: " « this->total_dispatch_kWh
        « " kWh  \n";

    ofs « "Levellized Cost of Energy: " « this->levellized_cost_of_energy_kWh
        « " per kWh dispatched  \n";
    ofs « "\n";

    ofs « "Running Hours: " « this->running_hours « "  \n";
    ofs « "Starts: " « this->n_starts « "  \n";
    ofs « "Replacements: " « this->n_replacements « "  \n";

    ofs « "Total Fuel Consumed: " « this->total_fuel_consumed_L « " L "
        « "(Annual Average: " « this->total_fuel_consumed_L / this->n_years
        « " L/yr)  \n";
    ofs « "\n";

    ofs « "Total Carbon Dioxide (CO2) Emissions: " «
        this->total_emissions.CO2_kg « " kg "
        « "(Annual Average: " «  this->total_emissions.CO2_kg / this->n_years
        « " kg/yr)  \n";

    ofs « "Total Carbon Monoxide (CO) Emissions: " «
        this->total_emissions.CO_kg « " kg "
        « "(Annual Average: " «  this->total_emissions.CO_kg / this->n_years
        « " kg/yr)  \n";

```

```
    ofs « "Total Nitrogen Oxides (NOx) Emissions: " «
        this->total_emissions.NOx_kg « " kg "
        « "(Annual Average: " «  this->total_emissions.NOx_kg / this->n_years
        « " kg/yr)  \n";

    ofs « "Total Sulfur Oxides (SOx) Emissions: " «
        this->total_emissions.SOx_kg « " kg "
        « "(Annual Average: " «  this->total_emissions.SOx_kg / this->n_years
        « " kg/yr)  \n";

    ofs « "Total Methane (CH4) Emissions: " « this->total_emissions.CH4_kg « " kg "
        « "(Annual Average: " «  this->total_emissions.CH4_kg / this->n_years
        « " kg/yr)  \n";

    ofs « "Total Particulate Matter (PM) Emissions: " «
        this->total_emissions.PM_kg « " kg "
        « "(Annual Average: " «  this->total_emissions.PM_kg / this->n_years
        « " kg/yr)  \n";

    ofs « "\n--------\n\n";

    ofs.close();
    return;
}   /* __writeSummary() */
```

#### 4.4.3.8 __writeTimeSeries()

```
void Diesel::__writeTimeSeries (
            std::string write_path,
            std::vector< double > * time_vec_hrs_ptr,
            int max_lines = -1 )  [private], [virtual]
```

Helper method to write time series results for Diesel.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |
| *max_lines* | The maximum number of lines of output to write. |

Reimplemented from Combustion.

```
{
    //  1. create filestream
    write_path += "time_series_results.csv";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  2. write time series results (comma separated value)
    ofs « "Time (since start of data) [hrs],";
    ofs « "Production [kW],";
    ofs « "Dispatch [kW],";
    ofs « "Storage [kW],";
    ofs « "Curtailment [kW],";
    ofs « "Is Running (N = 0 / Y = 1),";
    ofs « "Fuel Consumption [L],";
    ofs « "Fuel Cost (actual),";
    ofs « "Carbon Dioxide (CO2) Emissions [kg],";
    ofs « "Carbon Monoxide (CO) Emissions [kg],";
    ofs « "Nitrogen Oxides (NOx) Emissions [kg],";
    ofs « "Sulfur Oxides (SOx) Emissions [kg],";
    ofs « "Methane (CH4) Emissions [kg],";
    ofs « "Particulate Matter (PM) Emissions [kg],";
    ofs « "Capital Cost (actual),";
    ofs « "Operation and Maintenance Cost (actual),";
    ofs « "\n";

    for (int i = 0; i < max_lines; i++) {
        ofs « time_vec_hrs_ptr->at(i) « ",";
        ofs « this->production_vec_kW[i] « ",";
```

```
        ofs « this->dispatch_vec_kW[i] « ",";
        ofs « this->storage_vec_kW[i] « ",";
        ofs « this->curtailment_vec_kW[i] « ",";
        ofs « this->is_running_vec[i] « ",";
        ofs « this->fuel_consumption_vec_L[i] « ",";
        ofs « this->fuel_cost_vec[i] « ",";
        ofs « this->CO2_emissions_vec_kg[i] « ",";
        ofs « this->CO_emissions_vec_kg[i] « ",";
        ofs « this->NOx_emissions_vec_kg[i] « ",";
        ofs « this->SOx_emissions_vec_kg[i] « ",";
        ofs « this->CH4_emissions_vec_kg[i] « ",";
        ofs « this->PM_emissions_vec_kg[i] « ",";
        ofs « this->capital_cost_vec[i] « ",";
        ofs « this->operation_maintenance_cost_vec[i] « ",";
        ofs « "\n";
    }

    ofs.close();
    return;
}   /* __writeTimeSeries() */
```

#### 4.4.3.9 commit()

```
double Diesel::commit (
            int timestep,
            double dt_hrs,
            double production_kW,
            double load_kW )  [virtual]
```

Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *production_kW* | The production [kW] of the asset in this timestep. |
| *load_kW* | The load [kW] passed to the asset in this timestep. |

**Returns**

The load [kW] remaining after the dispatch is deducted from it.

Reimplemented from Combustion.

```
{
    //  1. handle start/stop, enforce minimum runtime constraint
    this->__handleStartStop(timestep, dt_hrs, production_kW);

    //  2. invoke base class method
    load_kW = Combustion :: commit(
        timestep,
        dt_hrs,
        production_kW,
        load_kW
    );

    if (this->is_running) {
        //  3. log time since last start
        this->time_since_last_start_hrs += dt_hrs;

        //  4. correct operation and maintenance costs (should be non-zero if idling)
        if (production_kW <= 0) {
            double produced_kWh = 0.01 * this->capacity_kW * dt_hrs;

            double operation_maintenance_cost =
```

```
                this->operation_maintenance_cost_kWh * produced_kWh;
            this->operation_maintenance_cost_vec[timestep] = operation_maintenance_cost;
        }
    }

    return load_kW;
}   /* commit() */
```

#### 4.4.3.10 handleReplacement()

```
void Diesel::handleReplacement (
              int timestep )  [virtual]
```

Method to handle asset replacement and capital cost incursion, if applicable.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |

Reimplemented from Combustion.

```
{
    //  1. reset attributes
    this->time_since_last_start_hrs = 0;

    //  2. invoke base class method
    Combustion :: handleReplacement(timestep);

    return;
}   /* __handleReplacement() */
```

#### 4.4.3.11 requestProductionkW()

```
double Diesel::requestProductionkW (
              int timestep,
              double dt_hrs,
              double request_kW )  [virtual]
```

Method which takes in production request, and then returns what the asset can deliver (subject to operating constraints, etc.).

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *request_kW* | The requested production [kW]. |

**Returns**

The production [kW] delivered by the diesel generator.

Reimplemented from Combustion.

```
{
```

```
    //  0. given production time series override
    if (this->normalized_production_series_given) {
        double production_kW = Production :: getProductionkW(timestep);

        return production_kW;
    }

    //  1. return on request of zero
    if (request_kW <= 0) {
        return 0;
    }

    double deliver_kW = request_kW;

    //  2. enforce capacity constraint
    if (deliver_kW > this->capacity_kW) {
        deliver_kW = this->capacity_kW;
    }

    //  3. enforce minimum load ratio
    if (deliver_kW < this->minimum_load_ratio * this->capacity_kW) {
        deliver_kW = this->minimum_load_ratio * this->capacity_kW;
    }

    return deliver_kW;
}   /* requestProductionkW() */
```

### 4.4.4 Member Data Documentation

#### 4.4.4.1 minimum_load_ratio

`double Diesel::minimum_load_ratio`

The minimum load ratio of the asset. That is, when the asset is producing, it must produce at least this ratio of its rated capacity.

#### 4.4.4.2 minimum_runtime_hrs

`double Diesel::minimum_runtime_hrs`

The minimum runtime [hrs] of the asset. This is the minimum time that must elapse between successive starts and stops.

#### 4.4.4.3 time_since_last_start_hrs

`double Diesel::time_since_last_start_hrs`

The time that has elapsed [hrs] since the last start of the asset.

The documentation for this class was generated from the following files:

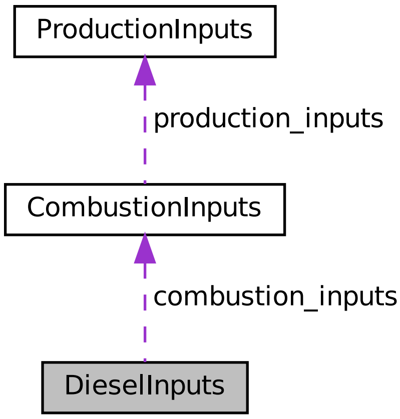
- header/Production/Combustion/Diesel.h
- source/Production/Combustion/Diesel.cpp

## 4.5 DieselInputs Struct Reference

A structure which bundles the necessary inputs for the Diesel constructor. Provides default values for every necessary input. Note that this structure encapsulates CombustionInputs.

```
#include <Diesel.h>
```

Collaboration diagram for DieselInputs:




### Public Attributes

- CombustionInputs combustion_inputs

  *An encapsulated CombustionInputs instance.*
- double replace_running_hrs = 30000

  *The number of running hours after which the asset must be replaced. Overwrites the ProductionInputs attribute.*
- double capital_cost = -1

  *The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].*
- double operation_maintenance_cost_kWh = -1

  *The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].*
- double fuel_cost_L = 1.70

  *The cost of fuel [1/L] (undefined currency).*
- double minimum_load_ratio = 0.2

  *The minimum load ratio of the asset. That is, when the asset is producing, it must produce at least this ratio of its rated capacity.*
- double minimum_runtime_hrs = 4

  *The minimum runtime [hrs] of the asset. This is the minimum time that must elapse between successive starts and stops.*
- double linear_fuel_slope_LkWh = -1

*The slope [L/kWh] to use in computing linearized fuel consumption. This is fuel consumption per unit energy produced. -1 is a sentinel value, which triggers a generic fuel consumption model on construction (in fact, any negative value here will trigger).*

- double linear_fuel_intercept_LkWh = -1

  *The intercept [L/kWh] to use in computing linearized fuel consumption. This is fuel consumption per unit energy produced. -1 is a sentinel value, which triggers a generic fuel consumption model on construction (in fact, any negative value here will trigger).*
- double CO2_emissions_intensity_kgL = 2.7

  *Carbon dioxide (CO2) emissions intensity [kg/L].*
- double CO_emissions_intensity_kgL = 0.0178

  *Carbon monoxide (CO) emissions intensity [kg/L].*
- double NOx_emissions_intensity_kgL = 0.0014

  *Nitrogen oxide (NOx) emissions intensity [kg/L].*
- double SOx_emissions_intensity_kgL = 0.0042

  *Sulfur oxide (SOx) emissions intensity [kg/L].*
- double CH4_emissions_intensity_kgL = 0.0007

  *Methane (CH4) emissions intensity [kg/L].*
- double PM_emissions_intensity_kgL = 0.0001

  *Particulate Matter (PM) emissions intensity [kg/L].*

### 4.5.1 Detailed Description

A structure which bundles the necessary inputs for the Diesel constructor. Provides default values for every necessary input. Note that this structure encapsulates CombustionInputs.

Ref: HOMER [2023c]
Ref: HOMER [2023d]
Ref: HOMER [2023e]
Ref: NRCan [2014]
Ref: CIMAC [2008]

### 4.5.2 Member Data Documentation

#### 4.5.2.1 capital_cost

```
double DieselInputs::capital_cost = -1
```

The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].

#### 4.5.2.2 CH4_emissions_intensity_kgL

```
double DieselInputs::CH4_emissions_intensity_kgL = 0.0007
```

Methane (CH4) emissions intensity [kg/L].

#### 4.5.2.3 CO2_emissions_intensity_kgL

```
double DieselInputs::CO2_emissions_intensity_kgL = 2.7
```

Carbon dioxide (CO2) emissions intensity [kg/L].

#### 4.5.2.4 CO_emissions_intensity_kgL

```
double DieselInputs::CO_emissions_intensity_kgL = 0.0178
```

Carbon monoxide (CO) emissions intensity [kg/L].

#### 4.5.2.5 combustion_inputs

```
CombustionInputs DieselInputs::combustion_inputs
```

An encapsulated CombustionInputs instance.

#### 4.5.2.6 fuel_cost_L

```
double DieselInputs::fuel_cost_L = 1.70
```

The cost of fuel [1/L] (undefined currency).

#### 4.5.2.7 linear_fuel_intercept_LkWh

```
double DieselInputs::linear_fuel_intercept_LkWh = -1
```

The intercept [L/kWh] to use in computing linearized fuel consumption. This is fuel consumption per unit energy produced. -1 is a sentinel value, which triggers a generic fuel consumption model on construction (in fact, any negative value here will trigger).

#### 4.5.2.8 linear_fuel_slope_LkWh

```
double DieselInputs::linear_fuel_slope_LkWh = -1
```

The slope [L/kWh] to use in computing linearized fuel consumption. This is fuel consumption per unit energy produced. -1 is a sentinel value, which triggers a generic fuel consumption model on construction (in fact, any negative value here will trigger).

#### 4.5.2.9 minimum_load_ratio

```
double DieselInputs::minimum_load_ratio = 0.2
```

The minimum load ratio of the asset. That is, when the asset is producing, it must produce at least this ratio of its rated capacity.

#### 4.5.2.10 minimum_runtime_hrs

```
double DieselInputs::minimum_runtime_hrs = 4
```

The minimum runtime [hrs] of the asset. This is the minimum time that must elapse between successive starts and stops.

#### 4.5.2.11 NOx_emissions_intensity_kgL

```
double DieselInputs::NOx_emissions_intensity_kgL = 0.0014
```

Nitrogen oxide (NOx) emissions intensity [kg/L].

#### 4.5.2.12 operation_maintenance_cost_kWh

```
double DieselInputs::operation_maintenance_cost_kWh = -1
```

The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].

#### 4.5.2.13 PM_emissions_intensity_kgL

```
double DieselInputs::PM_emissions_intensity_kgL = 0.0001
```

Particulate Matter (PM) emissions intensity [kg/L].

#### 4.5.2.14 replace_running_hrs

```
double DieselInputs::replace_running_hrs = 30000
```

The number of running hours after which the asset must be replaced. Overwrites the ProductionInputs attribute.

#### 4.5.2.15 SOx_emissions_intensity_kgL

```
double DieselInputs::SOx_emissions_intensity_kgL = 0.0042
```

Sulfur oxide (SOx) emissions intensity [kg/L].

The documentation for this struct was generated from the following file:

- header/Production/Combustion/Diesel.h

## 4.6 ElectricalLoad Class Reference

A class which contains time and electrical load data. Intended to serve as a component class of Model.

```
#include <ElectricalLoad.h>
```

### Public Member Functions

- ElectricalLoad (void)
  *Constructor (dummy) for the ElectricalLoad class.*
- ElectricalLoad (std::string)
  *Constructor (intended) for the ElectricalLoad class.*
- void readLoadData (std::string)
  *Method to read electrical load data into an already existing ElectricalLoad object. Clears and overwrites any existing attribute values.*
- void clear (void)
  *Method to clear all attributes of the ElectricalLoad object.*
- ∼ElectricalLoad (void)
  *Destructor for the ElectricalLoad class.*

### Public Attributes

- int n_points
  *The number of points in the modelling time series.*
- double n_years
  *The number of years being modelled (inferred from time_vec_hrs).*
- double min_load_kW
  *The minimum [kW] of the given electrical load time series.*
- double mean_load_kW
  *The mean, or average, [kW] of the given electrical load time series.*
- double max_load_kW
  *The maximum [kW] of the given electrical load time series.*
- std::string path_2_electrical_load_time_series
  *A string defining the path (either relative or absolute) to the given electrical load time series.*
- std::vector< double > time_vec_hrs
  *A vector to hold a given sequence of model times [hrs]. This defines the modelling time series.*
- std::vector< double > dt_vec_hrs
  *A vector to hold a sequence of model time deltas [hrs].*
- std::vector< double > load_vec_kW
  *A vector to hold a given sequence of electrical load values [kW].*

### 4.6.1 Detailed Description

A class which contains time and electrical load data. Intended to serve as a component class of Model.

### 4.6.2 Constructor & Destructor Documentation

#### 4.6.2.1 ElectricalLoad() [1/2]

```
ElectricalLoad::ElectricalLoad (
            void )
```

Constructor (dummy) for the ElectricalLoad class.

```
{
    return;
}   /* ElectricalLoad() */
```

#### 4.6.2.2 ElectricalLoad() [2/2]

```
ElectricalLoad::ElectricalLoad (
            std::string path_2_electrical_load_time_series )
```

Constructor (intended) for the ElectricalLoad class.

**Parameters**

| | |
|---|---|
| *path_2_electrical_load_time_series* | A string defining the path (either relative or absolute) to the given electrical load time series. |

```
{
    this->readLoadData(path_2_electrical_load_time_series);

    return;
}   /* ElectricalLoad() */
```

#### 4.6.2.3 ∼ElectricalLoad()

```
ElectricalLoad::~ElectricalLoad (
            void )
```

Destructor for the ElectricalLoad class.

```
{
    this->clear();
    return;
}   /* ~ElectricalLoad() */
```

### 4.6.3 Member Function Documentation

#### 4.6.3.1 clear()

```
void ElectricalLoad::clear (
            void )
```

Method to clear all attributes of the ElectricalLoad object.

```
{
    this->n_points = 0;
    this->n_years = 0;
    this->min_load_kW = 0;
    this->mean_load_kW = 0;
    this->max_load_kW = 0;

    this->path_2_electrical_load_time_series.clear();
    this->time_vec_hrs.clear();
    this->dt_vec_hrs.clear();
    this->load_vec_kW.clear();

    return;
}   /* clear() */
```

#### 4.6.3.2 readLoadData()

```
void ElectricalLoad::readLoadData (
            std::string path_2_electrical_load_time_series )
```

Method to read electrical load data into an already existing ElectricalLoad object. Clears and overwrites any existing attribute values.

**Parameters**

| | |
|---|---|
| *path_2_electrical_load_time_series* | A string defining the path (either relative or absolute) to the given electrical load time series. |

```
{
    //  1. clear
    this->clear();

    //  2. init CSV reader, record path
    io::CSVReader<2> CSV(path_2_electrical_load_time_series);

    CSV.read_header(
        io::ignore_extra_column,
        "Time (since start of data) [hrs]",
        "Electrical Load [kW]"
    );

    this->path_2_electrical_load_time_series = path_2_electrical_load_time_series;

    //  3. read in time and load data, increment n_points, track min and max load
    double time_hrs = 0;
    double load_kW = 0;
    double load_sum_kW = 0;

    this->n_points = 0;

    this->min_load_kW = std::numeric_limits<double>::infinity();
    this->max_load_kW = -1 * std::numeric_limits<double>::infinity();

    while (CSV.read_row(time_hrs, load_kW)) {
        this->time_vec_hrs.push_back(time_hrs);
        this->load_vec_kW.push_back(load_kW);

        load_sum_kW += load_kW;

        this->n_points++;

        if (this->min_load_kW > load_kW) {
            this->min_load_kW = load_kW;
        }

```

```
        if (this->max_load_kW < load_kW) {
            this->max_load_kW = load_kW;
        }
    }

    //  4. compute mean load
    this->mean_load_kW = load_sum_kW / this->n_points;

    //  5. set number of years (assuming 8,760 hours per year)
    this->n_years = this->time_vec_hrs[this->n_points - 1] / 8760;

    //  6. populate dt_vec_hrs
    this->dt_vec_hrs.resize(n_points, 0);

    for (int i = 0; i < n_points; i++) {
        if (i == n_points - 1) {
            this->dt_vec_hrs[i] = this->dt_vec_hrs[i - 1];
        }

        else {
            double dt_hrs = this->time_vec_hrs[i + 1] - this->time_vec_hrs[i];

            this->dt_vec_hrs[i] = dt_hrs;
        }
    }

    return;
}   /* readLoadData() */
```

## 4.6.4 Member Data Documentation

### 4.6.4.1 dt_vec_hrs

`std::vector<double> ElectricalLoad::dt_vec_hrs`

A vector to hold a sequence of model time deltas [hrs].

### 4.6.4.2 load_vec_kW

`std::vector<double> ElectricalLoad::load_vec_kW`

A vector to hold a given sequence of electrical load values [kW].

### 4.6.4.3 max_load_kW

`double ElectricalLoad::max_load_kW`

The maximum [kW] of the given electrical load time series.

#### 4.6.4.4 mean_load_kW

```
double ElectricalLoad::mean_load_kW
```

The mean, or average, [kW] of the given electrical load time series.

#### 4.6.4.5 min_load_kW

```
double ElectricalLoad::min_load_kW
```

The minimum [kW] of the given electrical load time series.

#### 4.6.4.6 n_points

```
int ElectricalLoad::n_points
```

The number of points in the modelling time series.

#### 4.6.4.7 n_years

```
double ElectricalLoad::n_years
```

The number of years being modelled (inferred from time_vec_hrs).

#### 4.6.4.8 path_2_electrical_load_time_series

```
std::string ElectricalLoad::path_2_electrical_load_time_series
```

A string defining the path (either relative or absolute) to the given electrical load time series.

#### 4.6.4.9 time_vec_hrs

```
std::vector<double> ElectricalLoad::time_vec_hrs
```

A vector to hold a given sequence of model times [hrs]. This defines the modelling time series.

The documentation for this class was generated from the following files:

- header/ElectricalLoad.h
- source/ElectricalLoad.cpp

# 4.7 Emissions Struct Reference

A structure which bundles the emitted masses of various emissions chemistries.

```
#include <Combustion.h>
```

## Public Attributes

- double CO2_kg = 0

  *The mass of carbon dioxide (CO2) emitted [kg].*
- double CO_kg = 0

  *The mass of carbon monoxide (CO) emitted [kg].*
- double NOx_kg = 0

  *The mass of nitrogen oxides (NOx) emitted [kg].*
- double SOx_kg = 0

  *The mass of sulfur oxides (SOx) emitted [kg].*
- double CH4_kg = 0

  *The mass of methane (CH4) emitted [kg].*
- double PM_kg = 0

  *The mass of particulate matter (PM) emitted [kg].*

## 4.7.1 Detailed Description

A structure which bundles the emitted masses of various emissions chemistries.

## 4.7.2 Member Data Documentation

### 4.7.2.1 CH4_kg

```
double Emissions::CH4_kg = 0
```

The mass of methane (CH4) emitted [kg].

### 4.7.2.2 CO2_kg

```
double Emissions::CO2_kg = 0
```

The mass of carbon dioxide (CO2) emitted [kg].

#### 4.7.2.3 CO_kg

```
double Emissions::CO_kg = 0
```

The mass of carbon monoxide (CO) emitted [kg].

#### 4.7.2.4 NOx_kg

```
double Emissions::NOx_kg = 0
```

The mass of nitrogen oxides (NOx) emitted [kg].

#### 4.7.2.5 PM_kg

```
double Emissions::PM_kg = 0
```

The mass of particulate matter (PM) emitted [kg].

#### 4.7.2.6 SOx_kg

```
double Emissions::SOx_kg = 0
```

The mass of sulfur oxides (SOx) emitted [kg].

The documentation for this struct was generated from the following file:

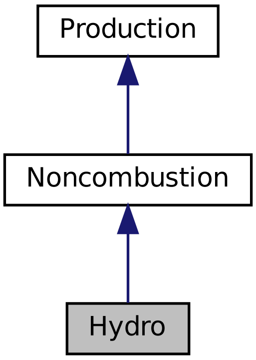
- header/Production/Combustion/Combustion.h

## 4.8 Hydro Class Reference

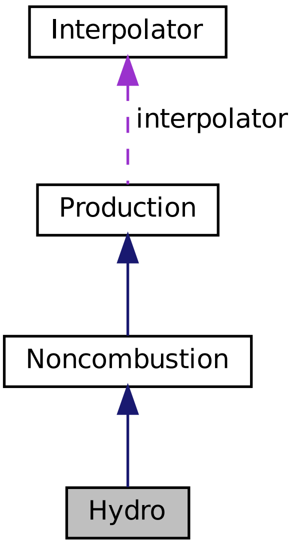
A derived class of the Noncombustion branch of Production which models production using a hydroelectric asset (either with reservoir or not).

`#include <Hydro.h>`

Inheritance diagram for Hydro:




Collaboration diagram for Hydro:



## Public Member Functions

- Hydro (void)

    *Constructor (dummy) for the Hydro class.*
- Hydro (int, double, HydroInputs, std::vector< double > *)

    *Constructor (intended) for the Hydro class.*
- void handleReplacement (int)

    *Method to handle asset replacement and capital cost incursion, if applicable.*
- double requestProductionkW (int, double, double, double)

    *Method which takes in production request, and then returns what the asset can deliver (subject to operating constraints, etc.).*
- double commit (int, double, double, double, double)

    *Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.*
- ∼Hydro (void)

    *Destructor for the Hydro class.*

## Public Attributes

- HydroTurbineType turbine_type

    *The type of hydroelectric turbine model to use.*
- double fluid_density_kgm3

    *The density [kg/m3] of the hydroelectric working fluid.*
- double net_head_m

    *The net head [m] of the asset.*
- double reservoir_capacity_m3

    *The capacity [m3] of the hydro reservoir.*
- double init_reservoir_state

    *The initial state of the reservoir (where state is volume of stored fluid divided by capacity).*
- double stored_volume_m3

    *The volume [m3] of stored fluid.*
- double minimum_power_kW

    *The minimum power [kW] that the asset can produce. Corresponds to minimum productive flow.*
- double minimum_flow_m3hr

    *The minimum required flow [m3/hr] for the asset to produce. Corresponds to minimum power.*
- double maximum_flow_m3hr

    *The maximum productive flow [m3/hr] that the asset can support.*
- std::vector< double > turbine_flow_vec_m3hr

    *A vector of the turbine flow [m3/hr] at each point in the modelling time series.*
- std::vector< double > spill_rate_vec_m3hr

    *A vector of the spill rate [m3/hr] at each point in the modelling time series.*
- std::vector< double > stored_volume_vec_m3

    *A vector of the stored volume [m3] in the reservoir at each point in the modelling time series.*

## Private Member Functions

- void __checkInputs (HydroInputs)

    *Helper method to check inputs to the Hydro constructor.*
- void __initInterpolator (void)

    *Helper method to set up turbine and generator efficiency interpolation.*
- double __getGenericCapitalCost (void)

    *Helper method to generate a generic hydroelectric capital cost.*
- double __getGenericOpMaintCost (void)

    *Helper method (private) to generate a generic hydroelectric operation and maintenance cost. This is a cost incurred per unit energy produced.*
- double __getEfficiencyFactor (double)

    *Helper method to compute the efficiency factor (product of turbine and generator efficiencies).*
- double __getMinimumFlowm3hr (void)

    *Helper method to compute and return the minimum required flow for production, based on turbine type.*
- double __getMaximumFlowm3hr (void)

    *Helper method to compute and return the maximum productive flow, based on turbine type.*
- double __flowToPower (double)

    *Helper method to translate a given flow into a corresponding power output.*
- double __powerToFlow (double)

    *Helper method to translate a given power output into a corresponding flow.*
- double __getAvailableFlow (double, double)

    *Helper method to determine what flow is currently available to the turbine.*
- double __getAcceptableFlow (double)

    *Helper method to determine what flow is currently acceptable by the reservoir.*
- void __updateState (int, double, double, double)

    *Helper method to update and log flow and reservoir state.*
- void __writeSummary (std::string)

    *Helper method to write summary results for Hydro.*
- void __writeTimeSeries (std::string, std::vector< double > *, int=-1)

    *Helper method to write time series results for Hydro.*

## 4.8.1 Detailed Description

A derived class of the Noncombustion branch of Production which models production using a hydroelectric asset (either with reservoir or not).

## 4.8.2 Constructor & Destructor Documentation

### 4.8.2.1 Hydro() [1/2]

```
Hydro::Hydro (
        void  )
```

Constructor (dummy) for the Hydro class.

```
859 {
860     return;
861 }   /* Hydro() */
```

#### 4.8.2.2 Hydro() [2/2]

```
Hydro::Hydro (
            int n_points,
            double n_years,
            HydroInputs hydro_inputs,
            std::vector< double > * time_vec_hrs_ptr )
```

Constructor (intended) for the Hydro class.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *n_years* | The number of years being modelled. |
| *hydro_inputs* | A structure of Hydro constructor inputs. |
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
  :
Noncombustion(
    n_points,
    n_years,
    hydro_inputs.noncombustion_inputs,
    time_vec_hrs_ptr
)
{
    //  1. check inputs
    this->__checkInputs(hydro_inputs);

    //  2. set attributes
    this->type = NoncombustionType :: HYDRO;
    this->type_str = "HYDRO";

    this->resource_key = hydro_inputs.resource_key;

    this->turbine_type = hydro_inputs.turbine_type;

    this->fluid_density_kgm3 = hydro_inputs.fluid_density_kgm3;
    this->net_head_m = hydro_inputs.net_head_m;

    this->reservoir_capacity_m3 = hydro_inputs.reservoir_capacity_m3;
    this->init_reservoir_state = hydro_inputs.init_reservoir_state;
    this->stored_volume_m3 =
        hydro_inputs.init_reservoir_state * hydro_inputs.reservoir_capacity_m3;

    this->minimum_power_kW = 0.1 * this->capacity_kW;   // <-- NEED TO DOUBLE CHECK THAT THIS MAKES
   SENSE IN GENERAL

    this->__initInterpolator();

    this->minimum_flow_m3hr = this->__getMinimumFlowm3hr();
    this->maximum_flow_m3hr = this->__getMaximumFlowm3hr();

    this->turbine_flow_vec_m3hr.resize(this->n_points, 0);
    this->spill_rate_vec_m3hr.resize(this->n_points, 0);
    this->stored_volume_vec_m3.resize(this->n_points, 0);

    if (hydro_inputs.capital_cost < 0) {
        this->capital_cost = this->__getGenericCapitalCost();
    }
    else {
        this->capital_cost = hydro_inputs.capital_cost;
    }

    if (hydro_inputs.operation_maintenance_cost_kWh < 0) {
        this->operation_maintenance_cost_kWh = this->__getGenericOpMaintCost();
    }
    else {
        this->operation_maintenance_cost_kWh =
            hydro_inputs.operation_maintenance_cost_kWh;
    }

    if (not this->is_sunk) {
        this->capital_cost_vec[0] = this->capital_cost;
    }

    return;
}   /* Hydro() */
```

#### 4.8.2.3 ∼Hydro()

```
Hydro::∼Hydro (
            void )
```

Destructor for the Hydro class.

```
{
    //  1. destruction print
    if (this->print_flag) {
        std::cout « "Hydro object at " « this « " destroyed" « std::endl;
    }

    return;
}   /* ~Hydro() */
```

### 4.8.3 Member Function Documentation

#### 4.8.3.1 __checkInputs()

```
void Hydro::__checkInputs (
            HydroInputs hydro_inputs )  [private]
```

Helper method to check inputs to the Hydro constructor.

**Parameters**

| | |
|---|---|
| *hydro_inputs* | A structure of Hydro constructor inputs. |

```
{
    //  1. check fluid_density_kgm3
    if (hydro_inputs.fluid_density_kgm3 <= 0) {
        std::string error_str = "ERROR:  Hydro():  fluid_density_kgm3 must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  2. check net_head_m
    if (hydro_inputs.net_head_m <= 0) {
        std::string error_str = "ERROR:  Hydro():  net_head_m must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  3. check reservoir_capacity_m3
    if (hydro_inputs.reservoir_capacity_m3 < 0) {
        std::string error_str = "ERROR:  Hydro():  reservoir_capacity_m3 must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

```

```
    //  4. check init_reservoir_state
    if (
        hydro_inputs.init_reservoir_state < 0 or
        hydro_inputs.init_reservoir_state > 1
    ) {
        std::string error_str = "ERROR:  Hydro():  init_reservoir_state must be in ";
        error_str += "the closed interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkInputs() */
```

### 4.8.3.2 __flowToPower()

```
double Hydro::__flowToPower (
            double flow_m3hr )  [private]
```

Helper method to translate a given flow into a corresponding power output.

Ref: Truelove [2023b]

**Parameters**

| | |
|---|---|
| *flow_m3hr* | The flow [m3/hr] through the turbine. |

**Returns**

The power output [kW] corresponding to a given flow [m3/hr].

```
{
    //  1. return on less than minimum flow
    if (flow_m3hr < this->minimum_flow_m3hr) {
        return 0;
    }

    //  2. interpolate flow to power
    double power_kW = this->interpolator.interp1D(
        HydroInterpKeys :: FLOW_TO_POWER_INTERP_KEY,
        flow_m3hr
    );

    return power_kW;
}   /* __flowToPower() */
```

### 4.8.3.3 __getAcceptableFlow()

```
double Hydro::__getAcceptableFlow (
            double dt_hrs )  [private]
```

Helper method to determine what flow is currently acceptable by the reservoir.

**Parameters**

| | |
|---|---|
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |

**Returns**

The flow [m3/hr] currently acceptable by the reservoir.

```
{
    //  1. if no reservoir, return
    if (this->reservoir_capacity_m3 <= 0) {
        return 0;
    }

    //  2. compute acceptable based on room in reservoir
    double acceptable_m3hr = (this->reservoir_capacity_m3 - this->stored_volume_m3) /
        dt_hrs;

    return acceptable_m3hr;
}   /* __getAcceptableFlow() */
```

#### 4.8.3.4 __getAvailableFlow()

```
double Hydro::__getAvailableFlow (
            double dt_hrs,
            double hydro_resource_m3hr )  [private]
```

Helper method to determine what flow is currently available to the turbine.

**Parameters**

| | |
|---|---|
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *hydro_resource_m3hr* | The currently available hydro flow resource [m3/hr]. |

**Returns**

The flow [m3/hr] currently available through the turbine.

```
{
    //  1. init to flow available from stored volume in reservoir
    double flow_m3hr = this->stored_volume_m3 / dt_hrs;

    //  2. add flow available from resource
    flow_m3hr += hydro_resource_m3hr;

    //  3. cap at maximum flow
    if (flow_m3hr > this->maximum_flow_m3hr) {
        flow_m3hr = this->maximum_flow_m3hr;
    }

    return flow_m3hr;
}   /* __getAvailableFlow() */
```

#### 4.8.3.5 __getEfficiencyFactor()

```
double Hydro::__getEfficiencyFactor (
            double power_kW )  [private]
```

Helper method to compute the efficiency factor (product of turbine and generator efficiencies).

Ref: Truelove [2023b]

**Parameters**

| | |
|---|---|
| *power_kW* | The power requested of the hydro plant. |

**Returns**

The product of the turbine and generator efficiencies.

```
{
    //  1. return on zero
    if (power_kW <= 0) {
        return 0;
    }

    //  2. compute power ratio (clip to [0, 1])
    double power_ratio = power_kW / this->capacity_kW;

    if (power_ratio < 0) {
        power_ratio = 0;
    }

    else if (power_ratio > 1) {
        power_ratio = 1;
    }


    //  3. init efficiency factor to the turbine efficiency
    double efficiency_factor = this->interpolator.interp1D(
        HydroInterpKeys :: TURBINE_EFFICIENCY_INTERP_KEY,
        power_ratio
    );

    //  4. include generator efficiency
    efficiency_factor *= this->interpolator.interp1D(
        HydroInterpKeys :: GENERATOR_EFFICIENCY_INTERP_KEY,
        power_ratio
    );

    return efficiency_factor;
}   /* __getEfficiencyFactor() */
```

#### 4.8.3.6 __getGenericCapitalCost()

```
double Hydro::__getGenericCapitalCost (
            void  )  [private]
```

Helper method to generate a generic hydroelectric capital cost.

This model was obtained by way of ...

**Returns**

A generic capital cost for the hydroelectric asset [CAD].

```
{
    double capital_cost_per_kW = 1000; //<-- WIP: need something better here!

    return capital_cost_per_kW * this->capacity_kW + 15000000; //<-- WIP: need something better here!
}   /* __getGenericCapitalCost() */
```

#### 4.8.3.7 __getGenericOpMaintCost()

```
double Hydro::__getGenericOpMaintCost (
            void ) [private]
```

Helper method (private) to generate a generic hydroelectric operation and maintenance cost. This is a cost incurred per unit energy produced.

This model was obtained by way of ...

**Returns**

A generic operation and maintenance cost, per unit energy produced, for the hydroelectric asset [CAD/kWh].

```
{
    double operation_maintenance_cost_kWh = 0.05;  //<-- WIP: need something better here!

    return operation_maintenance_cost_kWh;
}   /* __getGenericOpMaintCost() */
```

#### 4.8.3.8 __getMaximumFlowm3hr()

```
double Hydro::__getMaximumFlowm3hr (
            void ) [private]
```

Helper method to compute and return the maximum productive flow, based on turbine type.

This helper method assumes that the maximum flow is that which is associated with a power ratio of 1.

Ref: Truelove [2023b]

**Returns**

The maximum productive flow [m3/hr].

```
{
    return this->__powerToFlow(this->capacity_kW);
}   /* __getMaximumFlowm3hr() */
```

#### 4.8.3.9 __getMinimumFlowm3hr()

```
double Hydro::__getMinimumFlowm3hr (
            void ) [private]
```

Helper method to compute and return the minimum required flow for production, based on turbine type.

This helper method assumes that the minimum flow is that which is associated with a power ratio of 0.1. See constructor for initialization of minimum_power_kW.

Ref: Truelove [2023b]

**Returns**

The minimum required flow [m3/hr] for production.

```
{
    return this->__powerToFlow(this->minimum_power_kW);
}   /* __getMinimumFlowm3hr() */
```

#### 4.8.3.10 __initInterpolator()

```
void Hydro::__initInterpolator (
            void ) [private]
```

Helper method to set up turbine and generator efficiency interpolation.

Ref: Truelove [2023b]

```
{
    //  1. set up generator efficiency interpolation
    InterpolatorStruct1D generator_interp_struct_1D;

    generator_interp_struct_1D.n_points = 12;

    generator_interp_struct_1D.x_vec = {
        0,   0.1, 0.2,  0.3, 0.4, 0.5,
        0.6, 0.7, 0.75, 0.8, 0.9, 1
    };

    generator_interp_struct_1D.min_x = 0;
    generator_interp_struct_1D.max_x = 1;

    generator_interp_struct_1D.y_vec = {
        0.000, 0.800, 0.900, 0.913,
        0.925, 0.943, 0.947, 0.950,
        0.953, 0.954, 0.956, 0.958
    };

    this->interpolator.interp_map_1D.insert(
        std::pair<int, InterpolatorStruct1D>(
            HydroInterpKeys :: GENERATOR_EFFICIENCY_INTERP_KEY,
            generator_interp_struct_1D
        )
    );

    //  2. set up turbine efficiency interpolation
    InterpolatorStruct1D turbine_interp_struct_1D;

    turbine_interp_struct_1D.n_points = 11;

    turbine_interp_struct_1D.x_vec = {
        0,   0.1, 0.2, 0.3, 0.4,
        0.5, 0.6, 0.7, 0.8, 0.9,
        1
    };

    turbine_interp_struct_1D.min_x = 0;
    turbine_interp_struct_1D.max_x = 1;

    std::vector<double> efficiency_vec;

    switch (this->turbine_type) {
        case(HydroTurbineType :: HYDRO_TURBINE_PELTON): {
            efficiency_vec = {
                0.000, 0.780, 0.855, 0.875, 0.890,
                0.900, 0.908, 0.913, 0.918, 0.908,
                0.880
            };

            break;
        }

        case(HydroTurbineType :: HYDRO_TURBINE_FRANCIS): {
            efficiency_vec = {
                0.000, 0.400, 0.625, 0.745, 0.810,
                0.845, 0.880, 0.900, 0.910, 0.900,
                0.850
            };

            break;
        }

        case(HydroTurbineType :: HYDRO_TURBINE_KAPLAN): {
            efficiency_vec = {
                0.000, 0.265, 0.460, 0.550, 0.650,
                0.740, 0.805, 0.845, 0.900, 0.880,
                0.850
            };

            break;
        }
```

```
        default: {
            std::string error_str = "ERROR:  Hydro():  turbine type ";
            error_str += std::to_string(this->turbine_type);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    turbine_interp_struct_1D.y_vec = efficiency_vec;

    this->interpolator.interp_map_1D.insert(
        std::pair<int, InterpolatorStruct1D>(
            HydroInterpKeys :: TURBINE_EFFICIENCY_INTERP_KEY,
            turbine_interp_struct_1D
        )
    );

    //  3. set up flow to power interpolation
    InterpolatorStruct1D flow_to_power_interp_struct_1D;

    double power_ratio = 0.1;
    std::vector<double> power_ratio_vec (91, 0);

    for (size_t i = 0; i < power_ratio_vec.size(); i++) {
        power_ratio_vec[i] = power_ratio;

        power_ratio += 0.01;

        if (power_ratio < 0) {
            power_ratio = 0;
        }

        else if (power_ratio > 1) {
            power_ratio = 1;
        }
    }

    flow_to_power_interp_struct_1D.n_points = power_ratio_vec.size();

    std::vector<double> flow_vec_m3hr;
    std::vector<double> power_vec_kW;
    flow_vec_m3hr.resize(power_ratio_vec.size(), 0);
    power_vec_kW.resize(power_ratio_vec.size(), 0);

    for (size_t i = 0; i < power_ratio_vec.size(); i++) {
        flow_vec_m3hr[i] = this->__powerToFlow(power_ratio_vec[i] * this->capacity_kW);
        power_vec_kW[i] = power_ratio_vec[i] * this->capacity_kW;
        /*
        std::cout « flow_vec_m3hr[i] « "\t" « power_vec_kW[i] « " (" «
            power_ratio_vec[i] « ")" « std::endl;
        */
    }

    flow_to_power_interp_struct_1D.x_vec = flow_vec_m3hr;

    flow_to_power_interp_struct_1D.min_x = flow_vec_m3hr[0];
    flow_to_power_interp_struct_1D.max_x = flow_vec_m3hr[flow_vec_m3hr.size() - 1];

    flow_to_power_interp_struct_1D.y_vec = power_vec_kW;

    this->interpolator.interp_map_1D.insert(
        std::pair<int, InterpolatorStruct1D>(
            HydroInterpKeys :: FLOW_TO_POWER_INTERP_KEY,
            flow_to_power_interp_struct_1D
        )
    );

    return;
}   /* __initInterpolator() */
```

#### 4.8.3.11 __powerToFlow()

```
double Hydro::__powerToFlow (
              double power_kW )  [private]
```

Helper method to translate a given power output into a corresponding flow.

Ref: Truelove [2023b]

**Parameters**

| | |
|---|---|
| *power_kW* | The power output [kW] of the hydroelectric generator. |

**Returns**

```
{
    //  1. return on zero power
    if (power_kW <= 0) {
        return 0;
    }

    //  2. get efficiency factor
    double efficiency_factor = this->__getEfficiencyFactor(power_kW);

    //  3. compute flow
    double flow_m3hr = 3600 * 1000 * power_kW;
    flow_m3hr /= efficiency_factor * this->fluid_density_kgm3 * 9.81 * this->net_head_m;

    return flow_m3hr;
}   /* __powerToFlow() */
```

#### 4.8.3.12 __updateState()

```
void Hydro::__updateState (
            int timestep,
            double dt_hrs,
            double production_kW,
            double hydro_resource_m3hr )  [private]
```

Helper method to update and log flow and reservoir state.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *production_kW* | The production [kW] of the asset in this timestep. |
| *hydro_resource_m3hr* | The currently available hydro flow resource [m3/hr]. |

```
{
    //  1. get turbine flow, log
    double flow_m3hr = 0;

    if (production_kW >= this->minimum_power_kW) {
        flow_m3hr = this->__powerToFlow(production_kW);
    }

    double available_flow_m3hr = this->__getAvailableFlow(dt_hrs, hydro_resource_m3hr);

    if (flow_m3hr > available_flow_m3hr) {
        flow_m3hr = available_flow_m3hr;
    }

    this->turbine_flow_vec_m3hr[timestep] = flow_m3hr;

    //  3. compute net reservoir flow
```

```
    double net_flow_m3hr = hydro_resource_m3hr - flow_m3hr;

    //  4. compute flow acceptable by reservoir
    double acceptable_flow_m3hr = this->__getAcceptableFlow(dt_hrs);

    //  5. compute spill, update net flow (if applicable), log
    double spill_m3hr = 0;

    if (acceptable_flow_m3hr < net_flow_m3hr) {
        spill_m3hr = net_flow_m3hr - acceptable_flow_m3hr;
        net_flow_m3hr = acceptable_flow_m3hr;
    }

    this->spill_rate_vec_m3hr[timestep] = spill_m3hr;

    //  6. update reservoir state, log
    this->stored_volume_m3 += net_flow_m3hr * dt_hrs;
    this->stored_volume_vec_m3[timestep] = this->stored_volume_m3;

    return;
}   /* __updateState() */
```

#### 4.8.3.13 __writeSummary()

```
void Hydro::__writeSummary (
            std::string write_path )  [private], [virtual]
```

Helper method to write summary results for Hydro.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |

Reimplemented from Noncombustion.

```
{
    //  1. create filestream
    write_path += "summary_results.md";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  2. write to summary results (markdown)
    ofs « "# ";
    ofs « std::to_string(int(ceil(this->capacity_kW)));
    ofs « " kW HYDRO Summary Results\n";
    ofs « "\n--------\n\n";

    //  2.1. Production attributes
    ofs « "## Production Attributes\n";
    ofs « "\n";

    ofs « "Capacity: " « this->capacity_kW « " kW  \n";
    ofs « "\n";

    ofs « "Production Override: (N = 0 / Y = 1): "
        « this->normalized_production_series_given « "  \n";
    if (this->normalized_production_series_given) {
        ofs « "Path to Normalized Production Time Series: "
            « this->path_2_normalized_production_time_series « "  \n";
    }
    ofs « "\n";

    ofs « "Sunk Cost (N = 0 / Y = 1): " « this->is_sunk « "  \n";
    ofs « "Capital Cost: " « this->capital_cost « "  \n";
    ofs « "Operation and Maintenance Cost: " « this->operation_maintenance_cost_kWh
        « " per kWh produced  \n";
    ofs « "Nominal Inflation Rate (annual): " « this->nominal_inflation_annual
        « "  \n";
    ofs « "Nominal Discount Rate (annual): " « this->nominal_discount_annual
        « "  \n";
    ofs « "Real Discount Rate (annual): " « this->real_discount_annual « "  \n";
    ofs « "\n";
```

```

    ofs « "Replacement Running Hours: " « this->replace_running_hrs « "  \n";
    ofs « "\n--------\n\n";

    //  2.2. Noncombustion attributes
    ofs « "## Noncombustion Attributes\n";
    ofs « "\n";

    //...

    ofs « "\n--------\n\n";

    //  2.3. Hydro attributes
    ofs « "## Hydro Attributes\n";
    ofs « "\n";

    ofs « "Fluid Density: " « this->fluid_density_kgm3 « " kg/m3  \n";
    ofs « "Net Head: " « this->net_head_m « " m  \n";
    ofs « "\n";

    ofs « "Reservoir Volume: " « this->reservoir_capacity_m3 « " m3  \n";
    ofs « "Reservoir Initial State: " « this->init_reservoir_state « "  \n";
    ofs « "\n";

    ofs « "Turbine Type: ";
    switch(this->turbine_type) {
        case(HydroTurbineType :: HYDRO_TURBINE_PELTON): {
            ofs « "PELTON";

            break;
        }

        case(HydroTurbineType :: HYDRO_TURBINE_FRANCIS): {
            ofs « "FRANCIS";

            break;
        }

        case(HydroTurbineType :: HYDRO_TURBINE_KAPLAN): {
            ofs « "KAPLAN";

            break;
        }

        default: {
            // write nothing!

            break;
        }
    }
    ofs « "  \n";
    ofs « "\n";
    ofs « "Minimum Flow: " « this->minimum_flow_m3hr « " m3/hr  \n";
    ofs « "Maximum Flow: " « this->maximum_flow_m3hr « " m3/hr  \n";
    ofs « "\n";
    ofs « "Minimum Production: " « this->minimum_power_kW « " kW  \n";
    ofs « "\n";

    ofs « "\n--------\n\n";

    //  2.4. Hydro Results
    ofs « "## Results\n";
    ofs « "\n";

    ofs « "Net Present Cost: " « this->net_present_cost « "  \n";
    ofs « "\n";

    ofs « "Total Dispatch: " « this->total_dispatch_kWh
        « " kWh  \n";

    ofs « "Levellized Cost of Energy: " « this->levellized_cost_of_energy_kWh
        « " per kWh dispatched  \n";
    ofs « "\n";

    ofs « "Running Hours: " « this->running_hours « "  \n";
    ofs « "Replacements: " « this->n_replacements « "  \n";

    //...

    ofs « "\n--------\n\n";

    ofs.close();
    return;
}   /* __writeSummary() */
```

#### 4.8.3.14 __writeTimeSeries()

```
void Hydro::__writeTimeSeries (
            std::string write_path,
            std::vector< double > * time_vec_hrs_ptr,
            int max_lines = -1 )  [private], [virtual]
```

Helper method to write time series results for Hydro.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |
| *max_lines* | The maximum number of lines of output to write. |

Reimplemented from Noncombustion.

```
{
    //  1. create filestream
    write_path += "time_series_results.csv";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  2. write time series results (comma separated value)
    ofs « "Time (since start of data) [hrs],";
    ofs « "Production [kW],";
    ofs « "Dispatch [kW],";
    ofs « "Storage [kW],";
    ofs « "Curtailment [kW],";
    ofs « "Is Running (N = 0 / Y = 1),";
    ofs « "Turbine Flow [m3/hr],";
    ofs « "Spill Rate [m3/hr],";
    ofs « "Stored Volume [m3],";
    ofs « "Capital Cost (actual),";
    ofs « "Operation and Maintenance Cost (actual),";
    ofs « "\n";

    for (int i = 0; i < max_lines; i++) {
        ofs « time_vec_hrs_ptr->at(i) « ",";
        ofs « this->production_vec_kW[i] « ",";
        ofs « this->dispatch_vec_kW[i] « ",";
        ofs « this->storage_vec_kW[i] « ",";
        ofs « this->curtailment_vec_kW[i] « ",";
        ofs « this->is_running_vec[i] « ",";
        ofs « this->turbine_flow_vec_m3hr[i] « ",";
        ofs « this->spill_rate_vec_m3hr[i] « ",";
        ofs « this->stored_volume_vec_m3[i] « ",";
        ofs « this->capital_cost_vec[i] « ",";
        ofs « this->operation_maintenance_cost_vec[i] « ",";
        ofs « "\n";
    }

    ofs.close();
    return;
}   /* __writeTimeSeries() */
```

#### 4.8.3.15 commit()

```
double Hydro::commit (
            int timestep,
            double dt_hrs,
            double production_kW,
            double load_kW,
            double hydro_resource_m3hr )  [virtual]
```

Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *production_kW* | The production [kW] of the asset in this timestep. |
| *load_kW* | The load [kW] passed to the asset in this timestep. |

**Returns**

The load [kW] remaining after the dispatch is deducted from it.

Reimplemented from Noncombustion.

```
{
    //  1. invoke base class method
    load_kW = Noncombustion :: commit(
        timestep,
        dt_hrs,
        production_kW,
        load_kW
    );

    //  2. update state and record
    this->__updateState(
        timestep,
        dt_hrs,
        production_kW,
        hydro_resource_m3hr
    );

    return load_kW;
}   /* commit() */
```

#### 4.8.3.16 handleReplacement()

```
void Hydro::handleReplacement (
            int timestep )  [virtual]
```

Method to handle asset replacement and capital cost incursion, if applicable.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |

Reimplemented from Noncombustion.

```
{
    //  1. reset attributes
    //...

    //  2. invoke base class method
    Noncombustion :: handleReplacement(timestep);

    return;
}   /* __handleReplacement() */
```

#### 4.8.3.17 requestProductionkW()

```
double Hydro::requestProductionkW (
            int timestep,
```

```
double dt_hrs,
double request_kW,
double hydro_resource_m3hr )   [virtual]
```

Method which takes in production request, and then returns what the asset can deliver (subject to operating constraints, etc.).

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *request_kW* | The requested production [kW]. |
| *hydro_resource_m3hr* | The currently available hydro flow resource [m3/hr]. |

**Returns**

The production [kW] delivered by the hydro generator.

Reimplemented from Noncombustion.

```
{
    //  0. given production time series override
    if (this->normalized_production_series_given) {
        double production_kW = Production :: getProductionkW(timestep);

        return production_kW;
    }

    //  1. return on request of zero
    if (request_kW <= 0) {
        return 0;
    }

    //  2. if request is less than minimum power, set to minimum power
    if (request_kW < this->minimum_power_kW) {
        request_kW = this->minimum_power_kW;
    }

    //  3. check available flow, return if less than minimum flow
    double available_flow_m3hr = this->__getAvailableFlow(dt_hrs, hydro_resource_m3hr);

    if (available_flow_m3hr < this->minimum_flow_m3hr) {
        return 0;
    }

    //  4. init production to request, enforce capacity constraint (which also accounts
    //     for maximum flow constraint).
    double production_kW = request_kW;

    if (production_kW > this->capacity_kW) {
        production_kW = this->capacity_kW;
    }

    //  5. map production to flow
    double flow_m3hr = this->__powerToFlow(production_kW);

    //  6. if flow is in excess of available, then adjust production accordingly
    if (flow_m3hr > available_flow_m3hr) {
        production_kW = this->__flowToPower(available_flow_m3hr);
    }

    return production_kW;
}   /* requestProductionkW() */
```

## 4.8.4 Member Data Documentation

#### 4.8.4.1 fluid_density_kgm3

```
double Hydro::fluid_density_kgm3
```

The density [kg/m3] of the hydroelectric working fluid.

#### 4.8.4.2 init_reservoir_state

```
double Hydro::init_reservoir_state
```

The initial state of the reservoir (where state is volume of stored fluid divided by capacity).

#### 4.8.4.3 maximum_flow_m3hr

```
double Hydro::maximum_flow_m3hr
```

The maximum productive flow [m3/hr] that the asset can support.

#### 4.8.4.4 minimum_flow_m3hr

```
double Hydro::minimum_flow_m3hr
```

The minimum required flow [m3/hr] for the asset to produce. Corresponds to minimum power.

#### 4.8.4.5 minimum_power_kW

```
double Hydro::minimum_power_kW
```

The minimum power [kW] that the asset can produce. Corresponds to minimum productive flow.

#### 4.8.4.6 net_head_m

```
double Hydro::net_head_m
```

The net head [m] of the asset.

#### 4.8.4.7 reservoir_capacity_m3

```
double Hydro::reservoir_capacity_m3
```

The capacity [m3] of the hydro reservoir.

#### 4.8.4.8 spill_rate_vec_m3hr

```
std::vector<double> Hydro::spill_rate_vec_m3hr
```

A vector of the spill rate [m3/hr] at each point in the modelling time series.

#### 4.8.4.9 stored_volume_m3

```
double Hydro::stored_volume_m3
```

The volume [m3] of stored fluid.

#### 4.8.4.10 stored_volume_vec_m3

```
std::vector<double> Hydro::stored_volume_vec_m3
```

A vector of the stored volume [m3] in the reservoir at each point in the modelling time series.

#### 4.8.4.11 turbine_flow_vec_m3hr

```
std::vector<double> Hydro::turbine_flow_vec_m3hr
```

A vector of the turbine flow [m3/hr] at each point in the modelling time series.

#### 4.8.4.12 turbine_type

```
HydroTurbineType Hydro::turbine_type
```

The type of hydroelectric turbine model to use.

The documentation for this class was generated from the following files:

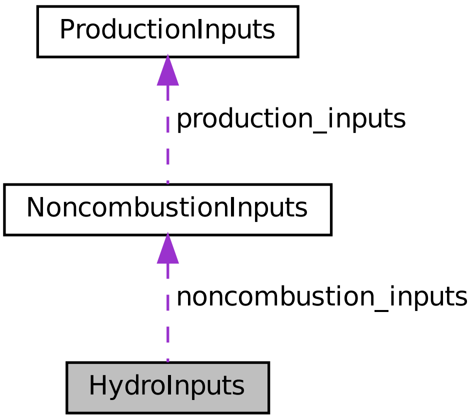
- header/Production/Noncombustion/Hydro.h
- source/Production/Noncombustion/Hydro.cpp

## 4.9 HydroInputs Struct Reference

A structure which bundles the necessary inputs for the Hydro constructor. Provides default values for every necessary input. Note that this structure encapsulates NoncombustionInputs.

```
#include <Hydro.h>
```

Collaboration diagram for HydroInputs:




### Public Attributes

- NoncombustionInputs noncombustion_inputs

  *An encapsulated NoncombustionInputs instance.*
- int resource_key = 0

  *A key used to index into the Resources object, to associate this asset with the appropriate resource time series.*
- double capital_cost = -1

  *The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].*
- double operation_maintenance_cost_kWh = -1

  *The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].*
- double fluid_density_kgm3 = 1000

  *The density [kg/m3] of the hydroelectric working fluid.*
- double net_head_m = 500

  *The net head [m] of the asset.*
- double reservoir_capacity_m3 = 0

  *The capacity [m3] of the hydro reservoir.*
- double init_reservoir_state = 0

  *The initial state of the reservoir (where state is volume of stored fluid divided by capacity).*
- HydroTurbineType turbine_type = HydroTurbineType :: HYDRO_TURBINE_PELTON

  *The type of hydroelectric turbine model to use.*

### 4.9.1 Detailed Description

A structure which bundles the necessary inputs for the Hydro constructor. Provides default values for every necessary input. Note that this structure encapsulates NoncombustionInputs.

### 4.9.2 Member Data Documentation

#### 4.9.2.1 capital_cost

```
double HydroInputs::capital_cost = -1
```

The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].

#### 4.9.2.2 fluid_density_kgm3

```
double HydroInputs::fluid_density_kgm3 = 1000
```

The density [kg/m3] of the hydroelectric working fluid.

#### 4.9.2.3 init_reservoir_state

```
double HydroInputs::init_reservoir_state = 0
```

The initial state of the reservoir (where state is volume of stored fluid divided by capacity).

#### 4.9.2.4 net_head_m

```
double HydroInputs::net_head_m = 500
```

The net head [m] of the asset.

#### 4.9.2.5 noncombustion_inputs

```
NoncombustionInputs HydroInputs::noncombustion_inputs
```

An encapsulated NoncombustionInputs instance.

#### 4.9.2.6 operation_maintenance_cost_kWh

```
double HydroInputs::operation_maintenance_cost_kWh = -1
```

The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].

#### 4.9.2.7 reservoir_capacity_m3

```
double HydroInputs::reservoir_capacity_m3 = 0
```

The capacity [m3] of the hydro reservoir.

#### 4.9.2.8 resource_key

```
int HydroInputs::resource_key = 0
```

A key used to index into the Resources object, to associate this asset with the appropriate resource time series.

#### 4.9.2.9 turbine_type

```
HydroTurbineType HydroInputs::turbine_type = HydroTurbineType :: HYDRO_TURBINE_PELTON
```

The type of hydroelectric turbine model to use.

The documentation for this struct was generated from the following file:

- header/Production/Noncombustion/Hydro.h

## 4.10 Interpolator Class Reference

A class which contains interpolation data and functionality. Intended to serve as a component of the Production and Storage hierarchies.

```
#include <Interpolator.h>
```

## Public Member Functions

- Interpolator (void)

  *Constructor for the Interpolator class.*
- void addData1D (int, std::string)

  *Method to add 1D interpolation data to the Interpolator.*
- void addData2D (int, std::string)

  *Method to add 2D interpolation data to the Interpolator.*
- double interp1D (int, double)

  *Method to perform a 1D interpolation.*
- double interp2D (int, double, double)

  *Method to perform a 2D interpolation.*
- ∼Interpolator (void)

  *Destructor for the Interpolator class.*

## Public Attributes

- std::map< int, InterpolatorStruct1D > interp_map_1D

  *A map <int, InterpolatorStruct1D> of given 1D interpolation data.*
- std::map< int, std::string > path_map_1D

  *A map <int, string> of the paths (either relative or absolute) to the given 1D interpolation data.*
- std::map< int, InterpolatorStruct2D > interp_map_2D

  *A map <int, InterpolatorStruct2D> of given 2D interpolation data.*
- std::map< int, std::string > path_map_2D

  *A map <int, string> of the paths (either relative or absolute) to the given 2D interpolation data.*

## Private Member Functions

- void __checkDataKey1D (int)

  *Helper method to check if given data key (1D) is already in use.*
- void __checkDataKey2D (int)

  *Helper method to check if given data key (2D) is already in use.*
- void __checkBounds1D (int, double)

  *Helper method to check that the given 1D interpolation value is contained within the given corresponding data domain. Also checks that the data key has been registered.*
- void __checkBounds2D (int, double, double)

  *Helper method to check that the given 2D interpolation value is contained within the given corresponding data domain. Also checks that the data key has been registered.*
- void __throwReadError (std::string, int)

  *Helper method to throw a read error whenever non-numeric data is encountered where only numeric data should be.*
- bool __isNonNumeric (std::string)

  *Helper method to determine if given string is non-numeric (i.e., contains.*
- int __getInterpolationIndex (double, std::vector< double > ∗)

  *Helper method to get appropriate interpolation index into given vector.*
- std::vector< std::string > __splitCommaSeparatedString (std::string, std::string="||")

  *Helper method to split a comma-separated string into a vector of substrings.*
- std::vector< std::vector< std::string > > __getDataStringMatrix (std::string)
- void __readData1D (int, std::string)

  *Helper method to read the given 1D interpolation data into Interpolator.*
- void __readData2D (int, std::string)

  *Helper method to read the given 2D interpolation data into Interpolator.*

### 4.10.1 Detailed Description

A class which contains interpolation data and functionality. Intended to serve as a component of the Production and Storage hierarchies.

### 4.10.2 Constructor & Destructor Documentation

#### 4.10.2.1 Interpolator()

```
Interpolator::Interpolator (
        void )
```

Constructor for the Interpolator class.

```
{
    //...

    return;
}   /* Interpolator() */
```

#### 4.10.2.2 ∼Interpolator()

```
Interpolator::~Interpolator (
        void )
```

Destructor for the Interpolator class.

```
{
    //...

    return;
}   /* ~Interpolator() */
```

### 4.10.3 Member Function Documentation

#### 4.10.3.1 __checkBounds1D()

```
void Interpolator::__checkBounds1D (
        int data_key,
        double interp_x )  [private]
```

Helper method to check that the given 1D interpolation value is contained within the given corresponding data domain. Also checks that the data key has been registered.

**Parameters**

| | |
|---|---|
| *data_key* | A key associated with the given interpolation data. |
| *interp←x* | The query value to be interpolated. |

```
{
    //  1. key error
    if (this->interp_map_1D.count(data_key) == 0) {
        std::string error_str = "ERROR:  Interpolator::interp1D()  ";
        error_str += "data key ";
        error_str += std::to_string(data_key);
        error_str += " has not been registered";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  2. bounds error
    if (
        interp_x < this->interp_map_1D[data_key].min_x or
        interp_x > this->interp_map_1D[data_key].max_x
    ) {
        std::string error_str = "ERROR:  Interpolator::interp1D()  ";
        error_str += "interpolation value ";
        error_str += std::to_string(interp_x);
        error_str += " is outside of the given interpolation data domain [";
        error_str += std::to_string(this->interp_map_1D[data_key].min_x);
        error_str += " , ";
        error_str += std::to_string(this->interp_map_1D[data_key].max_x);
        error_str += "]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkBounds1D() */
```

#### 4.10.3.2 __checkBounds2D()

```
void Interpolator::__checkBounds2D (
            int data_key,
            double interp_x,
            double interp_y )  [private]
```

Helper method to check that the given 2D interpolation value is contained within the given corresponding data domain. Also checks that the data key has been registered.

**Parameters**

| | |
|---|---|
| *data_key* | A key associated with the given interpolation data. |
| *interp_x* | The first query value to be interpolated. |
| *interp_y* | The second query value to be interpolated. |

```
{
    //  1. key error
    if (this->interp_map_2D.count(data_key) == 0) {
        std::string error_str = "ERROR:  Interpolator::interp2D()  ";
        error_str += "data key ";
        error_str += std::to_string(data_key);
        error_str += " has not been registered";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }
```

```

    //  2. bounds error (x_interp)
    if (
        interp_x < this->interp_map_2D[data_key].min_x or
        interp_x > this->interp_map_2D[data_key].max_x
    ) {
        std::string error_str = "ERROR:  Interpolator::interp2D()  ";
        error_str += "interpolation value interp_x = ";
        error_str += std::to_string(interp_x);
        error_str += " is outside of the given interpolation data domain [";
        error_str += std::to_string(this->interp_map_2D[data_key].min_x);
        error_str += " , ";
        error_str += std::to_string(this->interp_map_2D[data_key].max_x);
        error_str += "]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  2. bounds error (y_interp)
    if (
        interp_y < this->interp_map_2D[data_key].min_y or
        interp_y > this->interp_map_2D[data_key].max_y
    ) {
        std::string error_str = "ERROR:  Interpolator::interp2D()  ";
        error_str += "interpolation value interp_y = ";
        error_str += std::to_string(interp_y);
        error_str += " is outside of the given interpolation data domain [";
        error_str += std::to_string(this->interp_map_2D[data_key].min_y);
        error_str += " , ";
        error_str += std::to_string(this->interp_map_2D[data_key].max_y);
        error_str += "]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkBounds2D() */
```

### 4.10.3.3 __checkDataKey1D()

```
void Interpolator::__checkDataKey1D (
              int data_key )  [private]
```

Helper method to check if given data key (1D) is already in use.

**Parameters**

| | |
|---|---|
| *data_key* | The key associated with the given 1D interpolation data. |

```
{
    if (this->interp_map_1D.count(data_key) > 0) {
        std::string error_str = "ERROR:  Interpolator::addData1D()  ";
        error_str += "data key (1D) ";
        error_str += std::to_string(data_key);
        error_str += " is already in use";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkDataKey1D() */
```

#### 4.10.3.4 __checkDataKey2D()

```
void Interpolator::__checkDataKey2D (
            int data_key )  [private]
```

Helper method to check if given data key (2D) is already in use.

**Parameters**

| | |
|---|---|
| *data_key* | The key associated with the given 2D interpolation data. |

```
{
    if (this->interp_map_2D.count(data_key) > 0) {
        std::string error_str = "ERROR:  Interpolator::addData2D()  ";
        error_str += "data key (2D) ";
        error_str += std::to_string(data_key);
        error_str += " is already in use";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkDataKey2D() */
```

#### 4.10.3.5 __getDataStringMatrix()

```
std::vector< std::vector< std::string > > Interpolator::__getDataStringMatrix (
            std::string path_2_data )  [private]
```

```
{
    //  1. create input file stream
    std::ifstream ifs;
    ifs.open(path_2_data);

    //  2. check that open() worked
    if (not ifs.is_open()) {
        std::string error_str = "ERROR:  Interpolator::__getDataStringMatrix()  ";
        error_str += " failed to open ";
        error_str += path_2_data;

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  3. read file line by line
    bool is_header = true;
    std::string line;
    std::vector<std::string> line_split_vec;
    std::vector<std::vector<std::string» string_matrix;

    while (not ifs.eof()) {
        std::getline(ifs, line);

        if (is_header) {
            is_header = false;
            continue;
        }

        line_split_vec = this->__splitCommaSeparatedString(line);

        if (not line_split_vec.empty()) {
            string_matrix.push_back(line_split_vec);
        }
    }

    ifs.close();
    return string_matrix;
}   /* __getDataStringMatrix() */
```

#### 4.10.3.6 __getInterpolationIndex()

```
int Interpolator::__getInterpolationIndex (
            double interp_x,
            std::vector< double > * x_vec_ptr ) [private]
```

Helper method to get appropriate interpolation index into given vector.

**Parameters**

| | |
|---|---|
| *interp_x* | The query value to be interpolated. |
| *x_vec_ptr* | A pointer to the given vector of interpolation data. |

**Returns**

The appropriate interpolation index into the given vector.

```
{
    int idx = 0;
    while (
        not (interp_x >= x_vec_ptr->at(idx) and interp_x <= x_vec_ptr->at(idx + 1))
    ) {
        idx++;
    }

    return idx;
}   /* __getInterpolationIndex() */
```

#### 4.10.3.7 __isNonNumeric()

```
bool Interpolator::__isNonNumeric (
            std::string str ) [private]
```

Helper method to determine if given string is non-numeric (i.e., contains.

**Parameters**

| | |
|---|---|
| *str* | The string being tested. |

**Returns**

A boolean indicating if the given string is non-numeric.

```
{
    for (size_t i = 0; i < str.size(); i++) {;
        if (isalpha(str[i])) {
            return true;
        }
    }

    return false;
}   /* __isAlpha() */
```

#### 4.10.3.8 __readData1D()

```
void Interpolator::__readData1D (
            int data_key,
            std::string path_2_data ) [private]
```

Helper method to read the given 1D interpolation data into Interpolator.

**Parameters**

| | |
|---|---|
| *data_key* | A key associated with the given interpolation data. |
| *path_2_data* | The path (either relative or absolute) to the given interpolation data. |

```
{
    //  1. get string matrix
    std::vector<std::vector<std::string» string_matrix =
        this->__getDataStringMatrix(path_2_data);

    //  2. read string matrix contents into 1D interpolation struct
    InterpolatorStruct1D interp_struct_1D;

    interp_struct_1D.n_points = string_matrix.size();
    interp_struct_1D.x_vec.resize(interp_struct_1D.n_points, 0);
    interp_struct_1D.y_vec.resize(interp_struct_1D.n_points, 0);

    for (int i = 0; i < interp_struct_1D.n_points; i++) {
        try {
            interp_struct_1D.x_vec[i] = std::stod(string_matrix[i][0]);
            interp_struct_1D.y_vec[i] = std::stod(string_matrix[i][1]);
        }

        catch (...) {
            this->__throwReadError(path_2_data, 1);
        }
    }

    interp_struct_1D.min_x = interp_struct_1D.x_vec[0];
    interp_struct_1D.max_x = interp_struct_1D.x_vec[interp_struct_1D.n_points - 1];

    //  3. write struct to map
    this->interp_map_1D.insert(
        std::pair<int, InterpolatorStruct1D>(data_key, interp_struct_1D)
    );

    /*
    // ==== TEST PRINT ==== //
    std::cout « std::endl;
    std::cout « path_2_data « std::endl;
    std::cout « "--------" « std::endl;

    std::cout « "n_points: " « this->interp_map_1D[data_key].n_points « std::endl;

    std::cout « "x_vec: [";
    for (
        int i = 0;
        i < this->interp_map_1D[data_key].n_points;
        i++
    ) {
        std::cout « this->interp_map_1D[data_key].x_vec[i] « ", ";
    }
    std::cout « "]" « std::endl;

    std::cout « "y_vec: [";
    for (
        int i = 0;
        i < this->interp_map_1D[data_key].n_points;
        i++
    ) {
        std::cout « this->interp_map_1D[data_key].y_vec[i] « ", ";
    }
    std::cout « "]" « std::endl;

    std::cout « std::endl;
    // ==== END TEST PRINT ==== //
    //*/

    return;
}   /* __readData1D() */
```

#### 4.10.3.9 __readData2D()

```
void Interpolator::__readData2D (
            int data_key,
            std::string path_2_data )  [private]
```

Helper method to read the given 2D interpolation data into Interpolator.

**Parameters**

| | |
|---|---|
| *data_key* | A key associated with the given interpolation data. |
| *path_2_data* | The path (either relative or absolute) to the given interpolation data. |

```
{
    //  1. get string matrix
    std::vector<std::vector<std::string» string_matrix =
        this->__getDataStringMatrix(path_2_data);

    //  2. read string matrix contents into 2D interpolation map
    InterpolatorStruct2D interp_struct_2D;

    interp_struct_2D.n_rows = string_matrix.size() - 1;
    interp_struct_2D.n_cols = string_matrix[0].size() - 1;

    interp_struct_2D.x_vec.resize(interp_struct_2D.n_cols, 0);
    interp_struct_2D.y_vec.resize(interp_struct_2D.n_rows, 0);

    interp_struct_2D.z_matrix.resize(interp_struct_2D.n_rows, {});

    for (int i = 0; i < interp_struct_2D.n_rows; i++) {
        interp_struct_2D.z_matrix[i].resize(interp_struct_2D.n_cols, 0);
    }

    for (size_t i = 1; i < string_matrix[0].size(); i++) {
        try {
            interp_struct_2D.x_vec[i - 1] = std::stod(string_matrix[0][i]);
        }

        catch (...) {
            this->__throwReadError(path_2_data, 2);
        }
    }

    interp_struct_2D.min_x = interp_struct_2D.x_vec[0];
    interp_struct_2D.max_x = interp_struct_2D.x_vec[interp_struct_2D.n_cols - 1];

    for (size_t i = 1; i < string_matrix.size(); i++) {
        try {
            interp_struct_2D.y_vec[i - 1] = std::stod(string_matrix[i][0]);
        }

        catch (...) {
            this->__throwReadError(path_2_data, 2);
        }
    }

    interp_struct_2D.min_y = interp_struct_2D.y_vec[0];
    interp_struct_2D.max_y = interp_struct_2D.y_vec[interp_struct_2D.n_rows - 1];

    for (size_t i = 1; i < string_matrix.size(); i++) {
        for (size_t j = 1; j < string_matrix[0].size(); j++) {
            try {
                interp_struct_2D.z_matrix[i - 1][j - 1] = std::stod(string_matrix[i][j]);
            }

            catch (...) {
                this->__throwReadError(path_2_data, 2);
            }
        }
    }

    //  3. write struct to map
    this->interp_map_2D.insert(
        std::pair<int, InterpolatorStruct2D>(data_key, interp_struct_2D)
    );

    /*
    // ==== TEST PRINT ==== //
    std::cout « std::endl;
    std::cout « path_2_data « std::endl;
```

```
    std::cout « "--------" « std::endl;

    std::cout « "n_rows: " « this->interp_map_2D[data_key].n_rows « std::endl;
    std::cout « "n_cols: " « this->interp_map_2D[data_key].n_cols « std::endl;

    std::cout « "x_vec: [";
    for (
        int i = 0;
        i < this->interp_map_2D[data_key].n_cols;
        i++
    ) {
        std::cout « this->interp_map_2D[data_key].x_vec[i] « ", ";
    }
    std::cout « "]" « std::endl;

    std::cout « "y_vec: [";
    for (
        int i = 0;
        i < this->interp_map_2D[data_key].n_rows;
        i++
    ) {
        std::cout « this->interp_map_2D[data_key].y_vec[i] « ", ";
    }
    std::cout « "]" « std::endl;

    std::cout « "z_matrix:" « std::endl;
    for (
        int i = 0;
        i < this->interp_map_2D[data_key].n_rows;
        i++
    ) {
        std::cout « "\t[";

        for (
            int j = 0;
            j < this->interp_map_2D[data_key].n_cols;
            j++
        ) {
            std::cout « this->interp_map_2D[data_key].z_matrix[i][j] « ", ";
        }

        std::cout « "]" « std::endl;
    }
    std::cout « std::endl;

    std::cout « std::endl;
    // ==== END TEST PRINT ==== //
    //*/

    return;
}   /* __readData2D() */
```

### 4.10.3.10 __splitCommaSeparatedString()

```
std::vector< std::string > Interpolator::__splitCommaSeparatedString (
            std::string str,
            std::string break_str = "||" )   [private]
```

Helper method to split a comma-separated string into a vector of substrings.

**Parameters**

| | |
|---|---|
| *str* | The string to be split. |
| *break_str* | A string which triggers the function to break. What has been split up to the point of the break is then returned. |

**Returns**

A vector of substrings, which follows from splitting the given string in a comma separated manner.

```
{
    std::vector<std::string> str_split_vec;

    size_t idx = 0;
    std::string substr;

    while ((idx = str.find(',')) != std::string::npos) {
        substr = str.substr(0, idx);

        if (substr == break_str) {
            break;
        }

        str_split_vec.push_back(substr);

        str.erase(0, idx + 1);
    }

    return str_split_vec;
}   /* __splitCommaSeparatedString() */
```

#### 4.10.3.11 __throwReadError()

```
void Interpolator::__throwReadError (
            std::string path_2_data,
            int dimensions )  [private]
```

Helper method to throw a read error whenever non-numeric data is encountered where only numeric data should be.

**Parameters**

| | |
|---|---|
| *path_2_data* | The path (either relative or absolute) to the given interpolation data. |
| *dimensions* | The dimensionality of the data being read. |

```
{
    std::string error_str = "ERROR:  Interpolator::addData";
    error_str += std::to_string(dimensions);
    error_str += "D()  ";
    error_str += " failed to read ";
    error_str += path_2_data;
    error_str += " (this is probably a std::stod() error; is there non-numeric ";
    error_str += "data where only numeric data should be?)";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);

    return;
}   /* __throwReadError() */
```

#### 4.10.3.12 addData1D()

```
void Interpolator::addData1D (
            int data_key,
            std::string path_2_data )
```

Method to add 1D interpolation data to the Interpolator.

**Parameters**

| | |
|---|---|
| *data_key* | A key used to index into the Interpolator. |
| *path_2_data* | A path (either relative or absolute) to the given 1D interpolation data. |

```
{
    //  1. check key
    this->__checkDataKey1D(data_key);

    //  2. read data into map
    this->__readData1D(data_key, path_2_data);

    //  3. record path
    this->path_map_1D.insert(std::pair<int, std::string>(data_key, path_2_data));

    return;
}   /* addData1D() */
```

#### 4.10.3.13 addData2D()

```
void Interpolator::addData2D (
            int data_key,
            std::string path_2_data )
```

Method to add 2D interpolation data to the Interpolator.

**Parameters**

| | |
|---|---|
| *data_key* | A key used to index into the Interpolator. |
| *path_2_data* | A path (either relative or absolute) to the given 2D interpolation data. |

```
{
    //  1. check key
    this->__checkDataKey2D(data_key);

    //  2. read data into map
    this->__readData2D(data_key, path_2_data);

    //  3. record path
    this->path_map_2D.insert(std::pair<int, std::string>(data_key, path_2_data));

    return;
}   /* addData2D() */
```

#### 4.10.3.14 interp1D()

```
double Interpolator::interp1D (
            int data_key,
            double interp_x )
```

Method to perform a 1D interpolation.

**Parameters**

| | |
|---|---|
| *data_key* | A key used to index into the Interpolator. |
| *interp←_x* | The query value to be interpolated. If this value is outside the domain of the associated interpolation data, then an error will occur. |

**Returns**

An interpolation of the given query value.

```
{
    // 1. check bounds
    this->__checkBounds1D(data_key, interp_x);

    // 2. get interpolation index
    int idx = this->__getInterpolationIndex(
        interp_x,
        &(this->interp_map_1D[data_key].x_vec)
    );

    // 3. perform interpolation
    double x_0 = this->interp_map_1D[data_key].x_vec[idx];
    double x_1 = this->interp_map_1D[data_key].x_vec[idx + 1];

    double y_0 = this->interp_map_1D[data_key].y_vec[idx];
    double y_1 = this->interp_map_1D[data_key].y_vec[idx + 1];

    double interp_y = ((y_1 - y_0) / (x_1 - x_0)) * (interp_x - x_0) + y_0;

    return interp_y;
}   /* interp1D() */
```

#### 4.10.3.15 interp2D()

```
double Interpolator::interp2D (
            int data_key,
            double interp_x,
            double interp_y )
```

Method to perform a 2D interpolation.

**Parameters**

| | |
|---|---|
| *data_key* | A key used to index into the Interpolator. |
| *interp_x* | The first query value to be interpolated. If this value is outside the domain of the associated interpolation data, then an error will occur. |
| *interp_y* | The second query value to be interpolated. If this value is outside the domain of the associated interpolation data, then an error will occur. |

**Returns**

An interpolation of the given query values.

```
{
    // 1. check bounds
    this->__checkBounds2D(data_key, interp_x, interp_y);

    // 2. get interpolation indices
    int idx_x = this->__getInterpolationIndex(
        interp_x,
        &(this->interp_map_2D[data_key].x_vec)
    );

    int idx_y = this->__getInterpolationIndex(
        interp_y,
        &(this->interp_map_2D[data_key].y_vec)
    );

    // 3. perform first horizontal interpolation
    double x_0 = this->interp_map_2D[data_key].x_vec[idx_x];
    double x_1 = this->interp_map_2D[data_key].x_vec[idx_x + 1];

    double z_0 = this->interp_map_2D[data_key].z_matrix[idx_y][idx_x];
    double z_1 = this->interp_map_2D[data_key].z_matrix[idx_y][idx_x + 1];
```

```

    double interp_z_0 = ((z_1 - z_0) / (x_1 - x_0)) * (interp_x - x_0) + z_0;

    //  4. perform second horizontal interpolation
    z_0 = this->interp_map_2D[data_key].z_matrix[idx_y + 1][idx_x];
    z_1 = this->interp_map_2D[data_key].z_matrix[idx_y + 1][idx_x + 1];

    double interp_z_1 = ((z_1 - z_0) / (x_1 - x_0)) * (interp_x - x_0) + z_0;

    //  5. perform vertical interpolation
    double y_0 = this->interp_map_2D[data_key].y_vec[idx_y];
    double y_1 = this->interp_map_2D[data_key].y_vec[idx_y + 1];

    double interp_z =
        ((interp_z_1 - interp_z_0) / (y_1 - y_0)) * (interp_y - y_0) + interp_z_0;

    return interp_z;
}   /* interp2D() */
```

## 4.10.4 Member Data Documentation

### 4.10.4.1 interp_map_1D

`std::map<int, InterpolatorStruct1D> Interpolator::interp_map_1D`

A map <int, InterpolatorStruct1D> of given 1D interpolation data.

### 4.10.4.2 interp_map_2D

`std::map<int, InterpolatorStruct2D> Interpolator::interp_map_2D`

A map <int, InterpolatorStruct2D> of given 2D interpolation data.

### 4.10.4.3 path_map_1D

`std::map<int, std::string> Interpolator::path_map_1D`

A map <int, string> of the paths (either relative or absolute) to the given 1D interpolation data.

### 4.10.4.4 path_map_2D

`std::map<int, std::string> Interpolator::path_map_2D`

A map <int, string> of the paths (either relative or absolute) to the given 2D interpolation data.

The documentation for this class was generated from the following files:

- header/Interpolator.h
- source/Interpolator.cpp

## 4.11 InterpolatorStruct1D Struct Reference

A struct which holds two parallel vectors for use in 1D interpolation.

```
#include <Interpolator.h>
```

### Public Attributes

- int n_points = 0

  *The number of data points in each parallel vector.*
- std::vector< double > x_vec = {}

  *A vector of independent data.*
- double min_x = 0

  *The minimum (i.e., first) element of x_vec.*
- double max_x = 0

  *The maximum (i.e., last) element of x_vec.*
- std::vector< double > y_vec = {}

  *A vector of dependent data.*

### 4.11.1 Detailed Description

A struct which holds two parallel vectors for use in 1D interpolation.

### 4.11.2 Member Data Documentation

#### 4.11.2.1 max_x

```
double InterpolatorStruct1D::max_x = 0
```

The maximum (i.e., last) element of x_vec.

#### 4.11.2.2 min_x

```
double InterpolatorStruct1D::min_x = 0
```

The minimum (i.e., first) element of x_vec.

#### 4.11.2.3 n_points

```
int InterpolatorStruct1D::n_points = 0
```

The number of data points in each parallel vector.

#### 4.11.2.4 x_vec

```
std::vector<double> InterpolatorStruct1D::x_vec = {}
```

A vector of independent data.

#### 4.11.2.5 y_vec

```
std::vector<double> InterpolatorStruct1D::y_vec = {}
```

A vector of dependent data.

The documentation for this struct was generated from the following file:

- header/Interpolator.h

## 4.12 InterpolatorStruct2D Struct Reference

A struct which holds two parallel vectors and a matrix for use in 2D interpolation.

```
#include <Interpolator.h>
```

### Public Attributes

- int n_rows = 0

    *The number of rows in the matrix (also the length of y_vec)*
- int n_cols = 0

    *The number of cols in the matrix (also the length of x_vec)*
- std::vector< double > x_vec = {}

    *A vector of independent data (columns).*
- double min_x = 0

    *The minimum (i.e., first) element of x_vec.*
- double max_x = 0

    *The maximum (i.e., last) element of x_vec.*
- std::vector< double > y_vec = {}

    *A vector of independent data (rows).*
- double min_y = 0

    *The minimum (i.e., first) element of y_vec.*
- double max_y = 0

    *The maximum (i.e., last) element of y_vec.*
- std::vector< std::vector< double > > z_matrix = {}

    *A matrix of dependent data.*

### 4.12.1 Detailed Description

A struct which holds two parallel vectors and a matrix for use in 2D interpolation.

### 4.12.2 Member Data Documentation

#### 4.12.2.1 max_x

```
double InterpolatorStruct2D::max_x = 0
```

The maximum (i.e., last) element of x_vec.

#### 4.12.2.2 max_y

```
double InterpolatorStruct2D::max_y = 0
```

The maximum (i.e., last) element of y_vec.

#### 4.12.2.3 min_x

```
double InterpolatorStruct2D::min_x = 0
```

The minimum (i.e., first) element of x_vec.

#### 4.12.2.4 min_y

```
double InterpolatorStruct2D::min_y = 0
```

The minimum (i.e., first) element of y_vec.

#### 4.12.2.5 n_cols

```
int InterpolatorStruct2D::n_cols = 0
```

The number of cols in the matrix (also the length of x_vec)

#### 4.12.2.6 n_rows

```
int InterpolatorStruct2D::n_rows = 0
```

The number of rows in the matrix (also the length of y_vec)

#### 4.12.2.7 x_vec

```
std::vector<double> InterpolatorStruct2D::x_vec = {}
```

A vector of independent data (columns).

#### 4.12.2.8 y_vec

```
std::vector<double> InterpolatorStruct2D::y_vec = {}
```

A vector of independent data (rows).

#### 4.12.2.9 z_matrix

```
std::vector<std::vector<double> > InterpolatorStruct2D::z_matrix = {}
```

A matrix of dependent data.

The documentation for this struct was generated from the following file:

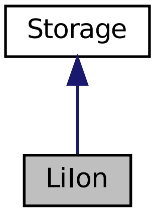
- header/Interpolator.h

## 4.13 LiIon Class Reference

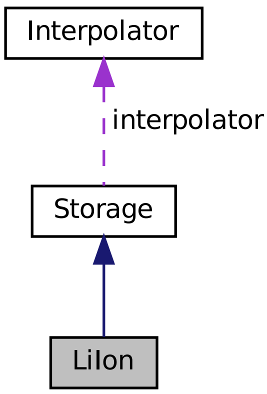
A derived class of Storage which models energy storage by way of lithium-ion batteries.

```
#include <LiIon.h>
```

Inheritance diagram for LiIon:




Collaboration diagram for LiIon:




### Public Member Functions

- LiIon (void)

    *Constructor (dummy) for the LiIon class.*
- LiIon (int, double, LiIonInputs)

    *Constructor (intended) for the LiIon class.*
- void handleReplacement (int)

    *Method to handle asset replacement and capital cost incursion, if applicable.*
- double getAvailablekW (double)

*Method to get the discharge power currently available from the asset.*
- double getAcceptablekW (double)

  *Method to get the charge power currently acceptable by the asset.*
- void commitCharge (int, double, double)

  *Method which takes in the charging power for the current timestep and records.*
- double commitDischarge (int, double, double, double)

  *Method which takes in the discharging power for the current timestep and records. Returns the load remaining after discharge.*
- ∼LiIon (void)

  *Destructor for the LiIon class.*

## Public Attributes

- bool power_degradation_flag

  *A flag which indicates whether or not power degradation should be modelled.*
- double dynamic_energy_capacity_kWh

  *The dynamic (i.e. degrading) energy capacity [kWh] of the asset.*
- double dynamic_power_capacity_kW

  *The dynamic (i.e. degrading) power capacity [kW] of the asset.*
- double SOH

  *The state of health of the asset.*
- double replace_SOH

  *The state of health at which the asset is considered "dead" and must be replaced.*
- double degradation_alpha

  *A dimensionless acceleration coefficient used in modelling energy capacity degradation.*
- double degradation_beta

  *A dimensionless acceleration exponent used in modelling energy capacity degradation.*
- double degradation_B_hat_cal_0

  *A reference (or base) pre-exponential factor [1/sqrt(hrs)] used in modelling energy capacity degradation.*
- double degradation_r_cal

  *A dimensionless constant used in modelling energy capacity degradation.*
- double degradation_Ea_cal_0

  *A reference (or base) activation energy [J/mol] used in modelling energy capacity degradation.*
- double degradation_a_cal

  *A pre-exponential factor [J/mol] used in modelling energy capacity degradation.*
- double degradation_s_cal

  *A dimensionless constant used in modelling energy capacity degradation.*
- double gas_constant_JmolK

  *The universal gas constant [J/mol.K].*
- double temperature_K

  *The absolute environmental temperature [K] of the lithium ion battery energy storage system.*
- double init_SOC

  *The initial state of charge of the asset.*
- double min_SOC

  *The minimum state of charge of the asset. Will toggle is_depleted when reached.*
- double hysteresis_SOC

  *The state of charge the asset must achieve to toggle is_depleted.*
- double max_SOC

  *The maximum state of charge of the asset.*
- double charging_efficiency

*The charging efficiency of the asset.*

- double discharging_efficiency

  *The discharging efficiency of the asset.*

- std::vector< double > SOH_vec

  *A vector of the state of health of the asset at each point in the modelling time series.*

## Private Member Functions

- void __checkInputs (LiIonInputs)

  *Helper method to check inputs to the LiIon constructor.*

- double __getGenericCapitalCost (void)

  *Helper method to generate a generic lithium ion battery energy storage system capital cost.*

- double __getGenericOpMaintCost (void)

  *Helper method to generate a generic lithium ion battery energy storage system operation and maintenance cost. This is a cost incurred per unit energy charged/discharged.*

- void __toggleDepleted (void)

  *Helper method to toggle the is_depleted attribute of LiIon.*

- void __handleDegradation (int, double, double)

  *Helper method to apply degradation modelling and update attributes.*

- void __modelDegradation (double, double)

  *Helper method to model energy capacity degradation as a function of operating state.*

- double __getBcal (double)

  *Helper method to compute and return the base pre-exponential factor for a given state of charge.*

- double __getEacal (double)

  *Helper method to compute and return the activation energy value for a given state of charge.*

- void __writeSummary (std::string)

  *Helper method to write summary results for LiIon.*

- void __writeTimeSeries (std::string, std::vector< double > ∗, int=-1)

  *Helper method to write time series results for LiIon.*

## 4.13.1 Detailed Description

A derived class of Storage which models energy storage by way of lithium-ion batteries.

## 4.13.2 Constructor & Destructor Documentation

#### 4.13.2.1 LiIon() [1/2]

```
LiIon::LiIon (
        void )
```

Constructor (dummy) for the LiIon class.

```
674 {
675     return;
676 }   /* LiIon() */
```

#### 4.13.2.2 LiIon() [2/2]

```
LiIon::LiIon (
        int n_points,
        double n_years,
        LiIonInputs liion_inputs )
```

Constructor (intended) for the LiIon class.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *n_years* | The number of years being modelled. |
| *liion_inputs* | A structure of LiIon constructor inputs. |

```
  :
Storage(
    n_points,
    n_years,
    liion_inputs.storage_inputs
)
{
    //  1. check inputs
    this->__checkInputs(liion_inputs);

    //  2. set attributes
    this->type = StorageType :: LIION;
    this->type_str = "LIION";

    this->dynamic_energy_capacity_kWh = this->energy_capacity_kWh;
    this->dynamic_power_capacity_kW = this->power_capacity_kW;

    this->SOH = 1;
    this->power_degradation_flag = liion_inputs.power_degradation_flag;
    this->replace_SOH = liion_inputs.replace_SOH;

    this->degradation_alpha = liion_inputs.degradation_alpha;
    this->degradation_beta = liion_inputs.degradation_beta;
    this->degradation_B_hat_cal_0 = liion_inputs.degradation_B_hat_cal_0;
    this->degradation_r_cal = liion_inputs.degradation_r_cal;
    this->degradation_Ea_cal_0 = liion_inputs.degradation_Ea_cal_0;
    this->degradation_a_cal = liion_inputs.degradation_a_cal;
    this->degradation_s_cal = liion_inputs.degradation_s_cal;
    this->gas_constant_JmolK = liion_inputs.gas_constant_JmolK;
    this->temperature_K = liion_inputs.temperature_K;

    this->init_SOC = liion_inputs.init_SOC;
    this->charge_kWh = this->init_SOC * this->energy_capacity_kWh;

    this->min_SOC = liion_inputs.min_SOC;
    this->hysteresis_SOC = liion_inputs.hysteresis_SOC;
    this->max_SOC = liion_inputs.max_SOC;

    this->charging_efficiency = liion_inputs.charging_efficiency;
    this->discharging_efficiency = liion_inputs.discharging_efficiency;

    if (liion_inputs.capital_cost < 0) {
        this->capital_cost = this->__getGenericCapitalCost();
    }
    else {
        this->capital_cost = liion_inputs.capital_cost;
    }

    if (liion_inputs.operation_maintenance_cost_kWh < 0) {
        this->operation_maintenance_cost_kWh = this->__getGenericOpMaintCost();
    }
    else {
        this->operation_maintenance_cost_kWh =
            liion_inputs.operation_maintenance_cost_kWh;
    }

    if (not this->is_sunk) {
        this->capital_cost_vec[0] = this->capital_cost;
    }

    this->SOH_vec.resize(this->n_points, 0);

    //  3. construction print
```

```
    if (this->print_flag) {
        std::cout « "LiIon object constructed at " « this « std::endl;
    }

    return;
}   /* LiIon() */
```

#### 4.13.2.3 ∼LiIon()

```
LiIon::∼LiIon (
              void )
```

Destructor for the LiIon class.

```
{
    //  1. destruction print
    if (this->print_flag) {
        std::cout « "LiIon object at " « this « " destroyed" « std::endl;
    }

    return;
}   /* ~LiIon() */
```

### 4.13.3 Member Function Documentation

#### 4.13.3.1 __checkInputs()

```
void LiIon::__checkInputs (
              LiIonInputs liion_inputs )   [private]
```

Helper method to check inputs to the LiIon constructor.

**Parameters**

| | |
|---|---|
| *liion_inputs* | A structure of LiIon constructor inputs. |

```
{
    //  1. check replace_SOH
    if (liion_inputs.replace_SOH < 0 or liion_inputs.replace_SOH > 1) {
        std::string error_str = "ERROR:  LiIon():  replace_SOH must be in the closed ";
        error_str += "interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  2. check init_SOC
    if (liion_inputs.init_SOC < 0 or liion_inputs.init_SOC > 1) {
        std::string error_str = "ERROR:  LiIon():  init_SOC must be in the closed ";
        error_str += "interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  3. check min_SOC
```

```
    if (liion_inputs.min_SOC < 0 or liion_inputs.min_SOC > 1) {
        std::string error_str = "ERROR:  LiIon():  min_SOC must be in the closed ";
        error_str += "interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

     //  4. check hysteresis_SOC
     if (liion_inputs.hysteresis_SOC < 0 or liion_inputs.hysteresis_SOC > 1) {
         std::string error_str = "ERROR:  LiIon():  hysteresis_SOC must be in the closed ";
         error_str += "interval [0, 1]";

         #ifdef _WIN32
             std::cout « error_str « std::endl;
         #endif

         throw std::invalid_argument(error_str);
     }

     //  5. check max_SOC
     if (liion_inputs.max_SOC < 0 or liion_inputs.max_SOC > 1) {
         std::string error_str = "ERROR:  LiIon():  max_SOC must be in the closed ";
         error_str += "interval [0, 1]";

         #ifdef _WIN32
             std::cout « error_str « std::endl;
         #endif

         throw std::invalid_argument(error_str);
     }

     //  6. check charging_efficiency
     if (liion_inputs.charging_efficiency <= 0 or liion_inputs.charging_efficiency > 1) {
         std::string error_str = "ERROR:  LiIon():  charging_efficiency must be in the ";
         error_str += "half-open interval (0, 1]";

         #ifdef _WIN32
             std::cout « error_str « std::endl;
         #endif

         throw std::invalid_argument(error_str);
     }

     //  7. check discharging_efficiency
     if (
         liion_inputs.discharging_efficiency <= 0 or
         liion_inputs.discharging_efficiency > 1
     ) {
         std::string error_str = "ERROR:  LiIon():  discharging_efficiency must be in the ";
         error_str += "half-open interval (0, 1]";

         #ifdef _WIN32
             std::cout « error_str « std::endl;
         #endif

         throw std::invalid_argument(error_str);
     }

     //  8. check degradation_alpha
     if (liion_inputs.degradation_alpha <= 0) {
         std::string error_str = "ERROR:  LiIon():  degradation_alpha must be > 0";

         #ifdef _WIN32
             std::cout « error_str « std::endl;
         #endif

         throw std::invalid_argument(error_str);
     }

     //  9. check degradation_beta
     if (liion_inputs.degradation_beta <= 0) {
         std::string error_str = "ERROR:  LiIon():  degradation_beta must be > 0";

         #ifdef _WIN32
             std::cout « error_str « std::endl;
         #endif

         throw std::invalid_argument(error_str);
     }

     //  10. check degradation_B_hat_cal_0
     if (liion_inputs.degradation_B_hat_cal_0 <= 0) {
         std::string error_str = "ERROR:  LiIon():  degradation_B_hat_cal_0 must be > 0";
```

```

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  11. check degradation_r_cal
    if (liion_inputs.degradation_r_cal < 0) {
        std::string error_str = "ERROR:  LiIon():  degradation_r_cal must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  12. check degradation_Ea_cal_0
    if (liion_inputs.degradation_Ea_cal_0 <= 0) {
        std::string error_str = "ERROR:  LiIon():  degradation_Ea_cal_0 must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  13. check degradation_a_cal
    if (liion_inputs.degradation_a_cal < 0) {
        std::string error_str = "ERROR:  LiIon():  degradation_a_cal must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  14. check degradation_s_cal
    if (liion_inputs.degradation_s_cal < 0) {
        std::string error_str = "ERROR:  LiIon():  degradation_s_cal must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  15. check gas_constant_JmolK
    if (liion_inputs.gas_constant_JmolK <= 0) {
        std::string error_str = "ERROR:  LiIon():  gas_constant_JmolK must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  16. check temperature_K
    if (liion_inputs.temperature_K < 0) {
        std::string error_str = "ERROR:  LiIon():  temperature_K must be >= 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkInputs() */
```

#### 4.13.3.2 __getBcal()

```
double LiIon::__getBcal (
            double SOC )   [private]
```

Helper method to compute and return the base pre-exponential factor for a given state of charge.

Ref: Truelove [2023a]

**Parameters**

| | |
|---|---|
| *SOC* | The current state of charge of the asset. |

**Returns**

The base pre-exponential factor for the given state of charge.

```
{
    double B_cal = this->degradation_B_hat_cal_0 *
        exp(this->degradation_r_cal * SOC);

    return B_cal;
}   /* __getBcal() */
```

#### 4.13.3.3 __getEacal()

```
double LiIon::__getEacal (
              double SOC )  [private]
```

Helper method to compute and return the activation energy value for a given state of charge.

Ref: Truelove [2023a]

**Parameters**

| | |
|---|---|
| *SOC* | The current state of charge of the asset. |

**Returns**

The activation energy value for the given state of charge.

```
{
    double Ea_cal = this->degradation_Ea_cal_0;

    Ea_cal -= this->degradation_a_cal *
        (exp(this->degradation_s_cal * SOC) - 1);

    return Ea_cal;
}   /* __getEacal( */
```

#### 4.13.3.4 __getGenericCapitalCost()

```
double LiIon::__getGenericCapitalCost (
              void  )  [private]
```

Helper method to generate a generic lithium ion battery energy storage system capital cost.

This model was obtained by way of surveying an assortment of published lithium ion battery energy storage system costs, and then constructing a best fit model. Note that this model expresses cost in terms of Canadian dollars [CAD].

**Returns**

A generic capital cost for the lithium ion battery energy storage system [CAD].

```
{
    double capital_cost_per_kWh = 250 * pow(this->energy_capacity_kWh, -0.15) + 650;

    return capital_cost_per_kWh * this->energy_capacity_kWh;
}   /* __getGenericCapitalCost() */
```

#### 4.13.3.5 __getGenericOpMaintCost()

```
double LiIon::__getGenericOpMaintCost (
            void ) [private]
```

Helper method to generate a generic lithium ion battery energy storage system operation and maintenance cost. This is a cost incurred per unit energy charged/discharged.

This model was obtained by way of surveying an assortment of published lithium ion battery energy storage system costs, and then constructing a best fit model. Note that this model expresses cost in terms of Canadian dollars [CAD/kWh].

**Returns**

A generic operation and maintenance cost, per unit energy charged/discharged, for the lithium ion battery energy storage system [CAD/kWh].

```
{
    return 0.01;
}   /* __getGenericOpMaintCost() */
```

#### 4.13.3.6 __handleDegradation()

```
void LiIon::__handleDegradation (
            int timestep,
            double dt_hrs,
            double charging_discharging_kW ) [private]
```

Helper method to apply degradation modelling and update attributes.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *charging_discharging_kW* | The charging/discharging power [kw] being sent to the asset. |

```
{
    //  1. model degradation
    this->__modelDegradation(dt_hrs, charging_discharging_kW);

    //  2. update and record
    this->SOH_vec[timestep] = this->SOH;
    this->dynamic_energy_capacity_kWh = this->SOH * this->energy_capacity_kWh;

    if (this->power_degradation_flag) {
        this->dynamic_power_capacity_kW = this->SOH * this->power_capacity_kW;
    }
```

```
    return;
} /* __handleDegradation() */
```

### 4.13.3.7 __modelDegradation()

```
void LiIon::__modelDegradation (
            double dt_hrs,
            double charging_discharging_kW ) [private]
```

Helper method to model energy capacity degradation as a function of operating state.

Ref: Truelove [2023a]

**Parameters**

| | |
|---|---|
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *charging_discharging_kW* | The charging/discharging power [kw] being sent to the asset. |

```
{
    // 1. compute SOC
    double SOC = this->charge_kWh / this->energy_capacity_kWh;

    // 2. compute C-rate and corresponding acceleration factor
    double C_rate = charging_discharging_kW / this->power_capacity_kW;

    double C_acceleration_factor =
        1 + this->degradation_alpha * pow(C_rate, this->degradation_beta);

    // 3. compute dSOH / dt
    double B_cal = __getBcal(SOC);
    double Ea_cal = __getEacal(SOC);

    double dSOH_dt = B_cal *
        exp((-1 * Ea_cal) / (this->gas_constant_JmolK * this->temperature_K));

    dSOH_dt *= dSOH_dt;
    dSOH_dt *= 1 / (2 * this->SOH);
    dSOH_dt *= C_acceleration_factor;

    // 4. update state of health
    this->SOH -= dSOH_dt * dt_hrs;

    return;
} /* __modelDegradation() */
```

### 4.13.3.8 __toggleDepleted()

```
void LiIon::__toggleDepleted (
            void ) [private]
```

Helper method to toggle the is_depleted attribute of LiIon.

```
{
    if (this->is_depleted) {
        double hysteresis_charge_kWh = this->hysteresis_SOC * this->energy_capacity_kWh;

        if (hysteresis_charge_kWh > this->dynamic_energy_capacity_kWh) {
            hysteresis_charge_kWh = this->dynamic_energy_capacity_kWh;
        }

        if (this->charge_kWh >= hysteresis_charge_kWh) {
            this->is_depleted = false;
```

```
        }
    }

    else {
        double min_charge_kWh = this->min_SOC * this->energy_capacity_kWh;

        if (this->charge_kWh <= min_charge_kWh) {
            this->is_depleted = true;
        }
    }

    return;
}   /* __toggleDepleted() */
```

#### 4.13.3.9 __writeSummary()

```
void LiIon::__writeSummary (
        std::string write_path )  [private], [virtual]
```

Helper method to write summary results for LiIon.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |

Reimplemented from Storage.

```
{
    // 1. create filestream
    write_path += "summary_results.md";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    // 2. write summary results (markdown)
    ofs « "# ";
    ofs « std::to_string(int(ceil(this->power_capacity_kW)));
    ofs « " kW ";
    ofs « std::to_string(int(ceil(this->energy_capacity_kWh)));
    ofs « " kWh LIION Summary Results\n";
    ofs « "\n--------\n\n";

    // 2.1. Storage attributes
    ofs « "## Storage Attributes\n";
    ofs « "\n";
    ofs « "Power Capacity: " « this->power_capacity_kW « " kW  \n";
    ofs « "Energy Capacity: " « this->energy_capacity_kWh « " kWh  \n";
    ofs « "\n";

    ofs « "Sunk Cost (N = 0 / Y = 1): " « this->is_sunk « "  \n";
    ofs « "Capital Cost: " « this->capital_cost « "  \n";
    ofs « "Operation and Maintenance Cost: " « this->operation_maintenance_cost_kWh
        « " per kWh charged/discharged  \n";
    ofs « "Nominal Inflation Rate (annual): " « this->nominal_inflation_annual
        « "  \n";
    ofs « "Nominal Discount Rate (annual): " « this->nominal_discount_annual
        « "  \n";
    ofs « "Real Discount Rate (annual): " « this->real_discount_annual « "  \n";

    ofs « "\n--------\n\n";

    // 2.2. LiIon attributes
    ofs « "## LiIon Attributes\n";
    ofs « "\n";

    ofs « "Charging Efficiency: " « this->charging_efficiency « "  \n";
    ofs « "Discharging Efficiency: " « this->discharging_efficiency « "  \n";
    ofs « "\n";

    ofs « "Initial State of Charge: " « this->init_SOC « "  \n";
    ofs « "Minimum State of Charge: " « this->min_SOC « "  \n";
    ofs « "Hyteresis State of Charge: " « this->hysteresis_SOC « "  \n";
    ofs « "Maximum State of Charge: " « this->max_SOC « "  \n";
```

```
    ofs « "\n";

    ofs « "Replacement State of Health: " « this->replace_SOH « "  \n";
    ofs « "\n";

    ofs « "Degradation Acceleration Coeff.: " « this->degradation_alpha « "  \n";
    ofs « "Degradation Acceleration Exp.: " « this->degradation_beta « "  \n";
    ofs « "Degradation Base Pre-Exponential Factor: "
        « this->degradation_B_hat_cal_0 « " 1/sqrt(hrs)  \n";
    ofs « "Degradation Dimensionless Constant (r_cal): "
        « this->degradation_r_cal « "  \n";
    ofs « "Degradation Base Activation Energy: "
        « this->degradation_Ea_cal_0 « " J/mol  \n";
    ofs « "Degradation Pre-Exponential Factor: "
        « this->degradation_a_cal « " J/mol  \n";
    ofs « "Degradation Dimensionless Constant (s_cal): "
        « this->degradation_s_cal « "  \n";
    ofs « "Universal Gas Constant: " « this->gas_constant_JmolK
        « " J/mol.K  \n";
    ofs « "Absolute Environmental Temperature: " « this->temperature_K « " K  \n";

    ofs « "\n--------\n\n";

    //  2.3. LiIon Results
    ofs « "## Results\n";
    ofs « "\n";

    ofs « "Net Present Cost: " « this->net_present_cost « "  \n";
    ofs « "\n";

    ofs « "Total Discharge: " « this->total_discharge_kWh
        « " kWh  \n";

    ofs « "Levellized Cost of Energy: " « this->levellized_cost_of_energy_kWh
        « " per kWh dispatched  \n";
    ofs « "\n";

    ofs « "Replacements: " « this->n_replacements « "  \n";

    ofs « "\n--------\n\n";
    ofs.close();
    return;
}   /* __writeSummary() */
```

#### 4.13.3.10 __writeTimeSeries()

```
void LiIon::__writeTimeSeries (
              std::string write_path,
              std::vector< double > * time_vec_hrs_ptr,
              int max_lines = -1 )  [private], [virtual]
```

Helper method to write time series results for LiIon.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |
| *max_lines* | The maximum number of lines of output to write. |

Reimplemented from Storage.

```
{
    //  1. create filestream
    write_path += "time_series_results.csv";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  2. write time series results (comma separated value)
    ofs « "Time (since start of data) [hrs],";
    ofs « "Charging Power [kW],";
```

```
    ofs « "Discharging Power [kW],";
    ofs « "Charge (at end of timestep) [kWh],";
    ofs « "State of Health (at end of timestep) [ ],";
    ofs « "Capital Cost (actual),";
    ofs « "Operation and Maintenance Cost (actual),";
    ofs « "\n";

    for (int i = 0; i < max_lines; i++) {
        ofs « time_vec_hrs_ptr->at(i) « ",";
        ofs « this->charging_power_vec_kW[i] « ",";
        ofs « this->discharging_power_vec_kW[i] « ",";
        ofs « this->charge_vec_kWh[i] « ",";
        ofs « this->SOH_vec[i] « ",";
        ofs « this->capital_cost_vec[i] « ",";
        ofs « this->operation_maintenance_cost_vec[i] « ",";
        ofs « "\n";
    }

    ofs.close();
    return;
}   /* __writeTimeSeries() */
```

#### 4.13.3.11 commitCharge()

```
void LiIon::commitCharge (
            int timestep,
            double dt_hrs,
            double charge_kW )  [virtual]
```

Method which takes in the charging power for the current timestep and records.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *charging_kW* | The charging power [kw] being sent to the asset. |

Reimplemented from Storage.

```
{
    //  1. record charging power
    this->charging_power_vec_kW[timestep] = charging_kW;

    //  2. update charge and record
    this->charge_kWh += this->charging_efficiency * charging_kW * dt_hrs;
    this->charge_vec_kWh[timestep] = this->charge_kWh;

    //  3. toggle depleted flag (if applicable)
    this->__toggleDepleted();

    //  4. model degradation
    this->__handleDegradation(timestep, dt_hrs, charging_kW);

    //  5. trigger replacement (if applicable)
    if (this->SOH <= this->replace_SOH) {
        this->handleReplacement(timestep);
    }

    //  6. capture operation and maintenance costs (if applicable)
    if (charging_kW > 0) {
        this->operation_maintenance_cost_vec[timestep] = charging_kW * dt_hrs *
            this->operation_maintenance_cost_kWh;
    }

    this->power_kW= 0;
    return;
}   /* commitCharge() */
```

#### 4.13.3.12 commitDischarge()

```
double LiIon::commitDischarge (
            int timestep,
            double dt_hrs,
            double discharging_kW,
            double load_kW ) [virtual]
```

Method which takes in the discharging power for the current timestep and records. Returns the load remaining after discharge.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *discharging_kW* | The discharging power [kw] being drawn from the asset. |
| *load_kW* | The load [kW] passed to the asset in this timestep. |

**Returns**

The load [kW] remaining after the discharge is deducted from it.

Reimplemented from Storage.

```
{
    // 1. record discharging power, update total
    this->discharging_power_vec_kW[timestep] = discharging_kW;
    this->total_discharge_kWh += discharging_kW * dt_hrs;

    // 2. update charge and record
    this->charge_kWh -= (discharging_kW * dt_hrs) / this->discharging_efficiency;
    this->charge_vec_kWh[timestep] = this->charge_kWh;

    // 3. update load
    load_kW -= discharging_kW;

    // 4. toggle depleted flag (if applicable)
    this->__toggleDepleted();

    // 5. model degradation
    this->__handleDegradation(timestep, dt_hrs, discharging_kW);

     // 6. trigger replacement (if applicable)
     if (this->SOH <= this->replace_SOH) {
         this->handleReplacement(timestep);
     }

     // 7. capture operation and maintenance costs (if applicable)
     if (discharging_kW > 0) {
         this->operation_maintenance_cost_vec[timestep] = discharging_kW * dt_hrs *
             this->operation_maintenance_cost_kWh;
     }

     this->power_kW = 0;
     return load_kW;
}   /* commitDischarge() */
```

#### 4.13.3.13 getAcceptablekW()

```
double LiIon::getAcceptablekW (
            double dt_hrs ) [virtual]
```

Method to get the charge power currently acceptable by the asset.

**Parameters**

| | |
|---|---|
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |

**Returns**

The charging power [kW] currently acceptable by the asset.

Reimplemented from Storage.

```
{
    //  1. get max charge
    double max_charge_kWh = this->max_SOC * this->energy_capacity_kWh;

    if (max_charge_kWh > this->dynamic_energy_capacity_kWh) {
        max_charge_kWh = this->dynamic_energy_capacity_kWh;
    }

    //  2. compute acceptable power
    //     (accounting for the power currently being charged/discharged by the asset)
    double acceptable_kW =
        (max_charge_kWh - this->charge_kWh) /
        (this->charging_efficiency * dt_hrs);

    acceptable_kW -= this->power_kW;

    if (acceptable_kW <= 0) {
        return 0;
    }

    //  3. apply power constraint
    if (acceptable_kW > this->dynamic_power_capacity_kW) {
        acceptable_kW = this->dynamic_power_capacity_kW;
    }

    return acceptable_kW;
}   /* getAcceptablekW( */
```

#### 4.13.3.14 getAvailablekW()

```
double LiIon::getAvailablekW (
              double dt_hrs )   [virtual]
```

Method to get the discharge power currently available from the asset.

**Parameters**

| | |
|---|---|
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |

**Returns**

The discharging power [kW] currently available from the asset.

Reimplemented from Storage.

```
{
    //  1. get min charge
    double min_charge_kWh = this->min_SOC * this->energy_capacity_kWh;

    //  2. compute available power
    //     (accounting for the power currently being charged/discharged by the asset)
    double available_kW =
        ((this->charge_kWh - min_charge_kWh) * this->discharging_efficiency) /
        dt_hrs;
```

```

    available_kW -= this->power_kW;

    if (available_kW <= 0) {
        return 0;
    }

    //  3. apply power constraint
    if (available_kW > this->dynamic_power_capacity_kW) {
        available_kW = this->dynamic_power_capacity_kW;
    }

    return available_kW;
}   /* getAvailablekW() */
```

#### 4.13.3.15 handleReplacement()

```
void LiIon::handleReplacement (
            int timestep )  [virtual]
```

Method to handle asset replacement and capital cost incursion, if applicable.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |

Reimplemented from Storage.

```
{
    //  1. reset attributes
    this->dynamic_energy_capacity_kWh = this->energy_capacity_kWh;
    this->dynamic_power_capacity_kW = this->power_capacity_kW;
    this->SOH = 1;

    // 2. invoke base class method
    Storage::handleReplacement(timestep);

    //  3. correct attributes
    this->charge_kWh = this->init_SOC * this->energy_capacity_kWh;
    this->is_depleted = false;

    return;
}   /* __handleReplacement() */
```

### 4.13.4 Member Data Documentation

#### 4.13.4.1 charging_efficiency

```
double LiIon::charging_efficiency
```

The charging efficiency of the asset.

#### 4.13.4.2 degradation_a_cal

```
double LiIon::degradation_a_cal
```

A pre-exponential factor [J/mol] used in modelling energy capacity degradation.

#### 4.13.4.3 degradation_alpha

```
double LiIon::degradation_alpha
```

A dimensionless acceleration coefficient used in modelling energy capacity degradation.

#### 4.13.4.4 degradation_B_hat_cal_0

```
double LiIon::degradation_B_hat_cal_0
```

A reference (or base) pre-exponential factor [1/sqrt(hrs)] used in modelling energy capacity degradation.

#### 4.13.4.5 degradation_beta

```
double LiIon::degradation_beta
```

A dimensionless acceleration exponent used in modelling energy capacity degradation.

#### 4.13.4.6 degradation_Ea_cal_0

```
double LiIon::degradation_Ea_cal_0
```

A reference (or base) activation energy [J/mol] used in modelling energy capacity degradation.

#### 4.13.4.7 degradation_r_cal

```
double LiIon::degradation_r_cal
```

A dimensionless constant used in modelling energy capacity degradation.

#### 4.13.4.8 degradation_s_cal

```
double LiIon::degradation_s_cal
```

A dimensionless constant used in modelling energy capacity degradation.

#### 4.13.4.9 discharging_efficiency

```
double LiIon::discharging_efficiency
```

The discharging efficiency of the asset.

#### 4.13.4.10 dynamic_energy_capacity_kWh

```
double LiIon::dynamic_energy_capacity_kWh
```

The dynamic (i.e. degrading) energy capacity [kWh] of the asset.

#### 4.13.4.11 dynamic_power_capacity_kW

```
double LiIon::dynamic_power_capacity_kW
```

The dynamic (i.e. degrading) power capacity [kW] of the asset.

#### 4.13.4.12 gas_constant_JmolK

```
double LiIon::gas_constant_JmolK
```

The universal gas constant [J/mol.K].

#### 4.13.4.13 hysteresis_SOC

```
double LiIon::hysteresis_SOC
```

The state of charge the asset must achieve to toggle is_depleted.

#### 4.13.4.14 init_SOC

```
double LiIon::init_SOC
```

The initial state of charge of the asset.

#### 4.13.4.15 max_SOC

```
double LiIon::max_SOC
```

The maximum state of charge of the asset.

#### 4.13.4.16 min_SOC

```
double LiIon::min_SOC
```

The minimum state of charge of the asset. Will toggle is_depleted when reached.

#### 4.13.4.17 power_degradation_flag

```
bool LiIon::power_degradation_flag
```

A flag which indicates whether or not power degradation should be modelled.

#### 4.13.4.18 replace_SOH

```
double LiIon::replace_SOH
```

The state of health at which the asset is considered "dead" and must be replaced.

#### 4.13.4.19 SOH

```
double LiIon::SOH
```

The state of health of the asset.

#### 4.13.4.20 SOH_vec

```
std::vector<double> LiIon::SOH_vec
```

A vector of the state of health of the asset at each point in the modelling time series.

#### 4.13.4.21 temperature_K

```
double LiIon::temperature_K
```

The absolute environmental temperature [K] of the lithium ion battery energy storage system.

The documentation for this class was generated from the following files:

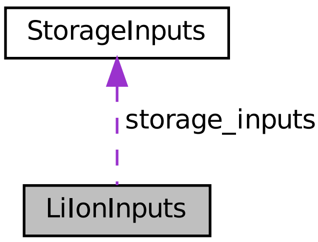
- header/Storage/LiIon.h
- source/Storage/LiIon.cpp

## 4.14 LiIonInputs Struct Reference

A structure which bundles the necessary inputs for the LiIon constructor. Provides default values for every necessary input. Note that this structure encapsulates StorageInputs.

```
#include <LiIon.h>
```

Collaboration diagram for LiIonInputs:



## Public Attributes

- StorageInputs storage_inputs

  *An encapsulated StorageInputs instance.*
- double capital_cost = -1

  *The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].*
- double operation_maintenance_cost_kWh = -1

  *The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy charged/discharged. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].*
- double init_SOC = 0.5

  *The initial state of charge of the asset.*
- double min_SOC = 0.15

  *The minimum state of charge of the asset. Will toggle is_depleted when reached.*
- double hysteresis_SOC = 0.5

  *The state of charge the asset must achieve to toggle is_depleted.*
- double max_SOC = 0.9

  *The maximum state of charge of the asset.*
- double charging_efficiency = 0.9

  *The charging efficiency of the asset.*
- double discharging_efficiency = 0.9

  *The discharging efficiency of the asset.*
- double replace_SOH = 0.8

  *The state of health at which the asset is considered "dead" and must be replaced.*
- bool power_degradation_flag = false

  *A flag which indicates whether or not power degradation should be modelled.*
- double degradation_alpha = 8.935

  *A dimensionless acceleration coefficient used in modelling energy capacity degradation.*
- double degradation_beta = 1

  *A dimensionless acceleration exponent used in modelling energy capacity degradation.*
- double degradation_B_hat_cal_0 = 5.22226e6

  *A reference (or base) pre-exponential factor [1/sqrt(hrs)] used in modelling energy capacity degradation.*
- double degradation_r_cal = 0.4361

  *A dimensionless constant used in modelling energy capacity degradation.*
- double degradation_Ea_cal_0 = 5.279e4

  *A reference (or base) activation energy [J/mol] used in modelling energy capacity degradation.*
- double degradation_a_cal = 100

  *A pre-exponential factor [J/mol] used in modelling energy capacity degradation.*
- double degradation_s_cal = 2

  *A dimensionless constant used in modelling energy capacity degradation.*
- double gas_constant_JmolK = 8.31446

  *The universal gas constant [J/mol.K].*
- double temperature_K = 273 + 20

  *The absolute environmental temperature [K] of the lithium ion battery energy storage system.*

### 4.14.1 Detailed Description

A structure which bundles the necessary inputs for the LiIon constructor. Provides default values for every necessary input. Note that this structure encapsulates StorageInputs.

Ref: Truelove [2023a]

## 4.14.2 Member Data Documentation

### 4.14.2.1 capital_cost

```
double LiIonInputs::capital_cost = -1
```

The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].

### 4.14.2.2 charging_efficiency

```
double LiIonInputs::charging_efficiency = 0.9
```

The charging efficiency of the asset.

### 4.14.2.3 degradation_a_cal

```
double LiIonInputs::degradation_a_cal = 100
```

A pre-exponential factor [J/mol] used in modelling energy capacity degradation.

### 4.14.2.4 degradation_alpha

```
double LiIonInputs::degradation_alpha = 8.935
```

A dimensionless acceleration coefficient used in modelling energy capacity degradation.

### 4.14.2.5 degradation_B_hat_cal_0

```
double LiIonInputs::degradation_B_hat_cal_0 = 5.22226e6
```

A reference (or base) pre-exponential factor [1/sqrt(hrs)] used in modelling energy capacity degradation.

#### 4.14.2.6 degradation_beta

```
double LiIonInputs::degradation_beta = 1
```

A dimensionless acceleration exponent used in modelling energy capacity degradation.

#### 4.14.2.7 degradation_Ea_cal_0

```
double LiIonInputs::degradation_Ea_cal_0 = 5.279e4
```

A reference (or base) activation energy [J/mol] used in modelling energy capacity degradation.

#### 4.14.2.8 degradation_r_cal

```
double LiIonInputs::degradation_r_cal = 0.4361
```

A dimensionless constant used in modelling energy capacity degradation.

#### 4.14.2.9 degradation_s_cal

```
double LiIonInputs::degradation_s_cal = 2
```

A dimensionless constant used in modelling energy capacity degradation.

#### 4.14.2.10 discharging_efficiency

```
double LiIonInputs::discharging_efficiency = 0.9
```

The discharging efficiency of the asset.

#### 4.14.2.11 gas_constant_JmolK

```
double LiIonInputs::gas_constant_JmolK = 8.31446
```

The universal gas constant [J/mol.K].

#### 4.14.2.12 hysteresis_SOC

```
double LiIonInputs::hysteresis_SOC = 0.5
```

The state of charge the asset must achieve to toggle is_depleted.

#### 4.14.2.13 init_SOC

```
double LiIonInputs::init_SOC = 0.5
```

The initial state of charge of the asset.

#### 4.14.2.14 max_SOC

```
double LiIonInputs::max_SOC = 0.9
```

The maximum state of charge of the asset.

#### 4.14.2.15 min_SOC

```
double LiIonInputs::min_SOC = 0.15
```

The minimum state of charge of the asset. Will toggle is_depleted when reached.

#### 4.14.2.16 operation_maintenance_cost_kWh

```
double LiIonInputs::operation_maintenance_cost_kWh = -1
```

The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy charged/discharged. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].

#### 4.14.2.17 power_degradation_flag

```
bool LiIonInputs::power_degradation_flag = false
```

A flag which indicates whether or not power degradation should be modelled.

#### 4.14.2.18 replace_SOH

```
double LiIonInputs::replace_SOH = 0.8
```

The state of health at which the asset is considered "dead" and must be replaced.

#### 4.14.2.19 storage_inputs

```
StorageInputs LiIonInputs::storage_inputs
```

An encapsulated StorageInputs instance.

#### 4.14.2.20 temperature_K

```
double LiIonInputs::temperature_K = 273 + 20
```

The absolute environmental temperature [K] of the lithium ion battery energy storage system.

The documentation for this struct was generated from the following file:

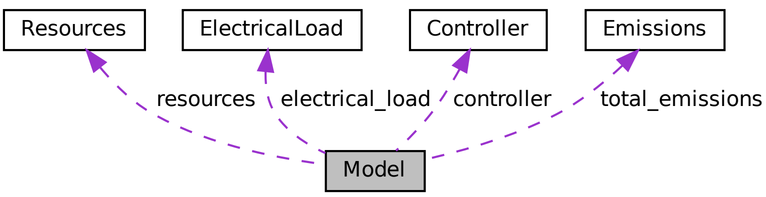
- header/Storage/LiIon.h

## 4.15 Model Class Reference

A container class which forms the centre of PGMcpp. The Model class is intended to serve as the primary user interface with the functionality of PGMcpp, and as such it contains all other classes.

```
#include <Model.h>
```

Collaboration diagram for Model:



## Public Member Functions

- Model (void)

    *Constructor (dummy) for the Model class.*
- Model (ModelInputs)

    *Constructor (intended) for the Model class.*
- void addDiesel (DieselInputs)

    *Method to add a Diesel asset to the Model.*
- void addResource (NoncombustionType, std::string, int)

    *A method to add a renewable resource time series to the Model.*
- void addResource (RenewableType, std::string, int)

    *A method to add a renewable resource time series to the Model.*
- void addHydro (HydroInputs)

    *Method to add a Hydro asset to the Model.*
- void addSolar (SolarInputs)

    *Method to add a Solar asset to the Model.*
- void addTidal (TidalInputs)

    *Method to add a Tidal asset to the Model.*
- void addWave (WaveInputs)

    *Method to add a Wave asset to the Model.*
- void addWind (WindInputs)

    *Method to add a Wind asset to the Model.*
- void addLiIon (LiIonInputs)

    *Method to add a LiIon asset to the Model.*
- void run (void)

    *A method to run the Model.*
- void reset (void)

    *Method which resets the model for use in assessing a new candidate microgrid design. This method only clears the asset pointer vectors and resets select Model attribues. It leaves the Controller, ElectricalLoad, and Resources objects of the Model alone.*
- void clear (void)

    *Method to clear all attributes of the Model object.*
- void writeResults (std::string, int=-1)

    *Method which writes Model results to an output directory. Also calls out to writeResults() for each contained asset.*
- ∼Model (void)

    *Destructor for the Model class.*

## Public Attributes

- double total_fuel_consumed_L

    *The total fuel consumed [L] over a model run.*
- Emissions total_emissions

    *An Emissions structure for holding total emissions [kg].*
- double net_present_cost

    *The net present cost of the Model (undefined currency).*
- double total_renewable_dispatch_kWh

    *The total energy dispatched [kWh] by all renewable assets over the Model run.*
- double total_dispatch_discharge_kWh

    *The total energy dispatched/discharged [kWh] over the Model run.*
- double levellized_cost_of_energy_kWh

    *The levellized cost of energy, per unit energy dispatched/discharged, of the Model [1/kWh] (undefined currency).*

- Controller controller

    *Controller component of Model.*
- ElectricalLoad electrical_load

    *ElectricalLoad component of Model.*
- Resources resources

    *Resources component of Model.*
- std::vector< Combustion * > combustion_ptr_vec

    *A vector of pointers to the various Combustion assets in the Model.*
- std::vector< Noncombustion * > noncombustion_ptr_vec

    *A vector of pointers to the various Noncombustion assets in the Model.*
- std::vector< Renewable * > renewable_ptr_vec

    *A vector of pointers to the various Renewable assets in the Model.*
- std::vector< Storage * > storage_ptr_vec

    *A vector of pointers to the various Storage assets in the Model.*

## Private Member Functions

- void __checkInputs (ModelInputs)

    *Helper method (private) to check inputs to the Model constructor.*
- void __computeFuelAndEmissions (void)

    *Helper method to compute the total fuel consumption and emissions over the Model run.*
- void __computeNetPresentCost (void)

    *Helper method to compute the overall net present cost, for the Model run, from the asset-wise net present costs. Also tallies up total dispatch and discharge.*
- void __computeLevellizedCostOfEnergy (void)

    *Helper method to compute the overall levellized cost of energy, for the Model run, from the asset-wise levellized costs of energy.*
- void __computeEconomics (void)

    *Helper method to compute key economic metrics for the Model run.*
- void __writeSummary (std::string)

    *Helper method to write summary results for Model.*
- void __writeTimeSeries (std::string, int=-1)

    *Helper method to write time series results for Model.*

## 4.15.1 Detailed Description

A container class which forms the centre of PGMcpp. The Model class is intended to serve as the primary user interface with the functionality of PGMcpp, and as such it contains all other classes.

## 4.15.2 Constructor & Destructor Documentation

#### 4.15.2.1 Model() [1/2]

```
Model::Model (
        void )
```

Constructor (dummy) for the Model class.

```
{
    return;
}   /* Model() */
```

#### 4.15.2.2 Model() [2/2]

```
Model::Model (
        ModelInputs model_inputs )
```

Constructor (intended) for the Model class.

**Parameters**

| | |
|---|---|
| *model_inputs* | A structure of Model constructor inputs. |

```
{
    //  1. check inputs
    this->__checkInputs(model_inputs);

    //  2. read in electrical load data
    this->electrical_load.readLoadData(model_inputs.path_2_electrical_load_time_series);

    //  3. set controller attributes
    this->controller.setControlMode(model_inputs.control_mode);
    this->controller.setLoadOperatingReserveFactor(model_inputs.load_operating_reserve_factor);
    this->controller.setMaxOperatingReserveFactor(model_inputs.max_operating_reserve_factor);

    //  4. set public attributes
    this->total_fuel_consumed_L = 0;
    this->net_present_cost = 0;
    this->total_dispatch_discharge_kWh = 0;
    this->total_renewable_dispatch_kWh = 0;
    this->levellized_cost_of_energy_kWh = 0;

    return;
}   /* Model() */
```

#### 4.15.2.3 ∼Model()

```
Model::∼Model (
        void )
```

Destructor for the Model class.

```
{
    this->clear();
    return;
}   /* ~Model() */
```

### 4.15.3 Member Function Documentation

#### 4.15.3.1 __checkInputs()

```
void Model::__checkInputs (
            ModelInputs model_inputs )   [private]
```

Helper method (private) to check inputs to the Model constructor.

**Parameters**

| | |
|---|---|
| *model_inputs* | A structure of Model constructor inputs. |

```
{
    //  1. check path_2_electrical_load_time_series
    if (model_inputs.path_2_electrical_load_time_series.empty()) {
        std::string error_str = "ERROR:  Model():  ";
        error_str += "ModelInputs::path_2_electrical_load_time_series cannot be empty";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  2. check load_operating_reserve_factor
    if (
        model_inputs.load_operating_reserve_factor < 0 or
        model_inputs.load_operating_reserve_factor > 1
    ) {
        std::string error_str = "ERROR:  Model():  ";
        error_str += "ModelInputs::load_operating_reserve_factor must be in the closed interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  3. check max_operating_reserve_factor
    if (
        model_inputs.max_operating_reserve_factor < 0 or
        model_inputs.max_operating_reserve_factor > 1
    ) {
        std::string error_str = "ERROR:  Model():  ";
        error_str += "ModelInputs::max_operating_reserve_factor must be in the closed interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkInputs() */
```

#### 4.15.3.2 __computeEconomics()

```
void Model::__computeEconomics (
            void )   [private]
```

Helper method to compute key economic metrics for the Model run.

```
{
    this->__computeNetPresentCost();
    this->__computeLevellizedCostOfEnergy();

    return;
}   /* __computeEconomics() */
```

#### 4.15.3.3 __computeFuelAndEmissions()

```
void Model::__computeFuelAndEmissions (
            void ) [private]
```

Helper method to compute the total fuel consumption and emissions over the Model run.

```
{
    for (size_t i = 0; i < this->combustion_ptr_vec.size(); i++) {
        this->combustion_ptr_vec[i]->computeFuelAndEmissions();

        this->total_fuel_consumed_L +=
            this->combustion_ptr_vec[i]->total_fuel_consumed_L;

        this->total_emissions.CO2_kg +=
            this->combustion_ptr_vec[i]->total_emissions.CO2_kg;

        this->total_emissions.CO_kg +=
            this->combustion_ptr_vec[i]->total_emissions.CO_kg;

        this->total_emissions.NOx_kg +=
            this->combustion_ptr_vec[i]->total_emissions.NOx_kg;

        this->total_emissions.SOx_kg +=
            this->combustion_ptr_vec[i]->total_emissions.SOx_kg;

        this->total_emissions.CH4_kg +=
            this->combustion_ptr_vec[i]->total_emissions.CH4_kg;

        this->total_emissions.PM_kg +=
            this->combustion_ptr_vec[i]->total_emissions.PM_kg;
    }

    return;
}   /* __computeFuelAndEmissions() */
```

#### 4.15.3.4 __computeLevellizedCostOfEnergy()

```
void Model::__computeLevellizedCostOfEnergy (
            void ) [private]
```

Helper method to compute the overall levellized cost of energy, for the Model run, from the asset-wise levellized costs of energy.

```
{
    //  1. account for Combustion economics in levellized cost of energy
    for (size_t i = 0; i < this->combustion_ptr_vec.size(); i++) {
        this->levellized_cost_of_energy_kWh +=
            (
                this->combustion_ptr_vec[i]->levellized_cost_of_energy_kWh *
                this->combustion_ptr_vec[i]->total_dispatch_kWh
            ) / this->total_dispatch_discharge_kWh;
    }

    //  2. account for Noncombustion economics in levellized cost of energy
    for (size_t i = 0; i < this->noncombustion_ptr_vec.size(); i++) {
        this->levellized_cost_of_energy_kWh +=
            (
                this->noncombustion_ptr_vec[i]->levellized_cost_of_energy_kWh *
                this->noncombustion_ptr_vec[i]->total_dispatch_kWh
            ) / this->total_dispatch_discharge_kWh;
    }

    //  3. account for Renewable economics in levellized cost of energy
    for (size_t i = 0; i < this->renewable_ptr_vec.size(); i++) {
        this->levellized_cost_of_energy_kWh +=
            (
                this->renewable_ptr_vec[i]->levellized_cost_of_energy_kWh *
                this->renewable_ptr_vec[i]->total_dispatch_kWh
            ) / this->total_dispatch_discharge_kWh;
    }

    //  4. account for Storage economics in levellized cost of energy
    for (size_t i = 0; i < this->storage_ptr_vec.size(); i++) {
        this->levellized_cost_of_energy_kWh +=
            (
```

```
                this->storage_ptr_vec[i]->levellized_cost_of_energy_kWh *
                this->storage_ptr_vec[i]->total_discharge_kWh
            ) / this->total_dispatch_discharge_kWh;
    }

    return;
}   /* __computeLevellizedCostOfEnergy() */
```

#### 4.15.3.5 __computeNetPresentCost()

```
void Model::__computeNetPresentCost (
            void ) [private]
```

Helper method to compute the overall net present cost, for the Model run, from the asset-wise net present costs. Also tallies up total dispatch and discharge.

```
{
    //  1. account for Combustion economics in net present cost
    //     increment total dispatch
    for (size_t i = 0; i < this->combustion_ptr_vec.size(); i++) {
        this->combustion_ptr_vec[i]->computeEconomics(
            &(this->electrical_load.time_vec_hrs)
        );

        this->net_present_cost += this->combustion_ptr_vec[i]->net_present_cost;

        this->total_dispatch_discharge_kWh +=
            this->combustion_ptr_vec[i]->total_dispatch_kWh;
    }

    //  2. account for Noncombustion economics in net present cost
    //     increment total dispatch
    for (size_t i = 0; i < this->noncombustion_ptr_vec.size(); i++) {
        this->noncombustion_ptr_vec[i]->computeEconomics(
            &(this->electrical_load.time_vec_hrs)
        );

        this->net_present_cost += this->noncombustion_ptr_vec[i]->net_present_cost;

        this->total_dispatch_discharge_kWh +=
            this->noncombustion_ptr_vec[i]->total_dispatch_kWh;
    }

    //  3. account for Renewable economics in net present cost,
    //     increment total dispatch
    for (size_t i = 0; i < this->renewable_ptr_vec.size(); i++) {
        this->renewable_ptr_vec[i]->computeEconomics(
            &(this->electrical_load.time_vec_hrs)
        );

        this->net_present_cost += this->renewable_ptr_vec[i]->net_present_cost;

        this->total_dispatch_discharge_kWh +=
            this->renewable_ptr_vec[i]->total_dispatch_kWh;

        this->total_renewable_dispatch_kWh +=
            this->renewable_ptr_vec[i]->total_dispatch_kWh;
    }

    //  4. account for Storage economics in net present cost
    //     increment total dispatch
    for (size_t i = 0; i < this->storage_ptr_vec.size(); i++) {
        this->storage_ptr_vec[i]->computeEconomics(
            &(this->electrical_load.time_vec_hrs)
        );

        this->net_present_cost += this->storage_ptr_vec[i]->net_present_cost;

        this->total_dispatch_discharge_kWh +=
            this->storage_ptr_vec[i]->total_discharge_kWh;
    }

    return;
}   /* __computeNetPresentCost() */
```

### 4.15.3.6 __writeSummary()

```
void Model::__writeSummary (
            std::string write_path )  [private]
```

Helper method to write summary results for Model.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |

```
{
    //  1. create subdirectory
    write_path += "Model/";
    std::filesystem::create_directory(write_path);

    //  2. create filestream
    write_path += "summary_results.md";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  3. write summary results (markdown)
    ofs « "# Model Summary Results\n";
    ofs « "\n--------\n\n";

    //  3.1. ElectricalLoad
    ofs « "## Electrical Load\n";
    ofs « "\n";
    ofs « "Path: " «
        this->electrical_load.path_2_electrical_load_time_series « "  \n";
    ofs « "Data Points: " « this->electrical_load.n_points « "  \n";
    ofs « "Years: " « this->electrical_load.n_years « "  \n";
    ofs « "Min: " « this->electrical_load.min_load_kW « " kW  \n";
    ofs « "Mean: " « this->electrical_load.mean_load_kW « " kW  \n";
    ofs « "Max: " « this->electrical_load.max_load_kW « " kW  \n";
    ofs « "\n--------\n\n";

    //  3.2. Controller
    ofs « "## Controller\n";
    ofs « "\n";
    ofs « "Control Mode: " « this->controller.control_string « "  \n";
    ofs « "Load Operating Reserve Factor: " «
        this->controller.load_operating_reserve_factor « "  \n";
    ofs « "Max Overall Operating Reserve Factor: " «
        this->controller.max_operating_reserve_factor « "  \n";
    ofs « "\n--------\n\n";

    //  3.3. Resources (1D)
    ofs « "## 1D Renewable Resources\n";
    ofs « "\n";

    std::map<int, std::string>::iterator string_map_1D_iter =
        this->resources.string_map_1D.begin();
    std::map<int, std::string>::iterator path_map_1D_iter =
        this->resources.path_map_1D.begin();

    while (
        string_map_1D_iter != this->resources.string_map_1D.end() and
        path_map_1D_iter != this->resources.path_map_1D.end()
    ) {
        ofs « "Resource Key: " « string_map_1D_iter->first « "  \n";
        ofs « "Type: " « string_map_1D_iter->second « "  \n";
        ofs « "Path: " « path_map_1D_iter->second « "  \n";
        ofs « "\n";

        string_map_1D_iter++;
        path_map_1D_iter++;
    }

    ofs « "\n--------\n\n";

    //  3.4. Resources (2D)
    ofs « "## 2D Renewable Resources\n";
    ofs « "\n";

    std::map<int, std::string>::iterator string_map_2D_iter =
        this->resources.string_map_2D.begin();
    std::map<int, std::string>::iterator path_map_2D_iter =
        this->resources.path_map_2D.begin();
```

```

    while (
        string_map_2D_iter != this->resources.string_map_2D.end() and
        path_map_2D_iter != this->resources.path_map_2D.end()
    ) {
        ofs « "Resource Key: " « string_map_2D_iter->first « "  \n";
        ofs « "Type: " « string_map_2D_iter->second « "  \n";
        ofs « "Path: " « path_map_2D_iter->second « "  \n";
        ofs « "\n";

        string_map_2D_iter++;
        path_map_2D_iter++;
    }

    ofs « "\n--------\n\n";

    //  3.5. Combustion
    ofs « "## Combustion Assets\n";
    ofs « "\n";

    for (size_t i = 0; i < this->combustion_ptr_vec.size(); i++) {
        ofs « "Asset Index: " « i « "  \n";
        ofs « "Type: " « this->combustion_ptr_vec[i]->type_str « "  \n";
        ofs « "Capacity: " « this->combustion_ptr_vec[i]->capacity_kW « " kW  \n";
        ofs « "\n";
    }

    ofs « "\n--------\n\n";

    //  3.6. Noncombustion
    ofs « "## Noncombustion Assets\n";
    ofs « "\n";

    for (size_t i = 0; i < this->noncombustion_ptr_vec.size(); i++) {
        ofs « "Asset Index: " « i « "  \n";
        ofs « "Type: " « this->noncombustion_ptr_vec[i]->type_str « "  \n";
        ofs « "Capacity: " « this->noncombustion_ptr_vec[i]->capacity_kW « " kW  \n";

        if (this->noncombustion_ptr_vec[i]->type == NoncombustionType :: HYDRO) {
            ofs « "Reservoir Capacity: " «
                ((Hydro*)(this->noncombustion_ptr_vec[i]))->reservoir_capacity_m3 «
                " m3  \n";
        }

        ofs « "\n";
    }

    ofs « "\n--------\n\n";

    //  3.7. Renewable
    ofs « "## Renewable Assets\n";
    ofs « "\n";

    for (size_t i = 0; i < this->renewable_ptr_vec.size(); i++) {
        ofs « "Asset Index: " « i « "  \n";
        ofs « "Type: " « this->renewable_ptr_vec[i]->type_str « "  \n";
        ofs « "Capacity: " « this->renewable_ptr_vec[i]->capacity_kW « " kW  \n";
        ofs « "\n";
    }

    ofs « "\n--------\n\n";

    //  3.8. Storage
    ofs « "## Storage Assets\n";
    ofs « "\n";

    for (size_t i = 0; i < this->storage_ptr_vec.size(); i++) {
        ofs « "Asset Index: " « i « "  \n";
        ofs « "Type: " « this->storage_ptr_vec[i]->type_str « "  \n";
        ofs « "Power Capacity: " « this->storage_ptr_vec[i]->power_capacity_kW
            « " kW  \n";
        ofs « "Energy Capacity: " « this->storage_ptr_vec[i]->energy_capacity_kWh
            « " kWh  \n";
        ofs « "\n";
    }

    ofs « "\n--------\n\n";

    //  3.9. Model Results
    ofs « "## Results\n";
    ofs « "\n";

    ofs « "Net Present Cost: " « this->net_present_cost « "  \n";
    ofs « "\n";

    ofs « "Total Dispatch + Discharge: " « this->total_dispatch_discharge_kWh
        « " kWh  \n";
```

```
    ofs « "Renewable Penetration: "
        « this->total_renewable_dispatch_kWh / this->total_dispatch_discharge_kWh
        « "  \n";
    ofs « "\n";

    ofs « "Levellized Cost of Energy: " « this->levellized_cost_of_energy_kWh
        « " per kWh dispatched/discharged  \n";
    ofs « "\n";

    ofs « "Total Fuel Consumed: " « this->total_fuel_consumed_L « " L "
        « "(Annual Average: " «
            this->total_fuel_consumed_L / this->electrical_load.n_years
        « " L/yr)  \n";
    ofs « "\n";

    ofs « "Total Carbon Dioxide (CO2) Emissions: " «
        this->total_emissions.CO2_kg « " kg "
        « "(Annual Average: " «
            this->total_emissions.CO2_kg / this->electrical_load.n_years
        « " kg/yr)  \n";

    ofs « "Total Carbon Monoxide (CO) Emissions: " «
        this->total_emissions.CO_kg « " kg "
        « "(Annual Average: " «
            this->total_emissions.CO_kg / this->electrical_load.n_years
        « " kg/yr)  \n";

    ofs « "Total Nitrogen Oxides (NOx) Emissions: " «
        this->total_emissions.NOx_kg « " kg "
        « "(Annual Average: " «
            this->total_emissions.NOx_kg / this->electrical_load.n_years
        « " kg/yr)  \n";

    ofs « "Total Sulfur Oxides (SOx) Emissions: " «
        this->total_emissions.SOx_kg « " kg "
        « "(Annual Average: " «
            this->total_emissions.SOx_kg / this->electrical_load.n_years
        « " kg/yr)  \n";

    ofs « "Total Methane (CH4) Emissions: " « this->total_emissions.CH4_kg « " kg "
        « "(Annual Average: " «
            this->total_emissions.CH4_kg / this->electrical_load.n_years
        « " kg/yr)  \n";

    ofs « "Total Particulate Matter (PM) Emissions: " «
        this->total_emissions.PM_kg « " kg "
        « "(Annual Average: " «
            this->total_emissions.PM_kg / this->electrical_load.n_years
        « " kg/yr)  \n";

    ofs « "\n--------\n\n";

    ofs.close();
    return;
}   /* __writeSummary() */
```

#### 4.15.3.7 __writeTimeSeries()

```
void Model::__writeTimeSeries (
            std::string write_path,
            int max_lines = -1 )   [private]
```

Helper method to write time series results for Model.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *max_lines* | The maximum number of lines of output to write. |

```
{
    //  1. create filestream
```

```
    write_path += "Model/time_series_results.csv";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  2. write time series results header (comma separated value)
    ofs « "Time (since start of data) [hrs],";
    ofs « "Electrical Load [kW],";
    ofs « "Net Load [kW],";
    ofs « "Missed Load [kW],";

    for (size_t i = 0; i < this->renewable_ptr_vec.size(); i++) {
        ofs « this->renewable_ptr_vec[i]->capacity_kW « " kW "
            « this->renewable_ptr_vec[i]->type_str « " Dispatch [kW],";
    }

    for (size_t i = 0; i < this->storage_ptr_vec.size(); i++) {
        ofs « this->storage_ptr_vec[i]->power_capacity_kW « " kW "
            « this->storage_ptr_vec[i]->energy_capacity_kWh « " kWh "
            « this->storage_ptr_vec[i]->type_str « " Discharge [kW],";
    }

    for (size_t i = 0; i < this->noncombustion_ptr_vec.size(); i++) {
        ofs « this->noncombustion_ptr_vec[i]->capacity_kW « " kW "
            « this->noncombustion_ptr_vec[i]->type_str « " Dispatch [kW],";
    }

    for (size_t i = 0; i < this->combustion_ptr_vec.size(); i++) {
        ofs « this->combustion_ptr_vec[i]->capacity_kW « " kW "
            « this->combustion_ptr_vec[i]->type_str « " Dispatch [kW],";
    }

    ofs « "\n";

    //  3. write time series results values (comma separated value)
    for (int i = 0; i < max_lines; i++) {
        //  3.1. load values
        ofs « this->electrical_load.time_vec_hrs[i] « ",";
        ofs « this->electrical_load.load_vec_kW[i] « ",";
        ofs « this->controller.net_load_vec_kW[i] « ",";
        ofs « this->controller.missed_load_vec_kW[i] « ",";

        //  3.2. asset-wise dispatch/discharge
        for (size_t j = 0; j < this->renewable_ptr_vec.size(); j++) {
            ofs « this->renewable_ptr_vec[j]->dispatch_vec_kW[i] « ",";
        }

        for (size_t j = 0; j < this->storage_ptr_vec.size(); j++) {
            ofs « this->storage_ptr_vec[j]->discharging_power_vec_kW[i] « ",";
        }

        for (size_t j = 0; j < this->noncombustion_ptr_vec.size(); j++) {
            ofs « this->noncombustion_ptr_vec[j]->dispatch_vec_kW[i] « ",";
        }

        for (size_t j = 0; j < this->combustion_ptr_vec.size(); j++) {
            ofs « this->combustion_ptr_vec[j]->dispatch_vec_kW[i] « ",";
        }

        ofs « "\n";
    }

    ofs.close();
    return;
}   /* __writeTimeSeries() */
```

#### 4.15.3.8 addDiesel()

```
void Model::addDiesel (
            DieselInputs diesel_inputs )
```

Method to add a Diesel asset to the Model.

**Parameters**

| | |
|---|---|
| *diesel_inputs* | A structure of Diesel constructor inputs. |

```
{
    Combustion* diesel_ptr = new Diesel(
        this->electrical_load.n_points,
        this->electrical_load.n_years,
        diesel_inputs,
        &(this->electrical_load.time_vec_hrs)
    );

    this->combustion_ptr_vec.push_back(diesel_ptr);

    return;
}   /* addDiesel() */
```

### 4.15.3.9 addHydro()

```
void Model::addHydro (
            HydroInputs hydro_inputs )
```

Method to add a Hydro asset to the Model.

**Parameters**

| | |
|---|---|
| *hydro_inputs* | A structure of Hydro constructor inputs. |

```
{
    Noncombustion* hydro_ptr = new Hydro(
        this->electrical_load.n_points,
        this->electrical_load.n_years,
        hydro_inputs,
        &(this->electrical_load.time_vec_hrs)
    );

    this->noncombustion_ptr_vec.push_back(hydro_ptr);

    return;
}   /* addHydro() */
```

### 4.15.3.10 addLiIon()

```
void Model::addLiIon (
            LiIonInputs liion_inputs )
```

Method to add a LiIon asset to the Model.

**Parameters**

| | |
|---|---|
| *liion_inputs* | A structure of LiIon constructor inputs. |

```
{
    Storage* liion_ptr = new LiIon(
        this->electrical_load.n_points,
        this->electrical_load.n_years,
        liion_inputs
    );

    this->storage_ptr_vec.push_back(liion_ptr);

    return;
}   /* addLiIon() */
```

#### 4.15.3.11 addResource() [1/2]

```
void Model::addResource (
            NoncombustionType noncombustion_type,
            std::string path_2_resource_data,
            int resource_key )
```

A method to add a renewable resource time series to the Model.

**Parameters**

| | |
|---|---|
| *noncombustion_type* | The type of renewable resource being added to the Model. |
| *path_2_resource_data* | A string defining the path (either relative or absolute) to the given resource time series. |
| *resource_key* | A key used to index into the Resources object, used to associate Renewable assets with the corresponding resource. |

```
{
    resources.addResource(
        noncombustion_type,
        path_2_resource_data,
        resource_key,
        &(this->electrical_load)
    );

    return;
}   /* addResource() */
```

#### 4.15.3.12 addResource() [2/2]

```
void Model::addResource (
            RenewableType renewable_type,
            std::string path_2_resource_data,
            int resource_key )
```

A method to add a renewable resource time series to the Model.

**Parameters**

| | |
|---|---|
| *renewable_type* | The type of renewable resource being added to the Model. |
| *path_2_resource_data* | A string defining the path (either relative or absolute) to the given resource time series. |
| *resource_key* | A key used to index into the Resources object, used to associate Renewable assets with the corresponding resource. |

```
{
    resources.addResource(
        renewable_type,
        path_2_resource_data,
        resource_key,
        &(this->electrical_load)
    );

    return;
}   /* addResource() */
```

### 4.15.3.13 addSolar()

```
void Model::addSolar (
            SolarInputs solar_inputs )
```

Method to add a Solar asset to the Model.

**Parameters**

| | |
|---|---|
| *solar_inputs* | A structure of Solar constructor inputs. |

```
{
    Renewable* solar_ptr = new Solar(
        this->electrical_load.n_points,
        this->electrical_load.n_years,
        solar_inputs,
        &(this->electrical_load.time_vec_hrs)
    );

    this->renewable_ptr_vec.push_back(solar_ptr);

    return;
}   /* addSolar() */
```

### 4.15.3.14 addTidal()

```
void Model::addTidal (
            TidalInputs tidal_inputs )
```

Method to add a Tidal asset to the Model.

**Parameters**

| | |
|---|---|
| *tidal_inputs* | A structure of Tidal constructor inputs. |

```
{
    Renewable* tidal_ptr = new Tidal(
        this->electrical_load.n_points,
        this->electrical_load.n_years,
        tidal_inputs,
        &(this->electrical_load.time_vec_hrs)
    );

    this->renewable_ptr_vec.push_back(tidal_ptr);

    return;
}   /* addTidal() */
```

### 4.15.3.15 addWave()

```
void Model::addWave (
            WaveInputs wave_inputs )
```

Method to add a Wave asset to the Model.

**Parameters**

| | |
|---|---|
| *wave_inputs* | A structure of Wave constructor inputs. |

```
{
    Renewable* wave_ptr = new Wave(
        this->electrical_load.n_points,
        this->electrical_load.n_years,
        wave_inputs,
        &(this->electrical_load.time_vec_hrs)
    );

    this->renewable_ptr_vec.push_back(wave_ptr);

    return;
}   /* addWave() */
```

#### 4.15.3.16 addWind()

```
void Model::addWind (
            WindInputs wind_inputs )
```

Method to add a Wind asset to the Model.

**Parameters**

| | |
|---|---|
| *wind_inputs* | A structure of Wind constructor inputs. |

```
{
    Renewable* wind_ptr = new Wind(
        this->electrical_load.n_points,
        this->electrical_load.n_years,
        wind_inputs,
        &(this->electrical_load.time_vec_hrs)
    );

    this->renewable_ptr_vec.push_back(wind_ptr);

    return;
}   /* addWind() */
```

#### 4.15.3.17 clear()

```
void Model::clear (
            void )
```

Method to clear all attributes of the Model object.

```
{
    //  1. reset
    this->reset();

    //  2. clear components
    controller.clear();
    electrical_load.clear();
    resources.clear();

    return;
}   /* clear() */
```

#### 4.15.3.18 reset()

```
void Model::reset (
        void )
```

Method which resets the model for use in assessing a new candidate microgrid design. This method only clears the asset pointer vectors and resets select Model attribues. It leaves the Controller, ElectricalLoad, and Resources objects of the Model alone.

```
{
    // 1. clear combustion_ptr_vec
    for (size_t i = 0; i < this->combustion_ptr_vec.size(); i++) {
        delete this->combustion_ptr_vec[i];
    }
    this->combustion_ptr_vec.clear();

    // 2. clear noncombustion_ptr_vec
    for (size_t i = 0; i < this->noncombustion_ptr_vec.size(); i++) {
        delete this->noncombustion_ptr_vec[i];
    }
    this->noncombustion_ptr_vec.clear();

    // 3. clear renewable_ptr_vec
    for (size_t i = 0; i < this->renewable_ptr_vec.size(); i++) {
        delete this->renewable_ptr_vec[i];
    }
    this->renewable_ptr_vec.clear();

    // 4. clear storage_ptr_vec
    for (size_t i = 0; i < this->storage_ptr_vec.size(); i++) {
        delete this->storage_ptr_vec[i];
    }
    this->storage_ptr_vec.clear();

    // 5. reset components and attributes
    this->controller.clear();

    this->total_fuel_consumed_L = 0;

    this->total_emissions.CO2_kg = 0;
    this->total_emissions.CO_kg = 0;
    this->total_emissions.NOx_kg = 0;
    this->total_emissions.SOx_kg = 0;
    this->total_emissions.CH4_kg = 0;
    this->total_emissions.PM_kg = 0;

    this->net_present_cost = 0;
    this->total_dispatch_discharge_kWh = 0;
    this->total_renewable_dispatch_kWh = 0;
    this->levellized_cost_of_energy_kWh = 0;

    return;
}   /* reset() */
```

#### 4.15.3.19 run()

```
void Model::run (
        void )
```

A method to run the Model.

```
{
    // 1. init Controller
    this->controller.init(
        &(this->electrical_load),
        &(this->renewable_ptr_vec),
        &(this->resources),
        &(this->combustion_ptr_vec)
    );

    // 2. apply dispatch control
    this->controller.applyDispatchControl(
        &(this->electrical_load),
        &(this->resources),
        &(this->combustion_ptr_vec),
        &(this->noncombustion_ptr_vec),
```

```
        &(this->renewable_ptr_vec),
        &(this->storage_ptr_vec)
    );

    //  3. compute total fuel consumption and emissions
    this->__computeFuelAndEmissions();

    //  4. compute key economic metrics
    this->__computeEconomics();

    return;
}   /* run() */
```

#### 4.15.3.20 writeResults()

```
void Model::writeResults (
            std::string write_path,
            int max_lines = -1 )
```

Method which writes Model results to an output directory. Also calls out to writeResults() for each contained asset.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *max_lines* | The maximum number of lines of output to write. If <0, then all available lines are written. If =0, then only summary results are written. |

```
{
    //  1. handle sentinel
    if (max_lines < 0) {
        max_lines = this->electrical_load.n_points;
    }

    //  2. check for pre-existing, warn (and remove), then create
    if (write_path.back() != '/') {
        write_path += '/';
    }

    if (std::filesystem::is_directory(write_path)) {
        std::string warning_str = "WARNING:  Model::writeResults():  ";
        warning_str += write_path;
        warning_str += " already exists, contents will be overwritten!";

        std::cout « warning_str « std::endl;

        std::filesystem::remove_all(write_path);
    }

    std::filesystem::create_directory(write_path);

    //  3. write summary
    this->__writeSummary(write_path);

    //  4. write time series
    if (max_lines > this->electrical_load.n_points) {
        max_lines = this->electrical_load.n_points;
    }

    if (max_lines > 0) {
        this->__writeTimeSeries(write_path, max_lines);
    }

    //  5. call out to Combustion :: writeResults()
    for (size_t i = 0; i < this->combustion_ptr_vec.size(); i++) {
        this->combustion_ptr_vec[i]->writeResults(
            write_path,
            &(this->electrical_load.time_vec_hrs),
            i,
            max_lines
        );
    }
```

```

    // 6. call out to Noncombustion :: writeResults()
    for (size_t i = 0; i < this->noncombustion_ptr_vec.size(); i++) {
        this->noncombustion_ptr_vec[i]->writeResults(
            write_path,
            &(this->electrical_load.time_vec_hrs),
            i,
            max_lines
        );
    }

    // 7. call out to Renewable :: writeResults()
    for (size_t i = 0; i < this->renewable_ptr_vec.size(); i++) {
        this->renewable_ptr_vec[i]->writeResults(
            write_path,
            &(this->electrical_load.time_vec_hrs),
            &(this->resources.resource_map_1D),
            &(this->resources.resource_map_2D),
            i,
            max_lines
        );
    }

    // 8. call out to Storage :: writeResults()
    for (size_t i = 0; i < this->storage_ptr_vec.size(); i++) {
        this->storage_ptr_vec[i]->writeResults(
            write_path,
            &(this->electrical_load.time_vec_hrs),
            i,
            max_lines
        );
    }

    return;
}   /* writeResults() */
```

## 4.15.4 Member Data Documentation

### 4.15.4.1 combustion_ptr_vec

`std::vector<Combustion*> Model::combustion_ptr_vec`

A vector of pointers to the various Combustion assets in the Model.

### 4.15.4.2 controller

`Controller Model::controller`

Controller component of Model.

### 4.15.4.3 electrical_load

`ElectricalLoad Model::electrical_load`

ElectricalLoad component of Model.

#### 4.15.4.4 levellized_cost_of_energy_kWh

```
double Model::levellized_cost_of_energy_kWh
```

The levellized cost of energy, per unit energy dispatched/discharged, of the Model [1/kWh] (undefined currency).

#### 4.15.4.5 net_present_cost

```
double Model::net_present_cost
```

The net present cost of the Model (undefined currency).

#### 4.15.4.6 noncombustion_ptr_vec

```
std::vector<Noncombustion*> Model::noncombustion_ptr_vec
```

A vector of pointers to the various Noncombustion assets in the Model.

#### 4.15.4.7 renewable_ptr_vec

```
std::vector<Renewable*> Model::renewable_ptr_vec
```

A vector of pointers to the various Renewable assets in the Model.

#### 4.15.4.8 resources

```
Resources Model::resources
```

Resources component of Model.

#### 4.15.4.9 storage_ptr_vec

```
std::vector<Storage*> Model::storage_ptr_vec
```

A vector of pointers to the various Storage assets in the Model.

#### 4.15.4.10 total_dispatch_discharge_kWh

```
double Model::total_dispatch_discharge_kWh
```

The total energy dispatched/discharged [kWh] over the Model run.

#### 4.15.4.11 total_emissions

```
Emissions Model::total_emissions
```

An Emissions structure for holding total emissions [kg].

#### 4.15.4.12 total_fuel_consumed_L

```
double Model::total_fuel_consumed_L
```

The total fuel consumed [L] over a model run.

#### 4.15.4.13 total_renewable_dispatch_kWh

```
double Model::total_renewable_dispatch_kWh
```

The total energy dispatched [kWh] by all renewable assets over the Model run.

The documentation for this class was generated from the following files:

- header/Model.h
- source/Model.cpp

## 4.16 ModelInputs Struct Reference

A structure which bundles the necessary inputs for the Model constructor. Provides default values for every necessary input (except path_2_electrical_load_time_series, for which a valid input must be provided).

```
#include <Model.h>
```

## Public Attributes

- std::string path_2_electrical_load_time_series = ""

  *A string defining the path (either relative or absolute) to the given electrical load time series.*
- ControlMode control_mode = ControlMode :: LOAD_FOLLOWING

  *The control mode to be applied by the Controller object.*
- double load_operating_reserve_factor = 0.2

  *An operating reserve factor [0, 1] to cover random fluctuations in load.*
- double max_operating_reserve_factor = 1

  *A maximum reserve factor [0, 1] that limits the required overall operating reserve to, at most, factor ∗ load_kW.*

## 4.16.1 Detailed Description

A structure which bundles the necessary inputs for the Model constructor. Provides default values for every necessary input (except path_2_electrical_load_time_series, for which a valid input must be provided).

## 4.16.2 Member Data Documentation

### 4.16.2.1 control_mode

```
ControlMode ModelInputs::control_mode = ControlMode :: LOAD_FOLLOWING
```

The control mode to be applied by the Controller object.

### 4.16.2.2 load_operating_reserve_factor

```
double ModelInputs::load_operating_reserve_factor = 0.2
```

An operating reserve factor [0, 1] to cover random fluctuations in load.

### 4.16.2.3 max_operating_reserve_factor

```
double ModelInputs::max_operating_reserve_factor = 1
```

A maximum reserve factor [0, 1] that limits the required overall operating reserve to, at most, factor ∗ load_kW.

#### 4.16.2.4 path_2_electrical_load_time_series

```
std::string ModelInputs::path_2_electrical_load_time_series = ""
```

A string defining the path (either relative or absolute) to the given electrical load time series.

The documentation for this struct was generated from the following file:

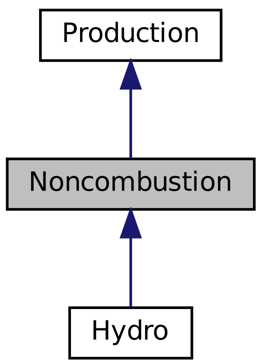
- header/Model.h

## 4.17 Noncombustion Class Reference

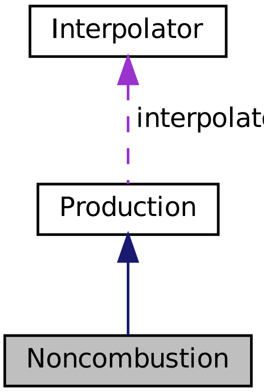
The root of the Noncombustion branch of the Production hierarchy. This branch contains derived classes which model controllable production which is not based on combustion.

```
#include <Noncombustion.h>
```

Inheritance diagram for Noncombustion:



Collaboration diagram for Noncombustion:




## Public Member Functions

- Noncombustion (void)

  *Constructor (dummy) for the Noncombustion class.*
- Noncombustion (int, double, NoncombustionInputs, std::vector< double > ∗)

  *Constructor (intended) for the Noncombustion class.*
- virtual void handleReplacement (int)

  *Method to handle asset replacement and capital cost incursion, if applicable.*
- void computeEconomics (std::vector< double > ∗)

  *Helper method to compute key economic metrics for the Model run.*
- virtual double requestProductionkW (int, double, double)
- virtual double requestProductionkW (int, double, double, double)
- virtual double commit (int, double, double, double)

  *Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.*
- virtual double commit (int, double, double, double, double)
- void writeResults (std::string, std::vector< double > ∗, int, int=-1)

  *Method which writes Noncombustion results to an output directory.*
- virtual ∼Noncombustion (void)

  *Destructor for the Noncombustion class.*

## Public Attributes

- NoncombustionType type

  *The type (NoncombustionType) of the asset.*
- int resource_key

  *A key used to index into the Resources object, to associate this asset with the appropriate resource time series.*

## Private Member Functions

- void __checkInputs (NoncombustionInputs)

  *Helper method to check inputs to the Noncombustion constructor.*
- void __handleStartStop (int, double, double)

  *Helper method to handle the starting/stopping of the Noncombustion asset.*
- virtual void __writeSummary (std::string)
- virtual void __writeTimeSeries (std::string, std::vector< double > *, int=-1)

## 4.17.1 Detailed Description

The root of the Noncombustion branch of the Production hierarchy. This branch contains derived classes which model controllable production which is not based on combustion.

## 4.17.2 Constructor & Destructor Documentation

### 4.17.2.1 Noncombustion() [1/2]

```
Noncombustion::Noncombustion (
            void )
```

Constructor (dummy) for the Noncombustion class.

```
{
    return;
}   /* Noncombustion() */
```

### 4.17.2.2 Noncombustion() [2/2]

```
Noncombustion::Noncombustion (
            int n_points,
            double n_years,
            NoncombustionInputs noncombustion_inputs,
            std::vector< double > * time_vec_hrs_ptr )
```

Constructor (intended) for the Noncombustion class.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *n_years* | The number of years being modelled. |
| *noncombustion_inputs* | A structure of Noncombustion constructor inputs. |
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
    :
Production(
    n_points,
```

```
    n_years,
    noncombustion_inputs.production_inputs,
    time_vec_hrs_ptr
)
{
    //  1. check inputs
    this->__checkInputs(noncombustion_inputs);

    //  2. set attributes
    //...

    //  3. construction print
    if (this->print_flag) {
        std::cout « "Noncombustion object constructed at " « this « std::endl;
    }

    return;
}   /* Noncombustion() */
```

#### 4.17.2.3 ∼Noncombustion()

```
Noncombustion::∼Noncombustion (
            void ) [virtual]
```

Destructor for the Noncombustion class.

```
{
    //  1. destruction print
    if (this->print_flag) {
        std::cout « "Noncombustion object at " « this « " destroyed" « std::endl;
    }

    return;
}   /* ~Noncombustion() */
```

### 4.17.3 Member Function Documentation

#### 4.17.3.1 __checkInputs()

```
void Noncombustion::__checkInputs (
            NoncombustionInputs noncombustion_inputs ) [private]
```

Helper method to check inputs to the Noncombustion constructor.

**Parameters**

| | |
|---|---|
| *noncombustion_inputs* | A structure of Noncombustion constructor inputs. |

```
{
    //...

    return;
}   /* __checkInputs() */
```

#### 4.17.3.2 __handleStartStop()

```
void Noncombustion::__handleStartStop (
```

```
int timestep,
double dt_hrs,
double production_kW )  [private]
```

Helper method to handle the starting/stopping of the Noncombustion asset.

```
{
    if (this->is_running) {
        // handle stopping
        if (production_kW <= 0) {
            this->is_running = false;
        }
    }

    else {
        // handle starting
        if (production_kW > 0) {
            this->is_running = true;
            this->n_starts++;
        }
    }

    return;
}   /* __handleStartStop() */
```

#### 4.17.3.3 __writeSummary()

```
virtual void Noncombustion::__writeSummary (
        std::string  )  [inline], [private], [virtual]
```

Reimplemented in Hydro.

```
{return;}
```

#### 4.17.3.4 __writeTimeSeries()

```
virtual void Noncombustion::__writeTimeSeries (
        std::string ,
        std::vector< double > * ,
        int  = -1 )  [inline], [private], [virtual]
```

Reimplemented in Hydro.

```
{return;}
```

#### 4.17.3.5 commit() [1/2]

```
double Noncombustion::commit (
        int timestep,
        double dt_hrs,
        double production_kW,
        double load_kW )  [virtual]
```

Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *production_kW* | The production [kW] of the asset in this timestep. |
| *load_kW* | The load [kW] passed to the asset in this timestep. |

**Returns**

The load [kW] remaining after the dispatch is deducted from it.

Reimplemented from Production.

```
{
    //  1. handle start/stop
    this->__handleStartStop(timestep, dt_hrs, production_kW);

    //  2. invoke base class method
    load_kW = Production :: commit(
        timestep,
        dt_hrs,
        production_kW,
        load_kW
    );


    //...

    return load_kW;
}   /* commit() */
```

#### 4.17.3.6 commit() [2/2]

```
virtual double Noncombustion::commit (
            int ,
            double ,
            double ,
            double ,
            double  )  [inline], [virtual]
```

Reimplemented in Hydro.

```
{return 0;}
```

#### 4.17.3.7 computeEconomics()

```
void Noncombustion::computeEconomics (
            std::vector< double > * time_vec_hrs_ptr )  [virtual]
```

Helper method to compute key economic metrics for the Model run.

Ref: HOMER [2023b]

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |

Reimplemented from Production.

```
{
    //  1. invoke base class method
    Production :: computeEconomics(time_vec_hrs_ptr);

    return;
}   /* computeEconomics() */
```

#### 4.17.3.8 handleReplacement()

```
void Noncombustion::handleReplacement (
             int timestep )  [virtual]
```

Method to handle asset replacement and capital cost incursion, if applicable.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |

Reimplemented from Production.

Reimplemented in Hydro.

```
{
    //  1. reset attributes
    //...

    //  2. invoke base class method
    Production :: handleReplacement(timestep);

    return;
}   /* __handleReplacement() */
```

#### 4.17.3.9 requestProductionkW() [1/2]

```
virtual double Noncombustion::requestProductionkW (
             int ,
             double ,
             double  )  [inline], [virtual]
```

```
{return 0;}
```

#### 4.17.3.10 requestProductionkW() [2/2]

```
virtual double Noncombustion::requestProductionkW (
             int ,
             double ,
             double ,
             double  )  [inline], [virtual]
```

Reimplemented in Hydro.

```
{return 0;}
```

#### 4.17.3.11 writeResults()

```
void Noncombustion::writeResults (
            std::string write_path,
            std::vector< double > * time_vec_hrs_ptr,
            int combustion_index,
            int max_lines = -1 )
```

Method which writes Noncombustion results to an output directory.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |
| *noncombustion_index* | An integer which corresponds to the index of the Noncombustion asset in the Model. |
| *max_lines* | The maximum number of lines of output to write. If <0, then all available lines are written. If =0, then only summary results are written. |

```
{
    //  1. handle sentinel
    if (max_lines < 0) {
        max_lines = this->n_points;
    }

    //  2. create subdirectories
    write_path += "Production/";
    if (not std::filesystem::is_directory(write_path)) {
        std::filesystem::create_directory(write_path);
    }

    write_path += "Noncombustion/";
    if (not std::filesystem::is_directory(write_path)) {
        std::filesystem::create_directory(write_path);
    }

    write_path += this->type_str;
    write_path += "_";
    write_path += std::to_string(int(ceil(this->capacity_kW)));
    write_path += "kW_idx";
    write_path += std::to_string(combustion_index);
    write_path += "/";
    std::filesystem::create_directory(write_path);

    //  3. write summary
    this->__writeSummary(write_path);

    //  4. write time series
    if (max_lines > this->n_points) {
        max_lines = this->n_points;
    }

    if (max_lines > 0) {
        this->__writeTimeSeries(write_path, time_vec_hrs_ptr, max_lines);
    }

    return;
}   /* writeResults() */
```

### 4.17.4 Member Data Documentation

#### 4.17.4.1 resource_key

```
int Noncombustion::resource_key
```

A key used to index into the Resources object, to associate this asset with the appropriate resource time series.

#### 4.17.4.2 type

```
NoncombustionType Noncombustion::type
```

The type (NoncombustionType) of the asset.

The documentation for this class was generated from the following files:

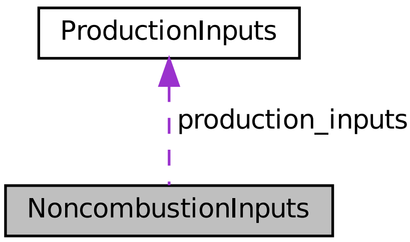
- header/Production/Noncombustion/Noncombustion.h
- source/Production/Noncombustion/Noncombustion.cpp

## 4.18 NoncombustionInputs Struct Reference

A structure which bundles the necessary inputs for the Noncombustion constructor. Provides default values for every necessary input. Note that this structure encapsulates ProductionInputs.

```
#include <Noncombustion.h>
```

Collaboration diagram for NoncombustionInputs:




### Public Attributes

- ProductionInputs production_inputs

    *An encapsulated ProductionInputs instance.*

### 4.18.1 Detailed Description

A structure which bundles the necessary inputs for the Noncombustion constructor. Provides default values for every necessary input. Note that this structure encapsulates ProductionInputs.

### 4.18.2 Member Data Documentation

#### 4.18.2.1 production_inputs

```
ProductionInputs NoncombustionInputs::production_inputs
```

An encapsulated ProductionInputs instance.

The documentation for this struct was generated from the following file:

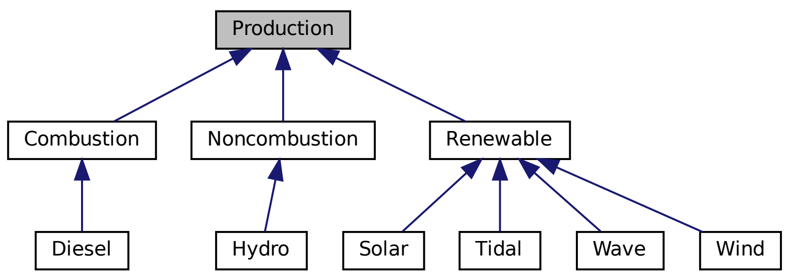
- header/Production/Noncombustion/Noncombustion.h

## 4.19 Production Class Reference

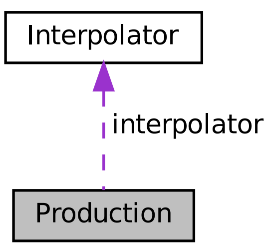
The base class of the Production hierarchy. This hierarchy contains derived classes which model the production of energy, be it renewable or otherwise.

```
#include <Production.h>
```

Inheritance diagram for Production:




Collaboration diagram for Production:



## Public Member Functions

- Production (void)

    *Constructor (dummy) for the Production class.*
- Production (int, double, ProductionInputs, std::vector< double > ∗)

    *Constructor (intended) for the Production class.*
- virtual void handleReplacement (int)

    *Method to handle asset replacement and capital cost incursion, if applicable.*
- double computeRealDiscountAnnual (double, double)

    *Method to compute the real, annual discount rate to be used in computing model economics. This enables application of the discount factor approach.*
- virtual void computeEconomics (std::vector< double > ∗)

    *Helper method to compute key economic metrics for the Model run.*
- double getProductionkW (int)

    *A method to simply fetch the normalized production at a particular point in the given normalized production time series, multiply by the rated capacity of the asset, and return.*
- virtual double commit (int, double, double, double)

    *Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.*
- virtual ∼Production (void)

    *Destructor for the Production class.*

## Public Attributes

- Interpolator interpolator

    *Interpolator component of Production.*
- bool print_flag

    *A flag which indicates whether or not object construct/destruction should be verbose.*
- bool is_running

    *A boolean which indicates whether or not the asset is running.*
- bool is_sunk

    *A boolean which indicates whether or not the asset should be considered a sunk cost (i.e., capital cost incurred at the start of the model, or no).*
- bool normalized_production_series_given

    *A boolen which indicates whether or not a normalized production time series is given.*
- int n_points

    *The number of points in the modelling time series.*
- int n_starts

    *The number of times the asset has been started.*
- int n_replacements

    *The number of times the asset has been replaced.*
- double n_years

    *The number of years being modelled.*
- double running_hours

    *The number of hours for which the assset has been operating.*
- double replace_running_hrs

    *The number of running hours after which the asset must be replaced.*
- double capacity_kW

    *The rated production capacity [kW] of the asset.*
- double nominal_inflation_annual

    *The nominal, annual inflation rate to use in computing model economics.*

- double nominal_discount_annual

  *The nominal, annual discount rate to use in computing model economics.*
- double real_discount_annual

  *The real, annual discount rate used in computing model economics. Is computed from the given nominal inflation and discount rates.*
- double capital_cost

  *The capital cost of the asset (undefined currency).*
- double operation_maintenance_cost_kWh

  *The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced.*
- double net_present_cost

  *The net present cost of this asset.*
- double total_dispatch_kWh

  *The total energy dispatched [kWh] over the Model run.*
- double levellized_cost_of_energy_kWh

  *The levellized cost of energy [1/kWh] (undefined currency) of this asset. This metric considers only dispatch.*
- std::string type_str

  *A string describing the type of the asset.*
- std::string path_2_normalized_production_time_series

  *A string defining the path (either relative or absolute) to the given normalized production time series.*
- std::vector< bool > is_running_vec

  *A boolean vector for tracking if the asset is running at a particular point in time.*
- std::vector< double > normalized_production_vec

  *A vector of normalizd production [ ] at each point in the modelling time series.*
- std::vector< double > production_vec_kW

  *A vector of production [kW] at each point in the modelling time series.*
- std::vector< double > dispatch_vec_kW

  *A vector of dispatch [kW] at each point in the modelling time series. Dispatch is the amount of production that is sent to the grid to satisfy load.*
- std::vector< double > storage_vec_kW

  *A vector of storage [kW] at each point in the modelling time series. Storage is the amount of production that is sent to storage.*
- std::vector< double > curtailment_vec_kW

  *A vector of curtailment [kW] at each point in the modelling time series. Curtailment is the amount of production that can be neither dispatched nor stored, and is hence curtailed.*
- std::vector< double > capital_cost_vec

  *A vector of capital costs (undefined currency) incurred over each modelling time step. These costs are not discounted (i.e., these are actual costs).*
- std::vector< double > operation_maintenance_cost_vec

  *A vector of operation and maintenance costs (undefined currency) incurred over each modelling time step. These costs are not discounted (i.e., these are actual costs).*

## Private Member Functions

- void __checkInputs (int, double, ProductionInputs)

  *Helper method to check inputs to the Production constructor.*
- void __checkTimePoint (double, double)

  *Helper method to check received time point against expected time point. The given time series should align point-wise with the previously given electrical load time series.*
- void __throwLengthError (void)

  *Helper method to throw data length error (if not the same as the given electrical load time series).*
- void __checkNormalizedProduction (double)

*Helper method to check that given data values are everywhere contained in the closed interval [0, 1]. A normalized production time series is expected, so this must be true everywhere.*

- void __readNormalizedProductionData (std::vector< double > *)

  *Helper method to read in a given time series of normalized production.*

### 4.19.1 Detailed Description

The base class of the Production hierarchy. This hierarchy contains derived classes which model the production of energy, be it renewable or otherwise.

### 4.19.2 Constructor & Destructor Documentation

#### 4.19.2.1 Production() [1/2]

```
Production::Production (
            void )
```

Constructor (dummy) for the Production class.

```
{
    return;
}   /* Production() */
```

#### 4.19.2.2 Production() [2/2]

```
Production::Production (
            int n_points,
            double n_years,
            ProductionInputs production_inputs,
            std::vector< double > * time_vec_hrs_ptr )
```

Constructor (intended) for the Production class.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *n_years* | The number of years being modelled. |
| *production_inputs* | A structure of Production constructor inputs. |
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
{
    //  1. check inputs
    this->__checkInputs(n_points, n_years, production_inputs);

    //  2. set attributes
    this->print_flag = production_inputs.print_flag;
    this->is_running = false;
    this->is_sunk = production_inputs.is_sunk;
    this->normalized_production_series_given = false;

```

```
    this->n_points = n_points;
    this->n_starts = 0;
    this->n_replacements = 0;

    this->n_years = n_years;

    this->running_hours = 0;
    this->replace_running_hrs = production_inputs.replace_running_hrs;

    this->capacity_kW = production_inputs.capacity_kW;

    this->nominal_inflation_annual = production_inputs.nominal_inflation_annual;
    this->nominal_discount_annual = production_inputs.nominal_discount_annual;

    this->real_discount_annual = this->computeRealDiscountAnnual(
        production_inputs.nominal_inflation_annual,
        production_inputs.nominal_discount_annual
    );

    this->capital_cost = 0;
    this->operation_maintenance_cost_kWh = 0;
    this->net_present_cost = 0;
    this->total_dispatch_kWh = 0;
    this->levellized_cost_of_energy_kWh = 0;

    this->path_2_normalized_production_time_series = "";

    this->is_running_vec.resize(this->n_points, 0);

    this->normalized_production_vec.resize(this->n_points, 0);
    this->production_vec_kW.resize(this->n_points, 0);
    this->dispatch_vec_kW.resize(this->n_points, 0);
    this->storage_vec_kW.resize(this->n_points, 0);
    this->curtailment_vec_kW.resize(this->n_points, 0);

    this->capital_cost_vec.resize(this->n_points, 0);
    this->operation_maintenance_cost_vec.resize(this->n_points, 0);

    //  3. read in normalized production time series (if given)
    if (not production_inputs.path_2_normalized_production_time_series.empty()) {
        this->normalized_production_series_given = true;

        this->path_2_normalized_production_time_series =
            production_inputs.path_2_normalized_production_time_series;

        this->__readNormalizedProductionData(time_vec_hrs_ptr);
    }

    //  4. construction print
    if (this->print_flag) {
        std::cout « "Production object constructed at " « this « std::endl;
    }

    return;
}   /* Production() */
```

#### 4.19.2.3 ∼Production()

```
Production::∼Production (
              void  )  [virtual]
```

Destructor for the Production class.

```
{
    //  1. destruction print
    if (this->print_flag) {
        std::cout « "Production object at " « this « " destroyed" « std::endl;
    }

    return;
}   /* ~Production() */
```

### 4.19.3 Member Function Documentation

#### 4.19.3.1 __checkInputs()

```
void Production::__checkInputs (
            int n_points,
            double n_years,
            ProductionInputs production_inputs )  [private]
```

Helper method to check inputs to the Production constructor.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *production_inputs* | A structure of Production constructor inputs. |

```
{
    //  1. check n_points
    if (n_points <= 0) {
        std::string error_str = "ERROR:  Production():  n_points must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  2. check n_years
    if (n_years <= 0) {
        std::string error_str = "ERROR:  Production():  n_years must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  3. check capacity_kW
    if (production_inputs.capacity_kW <= 0) {
        std::string error_str = "ERROR:  Production():  ";
        error_str += "ProductionInputs::capacity_kW must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  4. check replace_running_hrs
    if (production_inputs.replace_running_hrs <= 0) {
        std::string error_str = "ERROR:  Production():  ";
        error_str += "ProductionInputs::replace_running_hrs must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkInputs() */
```

#### 4.19.3.2 __checkNormalizedProduction()

```
void Production::__checkNormalizedProduction (
            double normalized_production )  [private]
```

Helper method to check that given data values are everywhere contained in the closed interval [0, 1]. A normalized production time series is expected, so this must be true everywhere.

**Parameters**

| | |
|---|---|
| *normalized_production* | The normalized production value to check |

```
{
    if (normalized_production < 0 or normalized_production > 1) {
        std::string error_str = "ERROR:  Production():  ";
        error_str += "the given normalized production time series at ";
        error_str += this->path_2_normalized_production_time_series;
        error_str += " contains normalized production values outside the closed ";
        error_str += "interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::runtime_error(error_str);
    }

    return;
}   /* __throwValueError() */
```

#### 4.19.3.3 __checkTimePoint()

```
void Production::__checkTimePoint (
            double time_received_hrs,
            double time_expected_hrs )  [private]
```

Helper method to check received time point against expected time point. The given time series should align point-wise with the previously given electrical load time series.

**Parameters**

| | |
|---|---|
| *time_received_hrs* | The point in time received from the given data. |
| *time_expected_hrs* | The point in time expected (this comes from the electrical load time series). |

```
{
    if (time_received_hrs != time_expected_hrs) {
        std::string error_str = "ERROR:  Production():  ";
        error_str += "the given normalized production time series at ";
        error_str += this->path_2_normalized_production_time_series;
        error_str += " does not align with the ";
        error_str += "previously given electrical load time series";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::runtime_error(error_str);
    }

    return;
}   /* __checkTimePoint() */
```

#### 4.19.3.4 __readNormalizedProductionData()

```
void Production::__readNormalizedProductionData (
            std::vector< double > * time_vec_hrs_ptr )  [private]
```

Helper method to read in a given time series of normalized production.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
{
    //  1. init CSV reader
    io::CSVReader<2> CSV(this->path_2_normalized_production_time_series);

    CSV.read_header(
        io::ignore_extra_column,
        "Time (since start of data) [hrs]",
        "Normalized Production [ ]"
    );

    //  2. read in normalized performance data,
    //     check values and check against time series (point-wise and length)
    int n_points = 0;
    double time_hrs = 0;
    double time_expected_hrs = 0;
    double normalized_production = 0;

    while (CSV.read_row(time_hrs, normalized_production)) {
        //  2.1. check length of data
        if (n_points > this->n_points) {
            this->__throwLengthError();
        }

        //  2.2. check normalized production value
        this->__checkNormalizedProduction(normalized_production);

        //  2.3. check time point
        time_expected_hrs = time_vec_hrs_ptr->at(n_points);
        this->__checkTimePoint(time_hrs, time_expected_hrs);

        //  2.4. write to normalized production vector, increment n_points
        this->normalized_production_vec[n_points] = normalized_production;
        n_points++;
    }

    //  3. check length of data
    if (n_points != this->n_points) {
        this->__throwLengthError();
    }

    return;
}   /* __readNormalizedProductionData() */
```

### 4.19.3.5 __throwLengthError()

```
void Production::__throwLengthError (
            void ) [private]
```

Helper method to throw data length error (if not the same as the given electrical load time series).

```
{
    std::string error_str = "ERROR:  Production():  ";
    error_str += "the given normalized production time series at ";
    error_str += this->path_2_normalized_production_time_series;
    error_str += " is not the same length as the previously given electrical";
    error_str += " load time series";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);

    return;
}   /* __throwLengthError() */
```

#### 4.19.3.6 commit()

```
double Production::commit (
            int timestep,
            double dt_hrs,
            double production_kW,
            double load_kW )  [virtual]
```

Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *production_kW* | The production [kW] of the asset in this timestep. |
| *load_kW* | The load [kW] passed to the asset in this timestep. |

**Returns**

The load [kW] remaining after the dispatch is deducted from it.

Reimplemented in Wind, Wave, Tidal, Solar, Renewable, Noncombustion, Diesel, and Combustion.

```
{
    //  1. record production
    this->production_vec_kW[timestep] = production_kW;

    //  2. compute and record dispatch and curtailment
    double dispatch_kW = 0;
    double curtailment_kW = 0;

    if (production_kW > load_kW) {
        dispatch_kW = load_kW;
        curtailment_kW = production_kW - dispatch_kW;
    }

    else {
        dispatch_kW = production_kW;
    }

    this->dispatch_vec_kW[timestep] = dispatch_kW;
    this->total_dispatch_kWh += dispatch_kW * dt_hrs;
    this->curtailment_vec_kW[timestep] = curtailment_kW;

    //  3. update load
    load_kW -= dispatch_kW;

    //  4. update and log running attributes
    if (this->is_running) {
        //  4.1. log running state, running hours
        this->is_running_vec[timestep] = this->is_running;
        this->running_hours += dt_hrs;

        //  4.2. incur operation and maintenance costs
        double produced_kWh = production_kW * dt_hrs;

        double operation_maintenance_cost =
            this->operation_maintenance_cost_kWh * produced_kWh;
        this->operation_maintenance_cost_vec[timestep] = operation_maintenance_cost;
    }

    //  5. trigger replacement, if applicable
    if (this->running_hours >= (this->n_replacements + 1) * this->replace_running_hrs) {
        this->handleReplacement(timestep);
    }

    return load_kW;
}   /* commit() */
```

#### 4.19.3.7 computeEconomics()

```
void Production::computeEconomics (
            std::vector< double > * time_vec_hrs_ptr )  [virtual]
```

Helper method to compute key economic metrics for the Model run.

Ref: HOMER [2023b]
Ref: HOMER [2023g]
Ref: HOMER [2023i]
Ref: HOMER [2023a]

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |

1. compute levellized cost of energy (per unit dispatched)

Reimplemented in Renewable, Noncombustion, and Combustion.

```
{
    //  1. compute net present cost
    double t_hrs = 0;
    double real_discount_scalar = 0;

    for (int i = 0; i < this->n_points; i++) {
        t_hrs = time_vec_hrs_ptr->at(i);

        real_discount_scalar = 1.0 / pow(
            1 + this->real_discount_annual,
            t_hrs / 8760
        );

        this->net_present_cost += real_discount_scalar * this->capital_cost_vec[i];

        this->net_present_cost +=
            real_discount_scalar * this->operation_maintenance_cost_vec[i];
    }

    //     assuming 8,760 hours per year
    if (this->total_dispatch_kWh <= 0) {
        this->levellized_cost_of_energy_kWh = this->net_present_cost;
    }

    else {
        double n_years = time_vec_hrs_ptr->at(this->n_points - 1) / 8760;

        double capital_recovery_factor =
            (this->real_discount_annual * pow(1 + this->real_discount_annual, n_years)) /
            (pow(1 + this->real_discount_annual, n_years) - 1);

        double total_annualized_cost = capital_recovery_factor *
            this->net_present_cost;

        this->levellized_cost_of_energy_kWh =
            (n_years * total_annualized_cost) /
            this->total_dispatch_kWh;
    }

    return;
}   /* computeEconomics() */
```

#### 4.19.3.8 computeRealDiscountAnnual()

```
double Production::computeRealDiscountAnnual (
            double nominal_inflation_annual,
            double nominal_discount_annual )
```

Method to compute the real, annual discount rate to be used in computing model economics. This enables application of the discount factor approach.

Ref: HOMER [2023h]
Ref: HOMER [2023b]

**Parameters**

| | |
|---|---|
| *nominal_inflation_annual* | The nominal, annual inflation rate to use in computing model economics. |
| *nominal_discount_annual* | The nominal, annual discount rate to use in computing model economics. |

**Returns**

The real, annual discount rate to use in computing model economics.

```
{
    double real_discount_annual = nominal_discount_annual - nominal_inflation_annual;
    real_discount_annual /= 1 + nominal_inflation_annual;

    return real_discount_annual;
}   /* __computeRealDiscountAnnual() */
```

#### 4.19.3.9 getProductionkW()

```
double Production::getProductionkW (
            int timestep )
```

A method to simply fetch the normalized production at a particular point in the given normalized production time series, multiply by the rated capacity of the asset, and return.

**Returns**

The production [kW] for the asset at the given point in time, as defined by the given normalized production time series.

```
{
    double production_kW =
        this->normalized_production_vec[timestep] * this->capacity_kW;

    return production_kW;
}   /* getProductionkW() */
```

#### 4.19.3.10 handleReplacement()

```
void Production::handleReplacement (
            int timestep )  [virtual]
```

Method to handle asset replacement and capital cost incursion, if applicable.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |

Reimplemented in Wind, Wave, Tidal, Solar, Renewable, Noncombustion, Hydro, Diesel, and Combustion.

```
{
    //  1. reset attributes
    this->is_running = false;

    //  2. log replacement
    this->n_replacements++;

    //  3. incur capital cost in timestep
    this->capital_cost_vec[timestep] = this->capital_cost;

    return;
}   /* __handleReplacement() */
```

## 4.19.4 Member Data Documentation

### 4.19.4.1 capacity_kW

`double Production::capacity_kW`

The rated production capacity [kW] of the asset.

### 4.19.4.2 capital_cost

`double Production::capital_cost`

The capital cost of the asset (undefined currency).

### 4.19.4.3 capital_cost_vec

`std::vector<double> Production::capital_cost_vec`

A vector of capital costs (undefined currency) incurred over each modelling time step. These costs are not discounted (i.e., these are actual costs).

### 4.19.4.4 curtailment_vec_kW

`std::vector<double> Production::curtailment_vec_kW`

A vector of curtailment [kW] at each point in the modelling time series. Curtailment is the amount of production that can be neither dispatched nor stored, and is hence curtailed.

#### 4.19.4.5 dispatch_vec_kW

`std::vector<double> Production::dispatch_vec_kW`

A vector of dispatch [kW] at each point in the modelling time series. Dispatch is the amount of production that is sent to the grid to satisfy load.

#### 4.19.4.6 interpolator

`Interpolator Production::interpolator`

Interpolator component of Production.

#### 4.19.4.7 is_running

`bool Production::is_running`

A boolean which indicates whether or not the asset is running.

#### 4.19.4.8 is_running_vec

`std::vector<bool> Production::is_running_vec`

A boolean vector for tracking if the asset is running at a particular point in time.

#### 4.19.4.9 is_sunk

`bool Production::is_sunk`

A boolean which indicates whether or not the asset should be considered a sunk cost (i.e., capital cost incurred at the start of the model, or no).

#### 4.19.4.10 levellized_cost_of_energy_kWh

`double Production::levellized_cost_of_energy_kWh`

The levellized cost of energy [1/kWh] (undefined currency) of this asset. This metric considers only dispatch.

#### 4.19.4.11 n_points

```
int Production::n_points
```

The number of points in the modelling time series.

#### 4.19.4.12 n_replacements

```
int Production::n_replacements
```

The number of times the asset has been replaced.

#### 4.19.4.13 n_starts

```
int Production::n_starts
```

The number of times the asset has been started.

#### 4.19.4.14 n_years

```
double Production::n_years
```

The number of years being modelled.

#### 4.19.4.15 net_present_cost

```
double Production::net_present_cost
```

The net present cost of this asset.

#### 4.19.4.16 nominal_discount_annual

```
double Production::nominal_discount_annual
```

The nominal, annual discount rate to use in computing model economics.

#### 4.19.4.17 nominal_inflation_annual

```
double Production::nominal_inflation_annual
```

The nominal, annual inflation rate to use in computing model economics.

#### 4.19.4.18 normalized_production_series_given

```
bool Production::normalized_production_series_given
```

A boolen which indicates whether or not a normalized production time series is given.

#### 4.19.4.19 normalized_production_vec

```
std::vector<double> Production::normalized_production_vec
```

A vector of normalizd production [ ] at each point in the modelling time series.

#### 4.19.4.20 operation_maintenance_cost_kWh

```
double Production::operation_maintenance_cost_kWh
```

The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced.

#### 4.19.4.21 operation_maintenance_cost_vec

```
std::vector<double> Production::operation_maintenance_cost_vec
```

A vector of operation and maintenance costs (undefined currency) incurred over each modelling time step. These costs are not discounted (i.e., these are actual costs).

#### 4.19.4.22 path_2_normalized_production_time_series

```
std::string Production::path_2_normalized_production_time_series
```

A string defining the path (either relative or absolute) to the given normalized production time series.

#### 4.19.4.23 print_flag

```
bool Production::print_flag
```

A flag which indicates whether or not object construct/destruction should be verbose.

#### 4.19.4.24 production_vec_kW

```
std::vector<double> Production::production_vec_kW
```

A vector of production [kW] at each point in the modelling time series.

#### 4.19.4.25 real_discount_annual

```
double Production::real_discount_annual
```

The real, annual discount rate used in computing model economics. Is computed from the given nominal inflation and discount rates.

#### 4.19.4.26 replace_running_hrs

```
double Production::replace_running_hrs
```

The number of running hours after which the asset must be replaced.

#### 4.19.4.27 running_hours

```
double Production::running_hours
```

The number of hours for which the assset has been operating.

#### 4.19.4.28 storage_vec_kW

```
std::vector<double> Production::storage_vec_kW
```

A vector of storage [kW] at each point in the modelling time series. Storage is the amount of production that is sent to storage.

#### 4.19.4.29 total_dispatch_kWh

```
double Production::total_dispatch_kWh
```

The total energy dispatched [kWh] over the Model run.

#### 4.19.4.30 type_str

```
std::string Production::type_str
```

A string describing the type of the asset.

The documentation for this class was generated from the following files:

- header/Production/Production.h
- source/Production/Production.cpp

## 4.20 ProductionInputs Struct Reference

A structure which bundles the necessary inputs for the Production constructor. Provides default values for every necessary input.

```
#include <Production.h>
```

### Public Attributes

- bool print_flag = false
  *A flag which indicates whether or not object construct/destruction should be verbose.*
- bool is_sunk = false
  *A boolean which indicates whether or not the asset should be considered a sunk cost (i.e., capital cost incurred at the start of the model, or no).*
- double capacity_kW = 100
  *The rated production capacity [kW] of the asset.*
- double nominal_inflation_annual = 0.02
  *The nominal, annual inflation rate to use in computing model economics.*
- double nominal_discount_annual = 0.04
  *The nominal, annual discount rate to use in computing model economics.*
- double replace_running_hrs = 90000
  *The number of running hours after which the asset must be replaced.*
- std::string path_2_normalized_production_time_series = ""
  *A string defining the path (either relative or absolute) to the given normalized production time series.*

### 4.20.1 Detailed Description

A structure which bundles the necessary inputs for the Production constructor. Provides default values for every necessary input.

### 4.20.2 Member Data Documentation

#### 4.20.2.1 capacity_kW

```
double ProductionInputs::capacity_kW = 100
```

The rated production capacity [kW] of the asset.

#### 4.20.2.2 is_sunk

```
bool ProductionInputs::is_sunk = false
```

A boolean which indicates whether or not the asset should be considered a sunk cost (i.e., capital cost incurred at the start of the model, or no).

#### 4.20.2.3 nominal_discount_annual

```
double ProductionInputs::nominal_discount_annual = 0.04
```

The nominal, annual discount rate to use in computing model economics.

#### 4.20.2.4 nominal_inflation_annual

```
double ProductionInputs::nominal_inflation_annual = 0.02
```

The nominal, annual inflation rate to use in computing model economics.

#### 4.20.2.5 path_2_normalized_production_time_series

```
std::string ProductionInputs::path_2_normalized_production_time_series = ""
```

A string defining the path (either relative or absolute) to the given normalized production time series.

#### 4.20.2.6 print_flag

```
bool ProductionInputs::print_flag = false
```

A flag which indicates whether or not object construct/destruction should be verbose.

#### 4.20.2.7 replace_running_hrs

```
double ProductionInputs::replace_running_hrs = 90000
```

The number of running hours after which the asset must be replaced.

The documentation for this struct was generated from the following file:

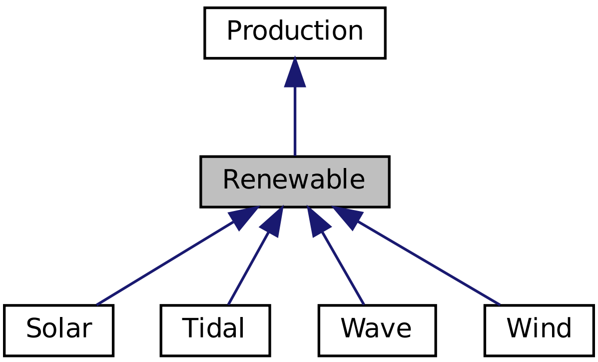
- header/Production/Production.h

## 4.21 Renewable Class Reference

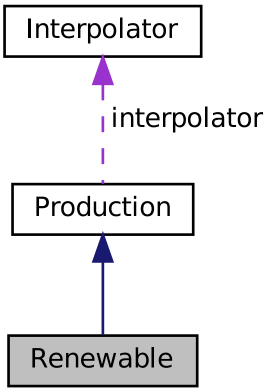
The root of the Renewable branch of the Production hierarchy. This branch contains derived classes which model the renewable production of energy.

```
#include <Renewable.h>
```

Inheritance diagram for Renewable:



Collaboration diagram for Renewable:




## Public Member Functions

- Renewable (void)

  *Constructor (dummy) for the Renewable class.*
- Renewable (int, double, RenewableInputs, std::vector< double > ∗)

  *Constructor (intended) for the Renewable class.*
- virtual void handleReplacement (int)

  *Method to handle asset replacement and capital cost incursion, if applicable.*
- void computeEconomics (std::vector< double > ∗)

  *Helper method to compute key economic metrics for the Model run.*
- virtual double computeProductionkW (int, double, double)
- virtual double computeProductionkW (int, double, double, double)
- virtual double commit (int, double, double, double)

  *Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.*
- void writeResults (std::string, std::vector< double > ∗, std::map< int, std::vector< double >> ∗, std::map< int, std::vector< std::vector< double >>> ∗, int, int=-1)

  *Method which writes Renewable results to an output directory.*
- virtual ∼Renewable (void)

  *Destructor for the Renewable class.*

## Public Attributes

- RenewableType type

  *The type (RenewableType) of the asset.*
- int resource_key

  *A key used to index into the Resources object, to associate this asset with the appropriate resource time series.*
- double firmness_factor

  *A factor [0, 1] which defines how firm the production from this asset is.*

## Private Member Functions

- void __checkInputs (RenewableInputs)
  *Helper method to check inputs to the Renewable constructor.*
- void __handleStartStop (int, double, double)
  *Helper method to handle the starting/stopping of the renewable asset.*
- virtual void __writeSummary (std::string)
- virtual void __writeTimeSeries (std::string, std::vector< double > *, std::map< int, std::vector< double >> *, std::map< int, std::vector< std::vector< double >>> *, int=-1)

## 4.21.1 Detailed Description

The root of the Renewable branch of the Production hierarchy. This branch contains derived classes which model the renewable production of energy.

## 4.21.2 Constructor & Destructor Documentation

### 4.21.2.1 Renewable() [1/2]

```
Renewable::Renewable (
            void )
```

Constructor (dummy) for the Renewable class.

```
{
    //...

    return;
}   /* Renewable() */
```

### 4.21.2.2 Renewable() [2/2]

```
Renewable::Renewable (
            int n_points,
            double n_years,
            RenewableInputs renewable_inputs,
            std::vector< double > * time_vec_hrs_ptr )
```

Constructor (intended) for the Renewable class.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *n_years* | The number of years being modelled. |
| *renewable_inputs* | A structure of Renewable constructor inputs. |
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
  :
Production(
    n_points,
    n_years,
    renewable_inputs.production_inputs,
    time_vec_hrs_ptr
)
{
    //  1. check inputs
    this->__checkInputs(renewable_inputs);

    //  2. set attributes
    //...

    //  3. construction print
    if (this->print_flag) {
        std::cout « "Renewable object constructed at " « this « std::endl;
    }

    return;
}   /* Renewable() */
```

#### 4.21.2.3 ∼Renewable()

```
Renewable::∼Renewable (
              void  )  [virtual]
```

Destructor for the Renewable class.

```
{
    //  1. destruction print
    if (this->print_flag) {
        std::cout « "Renewable object at " « this « " destroyed" « std::endl;
    }

    return;
}   /* ~Renewable() */
```

### 4.21.3 Member Function Documentation

#### 4.21.3.1 __checkInputs()

```
void Renewable::__checkInputs (
              RenewableInputs renewable_inputs )  [private]
```

Helper method to check inputs to the Renewable constructor.

```
{
    //...

    return;
}   /* __checkInputs() */
```

#### 4.21.3.2 __handleStartStop()

```
void Renewable::__handleStartStop (
            int timestep,
            double dt_hrs,
            double production_kW )  [private]
```

Helper method to handle the starting/stopping of the renewable asset.

```
{
    if (this->is_running) {
        // handle stopping
        if (production_kW <= 0) {
            this->is_running = false;
        }
    }

    else {
        // handle starting
        if (production_kW > 0) {
            this->is_running = true;
            this->n_starts++;
        }
    }

    return;
}   /* __handleStartStop() */
```

#### 4.21.3.3 __writeSummary()

```
virtual void Renewable::__writeSummary (
            std::string  )  [inline], [private], [virtual]
```

Reimplemented in Wind, Wave, Tidal, and Solar.

```
{return;}
```

#### 4.21.3.4 __writeTimeSeries()

```
virtual void Renewable::__writeTimeSeries (
            std::string ,
            std::vector< double > * ,
            std::map< int, std::vector< double >> * ,
            std::map< int, std::vector< std::vector< double >>> * ,
            int  = -1 )  [inline], [private], [virtual]
```

Reimplemented in Wind, Wave, Tidal, and Solar.

```
{return;}
```

#### 4.21.3.5 commit()

```
double Renewable::commit (
            int timestep,
            double dt_hrs,
            double production_kW,
            double load_kW )  [virtual]
```

Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *production_kW* | The production [kW] of the asset in this timestep. |
| *load_kW* | The load [kW] passed to the asset in this timestep. |

**Returns**

The load [kW] remaining after the dispatch is deducted from it.

Reimplemented from Production.

Reimplemented in Wind, Wave, Tidal, and Solar.

```
{
    //  1. handle start/stop
    this->__handleStartStop(timestep, dt_hrs, production_kW);

    //  2. invoke base class method
    load_kW = Production :: commit(
        timestep,
        dt_hrs,
        production_kW,
        load_kW
    );


    //...

    return load_kW;
}   /* commit() */
```

#### 4.21.3.6 computeEconomics()

```
void Renewable::computeEconomics (
            std::vector< double > * time_vec_hrs_ptr )  [virtual]
```

Helper method to compute key economic metrics for the Model run.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |

Reimplemented from Production.

```
{
    //  1. invoke base class method
    Production :: computeEconomics(time_vec_hrs_ptr);

    return;
}   /* computeEconomics() */
```

#### 4.21.3.7 computeProductionkW() [1/2]

```
virtual double Renewable::computeProductionkW (
            int ,
```

```
            double ,
            double  )  [inline], [virtual]
```

Reimplemented in Wind, Tidal, and Solar.

```
{return 0;}
```

#### 4.21.3.8 computeProductionkW() [2/2]

```
virtual double Renewable::computeProductionkW (
            int ,
            double ,
            double ,
            double  )  [inline], [virtual]
```

Reimplemented in Wave.

```
{return 0;}
```

#### 4.21.3.9 handleReplacement()

```
void Renewable::handleReplacement (
            int timestep )  [virtual]
```

Method to handle asset replacement and capital cost incursion, if applicable.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |

Reimplemented from Production.

Reimplemented in Wind, Wave, Tidal, and Solar.

```
{
    //  1. reset attributes
    //...

    //  2. invoke base class method
    Production :: handleReplacement(timestep);

    return;
}   /* __handleReplacement() */
```

#### 4.21.3.10 writeResults()

```
void Renewable::writeResults (
            std::string write_path,
            std::vector< double > * time_vec_hrs_ptr,
            std::map< int, std::vector< double >> * resource_map_1D_ptr,
            std::map< int, std::vector< std::vector< double >>> * resource_map_2D_ptr,
            int renewable_index,
            int max_lines = -1 )
```

Method which writes Renewable results to an output directory.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |
| *resource_map_1D_ptr* | A pointer to the 1D map of Resources. |
| *resource_map_2D_ptr* | A pointer to the 2D map of Resources. |
| *renewable_index* | An integer which corresponds to the index of the Renewable asset in the Model. |
| *max_lines* | The maximum number of lines of output to write. If <0, then all available lines are written. If =0, then only summary results are written. |

```
{
    //  1. handle sentinel
    if (max_lines < 0) {
        max_lines = this->n_points;
    }

    //  2. create subdirectories
    write_path += "Production/";
    if (not std::filesystem::is_directory(write_path)) {
        std::filesystem::create_directory(write_path);
    }

    write_path += "Renewable/";
    if (not std::filesystem::is_directory(write_path)) {
        std::filesystem::create_directory(write_path);
    }

    write_path += this->type_str;
    write_path += "_";
    write_path += std::to_string(int(ceil(this->capacity_kW)));
    write_path += "kW_idx";
    write_path += std::to_string(renewable_index);
    write_path += "/";
    std::filesystem::create_directory(write_path);

    //  3. write summary
    this->__writeSummary(write_path);

    //  4. write time series
    if (max_lines > this->n_points) {
        max_lines = this->n_points;
    }

    if (max_lines > 0) {
        this->__writeTimeSeries(
            write_path,
            time_vec_hrs_ptr,
            resource_map_1D_ptr,
            resource_map_2D_ptr,
            max_lines
        );
    }

    return;
}   /* writeResults() */
```

## 4.21.4 Member Data Documentation

### 4.21.4.1 firmness_factor

```
double Renewable::firmness_factor
```

A factor [0, 1] which defines how firm the production from this asset is.

#### 4.21.4.2 resource_key

```
int Renewable::resource_key
```

A key used to index into the Resources object, to associate this asset with the appropriate resource time series.

#### 4.21.4.3 type

```
RenewableType Renewable::type
```

The type (RenewableType) of the asset.

The documentation for this class was generated from the following files:

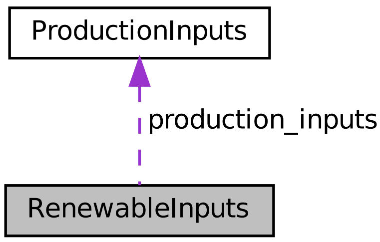
- header/Production/Renewable/Renewable.h
- source/Production/Renewable/Renewable.cpp

## 4.22 RenewableInputs Struct Reference

A structure which bundles the necessary inputs for the Renewable constructor. Provides default values for every necessary input. Note that this structure encapsulates ProductionInputs.

```
#include <Renewable.h>
```

Collaboration diagram for RenewableInputs:




### Public Attributes

- ProductionInputs production_inputs

  *An encapsulated ProductionInputs instance.*

### 4.22.1 Detailed Description

A structure which bundles the necessary inputs for the Renewable constructor. Provides default values for every necessary input. Note that this structure encapsulates ProductionInputs.

### 4.22.2 Member Data Documentation

#### 4.22.2.1 production_inputs

`ProductionInputs RenewableInputs::production_inputs`

An encapsulated ProductionInputs instance.

The documentation for this struct was generated from the following file:

- header/Production/Renewable/Renewable.h

## 4.23 Resources Class Reference

A class which contains renewable resource data. Intended to serve as a component class of Model.

`#include <Resources.h>`

### Public Member Functions

- Resources (void)

  *Constructor for the Resources class.*
- void addResource (NoncombustionType, std::string, int, ElectricalLoad ∗)

  *A method to add a renewable resource time series to Resources. Checks if given resource key is already in use. The associated helper methods also check against ElectricalLoad to ensure that all added time series align with the electrical load time series (both in terms of length and which points in time are included).*
- void addResource (RenewableType, std::string, int, ElectricalLoad ∗)

  *A method to add a renewable resource time series to Resources. Checks if given resource key is already in use. The associated helper methods also check against ElectricalLoad to ensure that all added time series align with the electrical load time series (both in terms of length and which points in time are included).*
- void clear (void)

  *Method to clear all attributes of the Resources object.*
- ∼Resources (void)

  *Destructor for the Resources class.*

## Public Attributes

- std::map< int, std::vector< double > > resource_map_1D

  *A map <int, vector<double>> of given 1D renewable resource time series.*
- std::map< int, std::string > string_map_1D

  *A map <int, string> of descriptors for the type of the given 1D renewable resource time series.*
- std::map< int, std::string > path_map_1D

  *A map <int, string> of the paths (either relative or absolute) to given 1D renewable resource time series.*
- std::map< int, std::vector< std::vector< double > > > resource_map_2D

  *A map <int, vector<vector<double>>> of given 2D renewable resource time series.*
- std::map< int, std::string > string_map_2D

  *A map <int, string> of descriptors for the type of the given 2D renewable resource time series.*
- std::map< int, std::string > path_map_2D

  *A map <int, string> of the paths (either relative or absolute) to given 2D renewable resource time series.*

## Private Member Functions

- void __checkResourceKey1D (int, RenewableType)

  *Helper method to check if given resource key (1D) is already in use.*
- void __checkResourceKey2D (int, RenewableType)

  *Helper method to check if given resource key (2D) is already in use.*
- void __checkResourceKey1D (int, NoncombustionType)

  *Helper method to check if given resource key (1D) is already in use.*
- void __checkTimePoint (double, double, std::string, ElectricalLoad ∗)

  *Helper method to check received time point against expected time point. The given time series should align point-wise with the previously given electrical load time series.*
- void __throwLengthError (std::string, ElectricalLoad ∗)

  *Helper method to throw data length error (if not the same as the given electrical load time series).*
- void __readHydroResource (std::string, int, ElectricalLoad ∗)

  *Helper method to handle reading a hydro resource time series into Resources.*
- void __readSolarResource (std::string, int, ElectricalLoad ∗)

  *Helper method to handle reading a solar resource time series into Resources.*
- void __readTidalResource (std::string, int, ElectricalLoad ∗)

  *Helper method to handle reading a tidal resource time series into Resources.*
- void __readWaveResource (std::string, int, ElectricalLoad ∗)

  *Helper method to handle reading a wave resource time series into Resources.*
- void __readWindResource (std::string, int, ElectricalLoad ∗)

  *Helper method to handle reading a wind resource time series into Resources.*

### 4.23.1 Detailed Description

A class which contains renewable resource data. Intended to serve as a component class of Model.

### 4.23.2 Constructor & Destructor Documentation

#### 4.23.2.1 Resources()

```
Resources::Resources (
            void )
```

Constructor for the Resources class.

```
{
    return;
}   /* Resources() */
```

#### 4.23.2.2 ∼Resources()

```
Resources::∼Resources (
            void )
```

Destructor for the Resources class.

```
{
    this->clear();
    return;
}   /* ~Resources() */
```

### 4.23.3 Member Function Documentation

#### 4.23.3.1 __checkResourceKey1D() [1/2]

```
void Resources::__checkResourceKey1D (
            int resource_key,
            NoncombustionType noncombustion_type )  [private]
```

Helper method to check if given resource key (1D) is already in use.

**Parameters**

| | |
|---|---|
| *resource_key* | The key associated with the given renewable resource. |
| *noncombustion_type* | The type of renewable resource being added to Resources. |

```
{
    if (this->resource_map_1D.count(resource_key) > 0) {
        std::string error_str = "ERROR:  Resources::addResource(";

        switch (noncombustion_type) {
            case (NoncombustionType :: HYDRO): {
                error_str += "HYDRO):  ";

                break;
            }

            default: {
                error_str += "UNDEFINED_TYPE):  ";

                break;
            }
        }

        error_str += "resource key (1D) ";
        error_str += std::to_string(resource_key);
```

```
        error_str += " is already in use";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkResourceKey1D() */
```

#### 4.23.3.2 __checkResourceKey1D() [2/2]

```
void Resources::__checkResourceKey1D (
              int resource_key,
              RenewableType renewable_type )  [private]
```

Helper method to check if given resource key (1D) is already in use.

**Parameters**

| | |
|---|---|
| *resource_key* | The key associated with the given renewable resource. |
| *renewable_type* | The type of renewable resource being added to Resources. |

```
{
    if (this->resource_map_1D.count(resource_key) > 0) {
        std::string error_str = "ERROR:  Resources::addResource(";

        switch (renewable_type) {
            case (RenewableType :: SOLAR): {
                error_str += "SOLAR):  ";

                break;
            }

            case (RenewableType :: TIDAL): {
                error_str += "TIDAL):  ";

                break;
            }

            case (RenewableType :: WIND): {
                error_str += "WIND):  ";

                break;
            }

            default: {
                error_str += "UNDEFINED_TYPE):  ";

                break;
            }
        }

        error_str += "resource key (1D) ";
        error_str += std::to_string(resource_key);
        error_str += " is already in use";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkResourceKey1D() */
```

#### 4.23.3.3 __checkResourceKey2D()

```
void Resources::__checkResourceKey2D (
            int resource_key,
            RenewableType renewable_type )  [private]
```

Helper method to check if given resource key (2D) is already in use.

**Parameters**

| | |
|---|---|
| *resource_key* | The key associated with the given renewable resource. |

```
{
    if (this->resource_map_2D.count(resource_key) > 0) {
        std::string error_str = "ERROR:  Resources::addResource(";

        switch (renewable_type) {
            case (RenewableType :: WAVE): {
                error_str += "WAVE):  ";

                break;
            }

            default: {
                error_str += "UNDEFINED_TYPE):  ";

                break;
            }
        }

        error_str += "resource key (2D) ";
        error_str += std::to_string(resource_key);
        error_str += " is already in use";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /*  __checkResourceKey2D() */
```

#### 4.23.3.4 __checkTimePoint()

```
void Resources::__checkTimePoint (
            double time_received_hrs,
            double time_expected_hrs,
            std::string path_2_resource_data,
            ElectricalLoad * electrical_load_ptr )  [private]
```

Helper method to check received time point against expected time point. The given time series should align point-wise with the previously given electrical load time series.

**Parameters**

| | |
|---|---|
| *time_received_hrs* | The point in time received from the given data. |
| *time_expected_hrs* | The point in time expected (this comes from the electrical load time series). |
| *path_2_resource_data* | The path (either relative or absolute) to the given resource time series. |
| *electrical_load_ptr* | A pointer to the Model's ElectricalLoad object. |

```
{
```

```
    if (time_received_hrs != time_expected_hrs) {
        std::string error_str = "ERROR:  Resources::addResource():  ";
        error_str += "the given resource time series at ";
        error_str += path_2_resource_data;
        error_str += " does not align with the ";
        error_str += "previously given electrical load time series at ";
        error_str += electrical_load_ptr->path_2_electrical_load_time_series;

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::runtime_error(error_str);
    }

    return;
}   /* __checkTimePoint() */
```

#### 4.23.3.5 __readHydroResource()

```
void Resources::__readHydroResource (
            std::string path_2_resource_data,
            int resource_key,
            ElectricalLoad * electrical_load_ptr )  [private]
```

Helper method to handle reading a hydro resource time series into Resources.

**Parameters**

| | |
|---|---|
| *path_2_resource_data* | The path (either relative or absolute) to the given resource time series. |
| *resource_key* | The key associated with the given renewable resource. |
| *electrical_load_ptr* | A pointer to the Model's ElectricalLoad object. |

```
{
    //  1. init CSV reader, record path and type
    io::CSVReader<2> CSV(path_2_resource_data);

    CSV.read_header(
        io::ignore_extra_column,
        "Time (since start of data) [hrs]",
        "Hydro Inflow [m3/hr]"
    );

    this->path_map_1D.insert(
        std::pair<int, std::string>(resource_key, path_2_resource_data)
    );

    this->string_map_1D.insert(std::pair<int, std::string>(resource_key, "HYDRO"));

    //  2. init map element
    this->resource_map_1D.insert(
        std::pair<int, std::vector<double»(resource_key, {})
    );
    this->resource_map_1D[resource_key].resize(electrical_load_ptr->n_points, 0);


    //  3. read in resource data, check against time series (point-wise and length)
    int n_points = 0;
    double time_hrs = 0;
    double time_expected_hrs = 0;
    double hydro_resource_m3hr = 0;

    while (CSV.read_row(time_hrs, hydro_resource_m3hr)) {
        if (n_points > electrical_load_ptr->n_points) {
            this->__throwLengthError(path_2_resource_data, electrical_load_ptr);
        }

        time_expected_hrs = electrical_load_ptr->time_vec_hrs[n_points];
        this->__checkTimePoint(
            time_hrs,
            time_expected_hrs,
            path_2_resource_data,
```

```
            electrical_load_ptr
        );

        this->resource_map_1D[resource_key][n_points] = hydro_resource_m3hr;

        n_points++;
    }

    //  4. check data length
    if (n_points != electrical_load_ptr->n_points) {
        this->__throwLengthError(path_2_resource_data, electrical_load_ptr);
    }

    return;
}   /* __readHydroResource() */
```

#### 4.23.3.6 __readSolarResource()

```
void Resources::__readSolarResource (
            std::string path_2_resource_data,
            int resource_key,
            ElectricalLoad * electrical_load_ptr )  [private]
```

Helper method to handle reading a solar resource time series into Resources.

**Parameters**

| | |
|---|---|
| *path_2_resource_data* | The path (either relative or absolute) to the given resource time series. |
| *resource_key* | The key associated with the given renewable resource. |
| *electrical_load_ptr* | A pointer to the Model's ElectricalLoad object. |

```
{
    //  1. init CSV reader, record path and type
    io::CSVReader<2> CSV(path_2_resource_data);

    CSV.read_header(
        io::ignore_extra_column,
        "Time (since start of data) [hrs]",
        "Solar GHI [kW/m2]"
    );

    this->path_map_1D.insert(
        std::pair<int, std::string>(resource_key, path_2_resource_data)
    );

    this->string_map_1D.insert(std::pair<int, std::string>(resource_key, "SOLAR"));

    //  2. init map element
    this->resource_map_1D.insert(
        std::pair<int, std::vector<double»(resource_key, {})
    );
    this->resource_map_1D[resource_key].resize(electrical_load_ptr->n_points, 0);


    //  3. read in resource data, check against time series (point-wise and length)
    int n_points = 0;
    double time_hrs = 0;
    double time_expected_hrs = 0;
    double solar_resource_kWm2 = 0;

    while (CSV.read_row(time_hrs, solar_resource_kWm2)) {
        if (n_points > electrical_load_ptr->n_points) {
            this->__throwLengthError(path_2_resource_data, electrical_load_ptr);
        }

        time_expected_hrs = electrical_load_ptr->time_vec_hrs[n_points];
        this->__checkTimePoint(
            time_hrs,
            time_expected_hrs,
            path_2_resource_data,
            electrical_load_ptr
        );
```

```

        this->resource_map_1D[resource_key][n_points] = solar_resource_kWm2;

        n_points++;
    }

    //  4. check data length
    if (n_points != electrical_load_ptr->n_points) {
        this->__throwLengthError(path_2_resource_data, electrical_load_ptr);
    }

    return;
}   /* __readSolarResource() */
```

#### 4.23.3.7 __readTidalResource()

```
void Resources::__readTidalResource (
            std::string path_2_resource_data,
            int resource_key,
            ElectricalLoad * electrical_load_ptr )  [private]
```

Helper method to handle reading a tidal resource time series into Resources.

**Parameters**

| | |
|---|---|
| *path_2_resource_data* | The path (either relative or absolute) to the given resource time series. |
| *resource_key* | The key associated with the given renewable resource. |
| *electrical_load_ptr* | A pointer to the Model's ElectricalLoad object. |

```
{
    //  1. init CSV reader, record path and type
    io::CSVReader<2> CSV(path_2_resource_data);

    CSV.read_header(
        io::ignore_extra_column,
        "Time (since start of data) [hrs]",
        "Tidal Speed (hub depth) [m/s]"
    );

    this->path_map_1D.insert(
        std::pair<int, std::string>(resource_key, path_2_resource_data)
    );

    this->string_map_1D.insert(std::pair<int, std::string>(resource_key, "TIDAL"));

    //  2. init map element
    this->resource_map_1D.insert(
        std::pair<int, std::vector<double»(resource_key, {})
    );
    this->resource_map_1D[resource_key].resize(electrical_load_ptr->n_points, 0);


    //  3. read in resource data, check against time series (point-wise and length)
    int n_points = 0;
    double time_hrs = 0;
    double time_expected_hrs = 0;
    double tidal_resource_ms = 0;

    while (CSV.read_row(time_hrs, tidal_resource_ms)) {
        if (n_points > electrical_load_ptr->n_points) {
            this->__throwLengthError(path_2_resource_data, electrical_load_ptr);
        }

        time_expected_hrs = electrical_load_ptr->time_vec_hrs[n_points];
        this->__checkTimePoint(
            time_hrs,
            time_expected_hrs,
            path_2_resource_data,
            electrical_load_ptr
        );

        this->resource_map_1D[resource_key][n_points] = tidal_resource_ms;
```

```
            n_points++;
        }

        //  4. check data length
        if (n_points != electrical_load_ptr->n_points) {
            this->__throwLengthError(path_2_resource_data, electrical_load_ptr);
        }

        return;
}   /* __readTidalResource() */
```

#### 4.23.3.8 __readWaveResource()

```
void Resources::__readWaveResource (
            std::string path_2_resource_data,
            int resource_key,
            ElectricalLoad * electrical_load_ptr ) [private]
```

Helper method to handle reading a wave resource time series into Resources.

**Parameters**

| | |
|---|---|
| *path_2_resource_data* | The path (either relative or absolute) to the given resource time series. |
| *resource_key* | The key associated with the given renewable resource. |
| *electrical_load_ptr* | A pointer to the Model's ElectricalLoad object. |

```
{
    //  1. init CSV reader, record path and type
    io::CSVReader<3> CSV(path_2_resource_data);

    CSV.read_header(
        io::ignore_extra_column,
        "Time (since start of data) [hrs]",
        "Significant Wave Height [m]",
        "Energy Period [s]"
    );

    this->path_map_2D.insert(
        std::pair<int, std::string>(resource_key, path_2_resource_data)
    );

    this->string_map_2D.insert(std::pair<int, std::string>(resource_key, "WAVE"));

    //  2. init map element
    this->resource_map_2D.insert(
        std::pair<int, std::vector<std::vector<double»>(resource_key, {})
    );
    this->resource_map_2D[resource_key].resize(electrical_load_ptr->n_points, {0, 0});


    //  3. read in resource data, check against time series (point-wise and length)
    int n_points = 0;
    double time_hrs = 0;
    double time_expected_hrs = 0;
    double significant_wave_height_m = 0;
    double energy_period_s = 0;

    while (CSV.read_row(time_hrs, significant_wave_height_m, energy_period_s)) {
        if (n_points > electrical_load_ptr->n_points) {
            this->__throwLengthError(path_2_resource_data, electrical_load_ptr);
        }

        time_expected_hrs = electrical_load_ptr->time_vec_hrs[n_points];
        this->__checkTimePoint(
            time_hrs,
            time_expected_hrs,
            path_2_resource_data,
            electrical_load_ptr
        );

        this->resource_map_2D[resource_key][n_points][0] = significant_wave_height_m;
```

```
        this->resource_map_2D[resource_key][n_points][1] = energy_period_s;

        n_points++;
    }

    //  4. check data length
    if (n_points != electrical_load_ptr->n_points) {
        this->__throwLengthError(path_2_resource_data, electrical_load_ptr);
    }

    return;
}   /* __readWaveResource() */
```

### 4.23.3.9 __readWindResource()

```
void Resources::__readWindResource (
            std::string path_2_resource_data,
            int resource_key,
            ElectricalLoad * electrical_load_ptr )  [private]
```

Helper method to handle reading a wind resource time series into Resources.

**Parameters**

| | |
|---|---|
| *path_2_resource_data* | The path (either relative or absolute) to the given resource time series. |
| *resource_key* | The key associated with the given renewable resource. |
| *electrical_load_ptr* | A pointer to the Model's ElectricalLoad object. |

```
{
    //  1. init CSV reader, record path and type
    io::CSVReader<2> CSV(path_2_resource_data);

    CSV.read_header(
        io::ignore_extra_column,
        "Time (since start of data) [hrs]",
        "Wind Speed (hub height) [m/s]"
    );

    this->path_map_1D.insert(
        std::pair<int, std::string>(resource_key, path_2_resource_data)
    );

    this->string_map_1D.insert(std::pair<int, std::string>(resource_key, "WIND"));

    //  2. init map element
    this->resource_map_1D.insert(
        std::pair<int, std::vector<double»(resource_key, {})
    );
    this->resource_map_1D[resource_key].resize(electrical_load_ptr->n_points, 0);


    //  3. read in resource data, check against time series (point-wise and length)
    int n_points = 0;
    double time_hrs = 0;
    double time_expected_hrs = 0;
    double wind_resource_ms = 0;

    while (CSV.read_row(time_hrs, wind_resource_ms)) {
        if (n_points > electrical_load_ptr->n_points) {
            this->__throwLengthError(path_2_resource_data, electrical_load_ptr);
        }

        time_expected_hrs = electrical_load_ptr->time_vec_hrs[n_points];
        this->__checkTimePoint(
            time_hrs,
            time_expected_hrs,
            path_2_resource_data,
            electrical_load_ptr
        );

        this->resource_map_1D[resource_key][n_points] = wind_resource_ms;

```

```
        n_points++;
    }

    //  4. check data length
    if (n_points != electrical_load_ptr->n_points) {
        this->__throwLengthError(path_2_resource_data, electrical_load_ptr);
    }

    return;
}   /* __readWindResource() */
```

#### 4.23.3.10 __throwLengthError()

```
void Resources::__throwLengthError (
            std::string path_2_resource_data,
            ElectricalLoad * electrical_load_ptr )  [private]
```

Helper method to throw data length error (if not the same as the given electrical load time series).

**Parameters**

| | |
|---|---|
| *path_2_resource_data* | The path (either relative or absolute) to the given resource time series. |
| *electrical_load_ptr* | A pointer to the Model's ElectricalLoad object. |

```
{
    std::string error_str = "ERROR:  Resources::addResource():  ";
    error_str += "the given resource time series at ";
    error_str += path_2_resource_data;
    error_str += " is not the same length as the previously given electrical";
    error_str += " load time series at ";
    error_str += electrical_load_ptr->path_2_electrical_load_time_series;

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);

    return;
}   /* __throwLengthError() */
```

#### 4.23.3.11 addResource() [1/2]

```
void Resources::addResource (
            NoncombustionType noncombustion_type,
            std::string path_2_resource_data,
            int resource_key,
            ElectricalLoad * electrical_load_ptr )
```

A method to add a renewable resource time series to Resources. Checks if given resource key is already in use. The associated helper methods also check against ElectricalLoad to ensure that all added time series align with the electrical load time series (both in terms of length and which points in time are included).

**Parameters**

| | |
|---|---|
| *noncombustion_type* | The type of renewable resource being added to Resources. |
| *path_2_resource_data* | A string defining the path (either relative or absolute) to the given resource time series. |
| *resource_key* | A key used to index into the Resources object, used to associate Renewable assets with the corresponding resource. |
| *electrical_load_ptr* | A pointer to the Model's ElectricalLoad object. |

```
{
    switch (noncombustion_type) {
        case (NoncombustionType :: HYDRO): {
            this->__checkResourceKey1D(resource_key, noncombustion_type);

            this->__readHydroResource(
                path_2_resource_data,
                resource_key,
                electrical_load_ptr
            );

            break;
        }

        default: {
            std::string error_str = "ERROR:  Resources :: addResource(:  ";
            error_str += "noncombustion type ";
            error_str += std::to_string(noncombustion_type);
            error_str += " has no associated resource";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    return;
}   /* addResource() */
```

#### 4.23.3.12 addResource() [2/2]

```
void Resources::addResource (
            RenewableType renewable_type,
            std::string path_2_resource_data,
            int resource_key,
            ElectricalLoad * electrical_load_ptr )
```

A method to add a renewable resource time series to Resources. Checks if given resource key is already in use. The associated helper methods also check against ElectricalLoad to ensure that all added time series align with the electrical load time series (both in terms of length and which points in time are included).

**Parameters**

| | |
|---|---|
| *renewable_type* | The type of renewable resource being added to Resources. |
| *path_2_resource_data* | A string defining the path (either relative or absolute) to the given resource time series. |
| *resource_key* | A key used to index into the Resources object, used to associate Renewable assets with the corresponding resource. |
| *electrical_load_ptr* | A pointer to the Model's ElectricalLoad object. |

```
{
    switch (renewable_type) {
        case (RenewableType :: SOLAR): {
            this->__checkResourceKey1D(resource_key, renewable_type);

            this->__readSolarResource(
                path_2_resource_data,
                resource_key,
                electrical_load_ptr
            );

            break;
        }

        case (RenewableType :: TIDAL): {
```

```
            this->__checkResourceKey1D(resource_key, renewable_type);

            this->__readTidalResource(
                path_2_resource_data,
                resource_key,
                electrical_load_ptr
            );

            break;
        }

        case (RenewableType :: WAVE): {
            this->__checkResourceKey2D(resource_key, renewable_type);

            this->__readWaveResource(
                path_2_resource_data,
                resource_key,
                electrical_load_ptr
            );

            break;
        }

        case (RenewableType :: WIND): {
            this->__checkResourceKey1D(resource_key, renewable_type);

            this->__readWindResource(
                path_2_resource_data,
                resource_key,
                electrical_load_ptr
            );

            break;
        }

        default: {
            std::string error_str = "ERROR:  Resources :: addResource(:  ";
            error_str += "renewable type ";
            error_str += std::to_string(renewable_type);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    return;
}   /* addResource() */
```

#### 4.23.3.13 clear()

```
void Resources::clear (
              void   )
```

Method to clear all attributes of the Resources object.

```
{
    this->resource_map_1D.clear();
    this->string_map_1D.clear();
    this->path_map_1D.clear();

    this->resource_map_2D.clear();
    this->string_map_2D.clear();
    this->path_map_2D.clear();

    return;
}   /* clear() */
```

### 4.23.4 Member Data Documentation

#### 4.23.4.1 path_map_1D

```
std::map<int, std::string> Resources::path_map_1D
```

A map <int, string> of the paths (either relative or absolute) to given 1D renewable resource time series.

#### 4.23.4.2 path_map_2D

```
std::map<int, std::string> Resources::path_map_2D
```

A map <int, string> of the paths (either relative or absolute) to given 2D renewable resource time series.

#### 4.23.4.3 resource_map_1D

```
std::map<int, std::vector<double> > Resources::resource_map_1D
```

A map <int, vector<double>> of given 1D renewable resource time series.

#### 4.23.4.4 resource_map_2D

```
std::map<int, std::vector<std::vector<double> > > Resources::resource_map_2D
```

A map <int, vector<vector<double>>> of given 2D renewable resource time series.

#### 4.23.4.5 string_map_1D

```
std::map<int, std::string> Resources::string_map_1D
```

A map <int, string> of descriptors for the type of the given 1D renewable resource time series.

#### 4.23.4.6 string_map_2D

```
std::map<int, std::string> Resources::string_map_2D
```

A map <int, string> of descriptors for the type of the given 2D renewable resource time series.

The documentation for this class was generated from the following files:

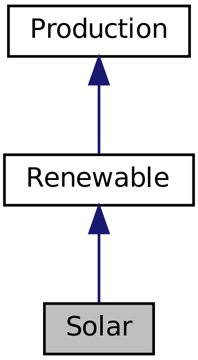
- header/Resources.h
- source/Resources.cpp

## 4.24 Solar Class Reference

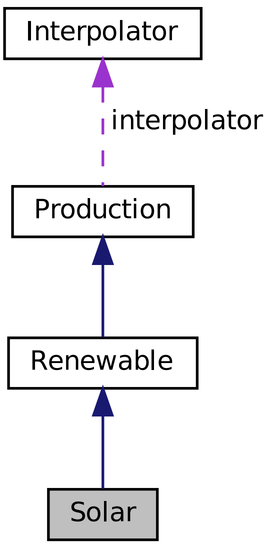
A derived class of the Renewable branch of Production which models solar production.

```
#include <Solar.h>
```

Inheritance diagram for Solar:




Collaboration diagram for Solar:



## Public Member Functions

- Solar (void)

    *Constructor (dummy) for the Solar class.*
- Solar (int, double, SolarInputs, std::vector< double > ∗)

    *Constructor (intended) for the Solar class.*
- void handleReplacement (int)

    *Method to handle asset replacement and capital cost incursion, if applicable.*
- double computeProductionkW (int, double, double)

    *Method which takes in the solar resource at a particular point in time, and then returns the solar PV production at that point in time.*
- double commit (int, double, double, double)

    *Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.*
- ∼Solar (void)

    *Destructor for the Solar class.*

## Public Attributes

- double derating

    *The derating of the solar PV array (i.e., shadowing, soiling, etc.).*
- double julian_day

    *The number of days (including partial days) since 12:00 on 1 Jan 2000.*
- double latitude_deg

    *The latitude of the solar PV array [deg].*
- double longitude_deg

    *The longitude of the solar PV array [deg].*
- double latitude_rad

    *The latitude of the solar PV array [rad].*
- double longitude_rad

    *The longitude of the solar PV array [rad].*
- double panel_azimuth_deg

    *The azimuth angle of the panels [deg], relative to north.*
- double panel_tilt_deg

    *The tilt angle of the panels [deg], relative to ground.*
- double panel_azimuth_rad

    *The azimuth angle of the panels [rad], relative to north.*
- double panel_tilt_rad

    *The tilt angle of the panels [rad], relative to ground.*
- double albedo_ground_reflectance

    *The albedo (ground reflectance) to be applied in modelling the solar PV array.*
- SolarPowerProductionModel power_model

    *The solar power production model to be applied.*
- std::string power_model_string

    *A string describing the active power production model.*

## Private Member Functions

- void __checkInputs (SolarInputs)

  *Helper method to check inputs to the Solar constructor.*
- double __getGenericCapitalCost (void)

  *Helper method to generate a generic solar PV array capital cost.*
- double __getGenericOpMaintCost (void)

  *Helper method to generate a generic solar PV array operation and maintenance cost. This is a cost incurred per unit energy produced.*
- double __getMeanLongitudeDeg (void)

  *Method to compute and return the mean longitude [deg], bound to the half-open interval [0, 360). From eqn (4.7) of Gilman.*
- double __getMeanAnomalyRad (void)

  *Method to compute and return the mean anomaly [rad], bound to the half-open interval [0, 2pi). From eqn (4.8) of Gilman.*
- double __getEclipticLongitudeRad (double, double)

  *Method to compute and return the ecliptic longitude [rad], bound to the half-open interval [0, 2pi). From eqn (4.9) of Gilman.*
- double __getObliquityOfEclipticRad (void)

  *Method to compute and return the obliquity of the ecliptic [rad], bound to the half-open interval [0, 2pi). From eqn (4.10) of Gilman.*
- double __getGreenwichMeanSiderialTimeHrs (void)

  *Method to compute the Greenwich mean siderial time [hrs], bound to the half-open interval [0, 24) hrs. From eqn (4.13) of Gilman.*
- double __getLocalMeanSiderialTimeHrs (double)

  *Method to compute and return the local mean siderial time [hrs], bound to the half-open interval [0, 24) hrs. From eqn (4.14) of Gilman.*
- double __getRightAscensionRad (double, double)

  *Method to compute and return the right ascension of the sun [rad], bound to the half-open interval [0, 2pi). From eqn (4.11) of Gilman.*
- double __getDeclinationRad (double, double)

  *Method to compute and return the declination of the sun [rad], bound to the closed interval [-pi/2, pi/2]. From eqn (4.12) of Gilman.*
- double __getHourAngleRad (double, double)

  *Method to compute and return the hour angle [rad] of the sun, bound to the open interval (-pi, pi). From eqn (4.15) of Gilman.*
- double __getSolarAltitudeRad (double, double)

  *Method to compute and return the sun altitude [rad], corrected for refraction and bound to the closed interval [0, pi/2]. From eqns (4.16) and (4.17) of Gilman.*
- double __getSolarAzimuthRad (double, double)

  *Method to copmute and return the solar azimuth [rad], bound to the closed interval [-pi, pi]. From eqns (4.16) and (4.18) of Gilman.*
- double __getSolarZenithRad (double, double)

  *Method to compute and return the solar zenith [rad], bound to the open interval (-pi/2, pi/2). From eqn (4.19) of Gilman.*
- double __getDiffuseHorizontalIrradiancekWm2 (double)

  *Method which takes in the solar resource at a particular point in time, and then returns the diffuse horizontal irradiance (DHI) [kW/m2] using a very simple, empirical model (simply DHI is proportional to GHI).*
- double __getDirectNormalIrradiancekWm2 (double, double, double)

  *Method which takes in the solar resource and DHI at a particular point in time, then the returns the direct normal irradiance (DNI) [kW/m2]. From definition of global horizontal irradiance (GHI).*
- double __getAngleOfIncidenceRad (double, double)

  *Method to compute and return the angle of incidence [rad] between the solar beam and the panel normal. From eqn (5.1) of Gilman.*

- double __getBeamIrradiancekWm2 (double, double)

  *Method which computes and returns the beam irradiance normal to the panels [kW/m2]. From eqn (6.1) of Gilman.*
- double __getDiffuseIrradiancekWm2 (double)

  *Method which computes and returns the (isotropic) diffuse sky irradiance [kW/m2]. From eqn (6.5) of Gilman.*
- double __getGroundReflectedIrradiancekWm2 (double)

  *Method to compute and return the ground reflected irradiance [kW/m2]. From eqn (6.21) of Gilman.*
- double __getPlaneOfArrayIrradiancekWm2 (int, double, double)

  *Method which takes in the solar resource at a particular point in time, and then returns the nominal plane of array irradiance. From eqn (7.1) of Gilman.*
- double __computeSimpleProductionkW (int, double, double)

  *Method which takes in the solar resource at a particular point in time, and then returns the solar PV production at that point in time base on a simple, "HOMER-like" model.*
- double __computeDetailedProductionkW (int, double, double)

  *Method which takes in the solar resource at a particular point in time, and then returns the solar PV production at that point in time base on a detailed, "PVWatts/SAM-like" model.*
- void __writeSummary (std::string)

  *Helper method to write summary results for Solar.*
- void __writeTimeSeries (std::string, std::vector< double > ∗, std::map< int, std::vector< double >> ∗, std::map< int, std::vector< std::vector< double >>> ∗, int=-1)

  *Helper method to write time series results for Solar.*

## 4.24.1 Detailed Description

A derived class of the Renewable branch of Production which models solar production.

## 4.24.2 Constructor & Destructor Documentation

### 4.24.2.1 Solar() [1/2]

```
Solar::Solar (
            void )
```

Constructor (dummy) for the Solar class.

```
1404 {
1405     //...
1406
1407     return;
1408 }    /* Solar() */
```

### 4.24.2.2 Solar() [2/2]

```
Solar::Solar (
            int n_points,
            double n_years,
            SolarInputs solar_inputs,
            std::vector< double > * time_vec_hrs_ptr )
```

Constructor (intended) for the Solar class.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *n_years* | The number of years being modelled. |
| *solar_inputs* | A structure of Solar constructor inputs. |
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
  :
Renewable(
    n_points,
    n_years,
    solar_inputs.renewable_inputs,
    time_vec_hrs_ptr
)
{
    //  1. check inputs
    this->__checkInputs(solar_inputs);

    //  2. set attributes
    this->type = RenewableType :: SOLAR;
    this->type_str = "SOLAR";

    this->resource_key = solar_inputs.resource_key;

    this->firmness_factor = solar_inputs.firmness_factor;

    this->derating = solar_inputs.derating;

    this->julian_day = solar_inputs.julian_day;

    this->latitude_deg = solar_inputs.latitude_deg;
    this->longitude_deg = solar_inputs.longitude_deg;

    this->latitude_rad = (M_PI / 180.0) * this->latitude_deg;
    this->longitude_rad = (M_PI / 180.0) * this->longitude_deg;

    this->panel_azimuth_deg = solar_inputs.panel_azimuth_deg;
    this->panel_tilt_deg = solar_inputs.panel_tilt_deg;

    this->panel_azimuth_rad = (M_PI / 180.0) * this->panel_azimuth_deg;
    this->panel_tilt_rad = (M_PI / 180.0) * this->panel_tilt_deg;

    this->albedo_ground_reflectance = solar_inputs.albedo_ground_reflectance;

    this->power_model = solar_inputs.power_model;

    switch (this->power_model) {
        case (SolarPowerProductionModel :: SOLAR_POWER_SIMPLE): {
            this->power_model_string = "SIMPLE";

            break;
        }

        case (SolarPowerProductionModel :: SOLAR_POWER_DETAILED): {
            this->power_model_string = "DETAILED";

            break;
        }

        default: {
            std::string error_str = "ERROR:  Solar():  ";
            error_str += "power production model ";
            error_str += std::to_string(this->power_model);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    if (solar_inputs.capital_cost < 0) {
        this->capital_cost = this->__getGenericCapitalCost();
    }
    else {
        this->capital_cost = solar_inputs.capital_cost;
    }

    if (solar_inputs.operation_maintenance_cost_kWh < 0) {
```

```
            this->operation_maintenance_cost_kWh = this->__getGenericOpMaintCost();
        }
        else {
            this->operation_maintenance_cost_kWh =
                solar_inputs.operation_maintenance_cost_kWh;
        }

        if (not this->is_sunk) {
            this->capital_cost_vec[0] = this->capital_cost;
        }

        //  3. construction print
        if (this->print_flag) {
            std::cout « "Solar object constructed at " « this « std::endl;
        }

        return;
}   /* Renewable() */
```

#### 4.24.2.3 ∼Solar()

```
Solar::∼Solar (
              void   )
```

Destructor for the Solar class.

```
{
        //  1. destruction print
        if (this->print_flag) {
            std::cout « "Solar object at " « this « " destroyed" « std::endl;
        }

        return;
}   /* ~Solar() */
```

### 4.24.3 Member Function Documentation

#### 4.24.3.1 __checkInputs()

```
void Solar::__checkInputs (
              SolarInputs solar_inputs )   [private]
```

Helper method to check inputs to the Solar constructor.

```
{
    //  1. check derating
    if (
        solar_inputs.derating < 0 or
        solar_inputs.derating > 1
    ) {
        std::string error_str = "ERROR:  Solar():  ";
        error_str += "SolarInputs::derating must be in the closed interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  2. check julian day
    if (solar_inputs.julian_day < 0) {
        std::string error_str = "ERROR:  Solar():  ";
        error_str += "SolarInputs::julian_day must be >= 0 days.";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
```

```
        #endif

        throw std::invalid_argument(error_str);
    }

    //  3. check latitude
    if (
        solar_inputs.latitude_deg < -90 or
        solar_inputs.latitude_deg > 90
    ) {
        std::string error_str = "ERROR:  Solar():  ";
        error_str += "SolarInputs::latitude_deg must be in the closed interval ";
        error_str += "[-90, 90] degrees";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  4. check longitude
    if (
        solar_inputs.longitude_deg < -180 or
        solar_inputs.longitude_deg > 180
    ) {
        std::string error_str = "ERROR:  Solar():  ";
        error_str += "SolarInputs::longitude_deg must be in the closed interval ";
        error_str += "[-180, 180] degrees";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  5. check panel tilt angle
    if (
        solar_inputs.panel_tilt_deg < 0 or
        solar_inputs.panel_tilt_deg > 90
    ) {
        std::string error_str = "ERROR:  Solar():  ";
        error_str += "SolarInputs::panel_tilt_deg must be in the closed interval ";
        error_str += "[0, 90] degrees";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  6. check albedo ground reflectance
    if (
        solar_inputs.albedo_ground_reflectance < 0 or
        solar_inputs.albedo_ground_reflectance > 1
    ) {
        std::string error_str = "ERROR:  Solar():  ";
        error_str += "SolarInputs::albedo_ground_reflectance must be in the closed ";
        error_str += "interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  7. check firmness_factor
    if (
        solar_inputs.firmness_factor < 0 or
        solar_inputs.firmness_factor > 1
    ) {
        std::string error_str = "ERROR:  Solar():  ";
        error_str += "SolarInputs::firmness_factor must be in the closed interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkInputs() */
```

#### 4.24.3.2 __computeDetailedProductionkW()

```
double Solar::__computeDetailedProductionkW (
            int timestep,
            double dt_hrs,
            double solar_resource_kWm2 )  [private]
```

Method which takes in the solar resource at a particular point in time, and then returns the solar PV production at that point in time base on a detailed, "PVWatts/SAM-like" model.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *solar_resource_kWm2* | Solar resource (i.e. global horizontal irradiance) [kW/m2]. |

**Returns**

The production [kW] of the solar PV array.

```
{
    // apply detailed production model (POA irradiance -> production)
    double plane_of_array_irradiance_kWm2 = this->__getPlaneOfArrayIrradiancekWm2(
        timestep,
        dt_hrs,
        solar_resource_kWm2
    );

    double production_kW =
        this->derating * plane_of_array_irradiance_kWm2 * this->capacity_kW;

    // cap production at capacity
    if (production_kW > this->capacity_kW) {
        production_kW = this->capacity_kW;
    }

    return production_kW;
}   /* __computeDetailedProductionkW() */
```

#### 4.24.3.3 __computeSimpleProductionkW()

```
double Solar::__computeSimpleProductionkW (
            int timestep,
            double dt_hrs,
            double solar_resource_kWm2 )  [private]
```

Method which takes in the solar resource at a particular point in time, and then returns the solar PV production at that point in time base on a simple, "HOMER-like" model.

Ref: HOMER [2023f]

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *solar_resource_kWm2* | Solar resource (i.e. global horizontal irradiance) [kW/m2]. |

**Returns**

The production [kW] of the solar PV array.

```
{
    // apply simple production model (GHI -> production)
    double production_kW = this->derating * solar_resource_kWm2 * this->capacity_kW;

    // cap production at capacity
    if (production_kW > this->capacity_kW) {
        production_kW = this->capacity_kW;
    }

    return production_kW;
}   /* __computeSimpleProductionkW() */
```

### 4.24.3.4 __getAngleOfIncidenceRad()

```
double Solar::__getAngleOfIncidenceRad (
            double solar_zenith_rad,
            double solar_azimuth_rad )  [private]
```

Method to compute and return the angle of incidence [rad] between the solar beam and the panel normal. From eqn (5.1) of Gilman.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *solar_zenith_rad* | The solar zenith [rad]. |
| *solar_azimuth_rad* | The solar azimuth [rad]. |

**Returns**

The angle of incidence [rad] between the solar beam and the panel normal.

```
{
    double a =
        sin(solar_zenith_rad) *
        cos(solar_azimuth_rad - this->panel_azimuth_rad) *
        sin(this->panel_tilt_rad) +
        cos(solar_zenith_rad) *
        cos(this->panel_tilt_rad);

    double angle_of_incidence_rad = 0;

    if (a < -1) {
        angle_of_incidence_rad = M_PI;
    }

    else if (a > 1) {
        angle_of_incidence_rad = 0;
    }

```

```
    else {
        angle_of_incidence_rad = acos(a);
    }

    return angle_of_incidence_rad;
}   /* __getAngleOfIncidenceRad() */
```

#### 4.24.3.5 __getBeamIrradiancekWm2()

```
double Solar::__getBeamIrradiancekWm2 (
            double direct_normal_irradiance_kWm2,
            double angle_of_incidence_rad )  [private]
```

Method which computes and returns the beam irradiance normal to the panels [kW/m2]. From eqn (6.1) of Gilman.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *direct_normal_irradiance_kWm2* | The DNI [kW/m2]. |
| *angle_of_incidence_rad* | The angle of incidence [rad] between the solar beam and the panel normal. |

**Returns**

The beam irradiance normal to the panels [kW/m2].

```
{
    double beam_irradiance_kWm2 = direct_normal_irradiance_kWm2 *
        cos(angle_of_incidence_rad);

    return beam_irradiance_kWm2;
}   /* __getBeamIrradiancekWm2() */
```

#### 4.24.3.6 __getDeclinationRad()

```
double Solar::__getDeclinationRad (
            double eclong_rad,
            double obleq_rad )  [private]
```

Method to compute and return the declination of the sun [rad], bound to the closed interval [-pi/2, pi/2]. From eqn (4.12) of Gilman.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *eclong_rad* | The ecliptic longitude [rad], bound to the half-open interval [0, 2pi). |
| *obleq_rad* | The obliquity of the ecliptic, bound to the half-open interval [0, 2pi). |

**Returns**

The declination of the sun [rad], bound to the closed interval [-pi/2, pi/2].

```
{
    double declination_rad = asin(sin(obleq_rad) * sin(eclong_rad));

    return declination_rad;
}   /* __getDeclinationRad() */
```

#### 4.24.3.7 __getDiffuseHorizontalIrradiancekWm2()

```
double Solar::__getDiffuseHorizontalIrradiancekWm2 (
              double solar_resource_kWm2 )  [private]
```

Method which takes in the solar resource at a particular point in time, and then returns the diffuse horizontal irradiance (DHI) [kW/m2] using a very simple, empirical model (simply DHI is proportional to GHI).

Ref: Safaripour and Mehrabian [2011]

**Parameters**

| | |
|---|---|
| *solar_resource_kWm2* | Solar resource (i.e. global horizontal irradiance) [kW/m2]. |

**Returns**

The diffuse horizontal irradiance [kW/m2].

```
{
    double GHI_2_DHI = 0.32;

    return GHI_2_DHI * solar_resource_kWm2;
}   /* __getDiffuseHorizontalIrradiancekWm2() */
```

#### 4.24.3.8 __getDiffuseIrradiancekWm2()

```
double Solar::__getDiffuseIrradiancekWm2 (
              double diffuse_horizontal_irradiance_kWm2 )  [private]
```

Method which computes and returns the (isotropic) diffuse sky irradiance [kW/m2]. From eqn (6.5) of Gilman.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *diffuse_horizontal_irradiance_kWm2* | The DHI [kW/m2] |

**Returns**

The (isotropic) diffuse sky irradiance [kW/m2]

```
{
    double diffuse_sky_irradiance_kWm2 = diffuse_horizontal_irradiance_kWm2 *
        cos(this->panel_tilt_rad);

    return diffuse_sky_irradiance_kWm2;
}   /* __getDiffuseIrradiancekWm2() */
```

#### 4.24.3.9 __getDirectNormalIrradiancekWm2()

```
double Solar::__getDirectNormalIrradiancekWm2 (
            double solar_resource_kWm2,
            double diffuse_horizontal_irradiance_kWm2,
            double solar_zenith_rad )  [private]
```

Method which takes in the solar resource and DHI at a particular point in time, then the returns the direct normal irradiance (DNI) [kW/m2]. From definition of global horizontal irradiance (GHI).

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *solar_resource_kWm2* | Solar resource (i.e. global horizontal irradiance) [kW/m2]. |
| *diffuse_horizontal_irradiance_kWm2* | The DHI [kW/m2]. |
| *solar_zenith_rad* | The solar zenith [rad]. |

**Returns**

The direct normal irradiance (DNI) [kW/m2].

```
{
    double direct_normal_irradiance_kWm2 =
        (solar_resource_kWm2 - diffuse_horizontal_irradiance_kWm2) /
        cos(solar_zenith_rad);

    return direct_normal_irradiance_kWm2;
}   /* __getDirectNormalIrradiancekWm2() */
```

#### 4.24.3.10 __getEclipticLongitudeRad()

```
double Solar::__getEclipticLongitudeRad (
            double mean_longitude_deg,
            double mean_anomaly_rad )  [private]
```

Method to compute and return the ecliptic longitude [rad], bound to the half-open interval [0, 2pi). From eqn (4.9) of Gilman.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *mean_longitude_deg* | The mean longitude [deg], bound to the half-open interval [0, 360) deg. |
| *mean_anomaly_rad* | The mean anomaly [rad], bound to the half-open interval [0, 2pi). |

**Returns**

The ecliptic longitude [rad], bound to the half-open interval [0, 2pi).

```
{
    // compute ecliioptic longitude
    double eclong_deg = mean_longitude_deg +
        1.915 * sin(mean_anomaly_rad) +
        0.02 * sin(2 * mean_anomaly_rad);

    // bound to half-open interval [0, 360) deg
    int eclong_deg_int = int(eclong_deg);
    double eclong_deg_frac = eclong_deg - eclong_deg_int;

    eclong_deg = eclong_deg_int % 360;
    eclong_deg += eclong_deg_frac;

    // translate to rads
    double eclong_rad = (M_PI / 180.0) * eclong_deg;

    return eclong_rad;
}   /* __getEclipticLongitudeRad() */
```

#### 4.24.3.11 __getGenericCapitalCost()

```
double Solar::__getGenericCapitalCost (
               void ) [private]
```

Helper method to generate a generic solar PV array capital cost.

This model was obtained by way of surveying an assortment of published solar PV costs, and then constructing a best fit model. Note that this model expresses cost in terms of Canadian dollars [CAD].

**Returns**

A generic capital cost for the solar PV array [CAD].

```
{
    double capital_cost_per_kW = 1000 * pow(this->capacity_kW, -0.15) + 3000;

    return capital_cost_per_kW * this->capacity_kW;
}   /* __getGenericCapitalCost() */
```

#### 4.24.3.12 __getGenericOpMaintCost()

```
double Solar::__getGenericOpMaintCost (
               void ) [private]
```

Helper method to generate a generic solar PV array operation and maintenance cost. This is a cost incurred per unit energy produced.

This model was obtained by way of surveying an assortment of published solar PV costs, and then constructing a best fit model. Note that this model expresses cost in terms of Canadian dollars [CAD/kWh].

**Returns**

A generic operation and maintenance cost, per unit energy produced, for the solar PV array [CAD/kWh].

```
{
    return 0.01;
}   /* __getGenericOpMaintCost() */
```

#### 4.24.3.13 __getGreenwichMeanSiderialTimeHrs()

```
double Solar::__getGreenwichMeanSiderialTimeHrs (
            void ) [private]
```

Method to compute the Greenwich mean siderial time [hrs], bound to the half-open interval [0, 24) hrs. From eqn (4.13) of Gilman.

Ref: Gilman et al. [2018]

**Returns**

Greenwich mean siderial time [hrs], bound to the half-open interval [0, 24) hrs.

```
{
    // compute Greenwich mean siderial time
    double Greenwich_mean_siderial_time_hrs = 6.697375 +
        0.0657098242 * this->julian_day -
        (this->longitude_deg / 15);

    // bound to the half-open interval [0, 24) hrs
    int Greenwich_mean_siderial_time_hrs_int = int(Greenwich_mean_siderial_time_hrs);
    double Greenwich_mean_siderial_time_hrs_frac = Greenwich_mean_siderial_time_hrs -
        Greenwich_mean_siderial_time_hrs_int;

    Greenwich_mean_siderial_time_hrs = Greenwich_mean_siderial_time_hrs_int % 24;
    Greenwich_mean_siderial_time_hrs += Greenwich_mean_siderial_time_hrs_frac;

    return Greenwich_mean_siderial_time_hrs;
}   /* __getGreenwichMeanSiderialTimeHrs() */
```

#### 4.24.3.14 __getGroundReflectedIrradiancekWm2()

```
double Solar::__getGroundReflectedIrradiancekWm2 (
            double solar_resource_kWm2 ) [private]
```

Method to compute and return the ground reflected irradiance [kW/m2]. From eqn (6.21) of Gilman.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *solar_resource_kWm2* | Solar resource (i.e. global horizontal irradiance) [kW/m2]. |

**Returns**

The ground reflected irradiance [kW/m2].

```
{
    double ground_reflected_irradiance_kWm2 =
        this->albedo_ground_reflectance * solar_resource_kWm2 *
        ((1 - cos(this->panel_tilt_rad)) / 2);

    return ground_reflected_irradiance_kWm2;
}   /* __getGroundReflectedIrradiancekWm2() */
```

#### 4.24.3.15 __getHourAngleRad()

```
double Solar::__getHourAngleRad (
            double local_mean_siderial_time_hrs,
            double right_ascension_rad )  [private]
```

Method to compute and return the hour angle [rad] of the sun, bound to the open interval (-pi, pi). From eqn (4.15) of Gilman.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *local_mean_siderial_time_hrs* | The local mean siderial time [hrs], bound to the half-open interval [0, 24) hrs. |
| *right_ascension_rad* | The right ascension of the sun [rad], bound to the half-open interval [0, 2pi). |

**Returns**

The hour angle [rad] of the sun, bound to the open interval (-pi, pi).

```
{
    // compute hour angle
    double b_rad = 15 * (M_PI / 180.0) * local_mean_siderial_time_hrs -
        right_ascension_rad;

    double hour_angle_rad = b_rad;

    // bound to open interval (-pi, pi)
    if (b_rad < -1 * M_PI) {
        hour_angle_rad += 2 * M_PI;
    }

    else if (b_rad > M_PI) {
        hour_angle_rad -= 2 * M_PI;
    }

    return hour_angle_rad;
}   /* __getHourAngleRad() */
```

#### 4.24.3.16 __getLocalMeanSiderialTimeHrs()

```
double Solar::__getLocalMeanSiderialTimeHrs (
            double Greenwich_mean_siderial_time_hrs )  [private]
```

Method to compute and return the local mean siderial time [hrs], bound to the half-open interval [0, 24) hrs. From eqn (4.14) of Gilman.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *Greenwich_mean_siderial_time_hrs* | The Greenwich mean siderial time [hrs], bound to the half-open interval [0, 24) hrs. |

**Returns**

The local mean siderial time [hrs], bound to the half-open interval [0, 24) hrs.

```
{
    // compute local mean siderial time
    double local_mean_siderial_time_hrs = Greenwich_mean_siderial_time_hrs +
        (this->longitude_deg / 15);

    // bound to the half-open interval [0, 24) hrs
    int local_mean_siderial_time_hrs_int = int(local_mean_siderial_time_hrs);
    double local_mean_siderial_time_hrs_frac = local_mean_siderial_time_hrs -
        local_mean_siderial_time_hrs_int;

    local_mean_siderial_time_hrs = local_mean_siderial_time_hrs_int % 24;
    local_mean_siderial_time_hrs += local_mean_siderial_time_hrs_frac;

    return local_mean_siderial_time_hrs;
}   /* __getLocalMeanSiderialTimeHrs() */
```

### 4.24.3.17 __getMeanAnomalyRad()

```
double Solar::__getMeanAnomalyRad (
            void ) [private]
```

Method to compute and return the mean anomaly [rad], bound to the half-open interval [0, 2pi). From eqn (4.8) of Gilman.

double Solar :: __getMeanAnomalyRad(void)

Ref: Gilman et al. [2018]

**Returns**

The mean anomaly [rad], bound to the half-open interval [0, 2pi).

```
{
    // compute mean anomaly
    double mean_anomaly_deg = 357.528 + 0.9856003 * this->julian_day;

    // bound to the half-open interval [0, 360) deg.
    int mean_anomaly_deg_int = int(mean_anomaly_deg);
    double mean_anomaly_deg_frac = mean_anomaly_deg - mean_anomaly_deg_int;

    mean_anomaly_deg = mean_anomaly_deg_int % 360;
    mean_anomaly_deg += mean_anomaly_deg_frac;

    // translate to rads
    double mean_anomaly_rad = (M_PI / 180.0) * mean_anomaly_deg;

    return mean_anomaly_rad;
}   /* __getMeanAnomalyRad() */
```

### 4.24.3.18 __getMeanLongitudeDeg()

```
double Solar::__getMeanLongitudeDeg (
            void ) [private]
```

Method to compute and return the mean longitude [deg], bound to the half-open interval [0, 360). From eqn (4.7) of Gilman.

Ref: Gilman et al. [2018]

**Returns**

The mean longitude [deg], bound to the half-open interval [0, 360).

```
{
    // compute mean longitude
    double mean_longitude_deg = 280.46 + 0.9856474 * this->julian_day;

    // bound to the half-open interval [0, 360) deg
    int mean_longitude_deg_int = int(mean_longitude_deg);
    double mean_longitude_deg_frac = mean_longitude_deg - mean_longitude_deg_int;

    mean_longitude_deg = mean_longitude_deg_int % 360;
    mean_longitude_deg += mean_longitude_deg_frac;

    return mean_longitude_deg;
}   /* __getMeanLongitudeDeg() */
```

### 4.24.3.19 __getObliquityOfEclipticRad()

```
double Solar::__getObliquityOfEclipticRad (
            void ) [private]
```

Method to compute and return the obliquity of the ecliptic [rad], bound to the half-open interval [0, 2pi). From eqn (4.10) of Gilman.

Ref: Gilman et al. [2018]

**Returns**

The obliquity of the ecliptic [rad], bound to the half-open interval [0, 2pi).

```
{
    // compute obliquity of ecliptic
    double obleq_deg = 23.439 - 0.0000004 * this->julian_day;

    // bound to half-open interval [0, 360) deg
    int obleq_deg_int = int(obleq_deg);
    double obleq_deg_frac = obleq_deg - obleq_deg_int;

    obleq_deg = obleq_deg_int % 360;
    obleq_deg += obleq_deg_frac;

    // translate to rads
    double obleq_rad = (M_PI / 180.0) * obleq_deg;

    return obleq_rad;
}   /* __getObliquityOfEclipticRad() */
```

### 4.24.3.20 __getPlaneOfArrayIrradiancekWm2()

```
double Solar::__getPlaneOfArrayIrradiancekWm2 (
            int timestep,
            double dt_hrs,
            double solar_resource_kWm2 ) [private]
```

Method which takes in the solar resource at a particular point in time, and then returns the nominal plane of array irradiance. From eqn (7.1) of Gilman.

Ref: Gilman et al. [2018]

#### Parameters

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *solar_resource_kWm2* | Solar resource (i.e. global horizontal irradiance) [kW/m2]. |

#### Returns

The nominal plane of array irradiance [kW/m2].

```
{
    // get mean longitude and mean anomaly
    double mean_longitude_deg = this->__getMeanLongitudeDeg();
    double mean_anomaly_rad = this->__getMeanAnomalyRad();


    // get ecliptic longitude and obliquity of the ecliptic
    double eclong_rad = this->__getEclipticLongitudeRad(
        mean_longitude_deg,
        mean_anomaly_rad
    );

    double obleq_rad = this->__getObliquityOfEclipticRad();


    // get local mean siderial time
    double Greenwich_mean_siderial_time_hrs = this->__getGreenwichMeanSiderialTimeHrs();

    double local_mean_siderial_time_hrs = this->__getLocalMeanSiderialTimeHrs(
        Greenwich_mean_siderial_time_hrs
    );


    // get right ascension, declination, and hour angle
    double right_ascension_rad = this->__getRightAscensionRad(eclong_rad, obleq_rad);
    double declination_rad = this->__getDeclinationRad(eclong_rad, obleq_rad);

    double hour_angle_rad = this->__getHourAngleRad(
        local_mean_siderial_time_hrs,
        right_ascension_rad
    );


    // get solar azimuth and zenith
    double solar_azimuth_rad = this->__getSolarAzimuthRad(
        declination_rad,
        hour_angle_rad
    );

    double solar_zenith_rad = this->__getSolarZenithRad(
        declination_rad,
        hour_angle_rad
    );


    // get diffuse horizontal irradiance (DHI) and direct normal irradiance (DNI)
    double diffuse_horizontal_irradiance_kWm2 = this->__getDiffuseHorizontalIrradiancekWm2(
        solar_resource_kWm2
    );

    double direct_normal_irradiance_kWm2 = this->__getDirectNormalIrradiancekWm2(
        solar_resource_kWm2,
        diffuse_horizontal_irradiance_kWm2,
        solar_zenith_rad
    );


    // get angle of incidence
    double angle_of_incidence_rad = this->__getAngleOfIncidenceRad(
        solar_zenith_rad,
        solar_azimuth_rad
    );


    // compute plane of array irradiance as superposition of beam, diffuse, and ground
    // reflected.
    double plane_of_array_irradiance_kWm2 = 0;

    plane_of_array_irradiance_kWm2 += this->__getBeamIrradiancekWm2(
        direct_normal_irradiance_kWm2,
        angle_of_incidence_rad
```

```
    );

    plane_of_array_irradiance_kWm2 += this->__getDiffuseIrradiancekWm2(
        diffuse_horizontal_irradiance_kWm2
    );

    plane_of_array_irradiance_kWm2 += this->__getGroundReflectedIrradiancekWm2(
        solar_resource_kWm2
    );

    return plane_of_array_irradiance_kWm2;
}   /* __getPlaneOfArrayIrradiance() */
```

#### 4.24.3.21 __getRightAscensionRad()

```
double Solar::__getRightAscensionRad (
              double eclong_rad,
              double obleq_rad )  [private]
```

Method to compute and return the right ascension of the sun [rad], bound to the half-open interval [0, 2pi). From eqn (4.11) of Gilman.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *eclong_rad* | The ecliptic longitude [rad], bound to the half-open interval [0, 2pi). |
| *obleq_rad* | The obliquity of the ecliptic, bound to the half-open interval [0, 2pi). |

**Returns**

The right ascension of the sun [rad], bound to the half-open interval [0, 2pi).

```
{
    // compute right ascension
    double right_ascension_rad = atan(
        (cos(obleq_rad) * sin(eclong_rad)) / cos(eclong_rad)
    );

    // bound to half-open interval [0, 2pi)
    if (cos(eclong_rad) < 0) {
        right_ascension_rad += M_PI;
    }

    else if (cos(obleq_rad) * sin(eclong_rad) < 0) {
        right_ascension_rad += 2 * M_PI;
    }

    return right_ascension_rad;
}   /* __getRightAscensionRad() */
```

#### 4.24.3.22 __getSolarAltitudeRad()

```
double Solar::__getSolarAltitudeRad (
              double declination_rad,
              double hour_angle_rad )  [private]
```

Method to compute and return the sun altitude [rad], corrected for refraction and bound to the closed interval [0, pi/2]. From eqns (4.16) and (4.17) of Gilman.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *declination_rad* | The declination of the sun [rad], bound to the closed interval [-pi/2, pi/2]. |
| *hour_angle_rad* | The hour angle of the sun [rad], bound to the open interval (-pi, pi). |

**Returns**

The sun altitude [rad], corrected for refraction and bound to the closed interval [0, pi/2].

```
{
    // compute un-corrected altitude
    double a = sin(declination_rad) * sin(this->latitude_rad) +
        cos(declination_rad) * cos(this->latitude_rad) * cos(hour_angle_rad);

    double altitude_rad = 0;

    if (a < -1) {
        altitude_rad = -1 * M_PI_2;
    }

    else if (a > 1) {
        altitude_rad = M_PI_2;
    }

    else {
        altitude_rad = asin(a);
    }

    // correct for refraction
    double altitude_deg = (180.0 / M_PI) * altitude_rad;

    double refraction = 0.56;

    if (altitude_deg > -0.56) {
        refraction = 3.51567 *
            (0.1594 + 0.0196 * altitude_deg + 0.00002 * pow(altitude_deg, 2)) *
            pow(1 + 0.505 * altitude_deg + 0.0845 * pow(altitude_deg, 2), -1);
    }

    double altitude_corrected_rad = 0;

    if (altitude_deg + refraction > 90) {
        altitude_corrected_rad = M_PI_2;
    }

    else {
        altitude_corrected_rad = (M_PI / 180.0) * (altitude_deg + refraction);
    }

    return altitude_corrected_rad;
}   /* __getSolarAltitudeRad() */
```

#### 4.24.3.23 __getSolarAzimuthRad()

```
double Solar::__getSolarAzimuthRad (
        double declination_rad,
        double hour_angle_rad )  [private]
```

Method to copmute and return the solar azimuth [rad], bound to the closed interval [-pi, pi]. From eqns (4.16) and (4.18) of Gilman.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *declination_rad* | The declination of the sun [rad], bound to the closed interval [-pi/2, pi/2]. |
| *hour_angle_rad* | The hour angle of the sun [rad], bound to the open interval (-pi, pi). |

**Returns**

The solar azimuth [rad], bound to the closed interval [-pi, pi].

```
{
    // compute un-corrected altitude
    double a = sin(declination_rad) * sin(this->latitude_rad) +
        cos(declination_rad) * cos(this->latitude_rad) * cos(hour_angle_rad);

    double altitude_rad = 0;

    if (a < -1) {
        altitude_rad = -1 * M_PI_2;
    }

    else if (a > 1) {
        altitude_rad = M_PI_2;
    }

    else {
        altitude_rad = asin(a);
    }

    // compute a term
    a = (sin(altitude_rad) * sin(this->latitude_rad) - sin(declination_rad)) /
        (cos(altitude_rad) * cos(this->latitude_rad));

    // compute b term
    double b_rad = 0;

    if (cos(altitude_rad) == 0 or a < -1) {
        b_rad = M_PI;
    }

    else if (a > 1) {
        b_rad = 0;
    }

    else {
        b_rad = acos(a);
    }

    // compute azimuth
    double azimuth_rad = 0;

    if (hour_angle_rad < -1 * M_PI) {
        azimuth_rad = b_rad;
    }

    else if (
        (hour_angle_rad >= -1 * M_PI and hour_angle_rad <= 0) or
        hour_angle_rad > M_PI
    ) {
        azimuth_rad = M_PI - b_rad;
    }

    else {
        azimuth_rad = M_PI + b_rad;
    }

    return azimuth_rad;
}   /* __getSolarAzimuth() */
```

#### 4.24.3.24 __getSolarZenithRad()

```
double Solar::__getSolarZenithRad (
            double declination_rad,
            double hour_angle_rad )   [private]
```

Method to compute and return the solar zenith [rad], bound to the open interval (-pi/2, pi/2). From eqn (4.19) of Gilman.

Ref: Gilman et al. [2018]

**Parameters**

| | |
|---|---|
| *declination_rad* | The declination of the sun [rad], bound to the closed interval [-pi/2, pi/2]. |
| *hour_angle_rad* | The hour angle of the sun [rad], bound to the open interval (-pi, pi). |

**Returns**

The solar zenith [rad], bound to the open interval (-pi/2, pi/2).

```
{
    double solar_zenith_rad = M_PI_2 - this->__getSolarAltitudeRad(
        declination_rad,
        hour_angle_rad
    );

    return solar_zenith_rad;
}   /* __getSolarZenith() */
```

### 4.24.3.25 __writeSummary()

```
void Solar::__writeSummary (
            std::string write_path )  [private], [virtual]
```

Helper method to write summary results for Solar.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |

Reimplemented from Renewable.

```
{
    //  1. create filestream
    write_path += "summary_results.md";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  2. write summary results (markdown)
    ofs « "# ";
    ofs « std::to_string(int(ceil(this->capacity_kW)));
    ofs « " kW SOLAR Summary Results\n";
    ofs « "\n--------\n\n";

    //  2.1. Production attributes
    ofs « "## Production Attributes\n";
    ofs « "\n";

    ofs « "Capacity: " « this->capacity_kW « " kW  \n";
    ofs « "\n";

    ofs « "Production Override: (N = 0 / Y = 1): "
        « this->normalized_production_series_given « "  \n";
    if (this->normalized_production_series_given) {
        ofs « "Path to Normalized Production Time Series: "
            « this->path_2_normalized_production_time_series « "  \n";
    }
    ofs « "\n";

    ofs « "Sunk Cost (N = 0 / Y = 1): " « this->is_sunk « "  \n";
    ofs « "Capital Cost: " « this->capital_cost « "  \n";
    ofs « "Operation and Maintenance Cost: " « this->operation_maintenance_cost_kWh
        « " per kWh produced  \n";
    ofs « "Nominal Inflation Rate (annual): " « this->nominal_inflation_annual
        « "  \n";
    ofs « "Nominal Discount Rate (annual): " « this->nominal_discount_annual
        « "  \n";
```

```
    ofs « "Real Discount Rate (annual): " « this->real_discount_annual « "  \n";
    ofs « "\n";

    ofs « "Replacement Running Hours: " « this->replace_running_hrs « "  \n";
    ofs « "\n--------\n\n";

    //  2.2. Renewable attributes
    ofs « "## Renewable Attributes\n";
    ofs « "\n";

    ofs « "Resource Key (1D): " « this->resource_key « "  \n";
    ofs « "Firmness Factor: " « this->firmness_factor « "  \n";

    ofs « "\n--------\n\n";

    //  2.3. Solar attributes
    ofs « "## Solar Attributes\n";
    ofs « "\n";

    ofs « "Derating Factor: " « this->derating « "  \n";

    ofs « "\n--------\n\n";

    //  2.4. Solar Results
    ofs « "## Results\n";
    ofs « "\n";

    ofs « "Net Present Cost: " « this->net_present_cost « "  \n";
    ofs « "\n";

    ofs « "Total Dispatch: " « this->total_dispatch_kWh
        « " kWh  \n";

    ofs « "Levellized Cost of Energy: " « this->levellized_cost_of_energy_kWh
        « " per kWh dispatched  \n";
    ofs « "\n";

    ofs « "Running Hours: " « this->running_hours « "  \n";
    ofs « "Replacements: " « this->n_replacements « "  \n";

    ofs « "\n--------\n\n";

    ofs.close();
    return;
}   /* __writeSummary() */
```

### 4.24.3.26 __writeTimeSeries()

```
void Solar::__writeTimeSeries (
            std::string write_path,
            std::vector< double > * time_vec_hrs_ptr,
            std::map< int, std::vector< double >> * resource_map_1D_ptr,
            std::map< int, std::vector< std::vector< double >>> * resource_map_2D_ptr,
            int max_lines = -1 )  [private], [virtual]
```

Helper method to write time series results for Solar.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |
| *resource_map_1D_ptr* | A pointer to the 1D map of Resources. |
| *resource_map_2D_ptr* | A pointer to the 2D map of Resources. |
| *max_lines* | The maximum number of lines of output to write. |

Reimplemented from Renewable.

```
{
    //  1. create filestream
    write_path += "time_series_results.csv";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  2. write time series results (comma separated value)
    ofs « "Time (since start of data) [hrs],";
    ofs « "Solar Resource [kW/m2],";
    ofs « "Production [kW],";
    ofs « "Dispatch [kW],";
    ofs « "Storage [kW],";
    ofs « "Curtailment [kW],";
    ofs « "Capital Cost (actual),";
    ofs « "Operation and Maintenance Cost (actual),";
    ofs « "\n";

    for (int i = 0; i < max_lines; i++) {
        ofs « time_vec_hrs_ptr->at(i) « ",";

        if (not this->normalized_production_series_given) {
            ofs « resource_map_1D_ptr->at(this->resource_key)[i] « ",";
        }

        else {
            ofs « "OVERRIDE" « ",";
        }

        ofs « this->production_vec_kW[i] « ",";
        ofs « this->dispatch_vec_kW[i] « ",";
        ofs « this->storage_vec_kW[i] « ",";
        ofs « this->curtailment_vec_kW[i] « ",";
        ofs « this->capital_cost_vec[i] « ",";
        ofs « this->operation_maintenance_cost_vec[i] « ",";
        ofs « "\n";
    }

    ofs.close();
    return;
}   /* __writeTimeSeries() */
```

#### 4.24.3.27 commit()

```
double Solar::commit (
            int timestep,
            double dt_hrs,
            double production_kW,
            double load_kW )  [virtual]
```

Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *production_kW* | The production [kW] of the asset in this timestep. |
| *load_kW* | The load [kW] passed to the asset in this timestep. |

**Returns**

The load [kW] remaining after the dispatch is deducted from it.

Reimplemented from Renewable.

```
{
```

```
    //  1. invoke base class method
    load_kW = Renewable :: commit(
        timestep,
        dt_hrs,
        production_kW,
        load_kW
    );


    //  2. increment julian day
    this->julian_day += dt_hrs / 24;

    return load_kW;
}   /* commit() */
```

#### 4.24.3.28 computeProductionkW()

```
double Solar::computeProductionkW (
            int timestep,
            double dt_hrs,
            double solar_resource_kWm2 )  [virtual]
```

Method which takes in the solar resource at a particular point in time, and then returns the solar PV production at that point in time.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *solar_resource_kWm2* | Solar resource (i.e. global horizontal irradiance) [kW/m2]. |

**Returns**

The production [kW] of the solar PV array.

Reimplemented from Renewable.

```
{
    //  given production time series override
    if (this->normalized_production_series_given) {
        double production_kW = Production :: getProductionkW(timestep);

        return production_kW;
    }

    // check if no resource
    if (solar_resource_kWm2 <= 0) {
        return 0;
    }

    // compute production
    double production_kW = 0;

    switch (this->power_model) {
        case (SolarPowerProductionModel :: SOLAR_POWER_SIMPLE): {
            production_kW = this->__computeSimpleProductionkW(
                timestep,
                dt_hrs,
                solar_resource_kWm2
            );

            break;
        }

        case (SolarPowerProductionModel :: SOLAR_POWER_DETAILED): {
            production_kW = this->__computeDetailedProductionkW(
                timestep,
```

```
                dt_hrs,
                solar_resource_kWm2
            );

            break;
        }

        default: {
            std::string error_str = "ERROR:  Solar::computeProductionkW():  ";
            error_str += "power model ";
            error_str += std::to_string(this->power_model);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    return production_kW;
}   /* computeProductionkW() */
```

#### 4.24.3.29 handleReplacement()

```
void Solar::handleReplacement (
              int timestep )  [virtual]
```

Method to handle asset replacement and capital cost incursion, if applicable.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |

Reimplemented from Renewable.

```
{
    //  1. reset attributes
    //...

    //  2. invoke base class method
    Renewable :: handleReplacement(timestep);

    return;
}   /* __handleReplacement() */
```

### 4.24.4 Member Data Documentation

#### 4.24.4.1 albedo_ground_reflectance

```
double Solar::albedo_ground_reflectance
```

The albedo (ground reflectance) to be applied in modelling the solar PV array.

#### 4.24.4.2 derating

```
double Solar::derating
```

The derating of the solar PV array (i.e., shadowing, soiling, etc.).

#### 4.24.4.3 julian_day

```
double Solar::julian_day
```

The number of days (including partial days) since 12:00 on 1 Jan 2000.

#### 4.24.4.4 latitude_deg

```
double Solar::latitude_deg
```

The latitude of the solar PV array [deg].

#### 4.24.4.5 latitude_rad

```
double Solar::latitude_rad
```

The latitude of the solar PV array [rad].

#### 4.24.4.6 longitude_deg

```
double Solar::longitude_deg
```

The longitude of the solar PV array [deg].

#### 4.24.4.7 longitude_rad

```
double Solar::longitude_rad
```

The longitude of the solar PV array [rad].

#### 4.24.4.8 panel_azimuth_deg

```
double Solar::panel_azimuth_deg
```

The azimuth angle of the panels [deg], relative to north.

#### 4.24.4.9 panel_azimuth_rad

```
double Solar::panel_azimuth_rad
```

The azimuth angle of the panels [rad], relative to north.

#### 4.24.4.10 panel_tilt_deg

```
double Solar::panel_tilt_deg
```

The tilt angle of the panels [deg], relative to ground.

#### 4.24.4.11 panel_tilt_rad

```
double Solar::panel_tilt_rad
```

The tilt angle of the panels [rad], relative to ground.

#### 4.24.4.12 power_model

```
SolarPowerProductionModel Solar::power_model
```

The solar power production model to be applied.

#### 4.24.4.13 power_model_string

```
std::string Solar::power_model_string
```

A string describing the active power production model.

The documentation for this class was generated from the following files:

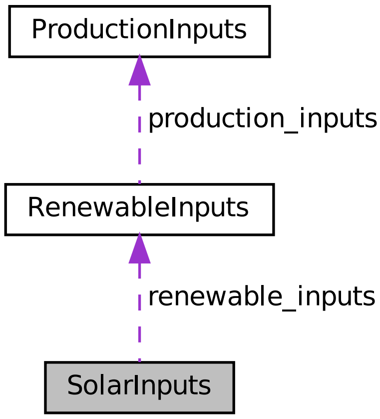
- header/Production/Renewable/Solar.h
- source/Production/Renewable/Solar.cpp

## 4.25 SolarInputs Struct Reference

A structure which bundles the necessary inputs for the Solar constructor. Provides default values for every necessary input. Note that this structure encapsulates RenewableInputs.

```
#include <Solar.h>
```

Collaboration diagram for SolarInputs:




### Public Attributes

- RenewableInputs renewable_inputs

  *An encapsulated RenewableInputs instance.*
- int resource_key = 0

  *A key used to index into the Resources object, to associate this asset with the appropriate resource time series.*
- double firmness_factor = 0.2

  *A factor [0, 1] which defines how firm the production from this asset is.*
- double capital_cost = -1

  *The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].*
- double operation_maintenance_cost_kWh = -1

  *The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].*
- double derating = 0.8

  *The derating of the solar PV array (i.e., shadowing, soiling, etc.).*
- double julian_day = 0

  *The number of days (including partial days) since 12:00 on 1 Jan 2000.*
- double latitude_deg = 0

  *The latitude of the solar PV array [deg].*
- double longitude_deg = 0

*The longitude of the solar PV array [deg].*
- double panel_azimuth_deg = 0

  *The azimuth angle of the panels [deg], relative to north.*
- double panel_tilt_deg = 0

  *The tilt angle of the panels [deg], relative to ground.*
- double albedo_ground_reflectance = 0.5

  *The albedo (ground reflectance) to be applied in modelling the solar PV array.*
- SolarPowerProductionModel power_model = SolarPowerProductionModel :: SOLAR_POWER_SIMPLE

  *The solar power production model to be applied.*

### 4.25.1 Detailed Description

A structure which bundles the necessary inputs for the Solar constructor. Provides default values for every necessary input. Note that this structure encapsulates RenewableInputs.

### 4.25.2 Member Data Documentation

#### 4.25.2.1 albedo_ground_reflectance

```
double SolarInputs::albedo_ground_reflectance = 0.5
```

The albedo (ground reflectance) to be applied in modelling the solar PV array.

#### 4.25.2.2 capital_cost

```
double SolarInputs::capital_cost = -1
```

The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].

#### 4.25.2.3 derating

```
double SolarInputs::derating = 0.8
```

The derating of the solar PV array (i.e., shadowing, soiling, etc.).

#### 4.25.2.4 firmness_factor

```
double SolarInputs::firmness_factor = 0.2
```

A factor [0, 1] which defines how firm the production from this asset is.

#### 4.25.2.5 julian_day

```
double SolarInputs::julian_day = 0
```

The number of days (including partial days) since 12:00 on 1 Jan 2000.

#### 4.25.2.6 latitude_deg

```
double SolarInputs::latitude_deg = 0
```

The latitude of the solar PV array [deg].

#### 4.25.2.7 longitude_deg

```
double SolarInputs::longitude_deg = 0
```

The longitude of the solar PV array [deg].

#### 4.25.2.8 operation_maintenance_cost_kWh

```
double SolarInputs::operation_maintenance_cost_kWh = -1
```

The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].

#### 4.25.2.9 panel_azimuth_deg

```
double SolarInputs::panel_azimuth_deg = 0
```

The azimuth angle of the panels [deg], relative to north.

#### 4.25.2.10 panel_tilt_deg

```
double SolarInputs::panel_tilt_deg = 0
```

The tilt angle of the panels [deg], relative to ground.

#### 4.25.2.11 power_model

```
SolarPowerProductionModel SolarInputs::power_model = SolarPowerProductionModel :: SOLAR_POWER_SIMPLE
```

The solar power production model to be applied.

#### 4.25.2.12 renewable_inputs

```
RenewableInputs SolarInputs::renewable_inputs
```

An encapsulated RenewableInputs instance.

#### 4.25.2.13 resource_key

```
int SolarInputs::resource_key = 0
```

A key used to index into the Resources object, to associate this asset with the appropriate resource time series.

The documentation for this struct was generated from the following file:

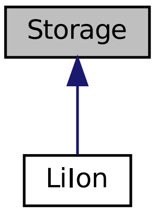
- header/Production/Renewable/Solar.h

## 4.26 Storage Class Reference

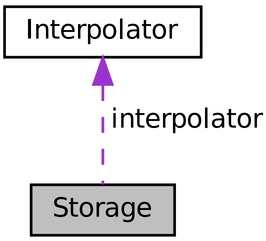
The base class of the Storage hierarchy. This hierarchy contains derived classes which model the storage of energy.

`#include <Storage.h>`

Inheritance diagram for Storage:




Collaboration diagram for Storage:




### Public Member Functions

- Storage (void)

  *Constructor (dummy) for the Storage class.*
- Storage (int, double, StorageInputs)

  *Constructor (intended) for the Storage class.*
- virtual void handleReplacement (int)

  *Method to handle asset replacement and capital cost incursion, if applicable.*
- void computeEconomics (std::vector< double > ∗)

  *Helper method to compute key economic metrics for the Model run.*
- virtual double getAvailablekW (double)
- virtual double getAcceptablekW (double)
- virtual void commitCharge (int, double, double)

- virtual double commitDischarge (int, double, double, double)
- void writeResults (std::string, std::vector$<$ double $>$ $*$, int, int=-1)

  *Method which writes Storage results to an output directory.*
- virtual ∼Storage (void)

  *Destructor for the Storage class.*

## Public Attributes

- StorageType type

  *The type (StorageType) of the asset.*
- Interpolator interpolator

  *Interpolator component of Storage.*
- bool print_flag

  *A flag which indicates whether or not object construct/destruction should be verbose.*
- bool is_depleted

  *A boolean which indicates whether or not the asset is currently considered depleted.*
- bool is_sunk

  *A boolean which indicates whether or not the asset should be considered a sunk cost (i.e., capital cost incurred at the start of the model, or no).*
- int n_points

  *The number of points in the modelling time series.*
- int n_replacements

  *The number of times the asset has been replaced.*
- double n_years

  *The number of years being modelled.*
- double power_capacity_kW

  *The rated power capacity [kW] of the asset.*
- double energy_capacity_kWh

  *The rated energy capacity [kWh] of the asset.*
- double charge_kWh

  *The energy [kWh] stored in the asset.*
- double power_kW

  *The power [kW] currently being charged/discharged by the asset.*
- double nominal_inflation_annual

  *The nominal, annual inflation rate to use in computing model economics.*
- double nominal_discount_annual

  *The nominal, annual discount rate to use in computing model economics.*
- double real_discount_annual

  *The real, annual discount rate used in computing model economics. Is computed from the given nominal inflation and discount rates.*
- double capital_cost

  *The capital cost of the asset (undefined currency).*
- double operation_maintenance_cost_kWh

  *The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy charged/discharged.*
- double net_present_cost

  *The net present cost of this asset.*
- double total_discharge_kWh

  *The total energy discharged [kWh] over the Model run.*
- double levellized_cost_of_energy_kWh

  *The levellized cost of energy [1/kWh] (undefined currency) of this asset. This metric considers only discharge.*

- std::string type_str

    *A string describing the type of the asset.*
- std::vector< double > charge_vec_kWh

    *A vector of the charge state [kWh] at each point in the modelling time series.*
- std::vector< double > charging_power_vec_kW

    *A vector of the charging power [kW] at each point in the modelling time series.*
- std::vector< double > discharging_power_vec_kW

    *A vector of the discharging power [kW] at each point in the modelling time series.*
- std::vector< double > capital_cost_vec

    *A vector of capital costs (undefined currency) incurred over each modelling time step. These costs are not discounted (i.e., these are actual costs).*
- std::vector< double > operation_maintenance_cost_vec

    *A vector of operation and maintenance costs (undefined currency) incurred over each modelling time step. These costs are not discounted (i.e., these are actual costs).*

## Private Member Functions

- void __checkInputs (int, double, StorageInputs)

    *Helper method to check inputs to the Storage constructor.*
- double __computeRealDiscountAnnual (double, double)

    *Helper method to compute the real, annual discount rate to be used in computing model economics. This enables application of the discount factor approach.*
- virtual void __writeSummary (std::string)
- virtual void __writeTimeSeries (std::string, std::vector< double > *, int=-1)

## 4.26.1 Detailed Description

The base class of the Storage hierarchy. This hierarchy contains derived classes which model the storage of energy.

## 4.26.2 Constructor & Destructor Documentation

### 4.26.2.1 Storage() [1/2]

```
Storage::Storage (
            void )
```

Constructor (dummy) for the Storage class.

```
176 {
177     return;
178 }   /* Storage() */
```

### 4.26.2.2 Storage() [2/2]

```
Storage::Storage (
            int n_points,
            double n_years,
            StorageInputs storage_inputs )
```

Constructor (intended) for the Storage class.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *n_years* | The number of years being modelled. |
| *storage_inputs* | A structure of Storage constructor inputs. |

```
{
    //  1. check inputs
    this->__checkInputs(n_points, n_years, storage_inputs);

    //  2. set attributes
    this->print_flag = storage_inputs.print_flag;
    this->is_depleted = false;
    this->is_sunk = storage_inputs.is_sunk;

    this->n_points = n_points;
    this->n_replacements = 0;

    this->n_years = n_years;

    this->power_capacity_kW = storage_inputs.power_capacity_kW;
    this->energy_capacity_kWh = storage_inputs.energy_capacity_kWh;

    this->charge_kWh = 0;
    this->power_kW = 0;

    this->nominal_inflation_annual = storage_inputs.nominal_inflation_annual;
    this->nominal_discount_annual = storage_inputs.nominal_discount_annual;

    this->real_discount_annual = this->__computeRealDiscountAnnual(
        storage_inputs.nominal_inflation_annual,
        storage_inputs.nominal_discount_annual
    );

    this->capital_cost = 0;
    this->operation_maintenance_cost_kWh = 0;
    this->net_present_cost = 0;
    this->total_discharge_kWh = 0;
    this->levellized_cost_of_energy_kWh = 0;

    this->charge_vec_kWh.resize(this->n_points, 0);
    this->charging_power_vec_kW.resize(this->n_points, 0);
    this->discharging_power_vec_kW.resize(this->n_points, 0);

    this->capital_cost_vec.resize(this->n_points, 0);
    this->operation_maintenance_cost_vec.resize(this->n_points, 0);

    //  3. construction print
    if (this->print_flag) {
        std::cout « "Storage object constructed at " « this « std::endl;
    }

    return;
}   /* Storage() */
```

### 4.26.2.3 ∼Storage()

```
Storage::∼Storage (
              void )  [virtual]
```

Destructor for the Storage class.

```
{
    //  1. destruction print
    if (this->print_flag) {
        std::cout « "Storage object at " « this « " destroyed" « std::endl;
    }

    return;
}   /* ~Storage() */
```

## 4.26.3 Member Function Documentation

#### 4.26.3.1 __checkInputs()

```
void Storage::__checkInputs (
            int n_points,
            double n_years,
            StorageInputs storage_inputs ) [private]
```

Helper method to check inputs to the Storage constructor.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *storage_inputs* | A structure of Storage constructor inputs. |

```
{
    //  1. check n_points
    if (n_points <= 0) {
        std::string error_str = "ERROR:  Storage():  n_points must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  2. check n_years
    if (n_years <= 0) {
        std::string error_str = "ERROR:  Storage():  n_years must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  3. check power_capacity_kW
    if (storage_inputs.power_capacity_kW <= 0) {
        std::string error_str = "ERROR:  Storage():  ";
        error_str += "StorageInputs::power_capacity_kW must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  4. check energy_capacity_kWh
    if (storage_inputs.energy_capacity_kWh <= 0) {
        std::string error_str = "ERROR:  Storage():  ";
        error_str += "StorageInputs::energy_capacity_kWh must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkInputs() */
```

#### 4.26.3.2 __computeRealDiscountAnnual()

```
double Storage::__computeRealDiscountAnnual (
            double nominal_inflation_annual,
            double nominal_discount_annual ) [private]
```

Helper method to compute the real, annual discount rate to be used in computing model economics. This enables application of the discount factor approach.

Ref: HOMER [2023h]
Ref: HOMER [2023b]

**Parameters**

| | |
|---|---|
| *nominal_inflation_annual* | The nominal, annual inflation rate to use in computing model economics. |
| *nominal_discount_annual* | The nominal, annual discount rate to use in computing model economics. |

**Returns**

The real, annual discount rate to use in computing model economics.

```
{
    double real_discount_annual = nominal_discount_annual - nominal_inflation_annual;
    real_discount_annual /= 1 + nominal_inflation_annual;

    return real_discount_annual;
}   /* __computeRealDiscountAnnual() */
```

### 4.26.3.3 __writeSummary()

```
virtual void Storage::__writeSummary (
            std::string )  [inline], [private], [virtual]
```

Reimplemented in LiIon.

```
{return;}
```

### 4.26.3.4 __writeTimeSeries()

```
virtual void Storage::__writeTimeSeries (
            std::string ,
            std::vector< double > * ,
            int  = -1 )  [inline], [private], [virtual]
```

Reimplemented in LiIon.

```
{return;}
```

### 4.26.3.5 commitCharge()

```
virtual void Storage::commitCharge (
            int ,
            double ,
            double  )  [inline], [virtual]
```

Reimplemented in LiIon.

```
{return;}
```

#### 4.26.3.6 commitDischarge()

```
virtual double Storage::commitDischarge (
            int ,
            double ,
            double ,
            double ) [inline], [virtual]
```

Reimplemented in LiIon.

```
{return 0;}
```

#### 4.26.3.7 computeEconomics()

```
void Storage::computeEconomics (
            std::vector< double > * time_vec_hrs_ptr )
```

Helper method to compute key economic metrics for the Model run.

Ref: HOMER [2023b]
Ref: HOMER [2023g]
Ref: HOMER [2023i]
Ref: HOMER [2023a]

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |

1. compute levellized cost of energy (per unit discharged)

```
{
    //  1. compute net present cost
    double t_hrs = 0;
    double real_discount_scalar = 0;

    for (int i = 0; i < this->n_points; i++) {
        t_hrs = time_vec_hrs_ptr->at(i);

        real_discount_scalar = 1.0 / pow(
            1 + this->real_discount_annual,
            t_hrs / 8760
        );

        this->net_present_cost += real_discount_scalar * this->capital_cost_vec[i];

        this->net_present_cost +=
            real_discount_scalar * this->operation_maintenance_cost_vec[i];
    }

    //     assuming 8,760 hours per year
    if (this->total_discharge_kWh <= 0) {
        this->levellized_cost_of_energy_kWh = this->net_present_cost;
    }

    else {
        double n_years = time_vec_hrs_ptr->at(this->n_points - 1) / 8760;

        double capital_recovery_factor =
            (this->real_discount_annual * pow(1 + this->real_discount_annual, n_years)) /
            (pow(1 + this->real_discount_annual, n_years) - 1);

        double total_annualized_cost = capital_recovery_factor *
            this->net_present_cost;
```

```
        this->levellized_cost_of_energy_kWh =
            (n_years * total_annualized_cost) /
            this->total_discharge_kWh;
    }

    return;
}   /* computeEconomics() */
```

#### 4.26.3.8 getAcceptablekW()

```
virtual double Storage::getAcceptablekW (
            double ) [inline], [virtual]
```

Reimplemented in LiIon.

```
{return 0;}
```

#### 4.26.3.9 getAvailablekW()

```
virtual double Storage::getAvailablekW (
            double ) [inline], [virtual]
```

Reimplemented in LiIon.

```
{return 0;}
```

#### 4.26.3.10 handleReplacement()

```
void Storage::handleReplacement (
            int timestep ) [virtual]
```

Method to handle asset replacement and capital cost incursion, if applicable.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |

Reimplemented in LiIon.

```
{
    //  1. reset attributes
    this->charge_kWh = 0;
    this->power_kW = 0;

    //  2. log replacement
    this->n_replacements++;

    //  3. incur capital cost in timestep
    this->capital_cost_vec[timestep] = this->capital_cost;

    return;
}   /* __handleReplacement() */
```

#### 4.26.3.11 writeResults()

```
void Storage::writeResults (
            std::string write_path,
            std::vector< double > * time_vec_hrs_ptr,
            int storage_index,
            int max_lines = -1 )
```

Method which writes Storage results to an output directory.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |
| *storage_index* | An integer which corresponds to the index of the Storage asset in the Model. |
| *max_lines* | The maximum number of lines of output to write. If $<$0, then all available lines are written. If =0, then only summary results are written. |

```
{
    //  1. handle sentinel
    if (max_lines < 0) {
        max_lines = this->n_points;
    }

    //  2. create subdirectories
    write_path += "Storage/";
    if (not std::filesystem::is_directory(write_path)) {
        std::filesystem::create_directory(write_path);
    }

    write_path += this->type_str;
    write_path += "_";
    write_path += std::to_string(int(ceil(this->power_capacity_kW)));
    write_path += "kW_";
    write_path += std::to_string(int(ceil(this->energy_capacity_kWh)));
    write_path += "kWh_idx";
    write_path += std::to_string(storage_index);
    write_path += "/";
    std::filesystem::create_directory(write_path);

    //  3. write summary
    this->__writeSummary(write_path);

    //  4. write time series
    if (max_lines > this->n_points) {
        max_lines = this->n_points;
    }

    if (max_lines > 0) {
        this->__writeTimeSeries(
            write_path,
            time_vec_hrs_ptr,
            max_lines
        );
    }

    return;
}   /* writeResults() */
```

## 4.26.4 Member Data Documentation

#### 4.26.4.1 capital_cost

```
double Storage::capital_cost
```

The capital cost of the asset (undefined currency).

#### 4.26.4.2 capital_cost_vec

```
std::vector<double> Storage::capital_cost_vec
```

A vector of capital costs (undefined currency) incurred over each modelling time step. These costs are not discounted (i.e., these are actual costs).

#### 4.26.4.3 charge_kWh

```
double Storage::charge_kWh
```

The energy [kWh] stored in the asset.

#### 4.26.4.4 charge_vec_kWh

```
std::vector<double> Storage::charge_vec_kWh
```

A vector of the charge state [kWh] at each point in the modelling time series.

#### 4.26.4.5 charging_power_vec_kW

```
std::vector<double> Storage::charging_power_vec_kW
```

A vector of the charging power [kW] at each point in the modelling time series.

#### 4.26.4.6 discharging_power_vec_kW

```
std::vector<double> Storage::discharging_power_vec_kW
```

A vector of the discharging power [kW] at each point in the modelling time series.

#### 4.26.4.7 energy_capacity_kWh

```
double Storage::energy_capacity_kWh
```

The rated energy capacity [kWh] of the asset.

#### 4.26.4.8 interpolator

```
Interpolator Storage::interpolator
```

Interpolator component of Storage.

#### 4.26.4.9 is_depleted

```
bool Storage::is_depleted
```

A boolean which indicates whether or not the asset is currently considered depleted.

#### 4.26.4.10 is_sunk

```
bool Storage::is_sunk
```

A boolean which indicates whether or not the asset should be considered a sunk cost (i.e., capital cost incurred at the start of the model, or no).

#### 4.26.4.11 levellized_cost_of_energy_kWh

```
double Storage::levellized_cost_of_energy_kWh
```

The levellized cost of energy [1/kWh] (undefined currency) of this asset. This metric considers only discharge.

#### 4.26.4.12 n_points

```
int Storage::n_points
```

The number of points in the modelling time series.

#### 4.26.4.13 n_replacements

```
int Storage::n_replacements
```

The number of times the asset has been replaced.

#### 4.26.4.14 n_years

```
double Storage::n_years
```

The number of years being modelled.

#### 4.26.4.15 net_present_cost

```
double Storage::net_present_cost
```

The net present cost of this asset.

#### 4.26.4.16 nominal_discount_annual

```
double Storage::nominal_discount_annual
```

The nominal, annual discount rate to use in computing model economics.

#### 4.26.4.17 nominal_inflation_annual

```
double Storage::nominal_inflation_annual
```

The nominal, annual inflation rate to use in computing model economics.

#### 4.26.4.18 operation_maintenance_cost_kWh

```
double Storage::operation_maintenance_cost_kWh
```

The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy charged/discharged.

#### 4.26.4.19 operation_maintenance_cost_vec

```
std::vector<double> Storage::operation_maintenance_cost_vec
```

A vector of operation and maintenance costs (undefined currency) incurred over each modelling time step. These costs are not discounted (i.e., these are actual costs).

#### 4.26.4.20 power_capacity_kW

```
double Storage::power_capacity_kW
```

The rated power capacity [kW] of the asset.

#### 4.26.4.21 power_kW

```
double Storage::power_kW
```

The power [kW] currently being charged/discharged by the asset.

#### 4.26.4.22 print_flag

```
bool Storage::print_flag
```

A flag which indicates whether or not object construct/destruction should be verbose.

#### 4.26.4.23 real_discount_annual

```
double Storage::real_discount_annual
```

The real, annual discount rate used in computing model economics. Is computed from the given nominal inflation and discount rates.

#### 4.26.4.24 total_discharge_kWh

```
double Storage::total_discharge_kWh
```

The total energy discharged [kWh] over the Model run.

#### 4.26.4.25 type

```
StorageType Storage::type
```

The type (StorageType) of the asset.

#### 4.26.4.26 type_str

```
std::string Storage::type_str
```

A string describing the type of the asset.

The documentation for this class was generated from the following files:

- header/Storage/Storage.h
- source/Storage/Storage.cpp

## 4.27 StorageInputs Struct Reference

A structure which bundles the necessary inputs for the Storage constructor. Provides default values for every necessary input.

```
#include <Storage.h>
```

### Public Attributes

- bool print_flag = false

  *A flag which indicates whether or not object construct/destruction should be verbose.*
- bool is_sunk = false

  *A boolean which indicates whether or not the asset should be considered a sunk cost (i.e., capital cost incurred at the start of the model, or no).*
- double power_capacity_kW = 100

  *The rated power capacity [kW] of the asset.*
- double energy_capacity_kWh = 1000

  *The rated energy capacity [kWh] of the asset.*
- double nominal_inflation_annual = 0.02

  *The nominal, annual inflation rate to use in computing model economics.*
- double nominal_discount_annual = 0.04

  *The nominal, annual discount rate to use in computing model economics.*

### 4.27.1 Detailed Description

A structure which bundles the necessary inputs for the Storage constructor. Provides default values for every necessary input.

## 4.27.2 Member Data Documentation

### 4.27.2.1 energy_capacity_kWh

```
double StorageInputs::energy_capacity_kWh = 1000
```

The rated energy capacity [kWh] of the asset.

### 4.27.2.2 is_sunk

```
bool StorageInputs::is_sunk = false
```

A boolean which indicates whether or not the asset should be considered a sunk cost (i.e., capital cost incurred at the start of the model, or no).

### 4.27.2.3 nominal_discount_annual

```
double StorageInputs::nominal_discount_annual = 0.04
```

The nominal, annual discount rate to use in computing model economics.

### 4.27.2.4 nominal_inflation_annual

```
double StorageInputs::nominal_inflation_annual = 0.02
```

The nominal, annual inflation rate to use in computing model economics.

### 4.27.2.5 power_capacity_kW

```
double StorageInputs::power_capacity_kW = 100
```

The rated power capacity [kW] of the asset.

#### 4.27.2.6 print_flag

```
bool StorageInputs::print_flag = false
```

A flag which indicates whether or not object construct/destruction should be verbose.

The documentation for this struct was generated from the following file:

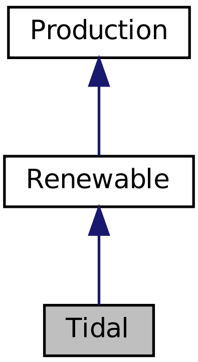
- header/Storage/Storage.h

## 4.28 Tidal Class Reference

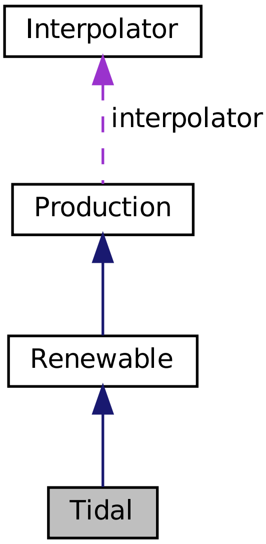
A derived class of the Renewable branch of Production which models tidal production.

```
#include <Tidal.h>
```

Inheritance diagram for Tidal:



Collaboration diagram for Tidal:




## Public Member Functions

- Tidal (void)

  *Constructor (dummy) for the Tidal class.*
- Tidal (int, double, TidalInputs, std::vector< double > ∗)

  *Constructor (intended) for the Tidal class.*
- void handleReplacement (int)

  *Method to handle asset replacement and capital cost incursion, if applicable.*
- double computeProductionkW (int, double, double)

  *Method which takes in the tidal resource at a particular point in time, and then returns the tidal turbine production at that point in time.*
- double commit (int, double, double, double)

  *Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.*
- ∼Tidal (void)

  *Destructor for the Tidal class.*

## Public Attributes

- double design_speed_ms

  *The tidal stream speed [m/s] at which the tidal turbine achieves its rated capacity.*
- TidalPowerProductionModel power_model

  *The tidal power production model to be applied.*
- std::string power_model_string

  *A string describing the active power production model.*

## Private Member Functions

- void __checkInputs (TidalInputs)

  *Helper method to check inputs to the Tidal constructor.*
- double __getGenericCapitalCost (void)

  *Helper method to generate a generic tidal turbine capital cost.*
- double __getGenericOpMaintCost (void)

  *Helper method to generate a generic tidal turbine operation and maintenance cost. This is a cost incurred per unit energy produced.*
- double __computeCubicProductionkW (int, double, double)

  *Helper method to compute tidal turbine production under a cubic production model.*
- double __computeExponentialProductionkW (int, double, double)

  *Helper method to compute tidal turbine production under an exponential production model.*
- double __computeLookupProductionkW (int, double, double)

  *Helper method to compute tidal turbine production by way of looking up using given power curve data.*
- void __writeSummary (std::string)

  *Helper method to write summary results for Tidal.*
- void __writeTimeSeries (std::string, std::vector< double > ∗, std::map< int, std::vector< double >> ∗, std↩ ::map< int, std::vector< std::vector< double >>> ∗, int=-1)

  *Helper method to write time series results for Tidal.*

## 4.28.1 Detailed Description

A derived class of the Renewable branch of Production which models tidal production.

## 4.28.2 Constructor & Destructor Documentation

### 4.28.2.1 Tidal() [1/2]

```
Tidal::Tidal (
            void )
```

Constructor (dummy) for the Tidal class.

```
497 {
498     return;
499 }   /* Tidal() */
```

### 4.28.2.2 Tidal() [2/2]

```
Tidal::Tidal (
            int n_points,
            double n_years,
            TidalInputs tidal_inputs,
            std::vector< double > * time_vec_hrs_ptr )
```

Constructor (intended) for the Tidal class.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *n_years* | The number of years being modelled. |
| *tidal_inputs* | A structure of Tidal constructor inputs. |
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
  :
Renewable(
    n_points,
    n_years,
    tidal_inputs.renewable_inputs,
    time_vec_hrs_ptr
)
{
    //  1. check inputs
    this->__checkInputs(tidal_inputs);

    //  2. set attributes
    this->type = RenewableType :: TIDAL;
    this->type_str = "TIDAL";

    this->resource_key = tidal_inputs.resource_key;

    this->firmness_factor = tidal_inputs.firmness_factor;

    this->design_speed_ms = tidal_inputs.design_speed_ms;

    this->power_model = tidal_inputs.power_model;

    switch (this->power_model) {
        case (TidalPowerProductionModel :: TIDAL_POWER_CUBIC): {
            this->power_model_string = "CUBIC";

            break;
        }

        case (TidalPowerProductionModel :: TIDAL_POWER_EXPONENTIAL): {
            this->power_model_string = "EXPONENTIAL";

            break;
        }

        case (TidalPowerProductionModel :: TIDAL_POWER_LOOKUP): {
            this->power_model_string = "LOOKUP";

            break;
        }

        default: {
            std::string error_str = "ERROR:  Tidal():  ";
            error_str += "power production model ";
            error_str += std::to_string(this->power_model);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    if (tidal_inputs.capital_cost < 0) {
        this->capital_cost = this->__getGenericCapitalCost();
    }
    else {
        this->capital_cost = tidal_inputs.capital_cost;
    }

    if (tidal_inputs.operation_maintenance_cost_kWh < 0) {
        this->operation_maintenance_cost_kWh = this->__getGenericOpMaintCost();
    }
    else {
        this->operation_maintenance_cost_kWh =
            tidal_inputs.operation_maintenance_cost_kWh;
    }

    if (not this->is_sunk) {
        this->capital_cost_vec[0] = this->capital_cost;
    }
```

```

    //  3. construction print
    if (this->print_flag) {
        std::cout « "Tidal object constructed at " « this « std::endl;
    }

    return;
}   /* Renewable() */
```

#### 4.28.2.3 ∼Tidal()

```
Tidal::∼Tidal (
            void   )
```

Destructor for the Tidal class.

```
{
    //  1. destruction print
    if (this->print_flag) {
        std::cout « "Tidal object at " « this « " destroyed" « std::endl;
    }

    return;
}   /* ~Tidal() */
```

### 4.28.3 Member Function Documentation

#### 4.28.3.1 __checkInputs()

```
void Tidal::__checkInputs (
            TidalInputs tidal_inputs )   [private]
```

Helper method to check inputs to the Tidal constructor.

Ref: Bir et al. [2011]
Ref: Lewis et al. [2021]

```
{
    //  1. check design_speed_ms
    if (tidal_inputs.design_speed_ms <= 0) {
        std::string error_str = "ERROR:  Tidal():  ";
        error_str += "TidalInputs::design_speed_ms must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    else if (tidal_inputs.design_speed_ms < 2) {
        std::string warning_str = "WARNING:  Tidal():  ";
        warning_str += "Setting TidalInputs::design_speed_ms to less than 2 m/s may be ";
        warning_str += "technically unrealistic";

        std::cout « warning_str « std::endl;
    }

    //  2. check firmness_factor
    if (
        tidal_inputs.firmness_factor < 0 or
        tidal_inputs.firmness_factor > 1
    ) {
        std::string error_str = "ERROR:  Tidal():  ";
```

```
        error_str += "TidalInputs::firmness_factor must be in the closed interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkInputs() */
```

#### 4.28.3.2 __computeCubicProductionkW()

```
double Tidal::__computeCubicProductionkW (
            int timestep,
            double dt_hrs,
            double tidal_resource_ms ) [private]
```

Helper method to compute tidal turbine production under a cubic production model.

Ref: Buckham et al. [2023]
Ref: Bir et al. [2011]
Ref: Lewis et al. [2021]
Ref: Whitby and Ugalde-Loo [2013]

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *tidal_resource_ms* | The available tidal stream resource [m/s]. |

**Returns**

The production [kW] of the tidal turbine, under a cubic model.

```
{
    double production = 0;

    if (
        tidal_resource_ms < 0.15 * this->design_speed_ms or
        tidal_resource_ms > 1.25 * this->design_speed_ms
    ){
        production = 0;
    }

    else if (
        0.15 * this->design_speed_ms <= tidal_resource_ms and
        tidal_resource_ms <= this->design_speed_ms
    ) {
        production = (1 / pow(this->design_speed_ms, 3)) * pow(tidal_resource_ms, 3);
    }

    else {
        production = 1;
    }

    return production * this->capacity_kW;
}   /* __computeCubicProductionkW() */
```

### 4.28.3.3 __computeExponentialProductionkW()

```
double Tidal::__computeExponentialProductionkW (
            int timestep,
            double dt_hrs,
            double tidal_resource_ms ) [private]
```

Helper method to compute tidal turbine production under an exponential production model.

Ref: Truelove et al. [2019]

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *tidal_resource_ms* | The available tidal stream resource [m/s]. |

**Returns**

The production [kW] of the tidal turbine, under an exponential model.

```
{
    double production = 0;

    double turbine_speed =
        (tidal_resource_ms - this->design_speed_ms) / this->design_speed_ms;

    if (turbine_speed < -0.71 or turbine_speed > 0.65) {
        production = 0;
    }

    else if (turbine_speed >= -0.71 and turbine_speed <= 0) {
        production = 1.69215 * exp(1.25909 * turbine_speed) - 0.69215;
    }

    else {
        production = 1;
    }

    return production * this->capacity_kW;
}   /* __computeExponentialProductionkW() */
```

### 4.28.3.4 __computeLookupProductionkW()

```
double Tidal::__computeLookupProductionkW (
            int timestep,
            double dt_hrs,
            double tidal_resource_ms ) [private]
```

Helper method to compute tidal turbine production by way of looking up using given power curve data.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *tidal_resource_ms* | The available tidal stream resource [m/s]. |

**Returns**

The interpolated production [kW] of the tidal tubrine.

```
{
    // *** WORK IN PROGRESS *** //

    return 0;
}   /* __computeLookupProductionkW() */
```

#### 4.28.3.5 __getGenericCapitalCost()

```
double Tidal::__getGenericCapitalCost (
            void ) [private]
```

Helper method to generate a generic tidal turbine capital cost.

Note that this model expresses cost in terms of Canadian dollars [CAD].

Ref: MacDougall [2019]

**Returns**

A generic capital cost for the tidal turbine [CAD].

```
{
    double capital_cost_per_kW = 2000 * pow(this->capacity_kW, -0.15) + 4000;

    return capital_cost_per_kW * this->capacity_kW;
}   /* __getGenericCapitalCost() */
```

#### 4.28.3.6 __getGenericOpMaintCost()

```
double Tidal::__getGenericOpMaintCost (
            void ) [private]
```

Helper method to generate a generic tidal turbine operation and maintenance cost. This is a cost incurred per unit energy produced.

Note that this model expresses cost in terms of Canadian dollars [CAD/kWh].

Ref: MacDougall [2019]

**Returns**

A generic operation and maintenance cost, per unit energy produced, for the tidal turbine [CAD/kWh].

```
{
    double operation_maintenance_cost_kWh = 0.05 * pow(this->capacity_kW, -0.2) + 0.05;

    return operation_maintenance_cost_kWh;
}   /* __getGenericOpMaintCost() */
```

#### 4.28.3.7 __writeSummary()

```
void Tidal::__writeSummary (
            std::string write_path ) [private], [virtual]
```

Helper method to write summary results for Tidal.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |

Reimplemented from Renewable.

```
{
    //  1. create filestream
    write_path += "summary_results.md";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  2. write summary results (markdown)
    ofs « "# ";
    ofs « std::to_string(int(ceil(this->capacity_kW)));
    ofs « " kW TIDAL Summary Results\n";
    ofs « "\n--------\n\n";

    //  2.1. Production attributes
    ofs « "## Production Attributes\n";
    ofs « "\n";

    ofs « "Capacity: " « this->capacity_kW « " kW  \n";
    ofs « "\n";

    ofs « "Production Override: (N = 0 / Y = 1): "
        « this->normalized_production_series_given « "  \n";
    if (this->normalized_production_series_given) {
        ofs « "Path to Normalized Production Time Series: "
            « this->path_2_normalized_production_time_series « "  \n";
    }
    ofs « "\n";

    ofs « "Sunk Cost (N = 0 / Y = 1): " « this->is_sunk « "  \n";
    ofs « "Capital Cost: " « this->capital_cost « "  \n";
    ofs « "Operation and Maintenance Cost: " « this->operation_maintenance_cost_kWh
        « " per kWh produced  \n";
    ofs « "Nominal Inflation Rate (annual): " « this->nominal_inflation_annual
        « "  \n";
    ofs « "Nominal Discount Rate (annual): " « this->nominal_discount_annual
        « "  \n";
    ofs « "Real Discount Rate (annual): " « this->real_discount_annual « "  \n";
    ofs « "\n";

    ofs « "Replacement Running Hours: " « this->replace_running_hrs « "  \n";
    ofs « "\n--------\n\n";

    //  2.2. Renewable attributes
    ofs « "## Renewable Attributes\n";
    ofs « "\n";

    ofs « "Resource Key (1D): " « this->resource_key « "  \n";
    ofs « "Firmness Factor: " « this->firmness_factor « "  \n";

    ofs « "\n--------\n\n";

    //  2.3. Tidal attributes
    ofs « "## Tidal Attributes\n";
    ofs « "\n";

    ofs « "Power Production Model: " « this->power_model_string « "  \n";
    ofs « "Design Speed: " « this->design_speed_ms « " m/s  \n";

    ofs « "\n--------\n\n";

    //  2.4. Tidal Results
    ofs « "## Results\n";
    ofs « "\n";

    ofs « "Net Present Cost: " « this->net_present_cost « "  \n";
    ofs « "\n";

    ofs « "Total Dispatch: " « this->total_dispatch_kWh
        « " kWh  \n";

    ofs « "Levellized Cost of Energy: " « this->levellized_cost_of_energy_kWh
        « " per kWh dispatched  \n";
    ofs « "\n";

    ofs « "Running Hours: " « this->running_hours « "  \n";
    ofs « "Replacements: " « this->n_replacements « "  \n";

    ofs « "\n--------\n\n";
```

```
    ofs.close();

    return;
}   /* __writeSummary() */
```

#### 4.28.3.8 __writeTimeSeries()

```
void Tidal::__writeTimeSeries (
            std::string write_path,
            std::vector< double > * time_vec_hrs_ptr,
            std::map< int, std::vector< double >> * resource_map_1D_ptr,
            std::map< int, std::vector< std::vector< double >>> * resource_map_2D_ptr,
            int max_lines = -1 )  [private], [virtual]
```

Helper method to write time series results for Tidal.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |
| *resource_map_1D_ptr* | A pointer to the 1D map of Resources. |
| *resource_map_2D_ptr* | A pointer to the 2D map of Resources. |
| *max_lines* | The maximum number of lines of output to write. |

Reimplemented from Renewable.

```
{
    //  1. create filestream
    write_path += "time_series_results.csv";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  2. write time series results (comma separated value)
    ofs « "Time (since start of data) [hrs],";
    ofs « "Tidal Resource [m/s],";
    ofs « "Production [kW],";
    ofs « "Dispatch [kW],";
    ofs « "Storage [kW],";
    ofs « "Curtailment [kW],";
    ofs « "Capital Cost (actual),";
    ofs « "Operation and Maintenance Cost (actual),";
    ofs « "\n";

    for (int i = 0; i < max_lines; i++) {
        ofs « time_vec_hrs_ptr->at(i) « ",";

        if (not this->normalized_production_series_given) {
            ofs « resource_map_1D_ptr->at(this->resource_key)[i] « ",";
        }

        else {
            ofs « "OVERRIDE" « ",";
        }

        ofs « this->production_vec_kW[i] « ",";
        ofs « this->dispatch_vec_kW[i] « ",";
        ofs « this->storage_vec_kW[i] « ",";
        ofs « this->curtailment_vec_kW[i] « ",";
        ofs « this->capital_cost_vec[i] « ",";
        ofs « this->operation_maintenance_cost_vec[i] « ",";
        ofs « "\n";
    }

    return;
}   /* __writeTimeSeries() */
```

#### 4.28.3.9 commit()

```
double Tidal::commit (
            int timestep,
            double dt_hrs,
            double production_kW,
            double load_kW ) [virtual]
```

Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *production_kW* | The production [kW] of the asset in this timestep. |
| *load_kW* | The load [kW] passed to the asset in this timestep. |

**Returns**

The load [kW] remaining after the dispatch is deducted from it.

Reimplemented from Renewable.

```
{
    // 1. invoke base class method
    load_kW = Renewable :: commit(
        timestep,
        dt_hrs,
        production_kW,
        load_kW
    );


    //...

    return load_kW;
}   /* commit() */
```

#### 4.28.3.10 computeProductionkW()

```
double Tidal::computeProductionkW (
            int timestep,
            double dt_hrs,
            double tidal_resource_ms ) [virtual]
```

Method which takes in the tidal resource at a particular point in time, and then returns the tidal turbine production at that point in time.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *tidal_resource_ms* | Tidal resource (i.e. tidal stream speed) [m/s]. |

**Returns**

The production [kW] of the tidal turbine.

Reimplemented from Renewable.

```
{
    //  given production time series override
    if (this->normalized_production_series_given) {
        double production_kW = Production :: getProductionkW(timestep);

        return production_kW;
    }

    // check if no resource
    if (tidal_resource_ms <= 0) {
        return 0;
    }

    // compute production
    double production_kW = 0;

    switch (this->power_model) {
        case (TidalPowerProductionModel :: TIDAL_POWER_CUBIC): {
            production_kW = this->__computeCubicProductionkW(
                timestep,
                dt_hrs,
                tidal_resource_ms
            );

            break;
        }


        case (TidalPowerProductionModel :: TIDAL_POWER_EXPONENTIAL): {
            production_kW = this->__computeExponentialProductionkW(
                timestep,
                dt_hrs,
                tidal_resource_ms
            );

            break;
        }

        case (TidalPowerProductionModel :: TIDAL_POWER_LOOKUP): {
            production_kW = this->__computeLookupProductionkW(
                timestep,
                dt_hrs,
                tidal_resource_ms
            );

            break;
        }

        default: {
            std::string error_str = "ERROR:  Tidal::computeProductionkW():  ";
            error_str += "power model ";
            error_str += std::to_string(this->power_model);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    return production_kW;
}   /* computeProductionkW() */
```

#### 4.28.3.11 handleReplacement()

```
void Tidal::handleReplacement (
            int timestep )  [virtual]
```

Method to handle asset replacement and capital cost incursion, if applicable.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |

Reimplemented from Renewable.

```
{
    //  1. reset attributes
    //...

    //  2. invoke base class method
    Renewable :: handleReplacement(timestep);

    return;
}   /* __handleReplacement() */
```

## 4.28.4 Member Data Documentation

### 4.28.4.1 design_speed_ms

```
double Tidal::design_speed_ms
```

The tidal stream speed [m/s] at which the tidal turbine achieves its rated capacity.

### 4.28.4.2 power_model

```
TidalPowerProductionModel Tidal::power_model
```

The tidal power production model to be applied.

### 4.28.4.3 power_model_string

```
std::string Tidal::power_model_string
```

A string describing the active power production model.

The documentation for this class was generated from the following files:

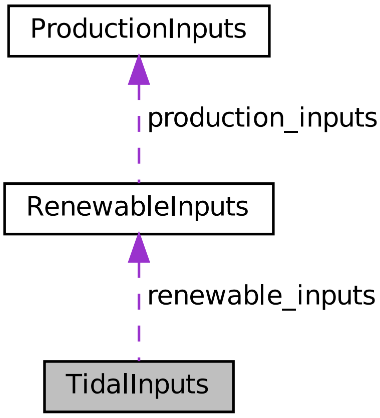
- header/Production/Renewable/Tidal.h
- source/Production/Renewable/Tidal.cpp

## 4.29 TidalInputs Struct Reference

A structure which bundles the necessary inputs for the Tidal constructor. Provides default values for every necessary input. Note that this structure encapsulates RenewableInputs.

```
#include <Tidal.h>
```

Collaboration diagram for TidalInputs:




### Public Attributes

- RenewableInputs renewable_inputs

  *An encapsulated RenewableInputs instance.*
- int resource_key = 0

  *A key used to index into the Resources object, to associate this asset with the appropriate resource time series.*
- double firmness_factor = 0.8

  *A factor [0, 1] which defines how firm the production from this asset is.*
- double capital_cost = -1

  *The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].*
- double operation_maintenance_cost_kWh = -1

  *The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].*
- double design_speed_ms = 3

  *The tidal stream speed [m/s] at which the tidal turbine achieves its rated capacity.*
- TidalPowerProductionModel power_model = TidalPowerProductionModel :: TIDAL_POWER_CUBIC

  *The tidal power production model to be applied.*

### 4.29.1 Detailed Description

A structure which bundles the necessary inputs for the Tidal constructor. Provides default values for every necessary input. Note that this structure encapsulates RenewableInputs.

### 4.29.2 Member Data Documentation

#### 4.29.2.1 capital_cost

```
double TidalInputs::capital_cost = -1
```

The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].

#### 4.29.2.2 design_speed_ms

```
double TidalInputs::design_speed_ms = 3
```

The tidal stream speed [m/s] at which the tidal turbine achieves its rated capacity.

#### 4.29.2.3 firmness_factor

```
double TidalInputs::firmness_factor = 0.8
```

A factor [0, 1] which defines how firm the production from this asset is.

#### 4.29.2.4 operation_maintenance_cost_kWh

```
double TidalInputs::operation_maintenance_cost_kWh = -1
```

The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].

#### 4.29.2.5 power_model

`TidalPowerProductionModel TidalInputs::power_model = TidalPowerProductionModel :: TIDAL_POWER_CUBIC`

The tidal power production model to be applied.

#### 4.29.2.6 renewable_inputs

`RenewableInputs TidalInputs::renewable_inputs`

An encapsulated RenewableInputs instance.

#### 4.29.2.7 resource_key

`int TidalInputs::resource_key = 0`

A key used to index into the Resources object, to associate this asset with the appropriate resource time series.

The documentation for this struct was generated from the following file:

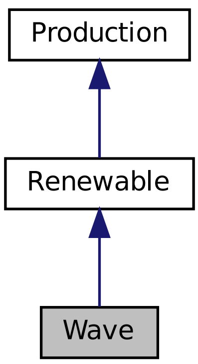
- header/Production/Renewable/Tidal.h

## 4.30 Wave Class Reference

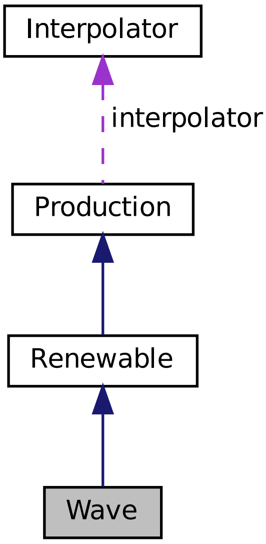
A derived class of the Renewable branch of Production which models wave production.

`#include <Wave.h>`

Inheritance diagram for Wave:



Collaboration diagram for Wave:




## Public Member Functions

- Wave (void)

    *Constructor (dummy) for the Wave class.*
- Wave (int, double, WaveInputs, std::vector< double > *)

    *Constructor (intended) for the Wave class.*
- void handleReplacement (int)

    *Method to handle asset replacement and capital cost incursion, if applicable.*
- double computeProductionkW (int, double, double, double)

    *Method which takes in the wave resource at a particular point in time, and then returns the wave turbine production at that point in time.*
- double commit (int, double, double, double)

    *Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.*
- ∼Wave (void)

    *Destructor for the Wave class.*

## Public Attributes

- double design_significant_wave_height_m

    *The significant wave height [m] at which the wave energy converter achieves its rated capacity.*
- double design_energy_period_s

    *The energy period [s] at which the wave energy converter achieves its rated capacity.*
- WavePowerProductionModel power_model

    *The wave power production model to be applied.*
- std::string power_model_string

    *A string describing the active power production model.*

## Private Member Functions

- void __checkInputs (WaveInputs)
  *Helper method to check inputs to the Wave constructor.*
- double __getGenericCapitalCost (void)
  *Helper method to generate a generic wave energy converter capital cost.*
- double __getGenericOpMaintCost (void)
  *Helper method to generate a generic wave energy converter operation and maintenance cost. This is a cost incurred per unit energy produced.*
- double __computeGaussianProductionkW (int, double, double, double)
  *Helper method to compute wave energy converter production under a Gaussian production model.*
- double __computeParaboloidProductionkW (int, double, double, double)
  *Helper method to compute wave energy converter production under a paraboloid production model.*
- double __computeLookupProductionkW (int, double, double, double)
  *Helper method to compute wave energy converter production by way of looking up using given performance matrix.*
- void __writeSummary (std::string)
  *Helper method to write summary results for Wave.*
- void __writeTimeSeries (std::string, std::vector< double > *, std::map< int, std::vector< double >> *, std↩ ::map< int, std::vector< std::vector< double >>> *, int=-1)
  *Helper method to write time series results for Wave.*

## 4.30.1 Detailed Description

A derived class of the Renewable branch of Production which models wave production.

## 4.30.2 Constructor & Destructor Documentation

### 4.30.2.1 Wave() [1/2]

```
Wave::Wave (
        void )
```

Constructor (dummy) for the Wave class.

```
559 {
560     return;
561 }   /* Wave() */
```

### 4.30.2.2 Wave() [2/2]

```
Wave::Wave (
        int n_points,
        double n_years,
        WaveInputs wave_inputs,
        std::vector< double > * time_vec_hrs_ptr )
```

Constructor (intended) for the Wave class.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *n_years* | The number of years being modelled. |
| *wave_inputs* | A structure of Wave constructor inputs. |
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
   :
Renewable(
    n_points,
    n_years,
    wave_inputs.renewable_inputs,
    time_vec_hrs_ptr
)
{
    //  1. check inputs
    this->__checkInputs(wave_inputs);

    //  2. set attributes
    this->type = RenewableType :: WAVE;
    this->type_str = "WAVE";

    this->resource_key = wave_inputs.resource_key;

    this->firmness_factor = wave_inputs.firmness_factor;

    this->design_significant_wave_height_m =
        wave_inputs.design_significant_wave_height_m;
    this->design_energy_period_s = wave_inputs.design_energy_period_s;

    this->power_model = wave_inputs.power_model;

    switch (this->power_model) {
        case (WavePowerProductionModel :: WAVE_POWER_GAUSSIAN): {
            this->power_model_string = "GAUSSIAN";

            break;
        }

        case (WavePowerProductionModel :: WAVE_POWER_PARABOLOID): {
            this->power_model_string = "PARABOLOID";

            break;
        }

        case (WavePowerProductionModel :: WAVE_POWER_LOOKUP): {
            this->power_model_string = "LOOKUP";

            this->interpolator.addData2D(
                0,
                wave_inputs.path_2_normalized_performance_matrix
            );

            break;
        }

        default: {
            std::string error_str = "ERROR:  Wave():  ";
            error_str += "power production model ";
            error_str += std::to_string(this->power_model);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    if (wave_inputs.capital_cost < 0) {
        this->capital_cost = this->__getGenericCapitalCost();
    }
    else {
        this->capital_cost = wave_inputs.capital_cost;
    }

    if (wave_inputs.operation_maintenance_cost_kWh < 0) {
        this->operation_maintenance_cost_kWh = this->__getGenericOpMaintCost();
    }
    else {
```

```
        this->operation_maintenance_cost_kWh =
            wave_inputs.operation_maintenance_cost_kWh;
    }

    if (not this->is_sunk) {
        this->capital_cost_vec[0] = this->capital_cost;
    }

    //  3. construction print
    if (this->print_flag) {
        std::cout « "Wave object constructed at " « this « std::endl;
    }

    return;
}   /* Renewable() */
```

#### 4.30.2.3 ∼Wave()

```
Wave::∼Wave (
        void )
```

Destructor for the Wave class.

```
{
    //  1. destruction print
    if (this->print_flag) {
        std::cout « "Wave object at " « this « " destroyed" « std::endl;
    }

    return;
}   /* ~Wave() */
```

### 4.30.3 Member Function Documentation

#### 4.30.3.1 __checkInputs()

```
void Wave::__checkInputs (
        WaveInputs wave_inputs )  [private]
```

Helper method to check inputs to the Wave constructor.

**Parameters**

| | |
|---|---|
| *wave_inputs* | A structure of Wave constructor inputs. |

```
{
    //  1. check design_significant_wave_height_m
    if (wave_inputs.design_significant_wave_height_m <= 0) {
        std::string error_str = "ERROR:  Wave():  ";
        error_str += "WaveInputs::design_significant_wave_height_m must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  2. check design_energy_period_s
    if (wave_inputs.design_energy_period_s <= 0) {
        std::string error_str = "ERROR:  Wave():  ";
        error_str += "WaveInputs::design_energy_period_s must be > 0";
```

```
        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  3. if WAVE_POWER_LOOKUP, check that path is given
    if (
        wave_inputs.power_model == WavePowerProductionModel :: WAVE_POWER_LOOKUP and
        wave_inputs.path_2_normalized_performance_matrix.empty()
    ) {
        std::string error_str = "ERROR:  Wave()  power model was set to ";
        error_str += "WavePowerProductionModel::WAVE_POWER_LOOKUP, but no path to a ";
        error_str += "normalized performance matrix was given";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    //  4. check firmness_factor
    if (
        wave_inputs.firmness_factor < 0 or
        wave_inputs.firmness_factor > 1
    ) {
        std::string error_str = "ERROR:  Wave():  ";
        error_str += "WaveInputs::firmness_factor must be in the closed interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkInputs() */
```

### 4.30.3.2 __computeGaussianProductionkW()

```
double Wave::__computeGaussianProductionkW (
            int timestep,
            double dt_hrs,
            double significant_wave_height_m,
            double energy_period_s )  [private]
```

Helper method to compute wave energy converter production under a Gaussian production model.

Ref: Truelove et al. [2019]

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *significant_wave_height←_m* | The significant wave height [m] in the vicinity of the wave energy converter. |
| *energy_period_s* | The energy period [s] in the vicinity of the wave energy converter |

**Returns**

The production [kW] of the wave energy converter, under an exponential model.

```
{
    double H_s_nondim =
        (significant_wave_height_m - this->design_significant_wave_height_m) /
        this->design_significant_wave_height_m;

    double T_e_nondim =
        (energy_period_s - this->design_energy_period_s) /
        this->design_energy_period_s;

    double production = exp(
        -2.25119 * pow(T_e_nondim, 2) +
        3.44570 * T_e_nondim * H_s_nondim -
        4.01508 * pow(H_s_nondim, 2)
    );

    return production * this->capacity_kW;
}   /* __computeGaussianProductionkW() */
```

### 4.30.3.3 __computeLookupProductionkW()

```
double Wave::__computeLookupProductionkW (
            int timestep,
            double dt_hrs,
            double significant_wave_height_m,
            double energy_period_s )  [private]
```

Helper method to compute wave energy converter production by way of looking up using given performance matrix.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *significant_wave_height←_m* | The significant wave height [m] in the vicinity of the wave energy converter. |
| *energy_period_s* | The energy period [s] in the vicinity of the wave energy converter |

**Returns**

The interpolated production [kW] of the wave energy converter.

```
{
    double prod = this->interpolator.interp2D(
        0,
        significant_wave_height_m,
        energy_period_s
    );

    return prod * this->capacity_kW;
}   /* __computeLookupProductionkW() */
```

### 4.30.3.4 __computeParaboloidProductionkW()

```
double Wave::__computeParaboloidProductionkW (
            int timestep,
            double dt_hrs,
            double significant_wave_height_m,
            double energy_period_s )  [private]
```

Helper method to compute wave energy converter production under a paraboloid production model.

Ref: Robertson et al. [2021]

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *significant_wave_height←_m* | The significant wave height [m] in the vicinity of the wave energy converter. |
| *energy_period_s* | The energy period [s] in the vicinity of the wave energy converter |

**Returns**

The production [kW] of the wave energy converter, under a paraboloid model.

```
{
    // first, check for idealized wave breaking (deep water)
    if (significant_wave_height_m >= 0.2184 * pow(energy_period_s, 2)) {
        return 0;
    }

    // otherwise, apply generic quadratic performance model
    // (with outputs bounded to [0, 1])
    double production =
        0.289 * significant_wave_height_m -
        0.00111 * pow(significant_wave_height_m, 2) * energy_period_s -
        0.0169 * energy_period_s;

    if (production < 0) {
        production = 0;
    }

    else if (production > 1) {
        production = 1;
    }

    return production * this->capacity_kW;
}   /* __computeParaboloidProductionkW() */
```

#### 4.30.3.5 __getGenericCapitalCost()

```
double Wave::__getGenericCapitalCost (
            void ) [private]
```

Helper method to generate a generic wave energy converter capital cost.

Note that this model expresses cost in terms of Canadian dollars [CAD].

Ref: MacDougall [2019]

**Returns**

A generic capital cost for the wave energy converter [CAD].

```
{
    double capital_cost_per_kW = 7000 * pow(this->capacity_kW, -0.15) + 5000;

    return capital_cost_per_kW * this->capacity_kW;
}   /* __getGenericCapitalCost() */
```

#### 4.30.3.6 __getGenericOpMaintCost()

```
double Wave::__getGenericOpMaintCost (
            void ) [private]
```

Helper method to generate a generic wave energy converter operation and maintenance cost. This is a cost incurred per unit energy produced.

Note that this model expresses cost in terms of Canadian dollars [CAD/kWh].

Ref: MacDougall [2019]

**Returns**

A generic operation and maintenance cost, per unit energy produced, for the wave energy converter [CAD/k↩ Wh].

```
{
    double operation_maintenance_cost_kWh = 0.05 * pow(this->capacity_kW, -0.2) + 0.05;

    return operation_maintenance_cost_kWh;
}   /* __getGenericOpMaintCost() */
```

#### 4.30.3.7 __writeSummary()

```
void Wave::__writeSummary (
            std::string write_path ) [private], [virtual]
```

Helper method to write summary results for Wave.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |

Reimplemented from Renewable.

```
{
    // 1. create filestream
    write_path += "summary_results.md";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    // 2. write summary results (markdown)
    ofs « "# ";
    ofs « std::to_string(int(ceil(this->capacity_kW)));
    ofs « " kW WAVE Summary Results\n";
    ofs « "\n--------\n\n";

    // 2.1. Production attributes
    ofs « "## Production Attributes\n";
    ofs « "\n";

    ofs « "Capacity: " « this->capacity_kW « " kW  \n";
    ofs « "\n";

    ofs « "Production Override: (N = 0 / Y = 1): "
        « this->normalized_production_series_given « "  \n";
    if (this->normalized_production_series_given) {
        ofs « "Path to Normalized Production Time Series: "
            « this->path_2_normalized_production_time_series « "  \n";
    }
    ofs « "\n";
```

```
    ofs « "Sunk Cost (N = 0 / Y = 1): " « this->is_sunk « "  \n";
    ofs « "Capital Cost: " « this->capital_cost « "  \n";
    ofs « "Operation and Maintenance Cost: " « this->operation_maintenance_cost_kWh
        « " per kWh produced  \n";
    ofs « "Nominal Inflation Rate (annual): " « this->nominal_inflation_annual
        « "  \n";
    ofs « "Nominal Discount Rate (annual): " « this->nominal_discount_annual
        « "  \n";
    ofs « "Real Discount Rate (annual): " « this->real_discount_annual « "  \n";
    ofs « "\n";

    ofs « "Replacement Running Hours: " « this->replace_running_hrs « "  \n";
    ofs « "\n--------\n\n";

    //  2.2. Renewable attributes
    ofs « "## Renewable Attributes\n";
    ofs « "\n";

    ofs « "Resource Key (2D): " « this->resource_key « "  \n";
    ofs « "Firmness Factor: " « this->firmness_factor « "  \n";

    ofs « "\n--------\n\n";

    //  2.3. Wave attributes
    ofs « "## Wave Attributes\n";
    ofs « "\n";

    ofs « "Power Production Model: " « this->power_model_string « "  \n";
    switch (this->power_model) {
        case (WavePowerProductionModel :: WAVE_POWER_GAUSSIAN): {
            ofs « "Design Significant Wave Height: "
                « this->design_significant_wave_height_m « " m  \n";

            ofs « "Design Energy Period: " « this->design_energy_period_s « " s  \n";

            break;
        }

        case (WavePowerProductionModel :: WAVE_POWER_LOOKUP): {
            ofs « "Normalized Performance Matrix: "
                « this->interpolator.path_map_2D[0] « "  \n";

            break;
        }

        default: {
            // write nothing!

            break;
        }
    }

    ofs « "\n--------\n\n";

    //  2.4. Wave Results
    ofs « "## Results\n";
    ofs « "\n";

    ofs « "Net Present Cost: " « this->net_present_cost « "  \n";
    ofs « "\n";

    ofs « "Total Dispatch: " « this->total_dispatch_kWh
        « " kWh  \n";

    ofs « "Levellized Cost of Energy: " « this->levellized_cost_of_energy_kWh
        « " per kWh dispatched  \n";
    ofs « "\n";

    ofs « "Running Hours: " « this->running_hours « "  \n";
    ofs « "Replacements: " « this->n_replacements « "  \n";

    ofs « "\n--------\n\n";

    ofs.close();

    return;
}   /* __writeSummary() */
```

#### 4.30.3.8 __writeTimeSeries()

```
void Wave::__writeTimeSeries (
```

```
std::string write_path,
std::vector< double > * time_vec_hrs_ptr,
std::map< int, std::vector< double >> * resource_map_1D_ptr,
std::map< int, std::vector< std::vector< double >>> * resource_map_2D_ptr,
int max_lines = -1 ) [private], [virtual]
```

Helper method to write time series results for Wave.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |
| *resource_map_1D_ptr* | A pointer to the 1D map of Resources. |
| *resource_map_2D_ptr* | A pointer to the 2D map of Resources. |
| *max_lines* | The maximum number of lines of output to write. |

Reimplemented from Renewable.

```
{
    //  1. create filestream
    write_path += "time_series_results.csv";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  2. write time series results (comma separated value)
    ofs « "Time (since start of data) [hrs],";
    ofs « "Significant Wave Height [m],";
    ofs « "Energy Period [s],";
    ofs « "Production [kW],";
    ofs « "Dispatch [kW],";
    ofs « "Storage [kW],";
    ofs « "Curtailment [kW],";
    ofs « "Capital Cost (actual),";
    ofs « "Operation and Maintenance Cost (actual),";
    ofs « "\n";

    for (int i = 0; i < max_lines; i++) {
        ofs « time_vec_hrs_ptr->at(i) « ",";

        if (not this->normalized_production_series_given) {
            ofs « resource_map_2D_ptr->at(this->resource_key)[i][0] « ",";
            ofs « resource_map_2D_ptr->at(this->resource_key)[i][1] « ",";
        }

        else {
            ofs « "OVERRIDE" « ",";
            ofs « "OVERRIDE" « ",";
        }

        ofs « this->production_vec_kW[i] « ",";
        ofs « this->dispatch_vec_kW[i] « ",";
        ofs « this->storage_vec_kW[i] « ",";
        ofs « this->curtailment_vec_kW[i] « ",";
        ofs « this->capital_cost_vec[i] « ",";
        ofs « this->operation_maintenance_cost_vec[i] « ",";
        ofs « "\n";
    }

    return;
}   /* __writeTimeSeries() */
```

#### 4.30.3.9 commit()

```
double Wave::commit (
            int timestep,
            double dt_hrs,
```

```
double production_kW,
double load_kW )  [virtual]
```

Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *production_kW* | The production [kW] of the asset in this timestep. |
| *load_kW* | The load [kW] passed to the asset in this timestep. |

**Returns**

The load [kW] remaining after the dispatch is deducted from it.

Reimplemented from Renewable.

```
{
    //  1. invoke base class method
    load_kW = Renewable :: commit(
        timestep,
        dt_hrs,
        production_kW,
        load_kW
    );


    //...

    return load_kW;
}   /* commit() */
```

### 4.30.3.10 computeProductionkW()

```
double Wave::computeProductionkW (
            int timestep,
            double dt_hrs,
            double significant_wave_height_m,
            double energy_period_s )  [virtual]
```

Method which takes in the wave resource at a particular point in time, and then returns the wave turbine production at that point in time.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *signficiant_wave_height←_m* | The significant wave height (wave statistic) [m]. |
| *energy_period_s* | The energy period (wave statistic) [s]. |

**Returns**

The production [kW] of the wave turbine.

Reimplemented from Renewable.

```
{
    //  given production time series override
    if (this->normalized_production_series_given) {
        double production_kW = Production :: getProductionkW(timestep);

        return production_kW;
    }

    // check if no resource
    if (significant_wave_height_m <= 0 or energy_period_s <= 0) {
        return 0;
    }

    // compute production
    double production_kW = 0;

    switch (this->power_model) {
        case (WavePowerProductionModel :: WAVE_POWER_PARABOLOID): {
            production_kW = this->__computeParaboloidProductionkW(
                timestep,
                dt_hrs,
                significant_wave_height_m,
                energy_period_s
            );

            break;
        }

        case (WavePowerProductionModel :: WAVE_POWER_GAUSSIAN): {
            production_kW = this->__computeGaussianProductionkW(
                timestep,
                dt_hrs,
                significant_wave_height_m,
                energy_period_s
            );

            break;
        }

        case (WavePowerProductionModel :: WAVE_POWER_LOOKUP): {
            production_kW = this->__computeLookupProductionkW(
                timestep,
                dt_hrs,
                significant_wave_height_m,
                energy_period_s
            );

            break;
        }

        default: {
            std::string error_str = "ERROR:  Wave::computeProductionkW():  ";
            error_str += "power model ";
            error_str += std::to_string(this->power_model);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    return production_kW;
}   /* computeProductionkW() */
```

### 4.30.3.11 handleReplacement()

```
void Wave::handleReplacement (
               int timestep )  [virtual]
```

Method to handle asset replacement and capital cost incursion, if applicable.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |

Reimplemented from Renewable.

```
{
    //  1. reset attributes
    //...

    //  2. invoke base class method
    Renewable :: handleReplacement(timestep);

    return;
}   /* __handleReplacement() */
```

## 4.30.4 Member Data Documentation

### 4.30.4.1 design_energy_period_s

`double Wave::design_energy_period_s`

The energy period [s] at which the wave energy converter achieves its rated capacity.

### 4.30.4.2 design_significant_wave_height_m

`double Wave::design_significant_wave_height_m`

The significant wave height [m] at which the wave energy converter achieves its rated capacity.

### 4.30.4.3 power_model

`WavePowerProductionModel Wave::power_model`

The wave power production model to be applied.

### 4.30.4.4 power_model_string

`std::string Wave::power_model_string`

A string describing the active power production model.

The documentation for this class was generated from the following files:

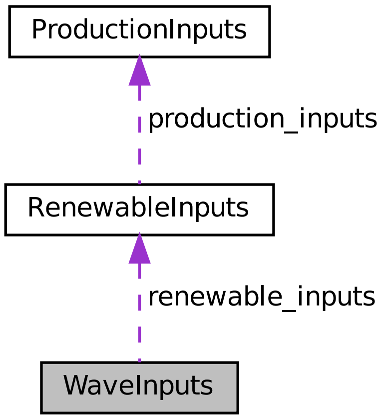
- header/Production/Renewable/Wave.h
- source/Production/Renewable/Wave.cpp

## 4.31 WaveInputs Struct Reference

A structure which bundles the necessary inputs for the Wave constructor. Provides default values for every necessary input. Note that this structure encapsulates RenewableInputs.

```
#include <Wave.h>
```

Collaboration diagram for WaveInputs:




### Public Attributes

- RenewableInputs renewable_inputs

  *An encapsulated RenewableInputs instance.*
- int resource_key = 0

  *A key used to index into the Resources object, to associate this asset with the appropriate resource time series.*
- double firmness_factor = 0.8

  *A factor [0, 1] which defines how firm the production from this asset is.*
- double capital_cost = -1

  *The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].*
- double operation_maintenance_cost_kWh = -1

  *The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].*
- double design_significant_wave_height_m = 3

  *The significant wave height [m] at which the wave energy converter achieves its rated capacity.*
- double design_energy_period_s = 10

  *The energy period [s] at which the wave energy converter achieves its rated capacity.*
- WavePowerProductionModel power_model = WavePowerProductionModel :: WAVE_POWER_PARABOLOID

  *The wave power production model to be applied.*
- std::string path_2_normalized_performance_matrix = ""

  *A path (either relative or absolute) to a normalized performance matrix for the wave energy converter.*

### 4.31.1 Detailed Description

A structure which bundles the necessary inputs for the Wave constructor. Provides default values for every necessary input. Note that this structure encapsulates RenewableInputs.

### 4.31.2 Member Data Documentation

#### 4.31.2.1 capital_cost

```
double WaveInputs::capital_cost = -1
```

The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].

#### 4.31.2.2 design_energy_period_s

```
double WaveInputs::design_energy_period_s = 10
```

The energy period [s] at which the wave energy converter achieves its rated capacity.

#### 4.31.2.3 design_significant_wave_height_m

```
double WaveInputs::design_significant_wave_height_m = 3
```

The significant wave height [m] at which the wave energy converter achieves its rated capacity.

#### 4.31.2.4 firmness_factor

```
double WaveInputs::firmness_factor = 0.8
```

A factor [0, 1] which defines how firm the production from this asset is.

#### 4.31.2.5 operation_maintenance_cost_kWh

```
double WaveInputs::operation_maintenance_cost_kWh = -1
```

The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].

#### 4.31.2.6 path_2_normalized_performance_matrix

```
std::string WaveInputs::path_2_normalized_performance_matrix = ""
```

A path (either relative or absolute) to a normalized performance matrix for the wave energy converter.

#### 4.31.2.7 power_model

```
WavePowerProductionModel WaveInputs::power_model = WavePowerProductionModel :: WAVE_POWER_PARABOLOID
```

The wave power production model to be applied.

#### 4.31.2.8 renewable_inputs

```
RenewableInputs WaveInputs::renewable_inputs
```

An encapsulated RenewableInputs instance.

#### 4.31.2.9 resource_key

```
int WaveInputs::resource_key = 0
```

A key used to index into the Resources object, to associate this asset with the appropriate resource time series.

The documentation for this struct was generated from the following file:

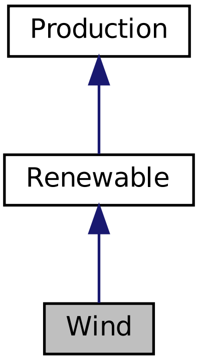
- header/Production/Renewable/Wave.h

## 4.32 Wind Class Reference

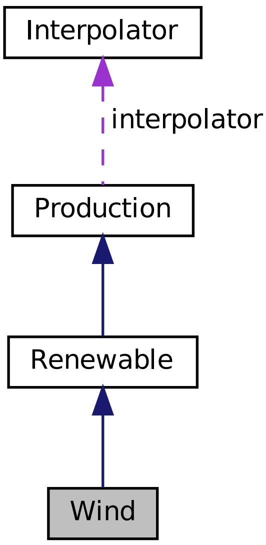
A derived class of the Renewable branch of Production which models wind production.

```
#include <Wind.h>
```

Inheritance diagram for Wind:




Collaboration diagram for Wind:



## Public Member Functions

- Wind (void)

  *Constructor (dummy) for the Wind class.*
- Wind (int, double, WindInputs, std::vector< double > ∗)

  *Constructor (intended) for the Wind class.*
- void handleReplacement (int)

  *Method to handle asset replacement and capital cost incursion, if applicable.*
- double computeProductionkW (int, double, double)

  *Method which takes in the wind resource at a particular point in time, and then returns the wind turbine production at that point in time.*
- double commit (int, double, double, double)

  *Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.*
- ∼Wind (void)

  *Destructor for the Wind class.*

## Public Attributes

- double design_speed_ms

  *The wind speed [m/s] at which the wind turbine achieves its rated capacity.*
- WindPowerProductionModel power_model

  *The wind power production model to be applied.*
- std::string power_model_string

  *A string describing the active power production model.*

## Private Member Functions

- void __checkInputs (WindInputs)

  *Helper method to check inputs to the Wind constructor.*
- double __getGenericCapitalCost (void)

  *Helper method to generate a generic wind turbine capital cost.*
- double __getGenericOpMaintCost (void)

  *Helper method to generate a generic wind turbine operation and maintenance cost. This is a cost incurred per unit energy produced.*
- double __computeCubicProductionkW (int, double, double)

  *Helper method to compute wind turbine production under a cubic production model.*
- double __computeExponentialProductionkW (int, double, double)

  *Helper method to compute wind turbine production under an exponential production model.*
- double __computeLookupProductionkW (int, double, double)

  *Helper method to compute wind turbine production by way of looking up using given power curve data.*
- void __writeSummary (std::string)

  *Helper method to write summary results for Wind.*
- void __writeTimeSeries (std::string, std::vector< double > ∗, std::map< int, std::vector< double >> ∗, std↩ ::map< int, std::vector< std::vector< double >>> ∗, int=-1)

  *Helper method to write time series results for Wind.*

### 4.32.1 Detailed Description

A derived class of the Renewable branch of Production which models wind production.

## 4.32.2 Constructor & Destructor Documentation

### 4.32.2.1 Wind() [1/2]

```
Wind::Wind (
        void )
```

Constructor (dummy) for the Wind class.

```
{
    return;
}   /* Wind() */
```

### 4.32.2.2 Wind() [2/2]

```
Wind::Wind (
        int n_points,
        double n_years,
        WindInputs wind_inputs,
        std::vector< double > * time_vec_hrs_ptr )
```

Constructor (intended) for the Wind class.

**Parameters**

| | |
|---|---|
| *n_points* | The number of points in the modelling time series. |
| *n_years* | The number of years being modelled. |
| *wind_inputs* | A structure of Wind constructor inputs. |
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
  :
Renewable(
    n_points,
    n_years,
    wind_inputs.renewable_inputs,
    time_vec_hrs_ptr
)
{
    //  1. check inputs
    this->__checkInputs(wind_inputs);

    //  2. set attributes
    this->type = RenewableType :: WIND;
    this->type_str = "WIND";

    this->resource_key = wind_inputs.resource_key;

    this->firmness_factor = wind_inputs.firmness_factor;

    this->design_speed_ms = wind_inputs.design_speed_ms;

    this->power_model = wind_inputs.power_model;

    switch (this->power_model) {
        case (WindPowerProductionModel :: WIND_POWER_CUBIC): {
            this->power_model_string = "CUBIC";

            break;
        }

        case (WindPowerProductionModel :: WIND_POWER_EXPONENTIAL): {
```

```
            this->power_model_string = "EXPONENTIAL";

            break;
        }

        case (WindPowerProductionModel :: WIND_POWER_LOOKUP): {
            this->power_model_string = "LOOKUP";

            break;
        }

        default: {
            std::string error_str = "ERROR:  Wind():  ";
            error_str += "power production model ";
            error_str += std::to_string(this->power_model);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    if (wind_inputs.capital_cost < 0) {
        this->capital_cost = this->__getGenericCapitalCost();
    }
    else {
        this->capital_cost = wind_inputs.capital_cost;
    }

    if (wind_inputs.operation_maintenance_cost_kWh < 0) {
        this->operation_maintenance_cost_kWh = this->__getGenericOpMaintCost();
    }
    else {
        this->operation_maintenance_cost_kWh =
            wind_inputs.operation_maintenance_cost_kWh;
    }

    if (not this->is_sunk) {
        this->capital_cost_vec[0] = this->capital_cost;
    }

    //  3. construction print
    if (this->print_flag) {
        std::cout « "Wind object constructed at " « this « std::endl;
    }

    return;
}   /* Renewable() */
```

#### 4.32.2.3 ∼Wind()

```
Wind::∼Wind (
            void  )
```

Destructor for the Wind class.

```
{
    //  1. destruction print
    if (this->print_flag) {
        std::cout « "Wind object at " « this « " destroyed" « std::endl;
    }

    return;
}   /* ~Wind() */
```

### 4.32.3 Member Function Documentation

#### 4.32.3.1 __checkInputs()

```
void Wind::__checkInputs (
            WindInputs wind_inputs )  [private]
```

Helper method to check inputs to the Wind constructor.

Ref: Zafar [2018]

**Parameters**

| | |
|---|---|
| *wind_inputs* | A structure of Wind constructor inputs. |

```
{
    //  1. check design_speed_ms
    if (wind_inputs.design_speed_ms <= 0) {
        std::string error_str = "ERROR:  Wind():  ";
        error_str += "WindInputs::design_speed_ms must be > 0";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    else if (wind_inputs.design_speed_ms < 12) {
        std::string warning_str = "WARNING:  Wind():  ";
        warning_str += "Setting WindInputs::design_speed_ms to less than 12 m/s may be ";
        warning_str += "technically unrealistic";

        std::cout « warning_str « std::endl;
    }

    //  2. check firmness_factor
    if (
        wind_inputs.firmness_factor < 0 or
        wind_inputs.firmness_factor > 1
    ) {
        std::string error_str = "ERROR:  Wind():  ";
        error_str += "WindInputs::firmness_factor must be in the closed interval [0, 1]";

        #ifdef _WIN32
            std::cout « error_str « std::endl;
        #endif

        throw std::invalid_argument(error_str);
    }

    return;
}   /* __checkInputs() */
```

#### 4.32.3.2 __computeCubicProductionkW()

```
double Wind::__computeCubicProductionkW (
            int timestep,
            double dt_hrs,
            double wind_resource_ms )  [private]
```

Helper method to compute wind turbine production under a cubic production model.

Ref: Milan et al. [2010]
Ref: Zafar [2018]

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *wind_resource_ms* | The available wind resource [m/s]. |

**Returns**

The production [kW] of the wind turbine, under an exponential model.

```
{
    double production = 0;

    double turbine_speed = (wind_resource_ms - this->design_speed_ms) /
        this->design_speed_ms;

    if (turbine_speed < -0.7857 or turbine_speed > 0.7857) {
        production = 0;
    }

    else if (turbine_speed >= -0.7857 and turbine_speed <= 0) {
        production = (1 / pow(this->design_speed_ms, 3)) * pow(wind_resource_ms, 3);
    }

    else {
        production = 1;
    }

    return production * this->capacity_kW;
}   /* __computeCubicProductionkW() */
```

#### 4.32.3.3 __computeExponentialProductionkW()

```
double Wind::__computeExponentialProductionkW (
            int timestep,
            double dt_hrs,
            double wind_resource_ms )  [private]
```

Helper method to compute wind turbine production under an exponential production model.

Ref: Truelove et al. [2019]

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *wind_resource_ms* | The available wind resource [m/s]. |

**Returns**

The production [kW] of the wind turbine, under an exponential model.

```
{
    double production = 0;

    double turbine_speed = (wind_resource_ms - this->design_speed_ms) /
        this->design_speed_ms;

    if (turbine_speed < -0.76 or turbine_speed > 0.68) {
        production = 0;
```

```
    }

    else if (turbine_speed >= -0.76 and turbine_speed <= 0) {
        production = 1.03273 * exp(-5.97588 * pow(turbine_speed, 2)) - 0.03273;
    }

    else {
        production = 0.16154 * exp(-9.30254 * pow(turbine_speed, 2)) + 0.83846;
    }

    return production * this->capacity_kW;
}   /* __computeExponentialProductionkW() */
```

#### 4.32.3.4 __computeLookupProductionkW()

```
double Wind::__computeLookupProductionkW (
            int timestep,
            double dt_hrs,
            double wind_resource_ms )   [private]
```

Helper method to compute wind turbine production by way of looking up using given power curve data.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |
| *dt_hrs* | The interval of time [hrs] associated with the action. |
| *wind_resource_ms* | The available wind resource [m/s]. |

**Returns**

The interpolated production [kW] of the wind turbine.

```
{
    // *** WORK IN PROGRESS *** //

    return 0;
}   /* __computeLookupProductionkW() */
```

#### 4.32.3.5 __getGenericCapitalCost()

```
double Wind::__getGenericCapitalCost (
            void )   [private]
```

Helper method to generate a generic wind turbine capital cost.

This model was obtained by way of surveying an assortment of published wind turbine costs, and then constructing a best fit model. Note that this model expresses cost in terms of Canadian dollars [CAD].

**Returns**

A generic capital cost for the wind turbine [CAD].

```
{
    double capital_cost_per_kW = 3000 * pow(this->capacity_kW, -0.15) + 3000;

    return capital_cost_per_kW * this->capacity_kW;
}   /* __getGenericCapitalCost() */
```

#### 4.32.3.6 __getGenericOpMaintCost()

```
double Wind::__getGenericOpMaintCost (
            void ) [private]
```

Helper method to generate a generic wind turbine operation and maintenance cost. This is a cost incurred per unit energy produced.

This model was obtained by way of surveying an assortment of published wind turbine costs, and then constructing a best fit model. Note that this model expresses cost in terms of Canadian dollars [CAD/kWh].

**Returns**

A generic operation and maintenance cost, per unit energy produced, for the wind turbine [CAD/kWh].

```
{
    double operation_maintenance_cost_kWh = 0.025 * pow(this->capacity_kW, -0.2) + 0.025;

    return operation_maintenance_cost_kWh;
}   /* __getGenericOpMaintCost() */
```

#### 4.32.3.7 __writeSummary()

```
void Wind::__writeSummary (
            std::string write_path ) [private], [virtual]
```

Helper method to write summary results for Wind.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |

Reimplemented from Renewable.

```
{
    //  1. create filestream
    write_path += "summary_results.md";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    //  2. write summary results (markdown)
    ofs « "# ";
    ofs « std::to_string(int(ceil(this->capacity_kW)));
    ofs « " kW WIND Summary Results\n";
    ofs « "\n--------\n\n";


    //  2.1. Production attributes
    ofs « "## Production Attributes\n";
    ofs « "\n";

    ofs « "Capacity: " « this->capacity_kW « " kW  \n";
    ofs « "\n";

    ofs « "Production Override: (N = 0 / Y = 1): "
        « this->normalized_production_series_given « "  \n";
    if (this->normalized_production_series_given) {
        ofs « "Path to Normalized Production Time Series: "
            « this->path_2_normalized_production_time_series « "  \n";
    }
    ofs « "\n";

    ofs « "Sunk Cost (N = 0 / Y = 1): " « this->is_sunk « "  \n";
    ofs « "Capital Cost: " « this->capital_cost « "  \n";
```

```
    ofs « "Operation and Maintenance Cost: " « this->operation_maintenance_cost_kWh
        « " per kWh produced  \n";
    ofs « "Nominal Inflation Rate (annual): " « this->nominal_inflation_annual
        « "  \n";
    ofs « "Nominal Discount Rate (annual): " « this->nominal_discount_annual
        « "  \n";
    ofs « "Real Discount Rate (annual): " « this->real_discount_annual « "  \n";
    ofs « "\n";

    ofs « "Replacement Running Hours: " « this->replace_running_hrs « "  \n";
    ofs « "\n--------\n\n";

    //  2.2. Renewable attributes
    ofs « "## Renewable Attributes\n";
    ofs « "\n";

    ofs « "Resource Key (1D): " « this->resource_key « "  \n";
    ofs « "Firmness Factor: " « this->firmness_factor « "  \n";

    ofs « "\n--------\n\n";

    //  2.3. Wind attributes
    ofs « "## Wind Attributes\n";
    ofs « "\n";

    ofs « "Power Production Model: " « this->power_model_string « "  \n";
    switch (this->power_model) {
        case (WindPowerProductionModel :: WIND_POWER_CUBIC): {
            ofs « "Design Speed: " « this->design_speed_ms « " m/s  \n";

            break;
        }

        case (WindPowerProductionModel :: WIND_POWER_EXPONENTIAL): {
            ofs « "Design Speed: " « this->design_speed_ms « " m/s  \n";

            break;
        }

        case (WindPowerProductionModel :: WIND_POWER_LOOKUP): {
            //...

            break;
        }

        default: {
            // write nothing!

            break;
        }
    }

    ofs « "\n--------\n\n";

    //  2.4. Wind Results
    ofs « "## Results\n";
    ofs « "\n";

    ofs « "Net Present Cost: " « this->net_present_cost « "  \n";
    ofs « "\n";

    ofs « "Total Dispatch: " « this->total_dispatch_kWh
        « " kWh  \n";

    ofs « "Levellized Cost of Energy: " « this->levellized_cost_of_energy_kWh
        « " per kWh dispatched  \n";
    ofs « "\n";

    ofs « "Running Hours: " « this->running_hours « "  \n";
    ofs « "Replacements: " « this->n_replacements « "  \n";

    ofs « "\n--------\n\n";

    ofs.close();

    return;
}   /* __writeSummary() */
```

#### 4.32.3.8 __writeTimeSeries()

```
void Wind::__writeTimeSeries (
            std::string write_path,
```

```
std::vector< double > * time_vec_hrs_ptr,
std::map< int, std::vector< double >> * resource_map_1D_ptr,
std::map< int, std::vector< std::vector< double >>> * resource_map_2D_ptr,
int max_lines = -1 ) [private], [virtual]
```

Helper method to write time series results for Wind.

**Parameters**

| | |
|---|---|
| *write_path* | A path (either relative or absolute) to the directory location where results are to be written. If already exists, will overwrite. |
| *time_vec_hrs_ptr* | A pointer to the time_vec_hrs attribute of the ElectricalLoad. |
| *resource_map_1D_ptr* | A pointer to the 1D map of Resources. |
| *resource_map_2D_ptr* | A pointer to the 2D map of Resources. |
| *max_lines* | The maximum number of lines of output to write. |

Reimplemented from Renewable.

```
{
    // 1. create filestream
    write_path += "time_series_results.csv";
    std::ofstream ofs;
    ofs.open(write_path, std::ofstream::out);

    // 2. write time series results (comma separated value)
    ofs « "Time (since start of data) [hrs],";
    ofs « "Wind Resource [m/s],";
    ofs « "Production [kW],";
    ofs « "Dispatch [kW],";
    ofs « "Storage [kW],";
    ofs « "Curtailment [kW],";
    ofs « "Capital Cost (actual),";
    ofs « "Operation and Maintenance Cost (actual),";
    ofs « "\n";

    for (int i = 0; i < max_lines; i++) {
        ofs « time_vec_hrs_ptr->at(i) « ",";

        if (not this->normalized_production_series_given) {
            ofs « resource_map_1D_ptr->at(this->resource_key)[i] « ",";
        }

        else {
            ofs « "OVERRIDE" « ",";
        }

        ofs « this->production_vec_kW[i] « ",";
        ofs « this->dispatch_vec_kW[i] « ",";
        ofs « this->storage_vec_kW[i] « ",";
        ofs « this->curtailment_vec_kW[i] « ",";
        ofs « this->capital_cost_vec[i] « ",";
        ofs « this->operation_maintenance_cost_vec[i] « ",";
        ofs « "\n";
    }

    return;
} /* __writeTimeSeries() */
```

#### 4.32.3.9 commit()

```
double Wind::commit (
            int timestep,
            double dt_hrs,
            double production_kW,
            double load_kW ) [virtual]
```

Method which takes in production and load for the current timestep, computes and records dispatch and curtailment, and then returns remaining load.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *production_kW* | The production [kW] of the asset in this timestep. |
| *load_kW* | The load [kW] passed to the asset in this timestep. |

**Returns**

The load [kW] remaining after the dispatch is deducted from it.

Reimplemented from Renewable.

```
{
    //  1. invoke base class method
    load_kW = Renewable :: commit(
        timestep,
        dt_hrs,
        production_kW,
        load_kW
    );


    //...

    return load_kW;
}   /* commit() */
```

### 4.32.3.10 computeProductionkW()

```
double Wind::computeProductionkW (
            int timestep,
            double dt_hrs,
            double wind_resource_ms )   [virtual]
```

Method which takes in the wind resource at a particular point in time, and then returns the wind turbine production at that point in time.

**Parameters**

| | |
|---|---|
| *timestep* | The timestep (i.e., time series index) for the request. |
| *dt_hrs* | The interval of time [hrs] associated with the timestep. |
| *wind_resource_ms* | Wind resource (i.e. wind speed) [m/s]. |

**Returns**

The production [kW] of the wind turbine.

Reimplemented from Renewable.

```
{
    //  given production time series override
    if (this->normalized_production_series_given) {
        double production_kW = Production :: getProductionkW(timestep);

        return production_kW;
    }

```

```
    // check if no resource
    if (wind_resource_ms <= 0) {
        return 0;
    }

    // compute production
    double production_kW = 0;

    switch (this->power_model) {
        case (WindPowerProductionModel :: WIND_POWER_CUBIC): {
            production_kW = this->__computeCubicProductionkW(
                timestep,
                dt_hrs,
                wind_resource_ms
            );

            break;
        }

        case (WindPowerProductionModel :: WIND_POWER_EXPONENTIAL): {
            production_kW = this->__computeExponentialProductionkW(
                timestep,
                dt_hrs,
                wind_resource_ms
            );

            break;
        }

        case (WindPowerProductionModel :: WIND_POWER_LOOKUP): {
            production_kW = this->__computeLookupProductionkW(
                timestep,
                dt_hrs,
                wind_resource_ms
            );

            break;
        }

        default: {
            std::string error_str = "ERROR:  Wind::computeProductionkW():  ";
            error_str += "power model ";
            error_str += std::to_string(this->power_model);
            error_str += " not recognized";

            #ifdef _WIN32
                std::cout « error_str « std::endl;
            #endif

            throw std::runtime_error(error_str);

            break;
        }
    }

    return production_kW;
}   /* computeProductionkW() */
```

#### 4.32.3.11 handleReplacement()

```
void Wind::handleReplacement (
               int timestep )  [virtual]
```

Method to handle asset replacement and capital cost incursion, if applicable.

**Parameters**

| | |
|---|---|
| *timestep* | The current time step of the Model run. |

Reimplemented from Renewable.

```
{
    //  1. reset attributes
    //...
```

```
    // 2. invoke base class method
    Renewable :: handleReplacement(timestep);

    return;
}   /* __handleReplacement() */
```

## 4.32.4 Member Data Documentation

### 4.32.4.1 design_speed_ms

`double Wind::design_speed_ms`

The wind speed [m/s] at which the wind turbine achieves its rated capacity.

### 4.32.4.2 power_model

`WindPowerProductionModel Wind::power_model`

The wind power production model to be applied.

### 4.32.4.3 power_model_string

`std::string Wind::power_model_string`

A string describing the active power production model.

The documentation for this class was generated from the following files:

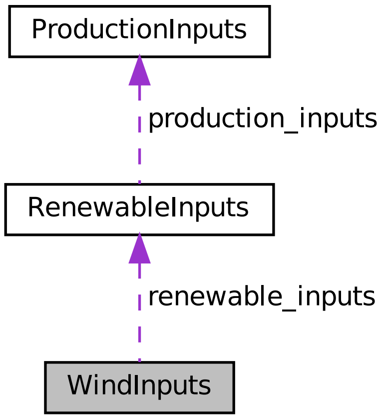
- header/Production/Renewable/Wind.h
- source/Production/Renewable/Wind.cpp

## 4.33 WindInputs Struct Reference

A structure which bundles the necessary inputs for the Wind constructor. Provides default values for every necessary input. Note that this structure encapsulates RenewableInputs.

```
#include <Wind.h>
```

Collaboration diagram for WindInputs:




### Public Attributes

- RenewableInputs renewable_inputs

    *An encapsulated RenewableInputs instance.*
- int resource_key = 0

    *A key used to index into the Resources object, to associate this asset with the appropriate resource time series.*
- double firmness_factor = 0.5

    *A factor [0, 1] which defines how firm the production from this asset is.*
- double capital_cost = -1

    *The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].*
- double operation_maintenance_cost_kWh = -1

    *The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].*
- double design_speed_ms = 14

    *The wind speed [m/s] at which the wind turbine achieves its rated capacity.*
- WindPowerProductionModel power_model = WindPowerProductionModel :: WIND_POWER_CUBIC

    *The wind power production model to be applied.*

### 4.33.1 Detailed Description

A structure which bundles the necessary inputs for the Wind constructor. Provides default values for every necessary input. Note that this structure encapsulates RenewableInputs.

### 4.33.2 Member Data Documentation

#### 4.33.2.1 capital_cost

```
double WindInputs::capital_cost = -1
```

The capital cost of the asset (undefined currency). -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD].

#### 4.33.2.2 design_speed_ms

```
double WindInputs::design_speed_ms = 14
```

The wind speed [m/s] at which the wind turbine achieves its rated capacity.

#### 4.33.2.3 firmness_factor

```
double WindInputs::firmness_factor = 0.5
```

A factor [0, 1] which defines how firm the production from this asset is.

#### 4.33.2.4 operation_maintenance_cost_kWh

```
double WindInputs::operation_maintenance_cost_kWh = -1
```

The operation and maintenance cost of the asset [1/kWh] (undefined currency). This is a cost incurred per unit of energy produced. -1 is a sentinel value, which triggers a generic cost model on construction (in fact, any negative value here will trigger). Note that the generic cost model is in terms of Canadian dollars [CAD/kWh].

#### 4.33.2.5 power_model

```
WindPowerProductionModel WindInputs::power_model = WindPowerProductionModel :: WIND_POWER_CUBIC
```

The wind power production model to be applied.

#### 4.33.2.6 renewable_inputs

```
RenewableInputs WindInputs::renewable_inputs
```

An encapsulated RenewableInputs instance.

#### 4.33.2.7 resource_key

```
int WindInputs::resource_key = 0
```

A key used to index into the Resources object, to associate this asset with the appropriate resource time series.

The documentation for this struct was generated from the following file:

- header/Production/Renewable/Wind.h

# Chapter 5

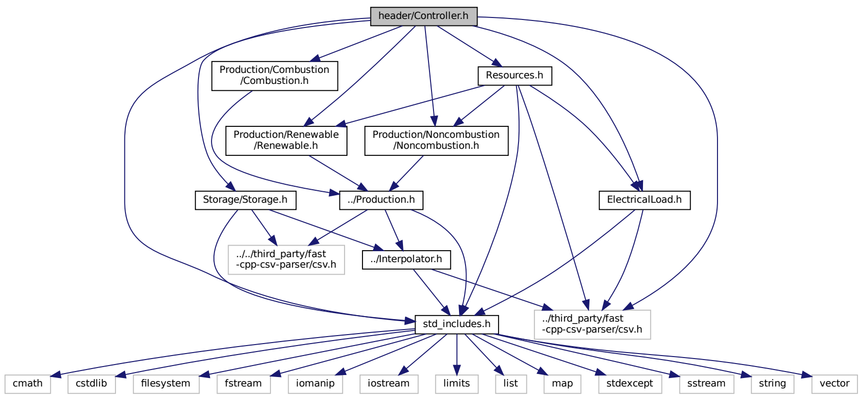
# File Documentation

## 5.1 header/Controller.h File Reference

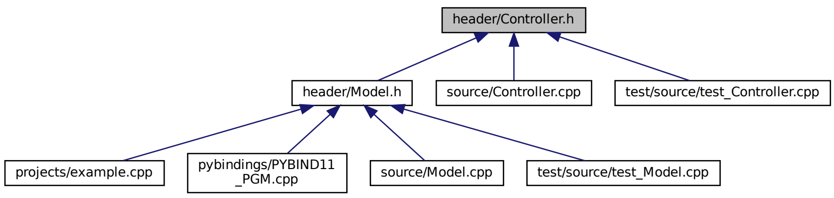
Header file for the Controller class.

```
#include "std_includes.h"
#include "../third_party/fast-cpp-csv-parser/csv.h"
#include "ElectricalLoad.h"
#include "Resources.h"
#include "Production/Combustion/Combustion.h"
#include "Production/Noncombustion/Noncombustion.h"
#include "Production/Renewable/Renewable.h"
#include "Storage/Storage.h"
```

Include dependency graph for Controller.h:




This graph shows which files directly or indirectly include this file:



## Classes

- class Controller

  *A class which contains a various dispatch control logic. Intended to serve as a component class of Model.*

## Enumerations

- enum ControlMode { LOAD_FOLLOWING , CYCLE_CHARGING , N_CONTROL_MODES }

  *An enumeration of the types of control modes supported by PGMcpp.*

### 5.1.1 Detailed Description

Header file for the Controller class.

### 5.1.2 Enumeration Type Documentation

#### 5.1.2.1 ControlMode

```
enum ControlMode
```

An enumeration of the types of control modes supported by PGMcpp.

**Enumerator**

| | |
|---|---|
| LOAD_FOLLOWING | Load following control, with in-order dispatch of non-Combustion assets and optimal dispatch of Combustion assets. |
| CYCLE_CHARGING | Cycle charging control, with in-order dispatch of non-Combustion assets and optimal dispatch of Combustion assets. |
| N_CONTROL_MODES | A simple hack to get the number of elements in ControlMode. |

```
                {
    LOAD_FOLLOWING,
    CYCLE_CHARGING,
    N_CONTROL_MODES
};
```

## 5.2 header/doxygen_cite.h File Reference

Header file which simply cites the doxygen tool.

### 5.2.1 Detailed Description

Header file which simply cites the doxygen tool.

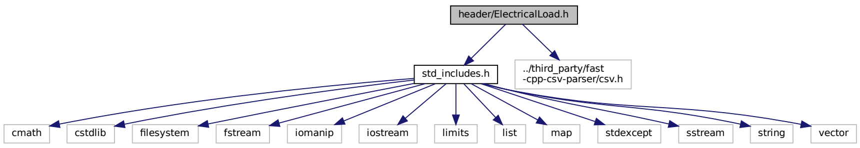
Ref: van Heesch. [2023]

# 5.3 header/ElectricalLoad.h File Reference

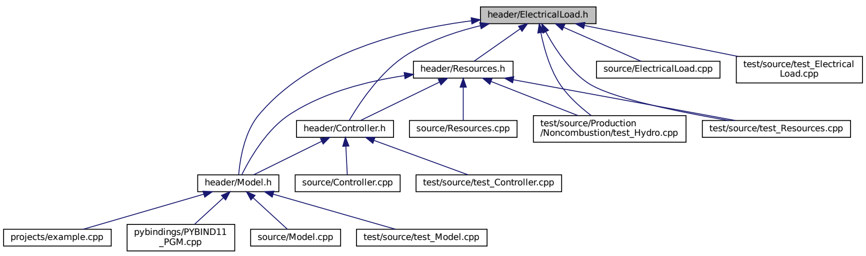
Header file for the ElectricalLoad class.

```
#include "std_includes.h"
#include "../third_party/fast-cpp-csv-parser/csv.h"
```

Include dependency graph for ElectricalLoad.h:




This graph shows which files directly or indirectly include this file:




## Classes

- class ElectricalLoad

  *A class which contains time and electrical load data. Intended to serve as a component class of Model.*

### 5.3.1 Detailed Description

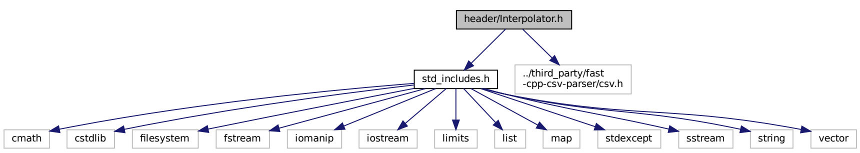
Header file for the ElectricalLoad class.

# 5.4 header/Interpolator.h File Reference

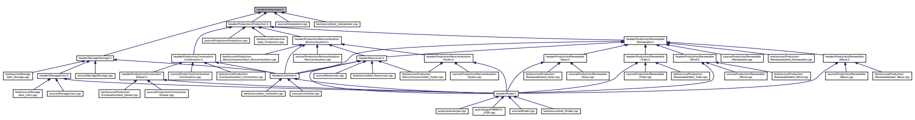
Header file for the Interpolator class.

```
#include "std_includes.h"
#include "../third_party/fast-cpp-csv-parser/csv.h"
```

Include dependency graph for Interpolator.h:



This graph shows which files directly or indirectly include this file:



## Classes

- struct InterpolatorStruct1D

  *A struct which holds two parallel vectors for use in 1D interpolation.*
- struct InterpolatorStruct2D

  *A struct which holds two parallel vectors and a matrix for use in 2D interpolation.*
- class Interpolator

  *A class which contains interpolation data and functionality. Intended to serve as a component of the Production and Storage hierarchies.*

### 5.4.1 Detailed Description

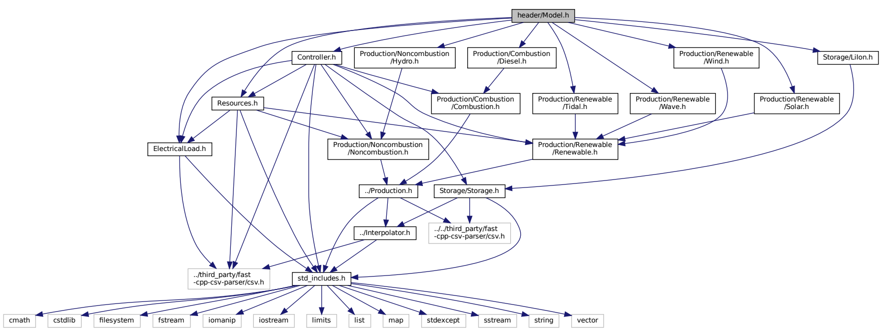
Header file for the Interpolator class.

## 5.5 header/Model.h File Reference

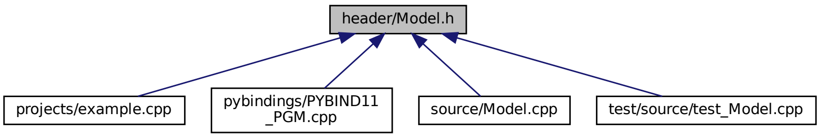
Header file for the Model class.

```
#include "Controller.h"
#include "ElectricalLoad.h"
#include "Resources.h"
#include "Production/Combustion/Diesel.h"
#include "Production/Noncombustion/Hydro.h"
#include "Production/Renewable/Solar.h"
#include "Production/Renewable/Tidal.h"
#include "Production/Renewable/Wave.h"
#include "Production/Renewable/Wind.h"
#include "Storage/LiIon.h"
```

Include dependency graph for Model.h:



This graph shows which files directly or indirectly include this file:




## Classes

- struct ModelInputs

  *A structure which bundles the necessary inputs for the Model constructor. Provides default values for every necessary input (except path_2_electrical_load_time_series, for which a valid input must be provided).*
- class Model

  *A container class which forms the centre of PGMcpp. The Model class is intended to serve as the primary user interface with the functionality of PGMcpp, and as such it contains all other classes.*

### 5.5.1 Detailed Description

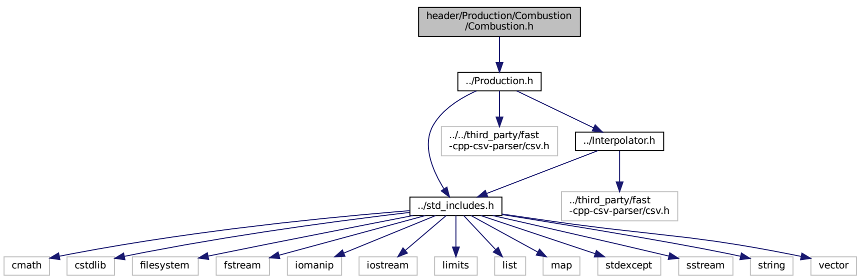
Header file for the Model class.

## 5.6 header/Production/Combustion/Combustion.h File Reference

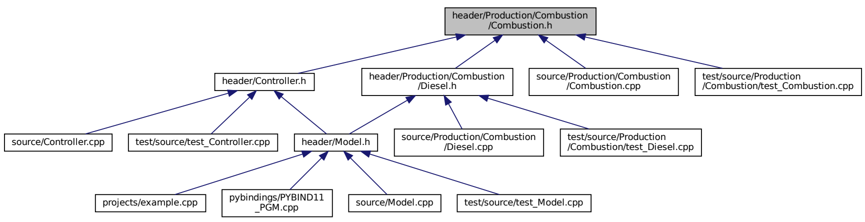
Header file for the Combustion class.

`#include "../Production.h"`

Include dependency graph for Combustion.h:




This graph shows which files directly or indirectly include this file:



## Classes

- struct CombustionInputs

  *A structure which bundles the necessary inputs for the Combustion constructor. Provides default values for every necessary input. Note that this structure encapsulates ProductionInputs.*
- struct Emissions

  *A structure which bundles the emitted masses of various emissions chemistries.*
- class Combustion

  *The root of the Combustion branch of the Production hierarchy. This branch contains derived classes which model the production of energy by way of combustibles.*

## Enumerations

- enum CombustionType { DIESEL , N_COMBUSTION_TYPES }

  *An enumeration of the types of Combustion asset supported by PGMcpp.*
- enum FuelMode { FUEL_MODE_LINEAR , FUEL_MODE_LOOKUP , N_FUEL_MODES }

  *An enumeration of the fuel modes for the Combustion asset which are supported by PGMcpp.*

### 5.6.1 Detailed Description

Header file for the Combustion class.

Header file for the Noncombustion class.

### 5.6.2 Enumeration Type Documentation

#### 5.6.2.1 CombustionType

`enum CombustionType`

An enumeration of the types of Combustion asset supported by PGMcpp.

**Enumerator**

| | |
|---|---|
| DIESEL | A diesel generator. |
| N_COMBUSTION_TYPES | A simple hack to get the number of elements in CombustionType. |

```
                  {
    DIESEL,
    N_COMBUSTION_TYPES
};
```

#### 5.6.2.2 FuelMode

`enum FuelMode`

An enumeration of the fuel modes for the Combustion asset which are supported by PGMcpp.

**Enumerator**

| | |
|---|---|
| FUEL_MODE_LINEAR | A linearized fuel curve model (i.e., HOMER-like model) |
| FUEL_MODE_LOOKUP | Interpolating over a given fuel lookup table. |
| N_FUEL_MODES | A simple hack to get the number of elements in FuelMode. |

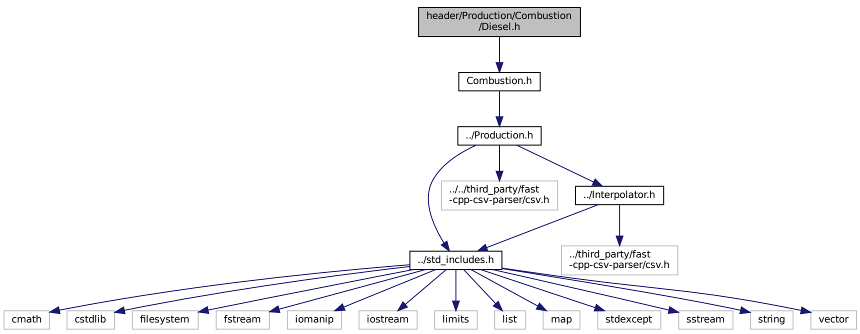
```
            {
    FUEL_MODE_LINEAR,
    FUEL_MODE_LOOKUP,
    N_FUEL_MODES
};
```

## 5.7 header/Production/Combustion/Diesel.h File Reference

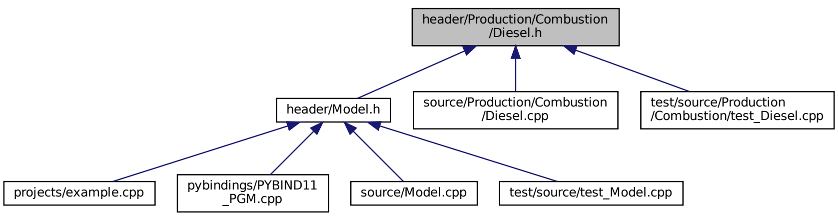
Header file for the Diesel class.

`#include "Combustion.h"`

Include dependency graph for Diesel.h:




This graph shows which files directly or indirectly include this file:




### Classes

- struct DieselInputs

  *A structure which bundles the necessary inputs for the Diesel constructor. Provides default values for every necessary input. Note that this structure encapsulates CombustionInputs.*
- class Diesel

  *A derived class of the Combustion branch of Production which models production using a diesel generator.*

### 5.7.1 Detailed Description

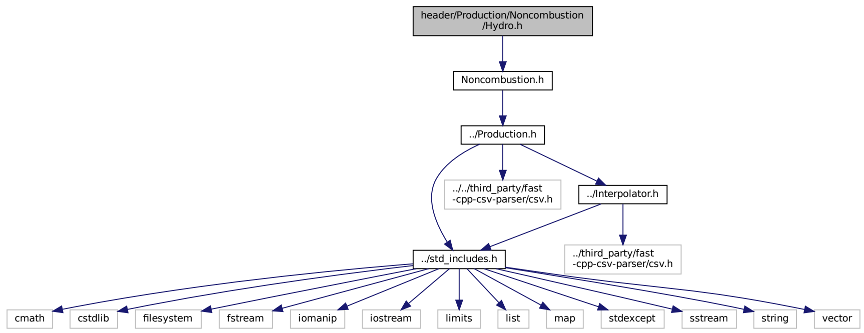
Header file for the Diesel class.

## 5.8 header/Production/Noncombustion/Hydro.h File Reference

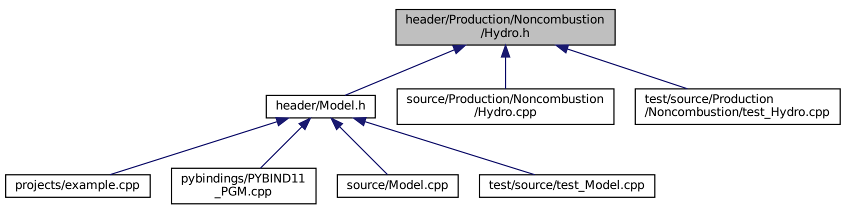
Header file for the Hydro class.

```
#include "Noncombustion.h"
```

Include dependency graph for Hydro.h:




This graph shows which files directly or indirectly include this file:




## Classes

- struct HydroInputs

    *A structure which bundles the necessary inputs for the Hydro constructor. Provides default values for every necessary input. Note that this structure encapsulates NoncombustionInputs.*
- class Hydro

    *A derived class of the Noncombustion branch of Production which models production using a hydroelectric asset (either with reservoir or not).*

## Enumerations

- enum HydroTurbineType { HYDRO_TURBINE_PELTON , HYDRO_TURBINE_FRANCIS , HYDRO_TURBINE_KAPLAN , N_HYDRO_TURBINES }

  *An enumeration of the types of hydroelectric turbine supported by PGMcpp.*
- enum HydroInterpKeys { GENERATOR_EFFICIENCY_INTERP_KEY , TURBINE_EFFICIENCY_INTERP_KEY , FLOW_TO_POWER_INTERP_KEY , N_HYDRO_INTERP_KEYS }

  *An enumeration of the Interpolator keys used by the Hydro asset.*

## 5.8.1 Detailed Description

Header file for the Hydro class.

## 5.8.2 Enumeration Type Documentation

### 5.8.2.1 HydroInterpKeys

`enum HydroInterpKeys`

An enumeration of the Interpolator keys used by the Hydro asset.

**Enumerator**

| | |
|---|---|
| GENERATOR_EFFICIENCY_INTERP_KEY | The key for generator efficiency interpolation. |
| TURBINE_EFFICIENCY_INTERP_KEY | The key for turbine efficiency interpolation. |
| FLOW_TO_POWER_INTERP_KEY | The key for flow to power interpolation. |
| N_HYDRO_INTERP_KEYS | A simple hack to get the number of elements in HydroInterpKeys. |

```
                    {
    GENERATOR_EFFICIENCY_INTERP_KEY,
    TURBINE_EFFICIENCY_INTERP_KEY,
    FLOW_TO_POWER_INTERP_KEY,
    N_HYDRO_INTERP_KEYS
};
```

### 5.8.2.2 HydroTurbineType

`enum HydroTurbineType`

An enumeration of the types of hydroelectric turbine supported by PGMcpp.

**Enumerator**

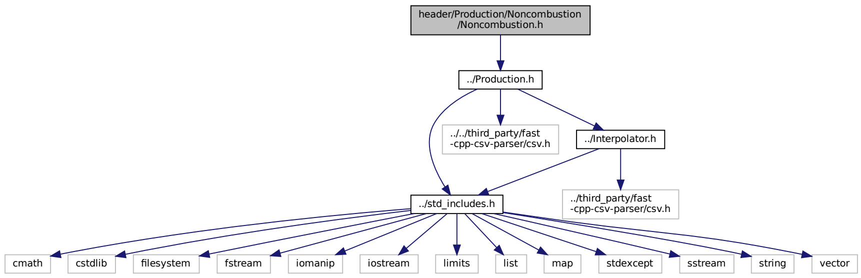
| | |
|---|---|
| HYDRO_TURBINE_PELTON | A Pelton turbine (impluse) |
| HYDRO_TURBINE_FRANCIS | A Francis turbine (reaction) |
| HYDRO_TURBINE_KAPLAN | A Kaplan turbine (reaction) |
| N_HYDRO_TURBINES | A simple hack to get the number of elements in HydroTurbineType. |

```
                {
    HYDRO_TURBINE_PELTON,
    HYDRO_TURBINE_FRANCIS,
    HYDRO_TURBINE_KAPLAN,
    N_HYDRO_TURBINES
};
```

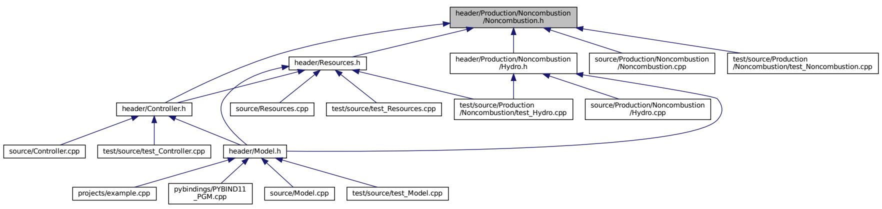
## 5.9 header/Production/Noncombustion/Noncombustion.h File Reference

`#include "../Production.h"`

Include dependency graph for Noncombustion.h:




This graph shows which files directly or indirectly include this file:




### Classes

- struct NoncombustionInputs

  *A structure which bundles the necessary inputs for the Noncombustion constructor. Provides default values for every necessary input. Note that this structure encapsulates ProductionInputs.*
- class Noncombustion

  *The root of the Noncombustion branch of the Production hierarchy. This branch contains derived classes which model controllable production which is not based on combustion.*

### Enumerations

- enum NoncombustionType { HYDRO , N_NONCOMBUSTION_TYPES }

  *An enumeration of the types of Noncombustion asset supported by PGMcpp.*

### 5.9.1 Enumeration Type Documentation

#### 5.9.1.1 NoncombustionType

`enum NoncombustionType`

An enumeration of the types of Noncombustion asset supported by PGMcpp.

**Enumerator**

| | |
|---|---|
| HYDRO | A hydroelectric generator (either with reservoir or not) |
| N_NONCOMBUSTION_TYPES | A simple hack to get the number of elements in NoncombustionType. |

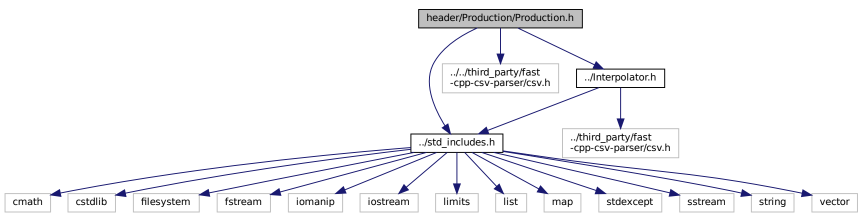
```
                    {
    HYDRO,
    N_NONCOMBUSTION_TYPES
};
```

## 5.10 header/Production/Production.h File Reference

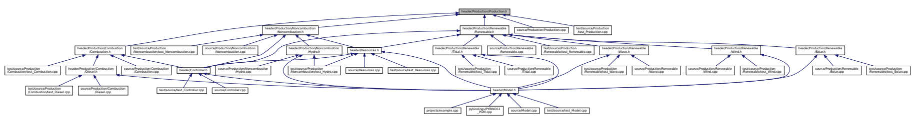
Header file for the Production class.

```
#include "../std_includes.h"
#include "../../third_party/fast-cpp-csv-parser/csv.h"
#include "../Interpolator.h"
```

Include dependency graph for Production.h:




This graph shows which files directly or indirectly include this file:



## Classes

- struct ProductionInputs

  *A structure which bundles the necessary inputs for the Production constructor. Provides default values for every necessary input.*
- class Production

  *The base class of the Production hierarchy. This hierarchy contains derived classes which model the production of energy, be it renewable or otherwise.*

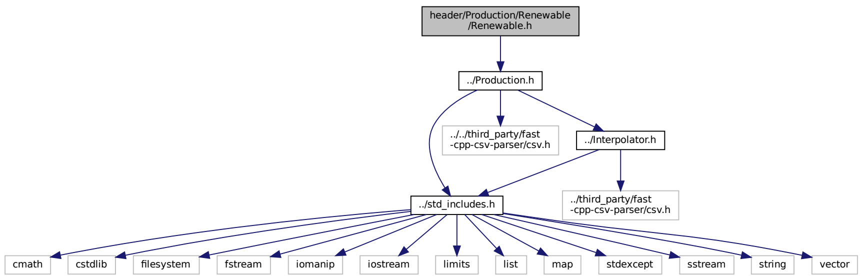
### 5.10.1 Detailed Description

Header file for the Production class.

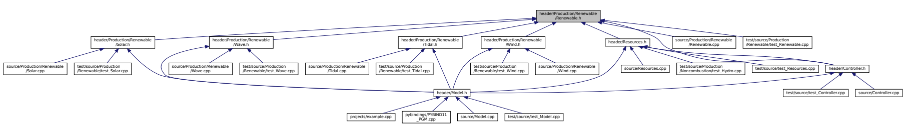
## 5.11 header/Production/Renewable/Renewable.h File Reference

Header file for the Renewable class.

`#include "../Production.h"`
Include dependency graph for Renewable.h:




This graph shows which files directly or indirectly include this file:



## Classes

- struct RenewableInputs

  *A structure which bundles the necessary inputs for the Renewable constructor. Provides default values for every necessary input. Note that this structure encapsulates ProductionInputs.*
- class Renewable

  *The root of the Renewable branch of the Production hierarchy. This branch contains derived classes which model the renewable production of energy.*

## Enumerations

- enum RenewableType {
  SOLAR , TIDAL , WAVE , WIND ,
  N_RENEWABLE_TYPES }

  *An enumeration of the types of Renewable asset supported by PGMcpp.*

### 5.11.1 Detailed Description

Header file for the Renewable class.

### 5.11.2 Enumeration Type Documentation

#### 5.11.2.1 RenewableType

```
enum RenewableType
```

An enumeration of the types of Renewable asset supported by PGMcpp.

**Enumerator**

| | |
|---|---|
| SOLAR | A solar photovoltaic (PV) array. |
| TIDAL | A tidal stream turbine (or tidal energy converter, TEC) |
| WAVE | A wave energy converter (WEC) |
| WIND | A wind turbine. |
| N_RENEWABLE_TYPES | A simple hack to get the number of elements in RenewableType. |

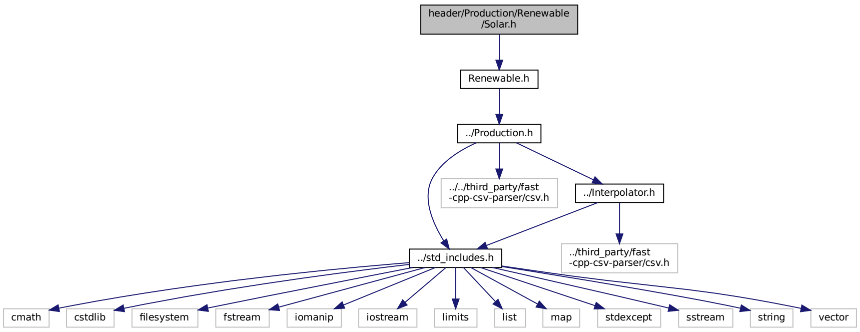
```
                      {
     SOLAR,
     TIDAL,
     WAVE,
     WIND,
     N_RENEWABLE_TYPES
};
```

## 5.12 header/Production/Renewable/Solar.h File Reference

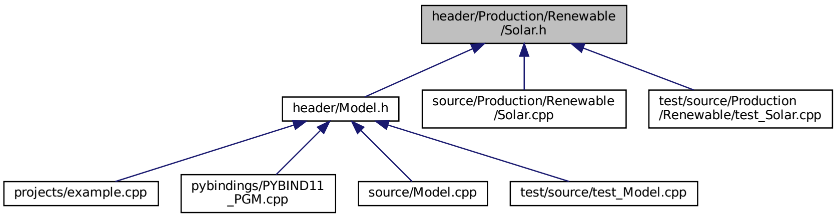
Header file for the Solar class.

```
#include "Renewable.h"
```

Include dependency graph for Solar.h:




This graph shows which files directly or indirectly include this file:




## Classes

- struct SolarInputs

  *A structure which bundles the necessary inputs for the Solar constructor. Provides default values for every necessary input. Note that this structure encapsulates RenewableInputs.*
- class Solar

  *A derived class of the Renewable branch of Production which models solar production.*

## Enumerations

- enum SolarPowerProductionModel { SOLAR_POWER_SIMPLE , SOLAR_POWER_DETAILED , N_SOLAR_POWER_PRODUCTION_MODELS }

## 5.12.1 Detailed Description

Header file for the Solar class.

## 5.12.2 Enumeration Type Documentation

### 5.12.2.1 SolarPowerProductionModel

```
enum SolarPowerProductionModel
```

#### Enumerator

| | |
|---|---|
| SOLAR_POWER_SIMPLE | A simple "HOMER-like" power production model. |
| SOLAR_POWER_DETAILED | A more detailed "PVWatts/SAM-like" production model. |
| N_SOLAR_POWER_PRODUCTION_MODELS | A simple hack to get the number of elements in SolarPowerProductionModel. |

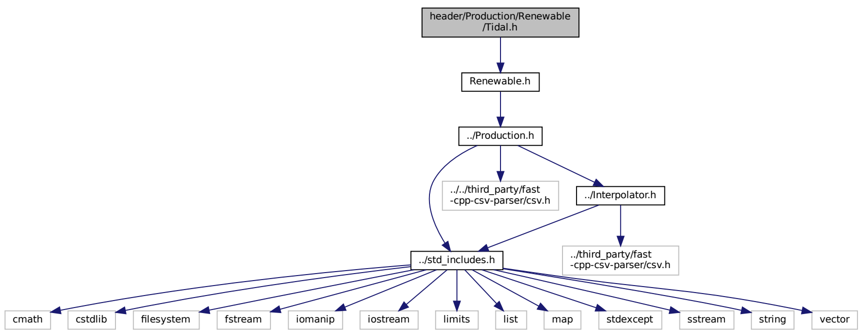
```
                              {
    SOLAR_POWER_SIMPLE,
    SOLAR_POWER_DETAILED,
    N_SOLAR_POWER_PRODUCTION_MODELS
};
```

## 5.13 header/Production/Renewable/Tidal.h File Reference

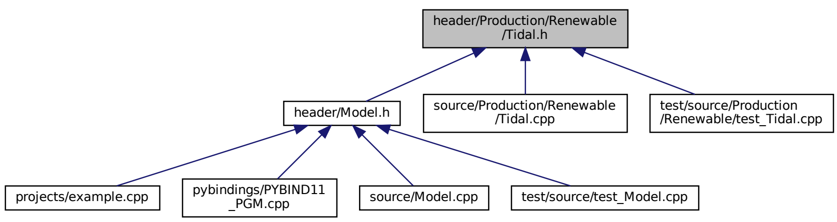
Header file for the Tidal class.

`#include "Renewable.h"`

Include dependency graph for Tidal.h:




This graph shows which files directly or indirectly include this file:




## Classes

- struct TidalInputs

  *A structure which bundles the necessary inputs for the Tidal constructor. Provides default values for every necessary input. Note that this structure encapsulates RenewableInputs.*
- class Tidal

  *A derived class of the Renewable branch of Production which models tidal production.*

## Enumerations

- enum TidalPowerProductionModel { TIDAL_POWER_CUBIC , TIDAL_POWER_EXPONENTIAL , TIDAL_POWER_LOOKUP , N_TIDAL_POWER_PRODUCTION_MODELS }

### 5.13.1 Detailed Description

Header file for the Tidal class.

### 5.13.2 Enumeration Type Documentation

#### 5.13.2.1 TidalPowerProductionModel

`enum TidalPowerProductionModel`

**Enumerator**

| | |
|---|---|
| TIDAL_POWER_CUBIC | A cubic power production model. |
| TIDAL_POWER_EXPONENTIAL | An exponential power production model. |
| TIDAL_POWER_LOOKUP | Lookup from a given set of power curve data. |
| N_TIDAL_POWER_PRODUCTION_MODELS | A simple hack to get the number of elements in TidalPowerProductionModel. |

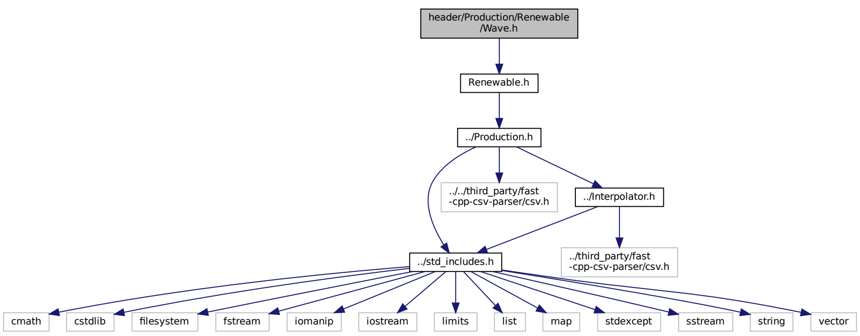
```
                          {
    TIDAL_POWER_CUBIC,
    TIDAL_POWER_EXPONENTIAL,
    TIDAL_POWER_LOOKUP,
    N_TIDAL_POWER_PRODUCTION_MODELS
};
```

## 5.14 header/Production/Renewable/Wave.h File Reference

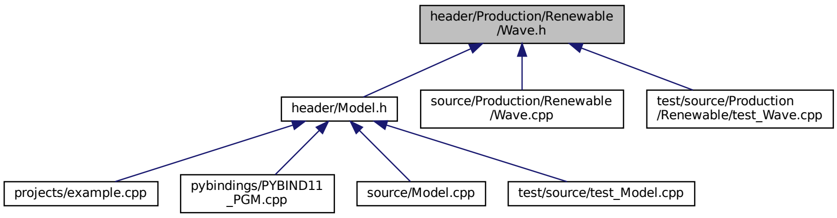
Header file for the Wave class.

`#include "Renewable.h"`

Include dependency graph for Wave.h:



This graph shows which files directly or indirectly include this file:




## Classes

- struct WaveInputs

  *A structure which bundles the necessary inputs for the Wave constructor. Provides default values for every necessary input. Note that this structure encapsulates RenewableInputs.*
- class Wave

  *A derived class of the Renewable branch of Production which models wave production.*

## Enumerations

- enum WavePowerProductionModel { WAVE_POWER_GAUSSIAN , WAVE_POWER_PARABOLOID , WAVE_POWER_LOOKUP , N_WAVE_POWER_PRODUCTION_MODELS }

## 5.14.1 Detailed Description

Header file for the Wave class.

## 5.14.2 Enumeration Type Documentation

### 5.14.2.1 WavePowerProductionModel

```
enum WavePowerProductionModel
```

**Enumerator**

| | |
|---|---|
| WAVE_POWER_GAUSSIAN | A Gaussian power production model. |
| WAVE_POWER_PARABOLOID | A paraboloid power production model. |
| WAVE_POWER_LOOKUP | Lookup from a given performance matrix. |
| N_WAVE_POWER_PRODUCTION_MODELS | A simple hack to get the number of elements in WavePowerProductionModel. |

```
                            {
    WAVE_POWER_GAUSSIAN,
```

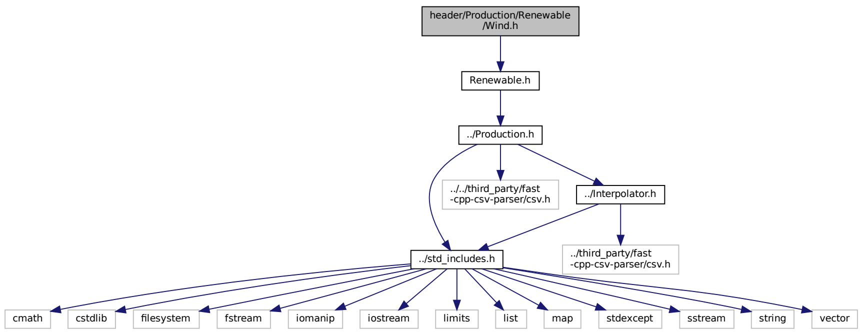
```
    WAVE_POWER_PARABOLOID,
    WAVE_POWER_LOOKUP,
    N_WAVE_POWER_PRODUCTION_MODELS
};
```

# 5.15 header/Production/Renewable/Wind.h File Reference

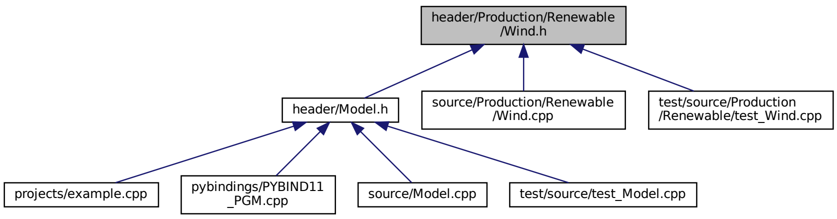
Header file for the Wind class.

`#include "Renewable.h"`

Include dependency graph for Wind.h:




This graph shows which files directly or indirectly include this file:




## Classes

- struct WindInputs

    *A structure which bundles the necessary inputs for the Wind constructor. Provides default values for every necessary input. Note that this structure encapsulates RenewableInputs.*
- class Wind

    *A derived class of the Renewable branch of Production which models wind production.*

## Enumerations

- enum WindPowerProductionModel { WIND_POWER_CUBIC , WIND_POWER_EXPONENTIAL , WIND_POWER_LOOKUP , N_WIND_POWER_PRODUCTION_MODELS }

### 5.15.1 Detailed Description

Header file for the Wind class.

### 5.15.2 Enumeration Type Documentation

#### 5.15.2.1 WindPowerProductionModel

```
enum WindPowerProductionModel
```

**Enumerator**

| | |
|---|---|
| WIND_POWER_CUBIC | A cubic power production model. |
| WIND_POWER_EXPONENTIAL | An exponential power production model. |
| WIND_POWER_LOOKUP | Lookup from a given set of power curve data. |
| N_WIND_POWER_PRODUCTION_MODELS | A simple hack to get the number of elements in WindPowerProductionModel. |

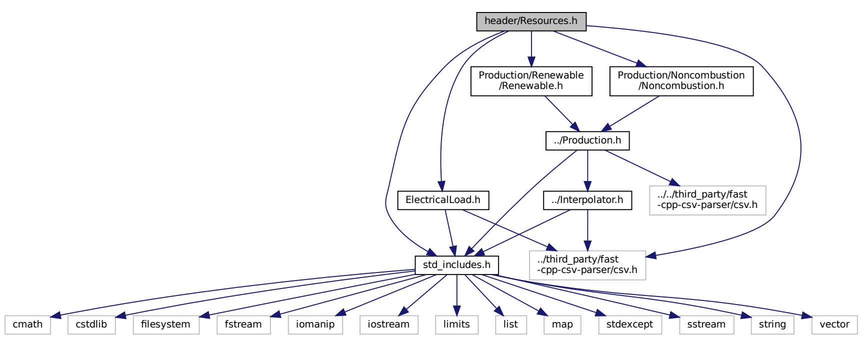
```
                           {
    WIND_POWER_CUBIC,
    WIND_POWER_EXPONENTIAL,
    WIND_POWER_LOOKUP,
    N_WIND_POWER_PRODUCTION_MODELS
};
```

## 5.16 header/Resources.h File Reference

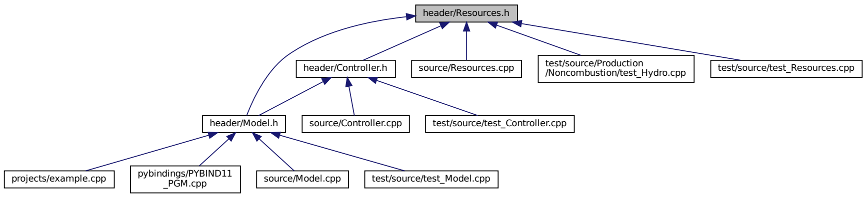
Header file for the Resources class.

```
#include "std_includes.h"
#include "../third_party/fast-cpp-csv-parser/csv.h"
#include "ElectricalLoad.h"
#include "Production/Noncombustion/Noncombustion.h"
#include "Production/Renewable/Renewable.h"
```

Include dependency graph for Resources.h:



This graph shows which files directly or indirectly include this file:




## Classes

- class Resources

  *A class which contains renewable resource data. Intended to serve as a component class of Model.*

### 5.16.1 Detailed Description

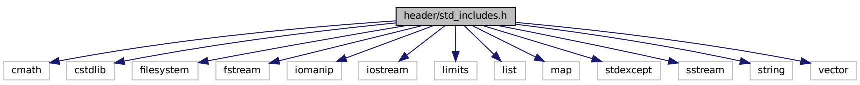
Header file for the Resources class.

## 5.17 header/std_includes.h File Reference

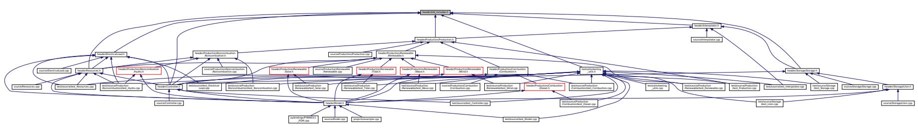
Header file which simply batches together some standard includes.

```
#include <cmath>
#include <cstdlib>
#include <filesystem>
#include <fstream>
#include <iomanip>
#include <iostream>
#include <limits>
#include <list>
#include <map>
#include <stdexcept>
#include <sstream>
#include <string>
#include <vector>
```

Include dependency graph for std_includes.h:




This graph shows which files directly or indirectly include this file:



## Macros

- #define _USE_MATH_DEFINES

### 5.17.1 Detailed Description

Header file which simply batches together some standard includes.

### 5.17.2 Macro Definition Documentation

#### 5.17.2.1 _USE_MATH_DEFINES

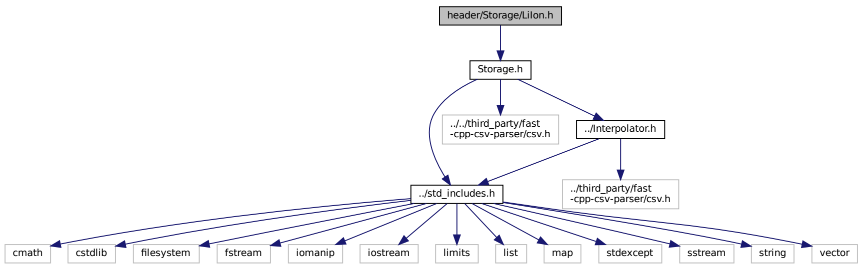
```
#define _USE_MATH_DEFINES
```

## 5.18 header/Storage/LiIon.h File Reference

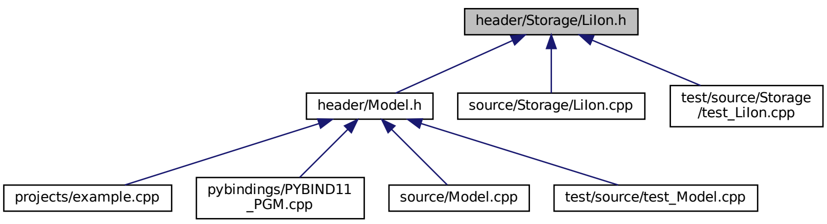
Header file for the LiIon class.

```
#include "Storage.h"
```

Include dependency graph for LiIon.h:




This graph shows which files directly or indirectly include this file:



## Classes

- struct LiIonInputs

  *A structure which bundles the necessary inputs for the LiIon constructor. Provides default values for every necessary input. Note that this structure encapsulates StorageInputs.*
- class LiIon

  *A derived class of Storage which models energy storage by way of lithium-ion batteries.*

### 5.18.1 Detailed Description

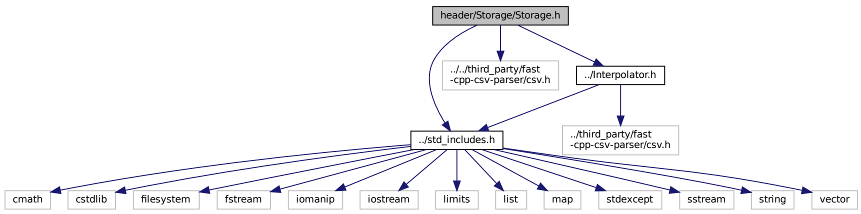
Header file for the LiIon class.

## 5.19 header/Storage/Storage.h File Reference

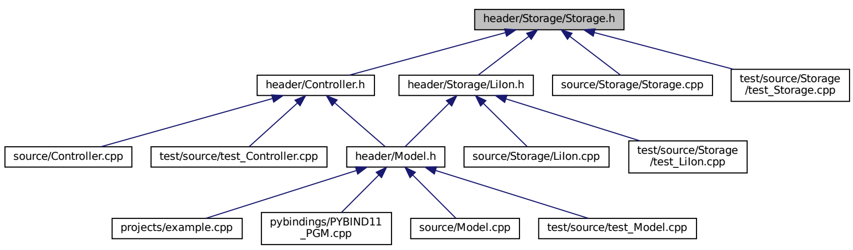
Header file for the Storage class.

```
#include "../std_includes.h"
#include "../../third_party/fast-cpp-csv-parser/csv.h"
#include "../Interpolator.h"
```

Include dependency graph for Storage.h:




This graph shows which files directly or indirectly include this file:




## Classes

- struct StorageInputs

  *A structure which bundles the necessary inputs for the Storage constructor. Provides default values for every necessary input.*
- class Storage

  *The base class of the Storage hierarchy. This hierarchy contains derived classes which model the storage of energy.*

## Enumerations

- enum StorageType { LIION , N_STORAGE_TYPES }

  *An enumeration of the types of Storage asset supported by PGMcpp.*

### 5.19.1 Detailed Description

Header file for the Storage class.

### 5.19.2 Enumeration Type Documentation

#### 5.19.2.1 StorageType

`enum StorageType`

An enumeration of the types of Storage asset supported by PGMcpp.

**Enumerator**

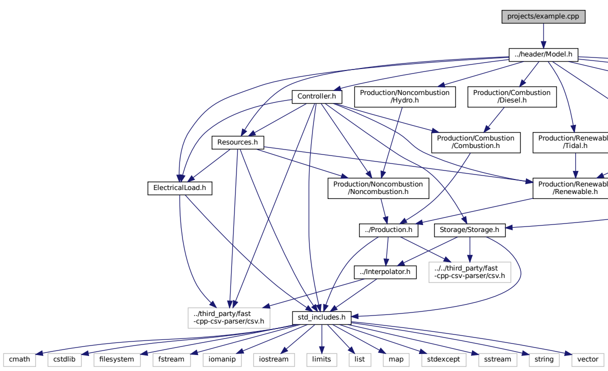
| | |
|---|---|
| LIION | A system of lithium ion batteries. |
| N_STORAGE_TYPES | A simple hack to get the number of elements in StorageType. |

```
            {
    LIION,
    N_STORAGE_TYPES
};
```

## 5.20 projects/example.cpp File Reference

`#include "../header/Model.h"`

Include dependency graph for example.cpp:



## Functions

- int main (int argc, char **argv)

## 5.20.1 Function Documentation

### 5.20.1.1 main()

```
int main (
        int argc,
        char ** argv )
```

```
{
    /*
     * 1. construct Model object
     *
     * This block constructs a Model object, which is the central container for the
     * entire microgrid model.
     *
     * The fist argument that must be provided to the Model constructor is a valid
     * path (either relative or absolute) to a time series of electrical load data.
     * For an example of the expected format, see
     *
     * data/test/electrical_load/electrical_load_generic_peak-500kW_1yr_dt-1hr.csv
     *
     * Note that the length of the given electrical load time series defines the
     * modelled project life (so if you want to model n years of microgrid operation,
     * then you must pass a path to n years worth of electrical load data). In addition,
     * the given electrical load time series defines which points in time are modelled.
     * As such, all subsequent time series data which is passed in must (1) be of the
     * same length as the electrical load time series, and (2) provide data for the
     * same set of points in time. Of course, the electrical load time series can be
     * of arbitrary length, and it need not be a uniform time series.
     *
     * The second argument that one can provide is the desired disptach control mode.
     * If nothing is given here, then the model will default to simple load following
     * control. However, one can stipulate which control mode to use by altering the
     * control_mode attribute of the ModelInputs structure. In this case, the
     * cycle charging control mode is being set.
     */

    std::string path_2_electrical_load_time_series =
        "data/test/electrical_load/electrical_load_generic_peak-500kW_1yr_dt-1hr.csv";

    ModelInputs model_inputs;

    model_inputs.path_2_electrical_load_time_series =
        path_2_electrical_load_time_series;

    model_inputs.control_mode = ControlMode :: CYCLE_CHARGING;

    Model model(model_inputs);



    /*
     * 2. add Diesel objects to Model
     *
     * This block defines and adds a set of diesel generators to the Model object.
     *
     * In this example, a single DieselInputs structure is used to define and add
     * three diesel generators to the model.
     *
     * The first diesel generator is defined as a 300 kW generator (which shows an
     * example of how to access and alter an encapsulated attribute of DieselInputs).
     * In addition, the diesel generator is taken to be a sunk cost (and so no capital
     * cost is incurred in the first time step; the opposite is true for non-sunk
     * assets).
     *
     * The last two diesel generators are defined as 150 kW each. Likewise, they are
     * also sunk assets (since the same DieselInputs structure is being re-used without
     * overwriting the is_sunk attribute).
     *
     * For more details on the various attributes of DieselInputs, refer to the
     * PGMcpp manual. For instance, note that no economic inputs are given; in this
```

```
     * example, the default values apply.
     */

    DieselInputs diesel_inputs;

    //  2.1. add 1 x 300 kW diesel generator (since mean load is ~250 kW)
    diesel_inputs.combustion_inputs.production_inputs.capacity_kW = 300;
    diesel_inputs.combustion_inputs.production_inputs.is_sunk = true;

    model.addDiesel(diesel_inputs);

    //  2.2. add 2 x 150 kW diesel generators (since max load is 500 kW)
    diesel_inputs.combustion_inputs.production_inputs.capacity_kW = 150;

    model.addDiesel(diesel_inputs);
    model.addDiesel(diesel_inputs);



    /*
     *  3. add renewable resources to Model
     *
     *  This block adds a set of renewable resource time series to the Model object.
     *
     *  The first resource added is a solar resource time series, which gives
     *  horizontal irradiance [kW/m2] at each point in time. Again, remember that all
     *  given time series must align with the electrical load time series (i.e., same
     *  length, same points). For an example of the expected format, see
     *
     *  data/test/resources/solar_GHI_peak-1kWm2_1yr_dt-1hr.csv
     *
     *  Finally, note the declaration of a solar resource key. This variable will be
     *  re-used later to associate a solar PV array object with this particular solar
     *  resource. This method of key association between resource and asset allows for
     *  greater flexibility in modelling production assets that are exposed to different
     *  renewable resources (due to being geographically separated, etc.).
     *
     *  The second resource added is a tidal resource time series, which gives tidal
     *  stream speed [m/s] at each point in time. For an example of the expected format,
     *  see
     *
     *  data/test/resources/tidal_speed_peak-3ms_1yr_dt-1hr.csv
     *
     *  Again, note the tidal resource key.
     *
     *  The third resource added is a wave resource time series, which gives significant
     *  wave height [m] and energy period [s] at each point in time. For an example of
     *  the expected format, see
     *
     *  data/test/resources/waves_H_s_peak-8m_T_e_peak-15s_1yr_dt-1hr.csv
     *
     *  Again, note the wave resource key.
     *
     *  The fourth resource added is a wind resource time series, which gives wind speed
     *  [m/s] at each point in time. For an example of the expected format, see
     *
     *  data/test/resources/wind_speed_peak-25ms_1yr_dt-1hr.csv
     *
     *  Again, note the wind resource key.
     *
     *  The fifth resource added is a hydro resource time series, which gives inflow
     *  rate [m3/hr] at each point in time. For an example of the expected format, see
     *
     *  data/test/resources/hydro_inflow_peak-20000m3hr_1yr_dt-1hr.csv
     *
     *  Again, note the hydro resource key.
     */

    //  3.1. add solar resource time series
    int solar_resource_key = 0;
    std::string path_2_solar_resource_data =
        "data/test/resources/solar_GHI_peak-1kWm2_1yr_dt-1hr.csv";

    model.addResource(
        RenewableType :: SOLAR,
        path_2_solar_resource_data,
        solar_resource_key
    );

    //  3.2. add tidal resource time series
    int tidal_resource_key = 1;
    std::string path_2_tidal_resource_data =
        "data/test/resources/tidal_speed_peak-3ms_1yr_dt-1hr.csv";

    model.addResource(
        RenewableType :: TIDAL,
        path_2_tidal_resource_data,
```

```
        tidal_resource_key
    );

    //  3.3. add wave resource time series
    int wave_resource_key = 2;
    std::string path_2_wave_resource_data =
        "data/test/resources/waves_H_s_peak-8m_T_e_peak-15s_1yr_dt-1hr.csv";

    model.addResource(
        RenewableType :: WAVE,
        path_2_wave_resource_data,
        wave_resource_key
    );

    //  3.4. add wind resource time series
    int wind_resource_key = 3;
    std::string path_2_wind_resource_data =
        "data/test/resources/wind_speed_peak-25ms_1yr_dt-1hr.csv";

    model.addResource(
        RenewableType :: WIND,
        path_2_wind_resource_data,
        wind_resource_key
    );

    //  3.5. add hydro resource time series
    int hydro_resource_key = 4;
    std::string path_2_hydro_resource_data =
        "data/test/resources/hydro_inflow_peak-20000m3hr_1yr_dt-1hr.csv";

    model.addResource(
        NoncombustionType :: HYDRO,
        path_2_hydro_resource_data,
        hydro_resource_key
    );



    /*
     *  4. add Hydro object to Model
     *
     *  This block defines and adds a hydroelectric asset to the Model object.
     *
     *  In this example, a 300 kW hydroelectric station with a 10,000 m3 reservoir
     *  is defined. The initial reservoir state is set to 50% (so half full), and the
     *  hydroelectric asset is taken to be a sunk asset (so no capital cost incurred
     *  in the first time step). Note the association with the previously given hydro
     *  resource series by way of the hydro resource key.
     *
     *  For more details on the various attributes of HydroInputs, refer to the
     *  PGMcpp manual. For instance, note that no economic inputs are given; in this
     *  example, the default values apply.
     */

    HydroInputs hydro_inputs;
    hydro_inputs.noncombustion_inputs.production_inputs.capacity_kW = 300;
    hydro_inputs.reservoir_capacity_m3 = 10000;
    hydro_inputs.init_reservoir_state = 0.5;
    hydro_inputs.noncombustion_inputs.production_inputs.is_sunk = true;
    hydro_inputs.resource_key = hydro_resource_key;

    model.addHydro(hydro_inputs);



    /*
     *  5. add Renewable objects to Model
     *
     *  This block defines and adds a set of renewable production assets to the Model
     *  object.
     *
     *  The first block defines and adds a solar PV array to the Model object. In this
     *  example, the installed solar capacity is set to 250 kW. Note the association
     *  with the previously given solar resource series by way of the solar resource
     *  key. Also, note that this asset is not taken as sunk (as the is_sunk attribute
     *  of the SolarInputs structure is unchanged and thus defaults to true). As such,
     *  this asset will incur a capital cost in the first time step.
     *
     *  For more details on the various attributes of SolarInputs, refer to the PGMcpp
     *  manual. For instance, note that no economic inputs are given; in this
     *  example, the default values apply.
     *
     *  The second block defines and adds a tidal turbine to the Model object. In this
     *  example, the installed tidal capacity is set to 120 kW. In addition, the design
     *  speed of the asset (i.e., the speed at which the rated capacity is achieved) is
     *  set to 2.5 m/s. Note the association with the previously given tidal resource
     *  series by way of the tidal resource key.
```

```
     *
     *  For more details on the various attributes of TidalInputs, refer to the PGMcpp
     *  manual. For instance, note that no economic inputs are given; in this
     *  example, the default values apply.
     *
     *  The third block defines and adds a wind turbine to the Model object. In this
     *  example, the installed wind capacity is set to 150 kW. In addition, the design
     *  speed of the asset is not given, and so will default to 8 m/s. Note the
     *  association with the previously given tidal resource series by way of the wind
     *  resource key.
     *
     *  For more details on the various attributes of WindInputs, refer to the PGMcpp
     *  manual. For instance, note that no economic inputs are given; in this
     *  example, the default values apply.
     *
     *  The fourth block defines and adds a wave energy converter to the Model object.
     *  In this example, the installed wave capacity is set to 100 kW. Note the
     *  association with the previously given wave resource series by way of the wave
     *  resource key.
     *
     *  For more details on the various attributes of WaveInputs, refer to the PGMcpp
     *  manual. For instance, note that no economic inputs are given; in this
     *  example, the default values apply.
     */

    //  5.1. add 1 x 250 kW solar PV array
    SolarInputs solar_inputs;

    solar_inputs.renewable_inputs.production_inputs.capacity_kW = 250;
    solar_inputs.resource_key = solar_resource_key;

    model.addSolar(solar_inputs);

    //  5.2. add 1 x 120 kW tidal turbine
    TidalInputs tidal_inputs;

    tidal_inputs.renewable_inputs.production_inputs.capacity_kW = 120;
    tidal_inputs.design_speed_ms = 2.5;
    tidal_inputs.resource_key = tidal_resource_key;

    model.addTidal(tidal_inputs);

    //  5.3. add 1 x 150 kW wind turbine
    WindInputs wind_inputs;

    wind_inputs.renewable_inputs.production_inputs.capacity_kW = 150;
    wind_inputs.resource_key = wind_resource_key;

    model.addWind(wind_inputs);

    //  5.4. add 1 x 100 kW wave energy converter
    WaveInputs wave_inputs;

    wave_inputs.renewable_inputs.production_inputs.capacity_kW = 100;
    wave_inputs.resource_key = wave_resource_key;

    model.addWave(wave_inputs);



    /*
     *  6. add LiIon object to Model
     *
     *  This block defines and adds a lithium ion battery energy storage system to the
     *  Model object.
     *
     *  In this example, a battery energy storage system with a 500 kW power capacity
     *  and a 1050 kWh energy capacity (which represents about four hours of mean load
     *  autonomy) is defined.
     *
     *  For more details on the various attributes of LiIonInputs, refer to the PGMcpp
     *  manual. For instance, note that no economic inputs are given; in this
     *  example, the default values apply.
     */

    //  6.1. add 1 x (500 kW, ) lithium ion battery energy storage system
    LiIonInputs liion_inputs;

    liion_inputs.storage_inputs.power_capacity_kW = 500;
    liion_inputs.storage_inputs.energy_capacity_kWh = 1050;

    model.addLiIon(liion_inputs);



    /*
     *  7. run and write results
```

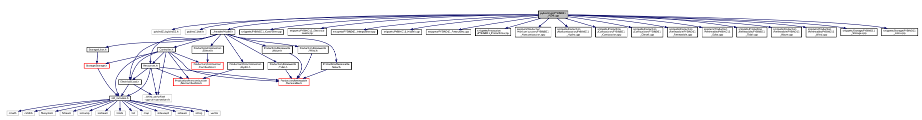
```
     *
     *  This block runs the model and then writes results to the given output path
     *  (either relative or absolute). Note that the writeResults() will create the
     *  last directory on the given path, but not any in-between directories, so be
     *  sure those exist before calling out to this method.
     */

    model.run();

    model.writeResults("projects/example_cpp");

    return 0;
}   /* main() */
```

## 5.21 pybindings/PYBIND11_PGM.cpp File Reference

Bindings file for PGMcpp.

```
#include <pybind11/pybind11.h>
#include <pybind11/stl.h>
#include "../header/Model.h"
#include "snippets/PYBIND11_Controller.cpp"
#include "snippets/PYBIND11_ElectricalLoad.cpp"
#include "snippets/PYBIND11_Interpolator.cpp"
#include "snippets/PYBIND11_Model.cpp"
#include "snippets/PYBIND11_Resources.cpp"
#include "snippets/Production/PYBIND11_Production.cpp"
#include "snippets/Production/Noncombustion/PYBIND11_Noncombustion.cpp"
#include "snippets/Production/Noncombustion/PYBIND11_Hydro.cpp"
#include "snippets/Production/Combustion/PYBIND11_Combustion.cpp"
#include "snippets/Production/Combustion/PYBIND11_Diesel.cpp"
#include "snippets/Production/Renewable/PYBIND11_Renewable.cpp"
#include "snippets/Production/Renewable/PYBIND11_Solar.cpp"
#include "snippets/Production/Renewable/PYBIND11_Tidal.cpp"
#include "snippets/Production/Renewable/PYBIND11_Wave.cpp"
#include "snippets/Production/Renewable/PYBIND11_Wind.cpp"
#include "snippets/Storage/PYBIND11_Storage.cpp"
#include "snippets/Storage/PYBIND11_LiIon.cpp"
```

Include dependency graph for PYBIND11_PGM.cpp:



### Functions

- PYBIND11_MODULE (PGMcpp, m)

### 5.21.1 Detailed Description

Bindings file for PGMcpp.

Ref: Jakob [2023]

A file which instructs pybind11 how to build Python bindings for PGMcpp. Only public attributes/methods are bound!

### 5.21.2 Function Documentation

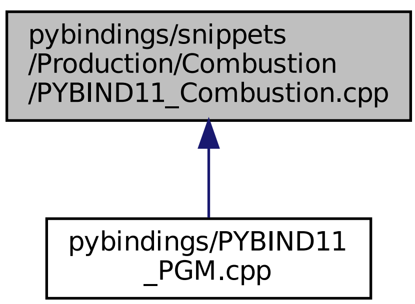
#### 5.21.2.1 PYBIND11_MODULE()

```
PYBIND11_MODULE (
            PGMcpp ,
            m )
                        {

    #include "snippets/PYBIND11_Controller.cpp"
    #include "snippets/PYBIND11_ElectricalLoad.cpp"
    #include "snippets/PYBIND11_Interpolator.cpp"
    #include "snippets/PYBIND11_Model.cpp"
    #include "snippets/PYBIND11_Resources.cpp"

    #include "snippets/Production/PYBIND11_Production.cpp"

    #include "snippets/Production/Noncombustion/PYBIND11_Noncombustion.cpp"
    #include "snippets/Production/Noncombustion/PYBIND11_Hydro.cpp"

    #include "snippets/Production/Combustion/PYBIND11_Combustion.cpp"
    #include "snippets/Production/Combustion/PYBIND11_Diesel.cpp"

    #include "snippets/Production/Renewable/PYBIND11_Renewable.cpp"
    #include "snippets/Production/Renewable/PYBIND11_Solar.cpp"
    #include "snippets/Production/Renewable/PYBIND11_Tidal.cpp"
    #include "snippets/Production/Renewable/PYBIND11_Wave.cpp"
    #include "snippets/Production/Renewable/PYBIND11_Wind.cpp"

    #include "snippets/Storage/PYBIND11_Storage.cpp"
    #include "snippets/Storage/PYBIND11_LiIon.cpp"

}   /* PYBIND11_MODULE() */
```

## 5.22 pybindings/snippets/Production/Combustion/PYBIND11_Combustion.cpp File Reference

Bindings file for the Combustion class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:



## Functions

- CombustionType::DIESEL value ("N_COMBUSTION_TYPES", CombustionType::N_COMBUSTION_↩ TYPES)
- FuelMode::FUEL_MODE_LINEAR value ("FUEL_MODE_LOOKUP", FuelMode::FUEL_MODE_LOOKUP) .value("N_FUEL_MODES"
- &CombustionInputs::production_inputs def_readwrite ("fuel_mode", &CombustionInputs::fuel_mode) .def_↩ readwrite("nominal_fuel_escalation_annual"
- &CombustionInputs::production_inputs &CombustionInputs::nominal_fuel_escalation_annual def_readwrite ("cycle_charging_setpoint", &CombustionInputs::cycle_charging_setpoint) .def_readwrite("path_2_fuel_↩ interp_data"
- &CombustionInputs::production_inputs &CombustionInputs::nominal_fuel_escalation_annual &CombustionInputs::path_2_fuel_ def (pybind11::init())
- &Emissions::CO2_kg def_readwrite ("CO_kg", &Emissions::CO_kg) .def_readwrite("NOx_kg"
- &Emissions::CO2_kg &Emissions::NOx_kg def_readwrite ("SOx_kg", &Emissions::SOx_kg) .def_↩ readwrite("CH4_kg"

## Variables

- &Emissions::CO2_kg &Emissions::NOx_kg &Emissions::CH4_kg def_readwrite("PM_kg", &Emissions::↩ PM_kg) .def(pybind11 &Combustion::type def_readwrite ("fuel_mode", &Combustion::fuel_mode) .def_↩ readwrite("total_emissions"

## 5.22.1 Detailed Description

Bindings file for the Combustion class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Combustion class. Only public attributes/methods are bound!

## 5.22.2 Function Documentation

### 5.22.2.1 def()

```
&InterpolatorStruct2D::n_rows &InterpolatorStruct2D::x_vec &InterpolatorStruct2D::max_x &InterpolatorStruct2D:
&InterpolatorStruct2D::z_matrix def (
            pybind11::init()   )
```

### 5.22.2.2 def_readwrite() [1/4]

```
& Emissions::CO2_kg def_readwrite (
            "CO_kg" ,
            &Emissions::CO_kg   )
```

#### 5.22.2.3 def_readwrite() [2/4]

```
& CombustionInputs::production_inputs & CombustionInputs::nominal_fuel_escalation_annual def←
_readwrite (
            "cycle_charging_setpoint" ,
            &CombustionInputs::cycle_charging_setpoint )
```

#### 5.22.2.4 def_readwrite() [3/4]

```
& CombustionInputs::production_inputs def_readwrite (
            "fuel_mode" ,
            &CombustionInputs::fuel_mode )
```

#### 5.22.2.5 def_readwrite() [4/4]

```
& Emissions::CO2_kg & Emissions::NOx_kg def_readwrite (
            "SOx_kg" ,
            &Emissions::SOx_kg )
```

#### 5.22.2.6 value() [1/2]

```
FuelMode::FUEL_MODE_LINEAR value (
            "FUEL_MODE_LOOKUP" ,
            FuelMode::FUEL_MODE_LOOKUP )
```

#### 5.22.2.7 value() [2/2]

```
CombustionType::DIESEL value (
            "N_COMBUSTION_TYPES" ,
            CombustionType::N_COMBUSTION_TYPES )
```

### 5.22.3 Variable Documentation

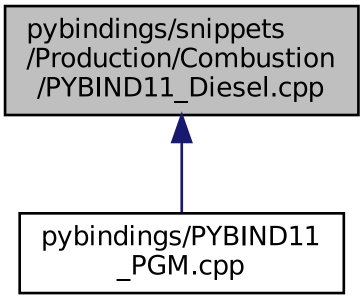
#### 5.22.3.1 def_readwrite

```
&StorageInputs::print_flag &StorageInputs::power_capacity_kW &StorageInputs::nominal_inflation_annual
def_readwrite (
            "fuel_mode" ,
            &Combustion::fuel_mode )
```

## 5.23 pybindings/snippets/Production/Combustion/PYBIND11_Diesel.cpp File Reference

Bindings file for the Diesel class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:




### Functions

- &DieselInputs::combustion_inputs def_readwrite ("replace_running_hrs", &DieselInputs::replace_running_hrs) .def_readwrite("capital_cost"
- &DieselInputs::combustion_inputs &DieselInputs::capital_cost def_readwrite ("operation_maintenance_cost_kWh", &DieselInputs::operation_maintenance_cost_kWh) .def_readwrite("fuel_cost_L"
- &DieselInputs::combustion_inputs &DieselInputs::capital_cost &DieselInputs::fuel_cost_L def_readwrite ("minimum_load_ratio", &DieselInputs::minimum_load_ratio) .def_readwrite("minimum_runtime_hrs"
- &DieselInputs::combustion_inputs &DieselInputs::capital_cost &DieselInputs::fuel_cost_L &DieselInputs::minimum_runtime_hr def_readwrite ("linear_fuel_slope_LkWh", &DieselInputs::linear_fuel_slope_LkWh) .def_readwrite("linear_fuel_intercept_LkWh"
- &DieselInputs::combustion_inputs &DieselInputs::capital_cost &DieselInputs::fuel_cost_L &DieselInputs::minimum_runtime_hr &DieselInputs::linear_fuel_intercept_LkWh def_readwrite ("CO2_emissions_intensity_kgL", &DieselInputs::CO2_emissions_intensity_kgL) .def_readwrite("CO_emissions_intensity_kgL"
- &DieselInputs::combustion_inputs &DieselInputs::capital_cost &DieselInputs::fuel_cost_L &DieselInputs::minimum_runtime_hr &DieselInputs::linear_fuel_intercept_LkWh &DieselInputs::CO_emissions_intensity_kgL def_readwrite ("NOx_emissions_intensity_kgL", &DieselInputs::NOx_emissions_intensity_kgL) .def_readwrite("SOx_emissions_intensity_kgL"
- &DieselInputs::combustion_inputs &DieselInputs::capital_cost &DieselInputs::fuel_cost_L &DieselInputs::minimum_runtime_hr &DieselInputs::linear_fuel_intercept_LkWh &DieselInputs::CO_emissions_intensity_kgL &DieselInputs::SOx_emissions_intens def_readwrite ("CH4_emissions_intensity_kgL", &DieselInputs::CH4_emissions_intensity_kgL) .def_readwrite("PM_emissions_intensity_kgL"
- &DieselInputs::combustion_inputs &DieselInputs::capital_cost &DieselInputs::fuel_cost_L &DieselInputs::minimum_runtime_hr &DieselInputs::linear_fuel_intercept_LkWh &DieselInputs::CO_emissions_intensity_kgL &DieselInputs::SOx_emissions_intens &DieselInputs::PM_emissions_intensity_kgL def (pybind11::init())
- &Diesel::minimum_load_ratio def_readwrite ("minimum_runtime_hrs", &Diesel::minimum_runtime_hrs) .def_readwrite("time_since_last_start_hrs"

### 5.23.1 Detailed Description

Bindings file for the Diesel class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Diesel class. Only public attributes/methods are bound!

### 5.23.2 Function Documentation

#### 5.23.2.1 def()

```
& DieselInputs::combustion_inputs & DieselInputs::capital_cost & DieselInputs::fuel_cost_L &
DieselInputs::minimum_runtime_hrs & DieselInputs::linear_fuel_intercept_LkWh & DieselInputs::CO_emissions_inte
& DieselInputs::SOx_emissions_intensity_kgL & DieselInputs::PM_emissions_intensity_kgL def (
            pybind11::init()  )
```

#### 5.23.2.2 def_readwrite() [1/8]

```
& DieselInputs::combustion_inputs & DieselInputs::capital_cost & DieselInputs::fuel_cost_L &
DieselInputs::minimum_runtime_hrs & DieselInputs::linear_fuel_intercept_LkWh & DieselInputs::CO_emissions_inte
& DieselInputs::SOx_emissions_intensity_kgL def_readwrite (
            "CH4_emissions_intensity_kgL" ,
            &DieselInputs::CH4_emissions_intensity_kgL  )
```

#### 5.23.2.3 def_readwrite() [2/8]

```
& DieselInputs::combustion_inputs & DieselInputs::capital_cost & DieselInputs::fuel_cost_L &
DieselInputs::minimum_runtime_hrs & DieselInputs::linear_fuel_intercept_LkWh def_readwrite (
            "CO2_emissions_intensity_kgL" ,
            &DieselInputs::CO2_emissions_intensity_kgL  )
```

#### 5.23.2.4 def_readwrite() [3/8]

```
& DieselInputs::combustion_inputs & DieselInputs::capital_cost & DieselInputs::fuel_cost_L &
DieselInputs::minimum_runtime_hrs def_readwrite (
            "linear_fuel_slope_LkWh" ,
            &DieselInputs::linear_fuel_slope_LkWh  )
```

#### 5.23.2.5 def_readwrite() [4/8]

```
& DieselInputs::combustion_inputs & DieselInputs::capital_cost & DieselInputs::fuel_cost_L
def_readwrite (
             "minimum_load_ratio" ,
             &DieselInputs::minimum_load_ratio  )
```

#### 5.23.2.6 def_readwrite() [5/8]

```
& Diesel::minimum_load_ratio def_readwrite (
             "minimum_runtime_hrs" ,
             &Diesel::minimum_runtime_hrs  )
```

#### 5.23.2.7 def_readwrite() [6/8]

```
& DieselInputs::combustion_inputs & DieselInputs::capital_cost & DieselInputs::fuel_cost_L &
DieselInputs::minimum_runtime_hrs & DieselInputs::linear_fuel_intercept_LkWh & DieselInputs::CO_emissions_inte
def_readwrite (
             "NOx_emissions_intensity_kgL" ,
             &DieselInputs::NOx_emissions_intensity_kgL  )
```

#### 5.23.2.8 def_readwrite() [7/8]

```
& DieselInputs::combustion_inputs & DieselInputs::capital_cost def_readwrite (
             "operation_maintenance_cost_kWh" ,
             &DieselInputs::operation_maintenance_cost_kWh  )
```

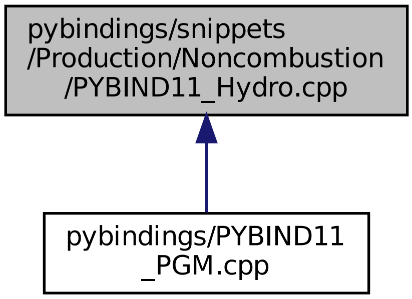
#### 5.23.2.9 def_readwrite() [8/8]

```
& DieselInputs::combustion_inputs def_readwrite (
             "replace_running_hrs" ,
             &DieselInputs::replace_running_hrs  )
```

## 5.24 pybindings/snippets/Production/Noncombustion/PYBIND11_Hydro.cpp File Reference

Bindings file for the Hydro class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:




### Functions

- HydroTurbineType::HYDRO_TURBINE_PELTON value ("HYDRO_TURBINE_FRANCIS", HydroTurbineType::HYDRO_TURBINE_FRANCIS) .value("HYDRO_TURBINE_KAPLAN"
- HydroTurbineType::HYDRO_TURBINE_PELTON HydroTurbineType::HYDRO_TURBINE_KAPLAN value ("N_HYDRO_TURBINES", HydroTurbineType::N_HYDRO_TURBINES)
- &HydroInputs::noncombustion_inputs def_readwrite ("resource_key", &HydroInputs::resource_key) .def_readwrite("capital_cost"
- &HydroInputs::noncombustion_inputs &HydroInputs::capital_cost def_readwrite ("operation_maintenance_cost_kWh", &HydroInputs::operation_maintenance_cost_kWh) .def_readwrite("fluid_density_kgm3"
- &HydroInputs::noncombustion_inputs &HydroInputs::capital_cost &HydroInputs::fluid_density_kgm3 def_readwrite ("net_head_m", &HydroInputs::net_head_m) .def_readwrite("reservoir_capacity_m3"
- &HydroInputs::noncombustion_inputs &HydroInputs::capital_cost &HydroInputs::fluid_density_kgm3 &HydroInputs::reservoir_capacity_m3 def_readwrite ("init_reservoir_state", &HydroInputs::init_reservoir_state) .def_readwrite("turbine_type"
- &HydroInputs::noncombustion_inputs &HydroInputs::capital_cost &HydroInputs::fluid_density_kgm3 &HydroInputs::reservoir_capacity_m3 &HydroInputs::turbine_type def (pybind11::init())
- &Hydro::turbine_type def_readwrite ("fluid_density_kgm3", &Hydro::fluid_density_kgm3) .def_readwrite("net_head_m"
- &Hydro::turbine_type &Hydro::net_head_m def_readwrite ("reservoir_capacity_m3", &Hydro::reservoir_capacity_m3) .def_readwrite("init_reservoir_state"
- &Hydro::turbine_type &Hydro::net_head_m &Hydro::init_reservoir_state def_readwrite ("stored_volume_m3", &Hydro::stored_volume_m3) .def_readwrite("minimum_power_kW"
- &Hydro::turbine_type &Hydro::net_head_m &Hydro::init_reservoir_state &Hydro::minimum_power_kW def_readwrite ("minimum_flow_m3hr", &Hydro::minimum_flow_m3hr) .def_readwrite("maximum_flow_m3hr"
- &Hydro::turbine_type &Hydro::net_head_m &Hydro::init_reservoir_state &Hydro::minimum_power_kW &Hydro::maximum_flow_m3hr def_readwrite ("turbine_flow_vec_m3hr", &Hydro::turbine_flow_vec_m3hr) .def_readwrite("spill_rate_vec_m3hr"

### 5.24.1 Detailed Description

Bindings file for the Hydro class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Hydro class. Only public attributes/methods are bound!

### 5.24.2 Function Documentation

#### 5.24.2.1 def()

```
& HydroInputs::noncombustion_inputs & HydroInputs::capital_cost & HydroInputs::fluid_density_kgm3
& HydroInputs::reservoir_capacity_m3 & HydroInputs::turbine_type def (
            pybind11::init() )
```

#### 5.24.2.2 def_readwrite() [1/9]

```
& Hydro::turbine_type def_readwrite (
            "fluid_density_kgm3" ,
            &Hydro::fluid_density_kgm3 )
```

#### 5.24.2.3 def_readwrite() [2/9]

```
& HydroInputs::noncombustion_inputs & HydroInputs::capital_cost & HydroInputs::fluid_density_kgm3
& HydroInputs::reservoir_capacity_m3 def_readwrite (
            "init_reservoir_state" ,
            &HydroInputs::init_reservoir_state )
```

#### 5.24.2.4 def_readwrite() [3/9]

```
& Hydro::turbine_type & Hydro::net_head_m & Hydro::init_reservoir_state & Hydro::minimum_power_kW
def_readwrite (
            "minimum_flow_m3hr" ,
            &Hydro::minimum_flow_m3hr )
```

#### 5.24.2.5 def_readwrite() [4/9]

```
& HydroInputs::noncombustion_inputs & HydroInputs::capital_cost & HydroInputs::fluid_density_kgm3
def_readwrite (
            "net_head_m" ,
            &HydroInputs::net_head_m )
```

#### 5.24.2.6 def_readwrite() [5/9]

```
& HydroInputs::noncombustion_inputs & HydroInputs::capital_cost def_readwrite (
            "operation_maintenance_cost_kWh" ,
            &HydroInputs::operation_maintenance_cost_kWh )
```

#### 5.24.2.7 def_readwrite() [6/9]

```
& Hydro::turbine_type & Hydro::net_head_m def_readwrite (
            "reservoir_capacity_m3" ,
            &Hydro::reservoir_capacity_m3 )
```

#### 5.24.2.8 def_readwrite() [7/9]

```
& HydroInputs::noncombustion_inputs def_readwrite (
            "resource_key" ,
            &HydroInputs::resource_key )
```

#### 5.24.2.9 def_readwrite() [8/9]

```
& Hydro::turbine_type & Hydro::net_head_m & Hydro::init_reservoir_state def_readwrite (
            "stored_volume_m3" ,
            &Hydro::stored_volume_m3 )
```

#### 5.24.2.10 def_readwrite() [9/9]

```
& Hydro::turbine_type & Hydro::net_head_m & Hydro::init_reservoir_state & Hydro::minimum_power_kW
& Hydro::maximum_flow_m3hr def_readwrite (
            "turbine_flow_vec_m3hr" ,
            &Hydro::turbine_flow_vec_m3hr )
```

#### 5.24.2.11 value() [1/2]

```
HydroTurbineType::HYDRO_TURBINE_PELTON value (
            "HYDRO_TURBINE_FRANCIS" ,
            HydroTurbineType::HYDRO_TURBINE_FRANCIS  )
```

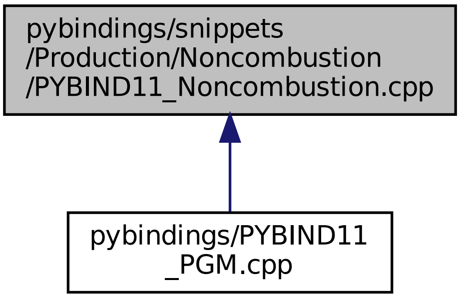
#### 5.24.2.12 value() [2/2]

```
HydroTurbineType::HYDRO_TURBINE_PELTON HydroTurbineType::HYDRO_TURBINE_KAPLAN value (
            "N_HYDRO_TURBINES" ,
            HydroTurbineType::N_HYDRO_TURBINES  )
```

## 5.25 pybindings/snippets/Production/Noncombustion/PYBIND11_↩ Noncombustion.cpp File Reference

Bindings file for the Noncombustion class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:




### Functions

- NoncombustionType::HYDRO value ("N_NONCOMBUSTION_TYPES", NoncombustionType::N_↩ NONCOMBUSTION_TYPES)
- &NoncombustionInputs::production_inputs def (pybind11::init())

### 5.25.1 Detailed Description

Bindings file for the Noncombustion class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Noncombustion class. Only public attributes/methods are bound!

### 5.25.2 Function Documentation

#### 5.25.2.1 def()

```
& NoncombustionInputs::production_inputs def (
            pybind11::init()   )
```

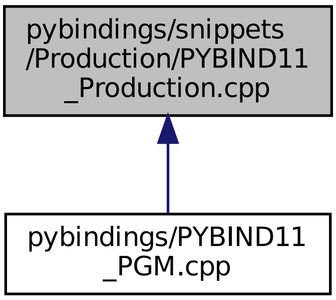
#### 5.25.2.2 value()

```
NoncombustionType::HYDRO value (
            "N_NONCOMBUSTION_TYPES" ,
            NoncombustionType::N_NONCOMBUSTION_TYPES   )
```

## 5.26 pybindings/snippets/Production/PYBIND11_Production.cpp File Reference

Bindings file for the Production class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:



## Functions

- &ProductionInputs::print_flag def_readwrite ("is_sunk", &ProductionInputs::is_sunk) .def_readwrite("capacity↩ _kW"
- &ProductionInputs::print_flag &ProductionInputs::capacity_kW def_readwrite ("nominal_inflation_annual", &ProductionInputs::nominal_inflation_annual) .def_readwrite("nominal_discount_annual"
- &ProductionInputs::print_flag &ProductionInputs::capacity_kW &ProductionInputs::nominal_discount_annual def_readwrite ("replace_running_hrs", &ProductionInputs::replace_running_hrs) .def_readwrite("path_2_↩ normalized_production_time_series"
- &ProductionInputs::print_flag &ProductionInputs::capacity_kW &ProductionInputs::nominal_discount_annual &ProductionInputs::path_2_normalized_production_time_series def (pybind11::init())
- &Production::interpolator def_readwrite ("print_flag", &Production::print_flag) .def_readwrite("is_running"
- &Production::interpolator &Production::is_running def_readwrite ("is_sunk", &Production::is_sunk) .def_↩ readwrite("normalized_production_series_given"
- &Production::interpolator &Production::is_running &Production::normalized_production_series_given def_readwrite ("n_points", &Production::n_points) .def_readwrite("n_starts"
- &Production::interpolator &Production::is_running &Production::normalized_production_series_given &Production::n_starts def_readwrite ("n_replacements", &Production::n_replacements) .def_readwrite("n_↩ years"
- &Production::interpolator &Production::is_running &Production::normalized_production_series_given &Production::n_starts &Production::n_years def_readwrite ("running_hours", &Production::running_hours) .def_readwrite("replace_running_hrs"
- &Production::interpolator &Production::is_running &Production::normalized_production_series_given &Production::n_starts &Production::n_years &Production::replace_running_hrs def_readwrite ("capacity_↩ kW", &Production::capacity_kW) .def_readwrite("nominal_inflation_annual"
- &Production::interpolator &Production::is_running &Production::normalized_production_series_given &Production::n_starts &Production::n_years &Production::replace_running_hrs &Production::nominal_inflation_annual def_readwrite ("nominal_discount_annual", &Production::nominal_discount_annual) .def_readwrite("real_↩ discount_annual"
- &Production::interpolator &Production::is_running &Production::normalized_production_series_given &Production::n_starts &Production::n_years &Production::replace_running_hrs &Production::nominal_inflation_annual &Production::real_discount_annual def_readwrite ("capital_cost", &Production::capital_cost) .def_↩ readwrite("operation_maintenance_cost_kWh"
- &Production::interpolator &Production::is_running &Production::normalized_production_series_given &Production::n_starts &Production::n_years &Production::replace_running_hrs &Production::nominal_inflation_annual &Production::real_discount_annual &Production::operation_maintenance_cost_kWh def_readwrite ("net_↩ present_cost", &Production::net_present_cost) .def_readwrite("total_dispatch_kWh"
- &Production::interpolator &Production::is_running &Production::normalized_production_series_given &Production::n_starts &Production::n_years &Production::replace_running_hrs &Production::nominal_inflation_annual &Production::real_discount_annual &Production::operation_maintenance_cost_kWh &Production::total_dispatch_kWh def_readwrite ("levellized_cost_of_energy_kWh", &Production::levellized_cost_of_energy_kWh) .def_↩ readwrite("type_str"
- &Production::interpolator &Production::is_running &Production::normalized_production_series_given &Production::n_starts &Production::n_years &Production::replace_running_hrs &Production::nominal_inflation_annual &Production::real_discount_annual &Production::operation_maintenance_cost_kWh &Production::total_dispatch_kWh &Production::type_str def_readwrite ("path_2_normalized_production_time_series", &Production::path_2_↩ normalized_production_time_series) .def_readwrite("is_running_vec"
- &Production::interpolator &Production::is_running &Production::normalized_production_series_given &Production::n_starts &Production::n_years &Production::replace_running_hrs &Production::nominal_inflation_annual &Production::real_discount_annual &Production::operation_maintenance_cost_kWh &Production::total_dispatch_kWh &Production::type_str &Production::is_running_vec def_readwrite ("normalized_production_vec", &Production↩ ::normalized_production_vec) .def_readwrite("production_vec_kW"
- &Production::interpolator &Production::is_running &Production::normalized_production_series_given &Production::n_starts &Production::n_years &Production::replace_running_hrs &Production::nominal_inflation_annual &Production::real_discount_annual &Production::operation_maintenance_cost_kWh &Production::total_dispatch_kWh &Production::type_str &Production::is_running_vec &Production::production_vec_kW def_readwrite ("dispatch_vec_kW", &Production::dispatch_vec_kW) .def_readwrite("storage_vec_kW"

- &Production::interpolator &Production::is_running &Production::normalized_production_series_given &Production::n_starts &Production::n_years &Production::replace_running_hrs &Production::nominal_inflation_annual &Production::real_discount_annual &Production::operation_maintenance_cost_kWh &Production::total_dispatch_kWh &Production::type_str &Production::is_running_vec &Production::production_vec_kW &Production::storage_vec_kW def_readwrite ("curtailment_vec_kW", &Production::curtailment_vec_kW) .def_readwrite("capital_cost_vec"

### 5.26.1 Detailed Description

Bindings file for the Production class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Production class. Only public attributes/methods are bound!

### 5.26.2 Function Documentation

#### 5.26.2.1 def()

```
& ProductionInputs::print_flag & ProductionInputs::capacity_kW & ProductionInputs::nominal_discount_annual
& ProductionInputs::path_2_normalized_production_time_series def (
            pybind11::init()  )
```

#### 5.26.2.2 def_readwrite() [1/17]

```
& Production::interpolator & Production::is_running & Production::normalized_production_series_given
& Production::n_starts & Production::n_years & Production::replace_running_hrs def_readwrite (
            "capacity_kW" ,
            &Production::capacity_kW  )
```

#### 5.26.2.3 def_readwrite() [2/17]

```
& Production::interpolator & Production::is_running & Production::normalized_production_series_given
& Production::n_starts & Production::n_years & Production::replace_running_hrs & Production::nominal_inflatior
& Production::real_discount_annual def_readwrite (
            "capital_cost" ,
            &Production::capital_cost  )
```

#### 5.26.2.4 def_readwrite() [3/17]

```
& Production::interpolator & Production::is_running & Production::normalized_production_series_given
& Production::n_starts & Production::n_years & Production::replace_running_hrs & Production::nominal_inflatior
& Production::real_discount_annual & Production::operation_maintenance_cost_kWh & Production::total_dispatch_k
& Production::type_str & Production::is_running_vec & Production::production_vec_kW & Production::storage_vec_
def_readwrite (
            "curtailment_vec_kW" ,
            &Production::curtailment_vec_kW )
```

#### 5.26.2.5 def_readwrite() [4/17]

```
& Production::interpolator & Production::is_running & Production::normalized_production_series_given
& Production::n_starts & Production::n_years & Production::replace_running_hrs & Production::nominal_inflatior
& Production::real_discount_annual & Production::operation_maintenance_cost_kWh & Production::total_dispatch_k
& Production::type_str & Production::is_running_vec & Production::production_vec_kW def_←
readwrite (
            "dispatch_vec_kW" ,
            &Production::dispatch_vec_kW )
```

#### 5.26.2.6 def_readwrite() [5/17]

```
& Production::interpolator & Production::is_running def_readwrite (
            "is_sunk" ,
            &Production::is_sunk )
```

#### 5.26.2.7 def_readwrite() [6/17]

```
& ProductionInputs::print_flag def_readwrite (
            "is_sunk" ,
            &ProductionInputs::is_sunk )
```

#### 5.26.2.8 def_readwrite() [7/17]

```
& Production::interpolator & Production::is_running & Production::normalized_production_series_given
& Production::n_starts & Production::n_years & Production::replace_running_hrs & Production::nominal_inflatior
& Production::real_discount_annual & Production::operation_maintenance_cost_kWh & Production::total_dispatch_k
def_readwrite (
            "levellized_cost_of_energy_kWh" ,
            &Production::levellized_cost_of_energy_kWh )
```

#### 5.26.2.9 def_readwrite() [8/17]

```
& Production::interpolator & Production::is_running & Production::normalized_production_series_given
def_readwrite (
             "n_points" ,
             &Production::n_points  )
```

#### 5.26.2.10 def_readwrite() [9/17]

```
& Production::interpolator & Production::is_running & Production::normalized_production_series_given
& Production::n_starts def_readwrite (
             "n_replacements" ,
             &Production::n_replacements  )
```

#### 5.26.2.11 def_readwrite() [10/17]

```
& Production::interpolator & Production::is_running & Production::normalized_production_series_given
& Production::n_starts & Production::n_years & Production::replace_running_hrs & Production::nominal_inflatio
& Production::real_discount_annual & Production::operation_maintenance_cost_kWh def_readwrite
(
             "net_present_cost" ,
             &Production::net_present_cost  )
```

#### 5.26.2.12 def_readwrite() [11/17]

```
& Production::interpolator & Production::is_running & Production::normalized_production_series_given
& Production::n_starts & Production::n_years & Production::replace_running_hrs & Production::nominal_inflatio
def_readwrite (
             "nominal_discount_annual" ,
             &Production::nominal_discount_annual  )
```

#### 5.26.2.13 def_readwrite() [12/17]

```
& ProductionInputs::print_flag & ProductionInputs::capacity_kW def_readwrite (
             "nominal_inflation_annual" ,
             &ProductionInputs::nominal_inflation_annual  )
```

#### 5.26.2.14 def_readwrite() [13/17]

```
& Production::interpolator & Production::is_running & Production::normalized_production_series_given
& Production::n_starts & Production::n_years & Production::replace_running_hrs & Production::nominal_inflatior
& Production::real_discount_annual & Production::operation_maintenance_cost_kWh & Production::total_dispatch_k
& Production::type_str & Production::is_running_vec def_readwrite (
            "normalized_production_vec" ,
            &Production::normalized_production_vec )
```

#### 5.26.2.15 def_readwrite() [14/17]

```
& Production::interpolator & Production::is_running & Production::normalized_production_series_given
& Production::n_starts & Production::n_years & Production::replace_running_hrs & Production::nominal_inflatior
& Production::real_discount_annual & Production::operation_maintenance_cost_kWh & Production::total_dispatch_k
& Production::type_str def_readwrite (
            "path_2_normalized_production_time_series" ,
            &Production::path_2_normalized_production_time_series )
```

#### 5.26.2.16 def_readwrite() [15/17]

```
& Production::interpolator def_readwrite (
            "print_flag" ,
            &Production::print_flag )
```

#### 5.26.2.17 def_readwrite() [16/17]

```
& ProductionInputs::print_flag & ProductionInputs::capacity_kW & ProductionInputs::nominal_discount_annual
def_readwrite (
            "replace_running_hrs" ,
            &ProductionInputs::replace_running_hrs )
```

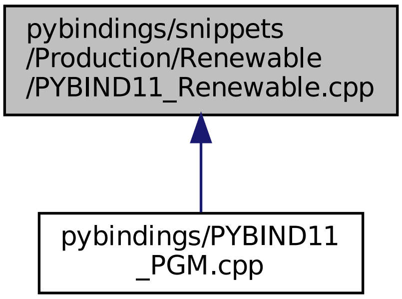
#### 5.26.2.18 def_readwrite() [17/17]

```
& Production::interpolator & Production::is_running & Production::normalized_production_series_given
& Production::n_starts & Production::n_years def_readwrite (
            "running_hours" ,
            &Production::running_hours )
```

## 5.27 pybindings/snippets/Production/Renewable/PYBIND11_Renewable.cpp File Reference

Bindings file for the Renewable class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:




### Functions

- RenewableType::SOLAR value ("TIDAL", RenewableType::TIDAL) .value("WAVE"
- RenewableType::SOLAR RenewableType::WAVE value ("WIND", RenewableType::WIND) .value("N_RENEWABLE_TYPES"
- &RenewableInputs::production_inputs def (pybind11::init())
- &Renewable::type def_readwrite ("resource_key", &Renewable::resource_key) .def_readwrite("firmness_factor"

### 5.27.1 Detailed Description

Bindings file for the Renewable class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Renewable class. Only public attributes/methods are bound!

### 5.27.2 Function Documentation

#### 5.27.2.1 def()

```
& RenewableInputs::production_inputs def (
            pybind11::init()  )
```

#### 5.27.2.2 def_readwrite()

```
& Renewable::type def_readwrite (
            "resource_key" ,
            &Renewable::resource_key )
```

#### 5.27.2.3 value() [1/2]

```
RenewableType::SOLAR value (
            "TIDAL" ,
            RenewableType::TIDAL )
```

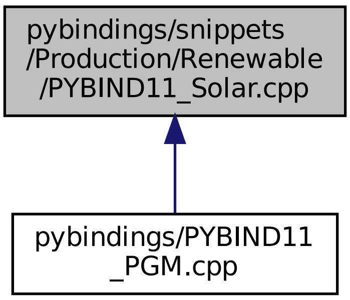
#### 5.27.2.4 value() [2/2]

```
RenewableType::SOLAR RenewableType::WAVE value (
            "WIND" ,
            RenewableType::WIND )
```

## 5.28 pybindings/snippets/Production/Renewable/PYBIND11_Solar.cpp File Reference

Bindings file for the Solar class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:



## Functions

- SolarPowerProductionModel::SOLAR_POWER_SIMPLE value ("SOLAR_POWER_DETAILED", Solar↩PowerProductionModel::SOLAR_POWER_DETAILED) .value("N_SOLAR_POWER_PRODUCTION_↩MODELS"
- &SolarInputs::renewable_inputs def_readwrite ("resource_key", &SolarInputs::resource_key) .def_↩readwrite("firmness_factor"
- &SolarInputs::renewable_inputs &SolarInputs::firmness_factor def_readwrite ("capital_cost", &SolarInputs↩::capital_cost) .def_readwrite("operation_maintenance_cost_kWh"
- &SolarInputs::renewable_inputs &SolarInputs::firmness_factor &SolarInputs::operation_maintenance_cost_kWh def_readwrite ("derating", &SolarInputs::derating) .def_readwrite("julian_day"
- &SolarInputs::renewable_inputs &SolarInputs::firmness_factor &SolarInputs::operation_maintenance_cost_kWh &SolarInputs::julian_day def_readwrite ("latitude_deg", &SolarInputs::latitude_deg) .def_readwrite("longitude↩_deg"
- &SolarInputs::renewable_inputs &SolarInputs::firmness_factor &SolarInputs::operation_maintenance_cost_kWh &SolarInputs::julian_day &SolarInputs::longitude_deg def_readwrite ("panel_azimuth_deg", &SolarInputs↩::panel_azimuth_deg) .def_readwrite("panel_tilt_deg"
- &SolarInputs::renewable_inputs &SolarInputs::firmness_factor &SolarInputs::operation_maintenance_cost_kWh &SolarInputs::julian_day &SolarInputs::longitude_deg &SolarInputs::panel_tilt_deg def_readwrite ("albedo↩_ground_reflectance", &SolarInputs::albedo_ground_reflectance) .def_readwrite("power_model"
- &SolarInputs::renewable_inputs &SolarInputs::firmness_factor &SolarInputs::operation_maintenance_cost_kWh &SolarInputs::julian_day &SolarInputs::longitude_deg &SolarInputs::panel_tilt_deg &SolarInputs::power_model def (pybind11::init())
- &Solar::derating def_readwrite ("power_model", &Solar::power_model) .def_readwrite("power_model_string"

## 5.28.1 Detailed Description

Bindings file for the Solar class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Solar class. Only public attributes/methods are bound!

## 5.28.2 Function Documentation

### 5.28.2.1 def()

```
& SolarInputs::renewable_inputs & SolarInputs::firmness_factor & SolarInputs::operation_maintenance_cost_kWh
& SolarInputs::julian_day & SolarInputs::longitude_deg & SolarInputs::panel_tilt_deg & SolarInputs::power_mode
def (
            pybind11::init() )
```

### 5.28.2.2 def_readwrite() [1/7]

```
& SolarInputs::renewable_inputs & SolarInputs::firmness_factor & SolarInputs::operation_maintenance_cost_kWh
& SolarInputs::julian_day & SolarInputs::longitude_deg & SolarInputs::panel_tilt_deg def_↩
readwrite (
            "albedo_ground_reflectance" ,
            &SolarInputs::albedo_ground_reflectance )
```

#### 5.28.2.3 def_readwrite() [2/7]

```
& SolarInputs::renewable_inputs & SolarInputs::firmness_factor def_readwrite (
            "capital_cost" ,
            &SolarInputs::capital_cost )
```

#### 5.28.2.4 def_readwrite() [3/7]

```
& SolarInputs::renewable_inputs & SolarInputs::firmness_factor & SolarInputs::operation_maintenance_cost_kWh
def_readwrite (
            "derating" ,
            &SolarInputs::derating )
```

#### 5.28.2.5 def_readwrite() [4/7]

```
& SolarInputs::renewable_inputs & SolarInputs::firmness_factor & SolarInputs::operation_maintenance_cost_kWh
& SolarInputs::julian_day def_readwrite (
            "latitude_deg" ,
            &SolarInputs::latitude_deg )
```

#### 5.28.2.6 def_readwrite() [5/7]

```
& SolarInputs::renewable_inputs & SolarInputs::firmness_factor & SolarInputs::operation_maintenance_cost_kWh
& SolarInputs::julian_day & SolarInputs::longitude_deg def_readwrite (
            "panel_azimuth_deg" ,
            &SolarInputs::panel_azimuth_deg )
```

#### 5.28.2.7 def_readwrite() [6/7]

```
& Solar::derating def_readwrite (
            "power_model" ,
            &Solar::power_model )
```

#### 5.28.2.8 def_readwrite() [7/7]

```
& SolarInputs::renewable_inputs def_readwrite (
            "resource_key" ,
            &SolarInputs::resource_key )
```

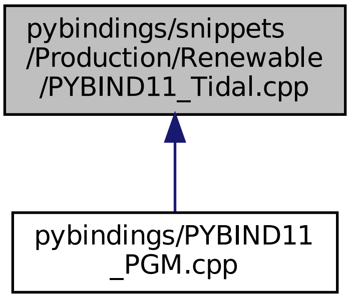
#### 5.28.2.9 value()

```
SolarPowerProductionModel::SOLAR_POWER_SIMPLE value (
            "SOLAR_POWER_DETAILED" ,
            SolarPowerProductionModel::SOLAR_POWER_DETAILED  )
```

## 5.29 pybindings/snippets/Production/Renewable/PYBIND11_Tidal.cpp File Reference

Bindings file for the Tidal class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:




### Functions

- TidalPowerProductionModel::TIDAL_POWER_CUBIC value ("TIDAL_POWER_EXPONENTIAL", Tidal←PowerProductionModel::TIDAL_POWER_EXPONENTIAL) .value("TIDAL_POWER_LOOKUP"
- TidalPowerProductionModel::TIDAL_POWER_CUBIC TidalPowerProductionModel::TIDAL_POWER_LOOKUP value ("N_TIDAL_POWER_PRODUCTION_MODELS", TidalPowerProductionModel::N_TIDAL_POWER_←PRODUCTION_MODELS)
- &TidalInputs::renewable_inputs def_readwrite ("resource_key", &TidalInputs::resource_key) .def_←readwrite("firmness_factor"
- &TidalInputs::renewable_inputs &TidalInputs::firmness_factor def_readwrite ("capital_cost", &TidalInputs←::capital_cost) .def_readwrite("operation_maintenance_cost_kWh"
- &TidalInputs::renewable_inputs &TidalInputs::firmness_factor &TidalInputs::operation_maintenance_cost_kWh def_readwrite ("design_speed_ms", &TidalInputs::design_speed_ms) .def_readwrite("power_model"
- &TidalInputs::renewable_inputs &TidalInputs::firmness_factor &TidalInputs::operation_maintenance_cost_kWh &TidalInputs::power_model def (pybind11::init())
- &Tidal::design_speed_ms def_readwrite ("power_model", &Tidal::power_model) .def_readwrite("power_←model_string"

### 5.29.1 Detailed Description

Bindings file for the Tidal class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Tidal class. Only public attributes/methods are bound!

### 5.29.2 Function Documentation

#### 5.29.2.1 def()

```
& TidalInputs::renewable_inputs & TidalInputs::firmness_factor & TidalInputs::operation_maintenance_cost_kWh
& TidalInputs::power_model def (
            pybind11::init()  )
```

#### 5.29.2.2 def_readwrite() [1/4]

```
& TidalInputs::renewable_inputs & TidalInputs::firmness_factor def_readwrite (
            "capital_cost" ,
            &TidalInputs::capital_cost  )
```

#### 5.29.2.3 def_readwrite() [2/4]

```
& TidalInputs::renewable_inputs & TidalInputs::firmness_factor & TidalInputs::operation_maintenance_cost_kWh
def_readwrite (
            "design_speed_ms" ,
            &TidalInputs::design_speed_ms  )
```

#### 5.29.2.4 def_readwrite() [3/4]

```
& Tidal::design_speed_ms def_readwrite (
            "power_model" ,
            &Tidal::power_model  )
```

#### 5.29.2.5 def_readwrite() [4/4]

```
& TidalInputs::renewable_inputs def_readwrite (
            "resource_key" ,
            &TidalInputs::resource_key )
```

#### 5.29.2.6 value() [1/2]

```
TidalPowerProductionModel::TIDAL_POWER_CUBIC TidalPowerProductionModel::TIDAL_POWER_LOOKUP
value (
            "N_TIDAL_POWER_PRODUCTION_MODELS" ,
            TidalPowerProductionModel::N_TIDAL_POWER_PRODUCTION_MODELS )
```

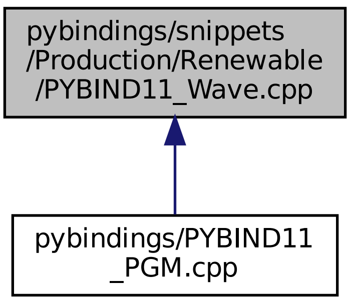
#### 5.29.2.7 value() [2/2]

```
TidalPowerProductionModel::TIDAL_POWER_CUBIC value (
            "TIDAL_POWER_EXPONENTIAL" ,
            TidalPowerProductionModel::TIDAL_POWER_EXPONENTIAL )
```

## 5.30 pybindings/snippets/Production/Renewable/PYBIND11_Wave.cpp File Reference

Bindings file for the Wave class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:



## Functions

- WavePowerProductionModel::WAVE_POWER_GAUSSIAN value ("WAVE_POWER_PARABOLOID", WavePowerProductionModel::WAVE_POWER_PARABOLOID) .value("WAVE_POWER_LOOKUP"
- WavePowerProductionModel::WAVE_POWER_GAUSSIAN WavePowerProductionModel::WAVE_POWER_LOOKUP value ("N_WAVE_POWER_PRODUCTION_MODELS", WavePowerProductionModel::N_WAVE_POWER↩_PRODUCTION_MODELS)
- &WaveInputs::renewable_inputs def_readwrite ("resource_key", &WaveInputs::resource_key) .def_↩readwrite("firmness_factor"
- &WaveInputs::renewable_inputs &WaveInputs::firmness_factor def_readwrite ("capital_cost", &Wave↩Inputs::capital_cost) .def_readwrite("operation_maintenance_cost_kWh"
- &WaveInputs::renewable_inputs &WaveInputs::firmness_factor &WaveInputs::operation_maintenance_cost_kWh def_readwrite ("design_significant_wave_height_m", &WaveInputs::design_significant_wave_height_m) .def_readwrite("design_energy_period_s"
- &WaveInputs::renewable_inputs &WaveInputs::firmness_factor &WaveInputs::operation_maintenance_cost_kWh &WaveInputs::design_energy_period_s def_readwrite ("power_model", &WaveInputs::power_model) .def_↩readwrite("path_2_normalized_performance_matrix"
- &WaveInputs::renewable_inputs &WaveInputs::firmness_factor &WaveInputs::operation_maintenance_cost_kWh &WaveInputs::design_energy_period_s &WaveInputs::path_2_normalized_performance_matrix def (pybind11↩::init())
- &Wave::design_significant_wave_height_m def_readwrite ("design_energy_period_s", &Wave::design_↩energy_period_s) .def_readwrite("power_model"

### 5.30.1 Detailed Description

Bindings file for the Wave class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Wave class. Only public attributes/methods are bound!

### 5.30.2 Function Documentation

#### 5.30.2.1 def()

```
& WaveInputs::renewable_inputs & WaveInputs::firmness_factor & WaveInputs::operation_maintenance_cost_kWh
& WaveInputs::design_energy_period_s & WaveInputs::path_2_normalized_performance_matrix def (
            pybind11::init()  )
```

#### 5.30.2.2 def_readwrite() [1/5]

```
& WaveInputs::renewable_inputs & WaveInputs::firmness_factor def_readwrite (
            "capital_cost" ,
            &WaveInputs::capital_cost  )
```

#### 5.30.2.3 def_readwrite() [2/5]

```
& Wave::design_significant_wave_height_m def_readwrite (
            "design_energy_period_s" ,
            &Wave::design_energy_period_s )
```

#### 5.30.2.4 def_readwrite() [3/5]

```
& WaveInputs::renewable_inputs & WaveInputs::firmness_factor & WaveInputs::operation_maintenance_cost_kWh
def_readwrite (
            "design_significant_wave_height_m" ,
            &WaveInputs::design_significant_wave_height_m )
```

#### 5.30.2.5 def_readwrite() [4/5]

```
& WaveInputs::renewable_inputs & WaveInputs::firmness_factor & WaveInputs::operation_maintenance_cost_kWh
& WaveInputs::design_energy_period_s def_readwrite (
            "power_model" ,
            &WaveInputs::power_model )
```

#### 5.30.2.6 def_readwrite() [5/5]

```
& WaveInputs::renewable_inputs def_readwrite (
            "resource_key" ,
            &WaveInputs::resource_key )
```

#### 5.30.2.7 value() [1/2]

```
WavePowerProductionModel::WAVE_POWER_GAUSSIAN WavePowerProductionModel::WAVE_POWER_LOOKUP
value (
            "N_WAVE_POWER_PRODUCTION_MODELS" ,
            WavePowerProductionModel::N_WAVE_POWER_PRODUCTION_MODELS )
```

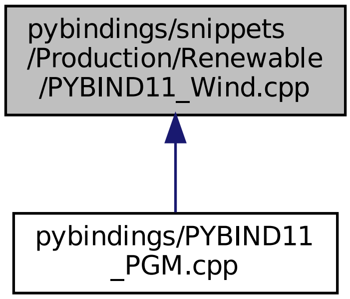
#### 5.30.2.8 value() [2/2]

```
WavePowerProductionModel::WAVE_POWER_GAUSSIAN value (
            "WAVE_POWER_PARABOLOID" ,
            WavePowerProductionModel::WAVE_POWER_PARABOLOID )
```

## 5.31 pybindings/snippets/Production/Renewable/PYBIND11_Wind.cpp File Reference

Bindings file for the Wind class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:




### Functions

- WindPowerProductionModel::WIND_POWER_CUBIC value ("WIND_POWER_EXPONENTIAL", WindPowerProductionModel::WIND_POWER_EXPONENTIAL) .value("WIND_POWER_LOOKUP"
- WindPowerProductionModel::WIND_POWER_CUBIC WindPowerProductionModel::WIND_POWER_LOOKUP value ("N_WIND_POWER_PRODUCTION_MODELS", WindPowerProductionModel::N_WIND_POWER_PRODUCTION_MODELS)
- &WindInputs::renewable_inputs def_readwrite ("resource_key", &WindInputs::resource_key) .def_readwrite("firmness_factor"
- &WindInputs::renewable_inputs &WindInputs::firmness_factor def_readwrite ("capital_cost", &WindInputs::capital_cost) .def_readwrite("operation_maintenance_cost_kWh"
- &WindInputs::renewable_inputs &WindInputs::firmness_factor &WindInputs::operation_maintenance_cost_kWh def_readwrite ("design_speed_ms", &WindInputs::design_speed_ms) .def_readwrite("power_model"
- &WindInputs::renewable_inputs &WindInputs::firmness_factor &WindInputs::operation_maintenance_cost_kWh &WindInputs::power_model def (pybind11::init())
- &Wind::design_speed_ms def_readwrite ("power_model", &Wind::power_model) .def_readwrite("power_model_string"

### 5.31.1 Detailed Description

Bindings file for the Wind class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Wind class. Only public attributes/methods are bound!

## 5.31.2 Function Documentation

### 5.31.2.1 def()

```
& WindInputs::renewable_inputs & WindInputs::firmness_factor & WindInputs::operation_maintenance_cost_kWh
& WindInputs::power_model def (
            pybind11::init() )
```

### 5.31.2.2 def_readwrite() [1/4]

```
& WindInputs::renewable_inputs & WindInputs::firmness_factor def_readwrite (
            "capital_cost" ,
            &WindInputs::capital_cost )
```

### 5.31.2.3 def_readwrite() [2/4]

```
& WindInputs::renewable_inputs & WindInputs::firmness_factor & WindInputs::operation_maintenance_cost_kWh
def_readwrite (
            "design_speed_ms" ,
            &WindInputs::design_speed_ms )
```

### 5.31.2.4 def_readwrite() [3/4]

```
& Wind::design_speed_ms def_readwrite (
            "power_model" ,
            &Wind::power_model )
```

### 5.31.2.5 def_readwrite() [4/4]

```
& WindInputs::renewable_inputs def_readwrite (
            "resource_key" ,
            &WindInputs::resource_key )
```

#### 5.31.2.6 value() [1/2]

```
WindPowerProductionModel::WIND_POWER_CUBIC WindPowerProductionModel::WIND_POWER_LOOKUP value (
            "N_WIND_POWER_PRODUCTION_MODELS" ,
            WindPowerProductionModel::N_WIND_POWER_PRODUCTION_MODELS  )
```

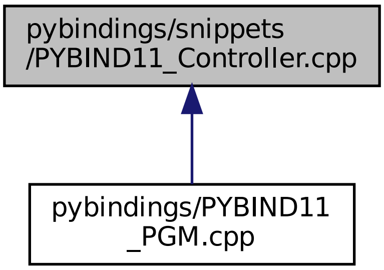
#### 5.31.2.7 value() [2/2]

```
WindPowerProductionModel::WIND_POWER_CUBIC value (
            "WIND_POWER_EXPONENTIAL" ,
            WindPowerProductionModel::WIND_POWER_EXPONENTIAL  )
```

## 5.32 pybindings/snippets/PYBIND11_Controller.cpp File Reference

Bindings file for the Controller class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:




### Functions

- ControlMode::LOAD_FOLLOWING value ("CYCLE_CHARGING", ControlMode::CYCLE_CHARGING) .value("N_CONTROL_MODES"
- &Controller::control_mode def_readwrite ("control_string", &Controller::control_string) .def_readwrite("load←_operating_reserve_factor"
- &Controller::control_mode &Controller::load_operating_reserve_factor def_readwrite ("max_operating_←reserve_factor", &Controller::max_operating_reserve_factor) .def_readwrite("net_load_vec_kW"
- &Controller::control_mode &Controller::load_operating_reserve_factor &Controller::net_load_vec_kW def_readwrite ("missed_load_vec_kW", &Controller::missed_load_vec_kW) .def_readwrite("combustion←_map"
- &Controller::control_mode &Controller::load_operating_reserve_factor &Controller::net_load_vec_kW &Controller::combustion_map def (pybind11::init<>()) .def("setControlMode"
- &Controller::control_mode &Controller::load_operating_reserve_factor &Controller::net_load_vec_kW &Controller::combustion_map &Controller::setControlMode def ("init", &Controller::init) .def("applyDispatch←Control"
- &Controller::control_mode &Controller::load_operating_reserve_factor &Controller::net_load_vec_kW &Controller::combustion_map &Controller::setControlMode &Controller::applyDispatchControl def ("clear", &Controller::clear)

## 5.32.1 Detailed Description

Bindings file for the Controller class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Controller class. Only public attributes/methods are bound!

## 5.32.2 Function Documentation

### 5.32.2.1 def() [1/3]

```
& Controller::control_mode & Controller::load_operating_reserve_factor & Controller::net_load_vec_kW
& Controller::combustion_map & Controller::setControlMode & Controller::applyDispatchControl
def (
            "clear" ,
            &Controller::clear  )
```

### 5.32.2.2 def() [2/3]

```
& Controller::control_mode & Controller::load_operating_reserve_factor & Controller::net_load_vec_kW
& Controller::combustion_map & Controller::setControlMode def (
            "init" ,
            &Controller::init  )
```

### 5.32.2.3 def() [3/3]

```
& Controller::control_mode & Controller::load_operating_reserve_factor & Controller::net_load_vec_kW
& Controller::combustion_map def (
            pybind11::init<> () )
```

### 5.32.2.4 def_readwrite() [1/3]

```
& Controller::control_mode def_readwrite (
            "control_string" ,
            &Controller::control_string  )
```

#### 5.32.2.5 def_readwrite() [2/3]

```
& Controller::control_mode & Controller::load_operating_reserve_factor def_readwrite (
            "max_operating_reserve_factor" ,
            &Controller::max_operating_reserve_factor )
```

#### 5.32.2.6 def_readwrite() [3/3]

```
& Controller::control_mode & Controller::load_operating_reserve_factor & Controller::net_load_vec_kW
def_readwrite (
            "missed_load_vec_kW" ,
            &Controller::missed_load_vec_kW )
```

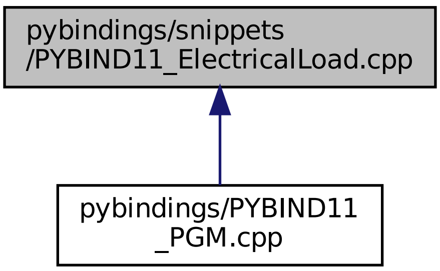
#### 5.32.2.7 value()

```
ControlMode::LOAD_FOLLOWING value (
            "CYCLE_CHARGING" ,
            ControlMode::CYCLE_CHARGING )
```

## 5.33 pybindings/snippets/PYBIND11_ElectricalLoad.cpp File Reference

Bindings file for the ElectricalLoad class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:



## Functions

- &ElectricalLoad::n_points def_readwrite ("n_years", &ElectricalLoad::n_years) .def_readwrite("min_load_↩ kW"
- &ElectricalLoad::n_points &ElectricalLoad::min_load_kW def_readwrite ("mean_load_kW", &Electrical↩ Load::mean_load_kW) .def_readwrite("max_load_kW"
- &ElectricalLoad::n_points &ElectricalLoad::min_load_kW &ElectricalLoad::max_load_kW def_readwrite ("path_2_electrical_load_time_series", &ElectricalLoad::path_2_electrical_load_time_series) .def_↩ readwrite("time_vec_hrs"
- &ElectricalLoad::n_points &ElectricalLoad::min_load_kW &ElectricalLoad::max_load_kW &ElectricalLoad::time_vec_hrs def_readwrite ("dt_vec_hrs", &ElectricalLoad::dt_vec_hrs) .def_readwrite("load_vec_kW"

## 5.33.1 Detailed Description

Bindings file for the ElectricalLoad class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the ElectricalLoad class. Only public attributes/methods are bound!

## 5.33.2 Function Documentation

### 5.33.2.1 def_readwrite() [1/4]

```
& ElectricalLoad::n_points & ElectricalLoad::min_load_kW & ElectricalLoad::max_load_kW & ElectricalLoad::time_
def_readwrite (
             "dt_vec_hrs" ,
             &ElectricalLoad::dt_vec_hrs )
```

### 5.33.2.2 def_readwrite() [2/4]

```
& ElectricalLoad::n_points & ElectricalLoad::min_load_kW def_readwrite (
             "mean_load_kW" ,
             &ElectricalLoad::mean_load_kW )
```

### 5.33.2.3 def_readwrite() [3/4]

```
& ElectricalLoad::n_points def_readwrite (
             "n_years" ,
             &ElectricalLoad::n_years )
```

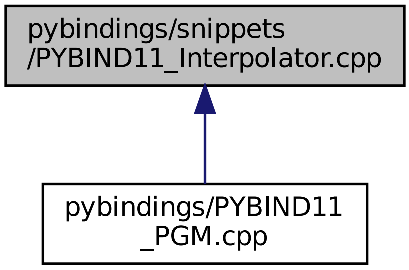
#### 5.33.2.4 def_readwrite() [4/4]

```
& ElectricalLoad::n_points & ElectricalLoad::min_load_kW & ElectricalLoad::max_load_kW def_↩
readwrite (
            "path_2_electrical_load_time_series" ,
            &ElectricalLoad::path_2_electrical_load_time_series  )
```

## 5.34 pybindings/snippets/PYBIND11_Interpolator.cpp File Reference

Bindings file for the Interpolator class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:




### Functions

- &InterpolatorStruct1D::n_points def_readwrite ("x_vec", &InterpolatorStruct1D::x_vec) .def_readwrite("min↩ _x"
- &InterpolatorStruct1D::n_points &InterpolatorStruct1D::min_x def_readwrite ("max_x", &Interpolator↩ Struct1D::max_x) .def_readwrite("y_vec"
- &InterpolatorStruct1D::n_points &InterpolatorStruct1D::min_x &InterpolatorStruct1D::y_vec def (pybind11↩ ::init())
- &InterpolatorStruct2D::n_rows def_readwrite ("n_cols", &InterpolatorStruct2D::n_cols) .def_readwrite("x_↩ vec"
- &InterpolatorStruct2D::n_rows &InterpolatorStruct2D::x_vec def_readwrite ("min_x", &InterpolatorStruct2↩ D::min_x) .def_readwrite("max_x"
- &InterpolatorStruct2D::n_rows &InterpolatorStruct2D::x_vec &InterpolatorStruct2D::max_x def_readwrite ("y_vec", &InterpolatorStruct2D::y_vec) .def_readwrite("min_y"
- &InterpolatorStruct2D::n_rows &InterpolatorStruct2D::x_vec &InterpolatorStruct2D::max_x &InterpolatorStruct2D::min_y def_readwrite ("max_y", &InterpolatorStruct2D::max_y) .def_readwrite("z_matrix"
- &Interpolator::interp_map_1D def_readwrite ("path_map_1D", &Interpolator::path_map_1D) .def_↩ readwrite("interp_map_2D"

### 5.34.1 Detailed Description

Bindings file for the Interpolator class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Interpolator class. Only public attributes/methods are bound!

## 5.34.2 Function Documentation

### 5.34.2.1 def()

```
& InterpolatorStruct1D::n_points & InterpolatorStruct1D::min_x & InterpolatorStruct1D::y_vec
def (
            pybind11::init()  )
```

### 5.34.2.2 def_readwrite() [1/7]

```
& InterpolatorStruct1D::n_points & InterpolatorStruct1D::min_x def_readwrite (
            "max_x" ,
            &InterpolatorStruct1D::max_x  )
```

### 5.34.2.3 def_readwrite() [2/7]

```
& InterpolatorStruct2D::n_rows & InterpolatorStruct2D::x_vec & InterpolatorStruct2D::max_x &
InterpolatorStruct2D::min_y def_readwrite (
            "max_y" ,
            &InterpolatorStruct2D::max_y  )
```

### 5.34.2.4 def_readwrite() [3/7]

```
& InterpolatorStruct2D::n_rows & InterpolatorStruct2D::x_vec def_readwrite (
            "min_x" ,
            &InterpolatorStruct2D::min_x  )
```

### 5.34.2.5 def_readwrite() [4/7]

```
& InterpolatorStruct2D::n_rows def_readwrite (
            "n_cols" ,
            &InterpolatorStruct2D::n_cols  )
```

#### 5.34.2.6 def_readwrite() [5/7]

```
& Interpolator::interp_map_1D def_readwrite (
            "path_map_1D" ,
            &Interpolator::path_map_1D )
```

#### 5.34.2.7 def_readwrite() [6/7]

```
& InterpolatorStruct1D::n_points def_readwrite (
            "x_vec" ,
            &InterpolatorStruct1D::x_vec )
```

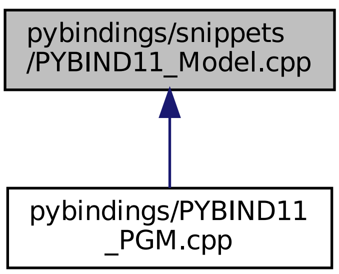
#### 5.34.2.8 def_readwrite() [7/7]

```
& InterpolatorStruct2D::n_rows & InterpolatorStruct2D::x_vec & InterpolatorStruct2D::max_x
def_readwrite (
            "y_vec" ,
            &InterpolatorStruct2D::y_vec )
```

## 5.35 pybindings/snippets/PYBIND11_Model.cpp File Reference

Bindings file for the Model class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:




### Functions

- &ModelInputs::path_2_electrical_load_time_series def_readwrite ("control_mode", &ModelInputs::control_mode) .def_readwrite("load_operating_reserve_factor"

## Variables

- &ModelInputs::path_2_electrical_load_time_series &ModelInputs::load_operating_reserve_factor def_↩ readwrite("max_operating_reserve_factor", &ModelInputs::max_operating_reserve_factor) .def(pybind11 &Model::total_fuel_consumed_L def_readwrite ("total_emissions", &Model::total_emissions) .def_↩ readwrite("net_present_cost"

### 5.35.1 Detailed Description

Bindings file for the Model class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Model class. Only public attributes/methods are bound!

### 5.35.2 Function Documentation

#### 5.35.2.1 def_readwrite()

```
& ModelInputs::path_2_electrical_load_time_series def_readwrite (
            "control_mode" ,
            &ModelInputs::control_mode )
```

### 5.35.3 Variable Documentation

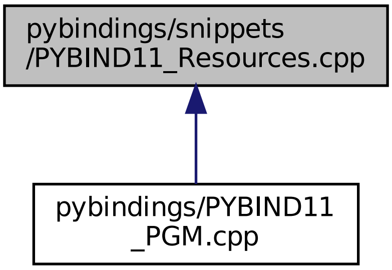
#### 5.35.3.1 def_readwrite

```
& ModelInputs::path_2_electrical_load_time_series & ModelInputs::load_operating_reserve_factor
def_readwrite ("max_operating_reserve_factor", &ModelInputs::max_operating_reserve_factor)
.def(pybind11 & Model::total_fuel_consumed_L & Model::net_present_cost & Model::total_dispatch_discharge_kWh
& Model::controller & Model::resources & Model::noncombustion_ptr_vec def_readwrite("renewable↩
_ptr_vec", &Model::renewable_ptr_vec) .def_readwrite("storage_ptr_vec" (
            "total_emissions" ,
            &Model::total_emissions )
```

## 5.36 pybindings/snippets/PYBIND11_Resources.cpp File Reference

Bindings file for the Resources class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:




### Functions

- &Resources::resource_map_1D def_readwrite ("string_map_1D", &Resources::string_map_1D) .def_↩ readwrite("path_map_1D"
- &Resources::resource_map_1D &Resources::path_map_1D def_readwrite ("resource_map_2D", &Resources↩ ::resource_map_2D) .def_readwrite("string_map_2D"

### 5.36.1 Detailed Description

Bindings file for the Resources class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Resources class. Only public attributes/methods are bound!

### 5.36.2 Function Documentation

#### 5.36.2.1 def_readwrite() [1/2]

```
& Resources::resource_map_1D & Resources::path_map_1D def_readwrite (
            "resource_map_2D" ,
            &Resources::resource_map_2D  )
```

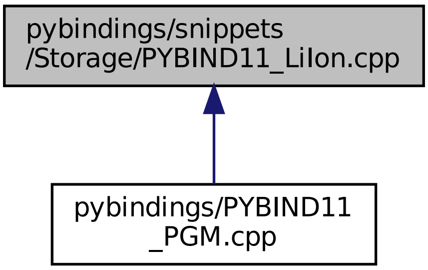
#### 5.36.2.2 def_readwrite() [2/2]

```
& Resources::resource_map_1D def_readwrite (
            "string_map_1D" ,
            &Resources::string_map_1D )
```

## 5.37 pybindings/snippets/Storage/PYBIND11_LiIon.cpp File Reference

Bindings file for the LiIon class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:




### Functions

- &LiIonInputs::storage_inputs def_readwrite ("capital_cost", &LiIonInputs::capital_cost) .def_readwrite("operation←_maintenance_cost_kWh"
- &LiIonInputs::storage_inputs &LiIonInputs::operation_maintenance_cost_kWh def_readwrite ("init_SOC", &LiIonInputs::init_SOC) .def_readwrite("min_SOC"
- &LiIonInputs::storage_inputs &LiIonInputs::operation_maintenance_cost_kWh &LiIonInputs::min_SOC def_readwrite ("hysteresis_SOC", &LiIonInputs::hysteresis_SOC) .def_readwrite("max_SOC"
- &LiIonInputs::storage_inputs &LiIonInputs::operation_maintenance_cost_kWh &LiIonInputs::min_SOC &LiIonInputs::max_SOC def_readwrite ("charging_efficiency", &LiIonInputs::charging_efficiency) .def_←readwrite("discharging_efficiency"
- &LiIonInputs::storage_inputs &LiIonInputs::operation_maintenance_cost_kWh &LiIonInputs::min_SOC &LiIonInputs::max_SOC &LiIonInputs::discharging_efficiency def_readwrite ("replace_SOH", &LiIonInputs←::replace_SOH) .def_readwrite("power_degradation_flag"
- &LiIonInputs::storage_inputs &LiIonInputs::operation_maintenance_cost_kWh &LiIonInputs::min_SOC &LiIonInputs::max_SOC &LiIonInputs::discharging_efficiency &LiIonInputs::power_degradation_flag def_readwrite ("degradation_alpha", &LiIonInputs::degradation_alpha) .def_readwrite("degradation_beta"
- &LiIonInputs::storage_inputs &LiIonInputs::operation_maintenance_cost_kWh &LiIonInputs::min_SOC &LiIonInputs::max_SOC &LiIonInputs::discharging_efficiency &LiIonInputs::power_degradation_flag &LiIonInputs::degradation_beta def_readwrite ("degradation_B_hat_cal_0", &LiIonInputs::degradation_←B_hat_cal_0) .def_readwrite("degradation_r_cal"
- &LiIonInputs::storage_inputs &LiIonInputs::operation_maintenance_cost_kWh &LiIonInputs::min_SOC &LiIonInputs::max_SOC &LiIonInputs::discharging_efficiency &LiIonInputs::power_degradation_flag &LiIonInputs::degradation_beta &LiIonInputs::degradation_r_cal def_readwrite ("degradation_Ea_cal_0", &LiIonInputs::degradation_Ea_cal_0) .def_readwrite("degradation_a_cal"
- &LiIonInputs::storage_inputs &LiIonInputs::operation_maintenance_cost_kWh &LiIonInputs::min_SOC &LiIonInputs::max_SOC &LiIonInputs::discharging_efficiency &LiIonInputs::power_degradation_flag &LiIonInputs::degradation_beta &LiIonInputs::degradation_r_cal &LiIonInputs::degradation_a_cal def_readwrite ("degradation_s_cal", &LiIonInputs::degradation_s_cal) .def_readwrite("gas_constant_JmolK"

### Variables

- &LiIonInputs::storage_inputs &LiIonInputs::operation_maintenance_cost_kWh &LiIonInputs::min_SOC &LiIonInputs::max_SOC &LiIonInputs::discharging_efficiency &LiIonInputs::power_degradation_flag &LiIonInputs::degradation_beta &LiIonInputs::degradation_r_cal &LiIonInputs::degradation_a_cal &LiIonInputs::gas_constant_ def_readwrite("gas_constant_JmolK", &LiIonInputs::gas_constant_JmolK) .def(pybind11 &LiIon::power_degradation_flag def_readwrite ("dynamic_energy_capacity_kWh", &LiIon::dynamic_energy_capacity_kWh) .def_readwrite("dynamic←_power_capacity_kW"

## 5.37.1 Detailed Description

Bindings file for the LiIon class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the LiIon class. Only public attributes/methods are bound!

## 5.37.2 Function Documentation

### 5.37.2.1 def_readwrite() [1/9]

```
& LiIonInputs::storage_inputs def_readwrite (
            "capital_cost" ,
            &LiIonInputs::capital_cost )
```

### 5.37.2.2 def_readwrite() [2/9]

```
& LiIonInputs::storage_inputs & LiIonInputs::operation_maintenance_cost_kWh & LiIonInputs::min_SOC
& LiIonInputs::max_SOC def_readwrite (
            "charging_efficiency" ,
            &LiIonInputs::charging_efficiency )
```

### 5.37.2.3 def_readwrite() [3/9]

```
& LiIonInputs::storage_inputs & LiIonInputs::operation_maintenance_cost_kWh & LiIonInputs::min_SOC
& LiIonInputs::max_SOC & LiIonInputs::discharging_efficiency & LiIonInputs::power_degradation_flag
def_readwrite (
            "degradation_alpha" ,
            &LiIonInputs::degradation_alpha )
```

#### 5.37.2.4 def_readwrite() [4/9]

& LiIonInputs::storage_inputs & LiIonInputs::operation_maintenance_cost_kWh & LiIonInputs::min_SOC & LiIonInputs::max_SOC & LiIonInputs::discharging_efficiency & LiIonInputs::power_degradation_flag & LiIonInputs::degradation_beta def_readwrite (
    "degradation_B_hat_cal_0" ,
    &LiIonInputs::degradation_B_hat_cal_0 )

#### 5.37.2.5 def_readwrite() [5/9]

& LiIonInputs::storage_inputs & LiIonInputs::operation_maintenance_cost_kWh & LiIonInputs::min_SOC & LiIonInputs::max_SOC & LiIonInputs::discharging_efficiency & LiIonInputs::power_degradation_flag & LiIonInputs::degradation_beta & LiIonInputs::degradation_r_cal def_readwrite (
    "degradation_Ea_cal_0" ,
    &LiIonInputs::degradation_Ea_cal_0 )

#### 5.37.2.6 def_readwrite() [6/9]

& LiIonInputs::storage_inputs & LiIonInputs::operation_maintenance_cost_kWh & LiIonInputs::min_SOC & LiIonInputs::max_SOC & LiIonInputs::discharging_efficiency & LiIonInputs::power_degradation_flag & LiIonInputs::degradation_beta & LiIonInputs::degradation_r_cal & LiIonInputs::degradation_a_cal def_readwrite (
    "degradation_s_cal" ,
    &LiIonInputs::degradation_s_cal )

#### 5.37.2.7 def_readwrite() [7/9]

& LiIonInputs::storage_inputs & LiIonInputs::operation_maintenance_cost_kWh & LiIonInputs::min_SOC def_readwrite (
    "hysteresis_SOC" ,
    &LiIonInputs::hysteresis_SOC )

#### 5.37.2.8 def_readwrite() [8/9]

& LiIonInputs::storage_inputs & LiIonInputs::operation_maintenance_cost_kWh def_readwrite (
    "init_SOC" ,
    &LiIonInputs::init_SOC )

#### 5.37.2.9 def_readwrite() [9/9]

```
& LiIonInputs::storage_inputs & LiIonInputs::operation_maintenance_cost_kWh & LiIonInputs::min_SOC
& LiIonInputs::max_SOC & LiIonInputs::discharging_efficiency def_readwrite (
            "replace_SOH" ,
            &LiIonInputs::replace_SOH )
```

### 5.37.3 Variable Documentation

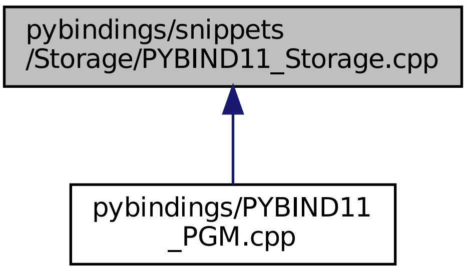
#### 5.37.3.1 def_readwrite

```
& LiIonInputs::storage_inputs & LiIonInputs::operation_maintenance_cost_kWh & LiIonInputs::min_SOC
& LiIonInputs::max_SOC & LiIonInputs::discharging_efficiency & LiIonInputs::power_degradation_flag
& LiIonInputs::degradation_beta & LiIonInputs::degradation_r_cal & LiIonInputs::degradation_a_cal
& LiIonInputs::gas_constant_JmolK def_readwrite ("gas_constant_JmolK", &LiIonInputs::gas_↩
constant_JmolK) .def(pybind11 & LiIon::power_degradation_flag & LiIon::dynamic_power_capacity_kW
& LiIon::replace_SOH & LiIon::degradation_beta & LiIon::degradation_r_cal & LiIon::degradation_a_cal
& LiIon::gas_constant_JmolK & LiIon::init_SOC & LiIon::hysteresis_SOC & LiIon::charging_efficiency
def_readwrite("discharging_efficiency", &LiIon::discharging_efficiency) .def_readwrite("SOH_↩
vec" (
            "dynamic_energy_capacity_kWh" ,
            &LiIon::dynamic_energy_capacity_kWh )
```

## 5.38 pybindings/snippets/Storage/PYBIND11_Storage.cpp File Reference

Bindings file for the Storage class. Intended to be #include'd in PYBIND11_PGM.cpp.

This graph shows which files directly or indirectly include this file:



## Functions

- StorageType::LIION value ("N_STORAGE_TYPES", StorageType::N_STORAGE_TYPES)
- &StorageInputs::print_flag def_readwrite ("is_sunk", &StorageInputs::is_sunk) .def_readwrite("power_↩ capacity_kW"
- &StorageInputs::print_flag &StorageInputs::power_capacity_kW def_readwrite ("energy_capacity_kWh", &StorageInputs::energy_capacity_kWh) .def_readwrite("nominal_inflation_annual"

## Variables

- &StorageInputs::print_flag &StorageInputs::power_capacity_kW &StorageInputs::nominal_inflation_annual def_readwrite("nominal_discount_annual", &StorageInputs::nominal_discount_annual) .def(pybind11 &Storage::type def_readwrite ("interpolator", &Storage::interpolator) .def_readwrite("print_flag"

## 5.38.1 Detailed Description

Bindings file for the Storage class. Intended to be #include'd in PYBIND11_PGM.cpp.

Ref: Jakob [2023]
A file which instructs pybind11 how to build Python bindings for the Storage class. Only public attributes/methods are bound!

## 5.38.2 Function Documentation

### 5.38.2.1 def_readwrite() [1/2]

```
& StorageInputs::print_flag & StorageInputs::power_capacity_kW def_readwrite (
            "energy_capacity_kWh" ,
            &StorageInputs::energy_capacity_kWh )
```

### 5.38.2.2 def_readwrite() [2/2]

```
& StorageInputs::print_flag def_readwrite (
            "is_sunk" ,
            &StorageInputs::is_sunk )
```

### 5.38.2.3 value()

```
StorageType::LIION value (
            "N_STORAGE_TYPES" ,
            StorageType::N_STORAGE_TYPES )
```

### 5.38.3 Variable Documentation

#### 5.38.3.1 def_readwrite

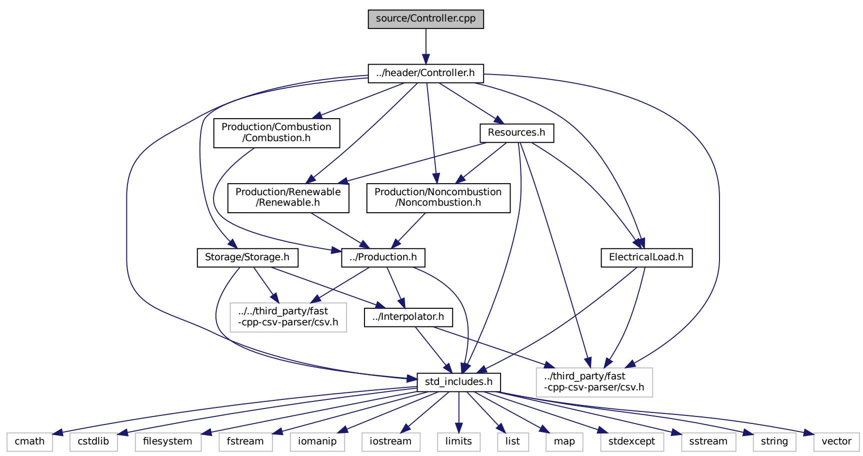
```
& StorageInputs::print_flag & StorageInputs::power_capacity_kW & StorageInputs::nominal_inflation_annual
def_readwrite ("nominal_discount_annual", &StorageInputs::nominal_discount_annual) .def(pybind11
& Storage::type & Storage::print_flag & Storage::is_sunk & Storage::n_replacements & Storage::power_capacity_k
& Storage::charge_kWh & Storage::nominal_inflation_annual & Storage::real_discount_annual &
Storage::operation_maintenance_cost_kWh & Storage::total_discharge_kWh & Storage::type_str &
Storage::charging_power_vec_kW def_readwrite("discharging_power_vec_kW", &Storage::discharging←
_power_vec_kW) .def_readwrite("capital_cost_vec" (
             "interpolator" ,
             &Storage::interpolator  )
```

## 5.39 source/Controller.cpp File Reference

Implementation file for the Controller class.

```
#include "../header/Controller.h"
```

Include dependency graph for Controller.cpp:




### 5.39.1 Detailed Description

Implementation file for the Controller class.

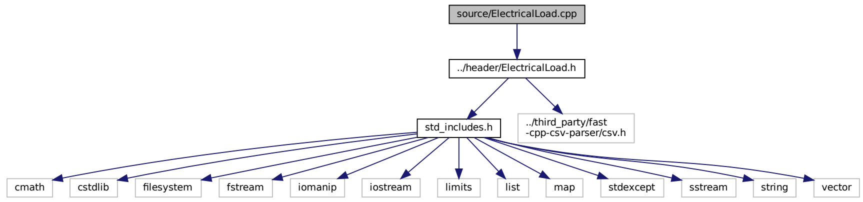
A class which contains a various dispatch control logic. Intended to serve as a component class of Controller.

# 5.40 source/ElectricalLoad.cpp File Reference

Implementation file for the ElectricalLoad class.

`#include "../header/ElectricalLoad.h"`

Include dependency graph for ElectricalLoad.cpp:




## 5.40.1 Detailed Description

Implementation file for the ElectricalLoad class.

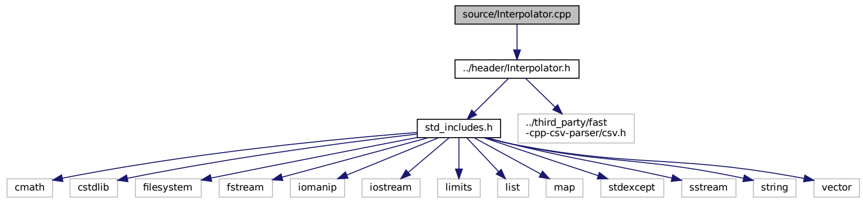
A class which contains time and electrical load data. Intended to serve as a component class of Model.

# 5.41 source/Interpolator.cpp File Reference

Implementation file for the Interpolator class.

`#include "../header/Interpolator.h"`

Include dependency graph for Interpolator.cpp:




## 5.41.1 Detailed Description

Implementation file for the Interpolator class.

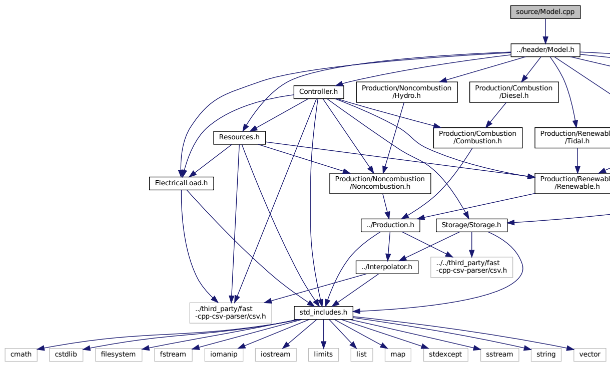
A class which contains interpolation data and functionality. Intended to serve as a component of the Production and Storage hierarchies.

# 5.42 source/Model.cpp File Reference

Implementation file for the Model class.

```
#include "../header/Model.h"
```

Include dependency graph for Model.cpp:




## 5.42.1 Detailed Description

Implementation file for the Model class.

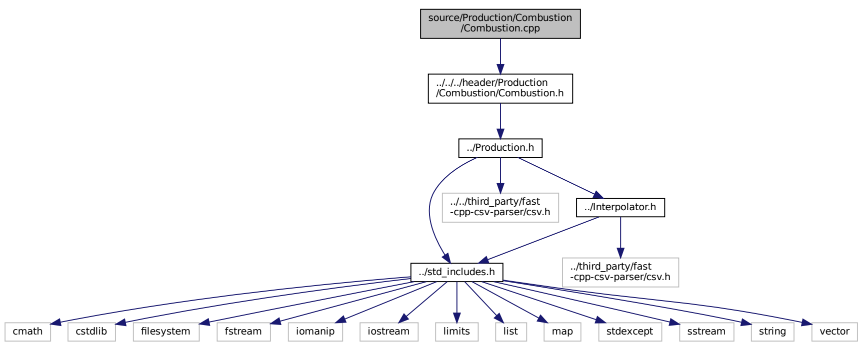
A container class which forms the centre of PGMcpp. The Model class is intended to serve as the primary user interface with the functionality of PGMcpp, and as such it contains all other classes.

# 5.43 source/Production/Combustion/Combustion.cpp File Reference

Implementation file for the Combustion class.

```
#include "../../../header/Production/Combustion/Combustion.h"
```

Include dependency graph for Combustion.cpp:



### 5.43.1 Detailed Description

Implementation file for the Combustion class.

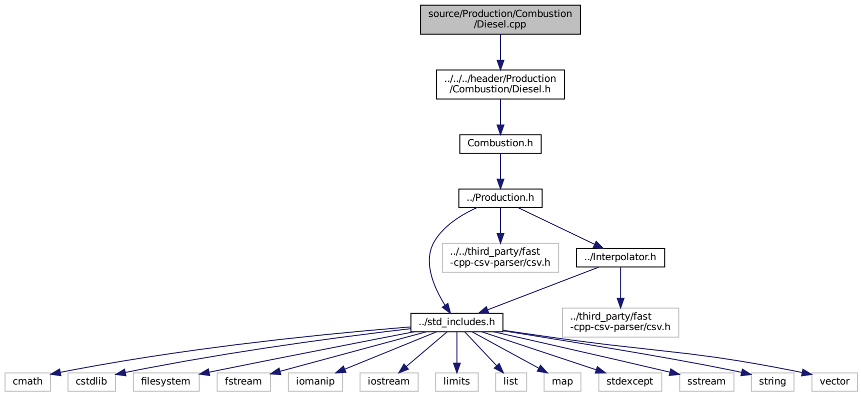
The root of the Combustion branch of the Production hierarchy. This branch contains derived classes which model the production of energy by way of combustibles.

## 5.44 source/Production/Combustion/Diesel.cpp File Reference

Implementation file for the Diesel class.

```
#include "../../../header/Production/Combustion/Diesel.h"
```

Include dependency graph for Diesel.cpp:




### 5.44.1 Detailed Description

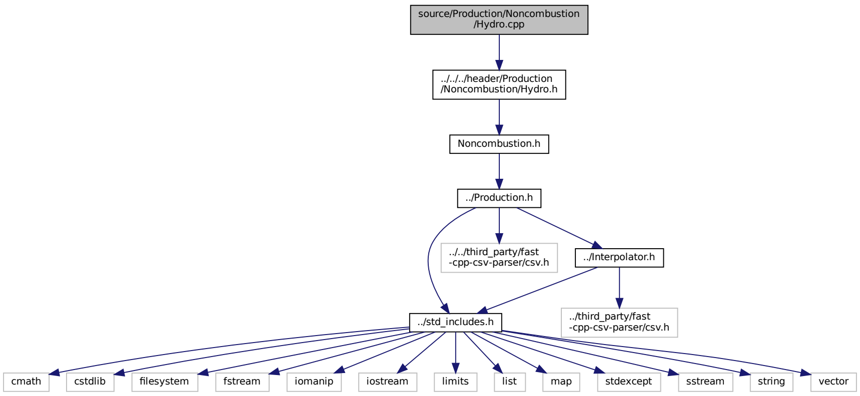
Implementation file for the Diesel class.

A derived class of the Combustion branch of Production which models production using a diesel generator.

## 5.45 source/Production/Noncombustion/Hydro.cpp File Reference

Implementation file for the Hydro class.

```
#include "../../../header/Production/Noncombustion/Hydro.h"
```
Include dependency graph for Hydro.cpp:




### 5.45.1 Detailed Description

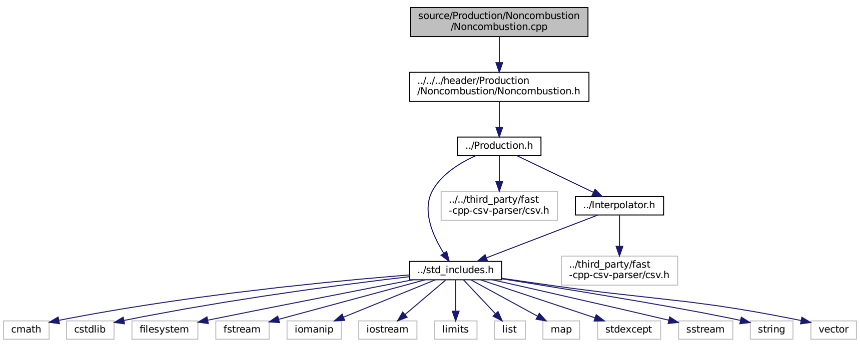
Implementation file for the Hydro class.

A derived class of the Noncombustion branch of Production which models production using a hydroelectric asset (either with reservoir or not).

## 5.46 source/Production/Noncombustion/Noncombustion.cpp File Reference

Implementation file for the Noncombustion class.

```
#include "../../../header/Production/Noncombustion/Noncombustion.h"
```
Include dependency graph for Noncombustion.cpp:




### 5.46.1 Detailed Description

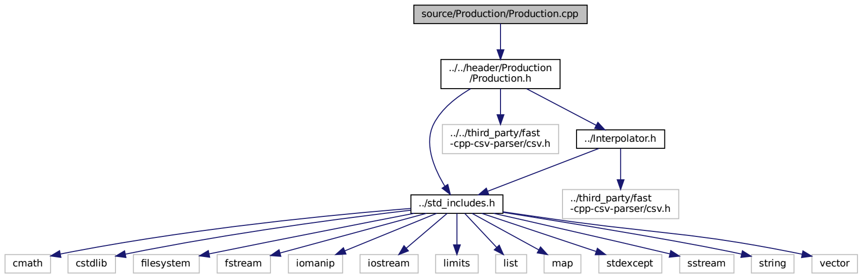
Implementation file for the Noncombustion class.

The root of the Noncombustion branch of the Production hierarchy. This branch contains derived classes which model controllable production which is not based on combustion.

# 5.47 source/Production/Production.cpp File Reference

Implementation file for the Production class.

`#include "../../header/Production/Production.h"`
Include dependency graph for Production.cpp:




## 5.47.1 Detailed Description

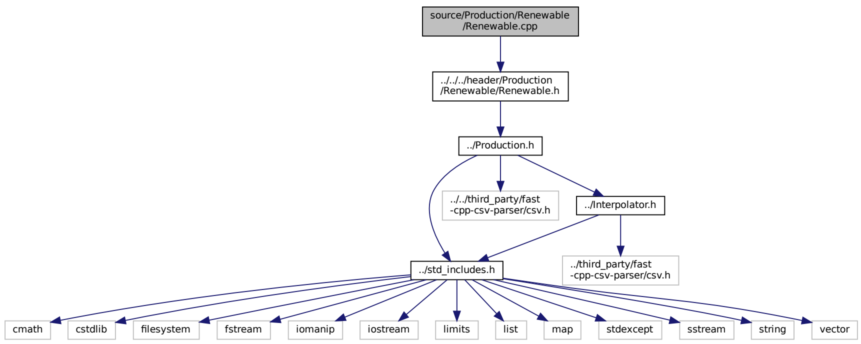
Implementation file for the Production class.

The base class of the Production hierarchy. This hierarchy contains derived classes which model the production of energy, be it renewable or otherwise.

# 5.48 source/Production/Renewable/Renewable.cpp File Reference

Implementation file for the Renewable class.

`#include "../../../header/Production/Renewable/Renewable.h"`
Include dependency graph for Renewable.cpp:




## 5.48.1 Detailed Description

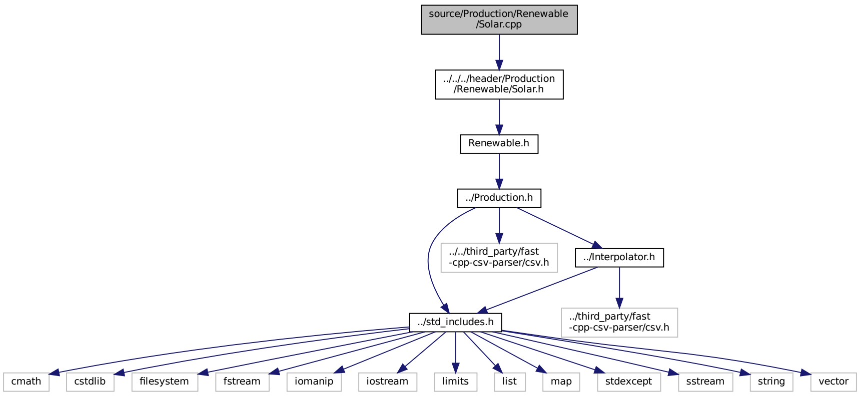
Implementation file for the Renewable class.

The root of the Renewable branch of the Production hierarchy. This branch contains derived classes which model the renewable production of energy.

## 5.49 source/Production/Renewable/Solar.cpp File Reference

Implementation file for the Solar class.

`#include "../../../header/Production/Renewable/Solar.h"`
Include dependency graph for Solar.cpp:




### 5.49.1 Detailed Description

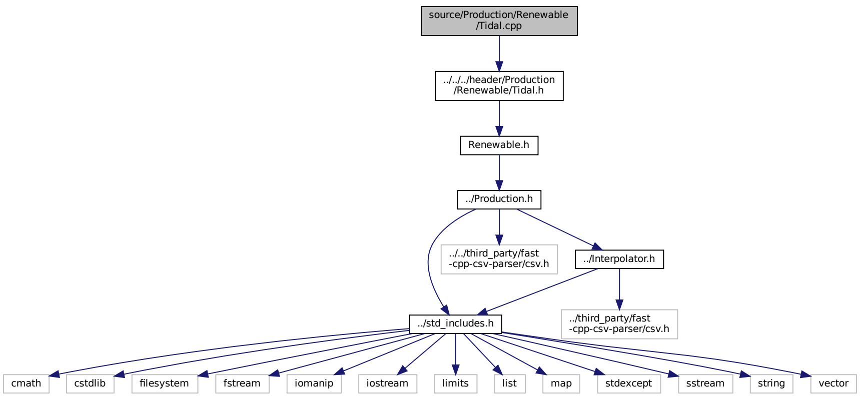
Implementation file for the Solar class.

A derived class of the Renewable branch of Production which models solar production.

## 5.50 source/Production/Renewable/Tidal.cpp File Reference

Implementation file for the Tidal class.

`#include "../../../header/Production/Renewable/Tidal.h"`
Include dependency graph for Tidal.cpp:



### 5.50.1 Detailed Description

Implementation file for the Tidal class.

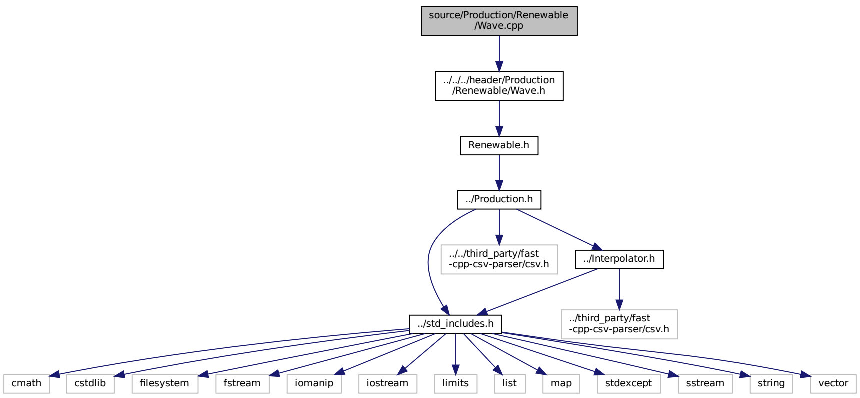
A derived class of the Renewable branch of Production which models tidal production.

## 5.51 source/Production/Renewable/Wave.cpp File Reference

Implementation file for the Wave class.

```
#include "../../../header/Production/Renewable/Wave.h"
```

Include dependency graph for Wave.cpp:




### 5.51.1 Detailed Description

Implementation file for the Wave class.

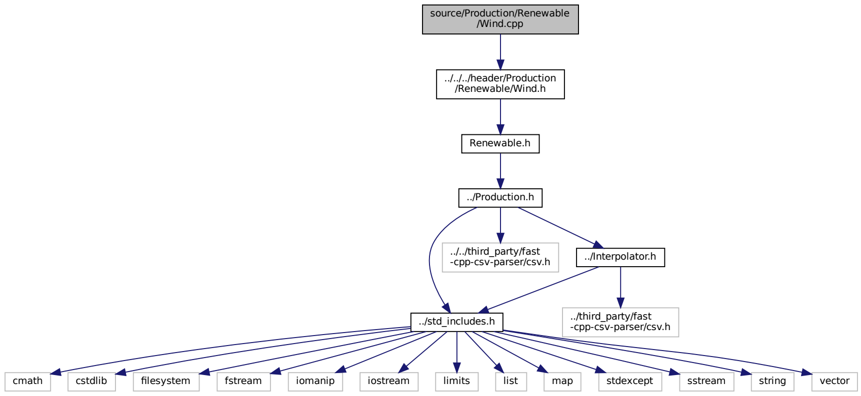
A derived class of the Renewable branch of Production which models wave production.

## 5.52 source/Production/Renewable/Wind.cpp File Reference

Implementation file for the Wind class.

```
#include "../../../header/Production/Renewable/Wind.h"
```

Include dependency graph for Wind.cpp:




### 5.52.1 Detailed Description

Implementation file for the Wind class.

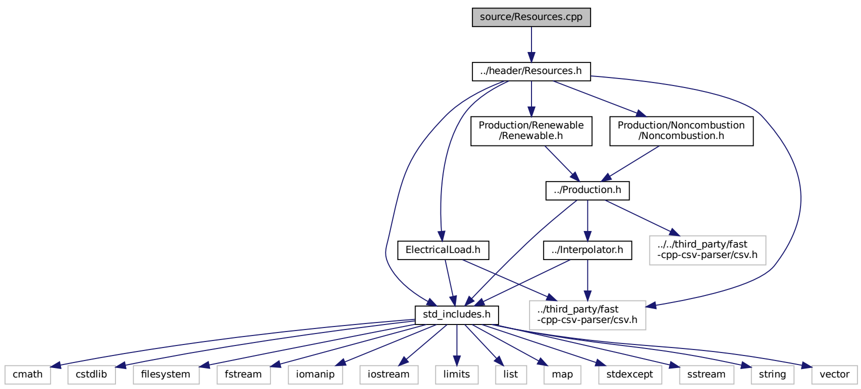
A derived class of the Renewable branch of Production which models wind production.

## 5.53 source/Resources.cpp File Reference

Implementation file for the Resources class.

```
#include "../header/Resources.h"
```

Include dependency graph for Resources.cpp:




### 5.53.1 Detailed Description

Implementation file for the Resources class.

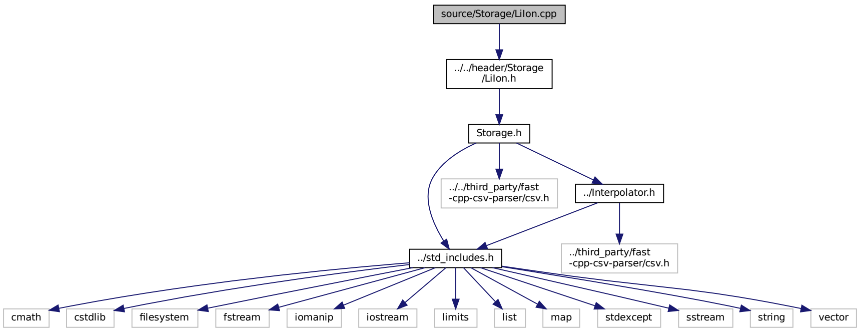
A class which contains renewable resource data. Intended to serve as a component class of Model.

## 5.54 source/Storage/LiIon.cpp File Reference

Implementation file for the LiIon class.

`#include "../../header/Storage/LiIon.h"`

Include dependency graph for LiIon.cpp:




### 5.54.1 Detailed Description

Implementation file for the LiIon class.

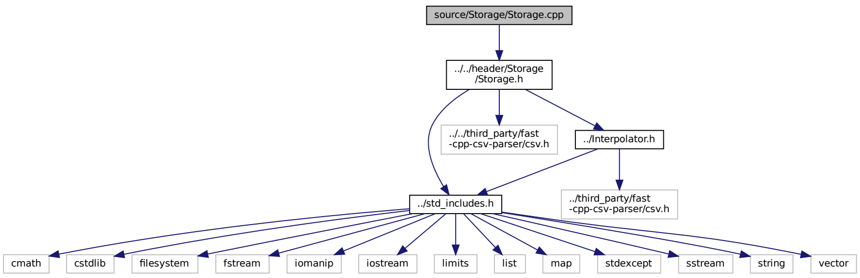
A derived class of Storage which models energy storage by way of lithium-ion batteries.

## 5.55 source/Storage/Storage.cpp File Reference

Implementation file for the Storage class.

`#include "../../header/Storage/Storage.h"`

Include dependency graph for Storage.cpp:




### 5.55.1 Detailed Description

Implementation file for the Storage class.

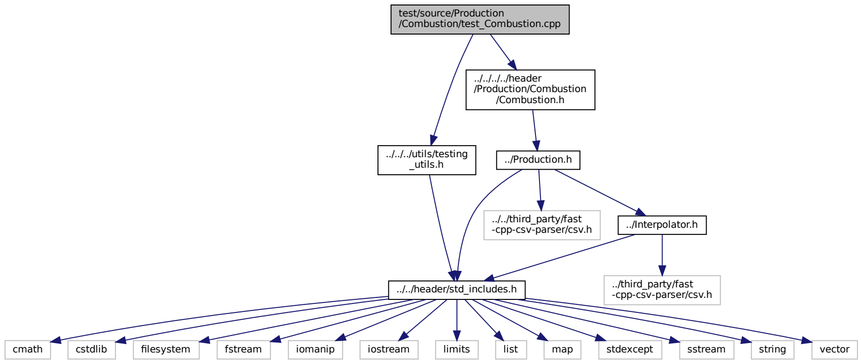
The base class of the Storage hierarchy. This hierarchy contains derived classes which model the storage of energy.

## 5.56 test/source/Production/Combustion/test_Combustion.cpp File Reference

Testing suite for Combustion class.

```
#include "../../../utils/testing_utils.h"
#include "../../../../header/Production/Combustion/Combustion.h"
```

Include dependency graph for test_Combustion.cpp:




### Functions

- Combustion ∗ testConstruct_Combustion (std::vector< double > ∗time_vec_hrs_ptr)

    *A function to construct a Combustion object and spot check some post-construction attributes.*
- int main (int argc, char ∗∗argv)

### 5.56.1 Detailed Description

Testing suite for Combustion class.

A suite of tests for the Combustion class.

### 5.56.2 Function Documentation

#### 5.56.2.1 main()

```
int main (
            int argc,
            char ** argv )
```

```
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Production <-- Combustion");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    std::vector<double> time_vec_hrs (8760, 0);
    for (size_t i = 0; i < time_vec_hrs.size(); i++) {
        time_vec_hrs[i] = i;
    }

    Combustion* test_combustion_ptr = testConstruct_Combustion(&time_vec_hrs);


    try {
        //...
    }


    catch (...) {
        delete test_combustion_ptr;

        printGold(" ................ ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_combustion_ptr;

    printGold(" ................ ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;

}   /* main() */
```

#### 5.56.2.2 testConstruct_Combustion()

```
Combustion * testConstruct_Combustion (
            std::vector< double > * time_vec_hrs_ptr )
```

A function to construct a Combustion object and spot check some post-construction attributes.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

**Returns**

A pointer to a test Combustion object.

```
{
    CombustionInputs combustion_inputs;

```

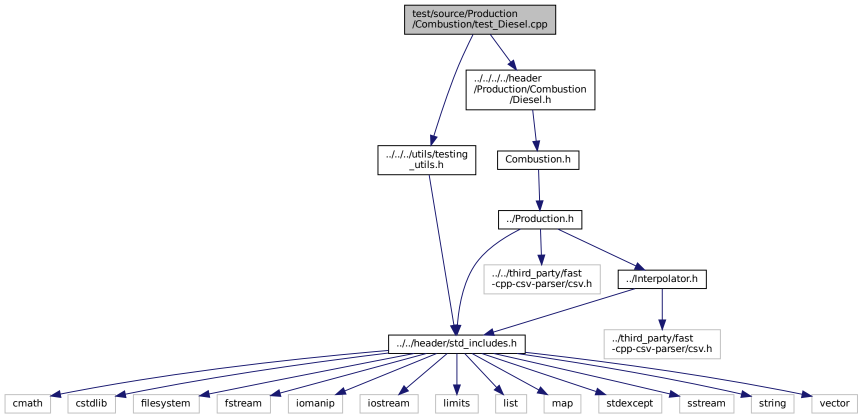
```
    Combustion* test_combustion_ptr = new Combustion(
        8760,
        1,
        combustion_inputs,
        time_vec_hrs_ptr
    );

    testTruth(
        not combustion_inputs.production_inputs.print_flag,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_combustion_ptr->fuel_consumption_vec_L.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_combustion_ptr->fuel_cost_vec.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_combustion_ptr->CO2_emissions_vec_kg.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_combustion_ptr->CO_emissions_vec_kg.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_combustion_ptr->NOx_emissions_vec_kg.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_combustion_ptr->SOx_emissions_vec_kg.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_combustion_ptr->CH4_emissions_vec_kg.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_combustion_ptr->PM_emissions_vec_kg.size(),
        8760,
        __FILE__,
        __LINE__
    );

    return test_combustion_ptr;
}   /* testConstruct_Combustion() */
```

## 5.57 test/source/Production/Combustion/test_Diesel.cpp File Reference

Testing suite for Diesel class.

```
#include "../../../utils/testing_utils.h"
#include "../../../../header/Production/Combustion/Diesel.h"
```

Include dependency graph for test_Diesel.cpp:




## Functions

- Combustion ∗ testConstruct_Diesel (std::vector< double > ∗time_vec_hrs_ptr)

  *A function to construct a Diesel object and spot check some post-construction attributes.*
- Combustion ∗ testConstructLookup_Diesel (std::vector< double > ∗time_vec_hrs_ptr)

  *A function to construct a Diesel object using fuel consumption lookup.*
- void testBadConstruct_Diesel (std::vector< double > ∗time_vec_hrs_ptr)

  *Function to test the trying to construct a Diesel object given bad inputs is being handled as expected.*
- void testCapacityConstraint_Diesel (Combustion ∗test_diesel_ptr)

  *Test to check that the installed capacity constraint is active and behaving as expected.*
- void testMinimumLoadRatioConstraint_Diesel (Combustion ∗test_diesel_ptr)

  *Test to check that the minimum load ratio constraint is active and behaving as expected.*
- void testCommit_Diesel (Combustion ∗test_diesel_ptr)

  *Function to test if the commit method is working as expected, by checking some post-call attributes of the test Diesel object.*
- void testMinimumRuntimeConstraint_Diesel (Combustion ∗test_diesel_ptr)

  *Function to check that the minimum runtime constraint is active and behaving as expected.*
- void testFuelConsumptionEmissions_Diesel (Combustion ∗test_diesel_ptr)

  *Function to test that post-commit fuel consumption and emissions are > 0 when the test Diesel object is running, and = 0 when it is not (as expected).*
- void testEconomics_Diesel (Combustion ∗test_diesel_ptr)

  *Function to test that the post-commit model economics for the test Diesel object are as expected (> 0 when running, = 0 when not).*
- void testFuelLookup_Diesel (Combustion ∗test_diesel_lookup_ptr)

  *Function to test that fuel consumption lookup (i.e., interpolation) is returning the expected values.*
- int main (int argc, char ∗∗argv)

### 5.57.1 Detailed Description

Testing suite for Diesel class.

A suite of tests for the Diesel class.

## 5.57.2 Function Documentation

### 5.57.2.1 main()

```
int main (
            int argc,
            char ** argv )
```

```
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Production <-- Combustion <-- Diesel");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    std::vector<double> time_vec_hrs (8760, 0);
    for (size_t i = 0; i < time_vec_hrs.size(); i++) {
        time_vec_hrs[i] = i;
    }


    Combustion* test_diesel_ptr = testConstruct_Diesel(&time_vec_hrs);
    Combustion* test_diesel_lookup_ptr = testConstructLookup_Diesel(&time_vec_hrs);

    try {
        testBadConstruct_Diesel(&time_vec_hrs);

        testCapacityConstraint_Diesel(test_diesel_ptr);
        testMinimumLoadRatioConstraint_Diesel(test_diesel_ptr);

        testCommit_Diesel(test_diesel_ptr);

        testMinimumRuntimeConstraint_Diesel(test_diesel_ptr);

        testFuelConsumptionEmissions_Diesel(test_diesel_ptr);
        testEconomics_Diesel(test_diesel_ptr);

        testFuelLookup_Diesel(test_diesel_lookup_ptr);
    }


    catch (...) {
        delete test_diesel_ptr;
        delete test_diesel_lookup_ptr;

        printGold(" ..... ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_diesel_ptr;
    delete test_diesel_lookup_ptr;

    printGold(" ..... ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;

}   /* main() */
```

### 5.57.2.2 testBadConstruct_Diesel()

```
void testBadConstruct_Diesel (
            std::vector< double > * time_vec_hrs_ptr )
```

Function to test the trying to construct a Diesel object given bad inputs is being handled as expected.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
{
    bool error_flag = true;

    try {
        DieselInputs bad_diesel_inputs;
        bad_diesel_inputs.fuel_cost_L = -1;

        Diesel bad_diesel(
            8760,
            1,
            bad_diesel_inputs,
            time_vec_hrs_ptr
        );

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    return;
}   /* testBadConstruct_Diesel() */
```

### 5.57.2.3 testCapacityConstraint_Diesel()

```
void testCapacityConstraint_Diesel (
            Combustion * test_diesel_ptr )
```

Test to check that the installed capacity constraint is active and behaving as expected.

**Parameters**

| | |
|---|---|
| *test_diesel_ptr* | A Combustion pointer to the test Diesel object. |

```
{
    testFloatEquals(
        test_diesel_ptr->requestProductionkW(0, 1, 2 * test_diesel_ptr->capacity_kW),
        test_diesel_ptr->capacity_kW,
        __FILE__,
        __LINE__
    );

    return;
}   /* testCapacityConstraint_Diesel() */
```

### 5.57.2.4 testCommit_Diesel()

```
void testCommit_Diesel (
            Combustion * test_diesel_ptr )
```

Function to test if the commit method is working as expected, by checking some post-call attributes of the test Diesel object.

**Parameters**

| | |
|---|---|
| *test_diesel_ptr* | A Combustion pointer to the test Diesel object. |

```
{
    std::vector<double> dt_vec_hrs (48, 1);

    std::vector<double> load_vec_kW = {
        1, 1, 0, 1, 0, 0, 1, 1, 1, 0, 1, 1,
        1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0,
        1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1,
        1, 0, 0, 0, 1, 1, 1, 0, 1, 1, 0, 0
    };

    double load_kW = 0;
    double production_kW = 0;
    double roll = 0;

    for (int i = 0; i < 48; i++) {
        roll = (double)rand() / RAND_MAX;

        if (roll >= 0.95) {
            roll = 1.25;
        }

        load_vec_kW[i] *= roll * test_diesel_ptr->capacity_kW;
        load_kW = load_vec_kW[i];

        production_kW = test_diesel_ptr->requestProductionkW(
            i,
            dt_vec_hrs[i],
            load_kW
        );

        load_kW = test_diesel_ptr->commit(
            i,
            dt_vec_hrs[i],
            production_kW,
            load_kW
        );

        // load_kW <= load_vec_kW (i.e., after vs before)
        testLessThanOrEqualTo(
            load_kW,
            load_vec_kW[i],
            __FILE__,
            __LINE__
        );

        // production = dispatch + storage + curtailment
        testFloatEquals(
            test_diesel_ptr->production_vec_kW[i] -
            test_diesel_ptr->dispatch_vec_kW[i] -
            test_diesel_ptr->storage_vec_kW[i] -
            test_diesel_ptr->curtailment_vec_kW[i],
            0,
            __FILE__,
            __LINE__
        );

        // capacity constraint
        if (load_vec_kW[i] > test_diesel_ptr->capacity_kW) {
            testFloatEquals(
                test_diesel_ptr->production_vec_kW[i],
                test_diesel_ptr->capacity_kW,
                __FILE__,
                __LINE__
            );
        }

        // minimum load ratio constraint
        else if (
            test_diesel_ptr->is_running and
            test_diesel_ptr->production_vec_kW[i] > 0 and
            load_vec_kW[i] <
            ((Diesel*)test_diesel_ptr)->minimum_load_ratio * test_diesel_ptr->capacity_kW
        ) {
            testFloatEquals(
                test_diesel_ptr->production_vec_kW[i],
                ((Diesel*)test_diesel_ptr)->minimum_load_ratio *
                    test_diesel_ptr->capacity_kW,
                __FILE__,
                __LINE__
            );
        }
    }
```

```
    return;
}   /* testCommit_Diesel() */
```

### 5.57.2.5 testConstruct_Diesel()

```
Combustion * testConstruct_Diesel (
              std::vector< double > * time_vec_hrs_ptr )
```

A function to construct a Diesel object and spot check some post-construction attributes.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

**Returns**

A Combustion pointer to a test Diesel object.

```
{
    DieselInputs diesel_inputs;

    Combustion* test_diesel_ptr =  new Diesel(
        8760,
        1,
        diesel_inputs,
        time_vec_hrs_ptr
    );

    testTruth(
        not diesel_inputs.combustion_inputs.production_inputs.print_flag,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_diesel_ptr->type,
        CombustionType :: DIESEL,
        __FILE__,
        __LINE__
    );

    testTruth(
        test_diesel_ptr->type_str == "DIESEL",
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_diesel_ptr->linear_fuel_slope_LkWh,
        0.265675,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_diesel_ptr->linear_fuel_intercept_LkWh,
        0.026676,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_diesel_ptr->capital_cost,
        94125.375446,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_diesel_ptr->operation_maintenance_cost_kWh,
        0.069905,
```

```
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((Diesel*)test_diesel_ptr)->minimum_load_ratio,
        0.2,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((Diesel*)test_diesel_ptr)->minimum_runtime_hrs,
        4,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_diesel_ptr->replace_running_hrs,
        30000,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_diesel_ptr->cycle_charging_setpoint,
        0.85,
        __FILE__,
        __LINE__
    );

    return test_diesel_ptr;
}   /* testConstruct_Diesel() */
```

#### 5.57.2.6 testConstructLookup_Diesel()

```
Combustion * testConstructLookup_Diesel (
            std::vector< double > * time_vec_hrs_ptr )
```

A function to construct a Diesel object using fuel consumption lookup.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

**Returns**

A Combustion pointer to a test Diesel object.

```
{
    DieselInputs diesel_inputs;

    diesel_inputs.combustion_inputs.fuel_mode = FuelMode :: FUEL_MODE_LOOKUP;
    diesel_inputs.combustion_inputs.path_2_fuel_interp_data =
        "data/test/interpolation/diesel_fuel_curve.csv";

    Combustion* test_diesel_lookup_ptr = new Diesel(
        8760,
        1,
        diesel_inputs,
        time_vec_hrs_ptr
    );

    return test_diesel_lookup_ptr;
}   /* testConstructLookup_Diesel() */
```

#### 5.57.2.7 testEconomics_Diesel()

```
void testEconomics_Diesel (
            Combustion * test_diesel_ptr )
```

Function to test that the post-commit model economics for the test Diesel object are as expected (> 0 when running, = 0 when not).

**Parameters**

| | |
|---|---|
| *test_diesel_ptr* | A Combustion pointer to the test Diesel object. |

```
{
    std::vector<bool> expected_is_running_vec = {
        1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1,
        1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 1,
        1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1,
        1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 0
    };

    bool is_running = false;

    for (int i = 0; i < 48; i++) {
        is_running = test_diesel_ptr->is_running_vec[i];

        testFloatEquals(
            is_running,
            expected_is_running_vec[i],
            __FILE__,
            __LINE__
        );

        // O&M, fuel consumption, and emissions > 0 whenever diesel is running
        if (is_running) {
            testGreaterThan(
                test_diesel_ptr->operation_maintenance_cost_vec[i],
                0,
                __FILE__,
                __LINE__
            );
        }

        // O&M, fuel consumption, and emissions = 0 whenever diesel is not running
        else {
            testFloatEquals(
                test_diesel_ptr->operation_maintenance_cost_vec[i],
                0,
                __FILE__,
                __LINE__
            );
        }
    }

    return;
}   /* testEconomics_Diesel() */
```

#### 5.57.2.8 testFuelConsumptionEmissions_Diesel()

```
void testFuelConsumptionEmissions_Diesel (
            Combustion * test_diesel_ptr )
```

Function to test that post-commit fuel consumption and emissions are > 0 when the test Diesel object is running, and = 0 when it is not (as expected).

**Parameters**

| | |
|---|---|
| *test_diesel_ptr* | A Combustion pointer to the test Diesel object. |

```
{
    std::vector<bool> expected_is_running_vec = {
        1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1,
        1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 1,
        1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1,
        1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 0
    };

    bool is_running = false;

    for (int i = 0; i < 48; i++) {
        is_running = test_diesel_ptr->is_running_vec[i];

        testFloatEquals(
            is_running,
            expected_is_running_vec[i],
            __FILE__,
            __LINE__
        );

        // O&M, fuel consumption, and emissions > 0 whenever diesel is running
        if (is_running) {
            testGreaterThan(
                test_diesel_ptr->fuel_consumption_vec_L[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThan(
                test_diesel_ptr->fuel_cost_vec[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThan(
                test_diesel_ptr->CO2_emissions_vec_kg[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThan(
                test_diesel_ptr->CO_emissions_vec_kg[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThan(
                test_diesel_ptr->NOx_emissions_vec_kg[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThan(
                test_diesel_ptr->SOx_emissions_vec_kg[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThan(
                test_diesel_ptr->CH4_emissions_vec_kg[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThan(
                test_diesel_ptr->PM_emissions_vec_kg[i],
                0,
                __FILE__,
                __LINE__
            );
        }

        // O&M, fuel consumption, and emissions = 0 whenever diesel is not running
        else {
            testFloatEquals(
                test_diesel_ptr->fuel_consumption_vec_L[i],
                0,
                __FILE__,
                __LINE__
            );
```

```
            testFloatEquals(
                test_diesel_ptr->fuel_cost_vec[i],
                0,
                __FILE__,
                __LINE__
            );

            testFloatEquals(
                test_diesel_ptr->CO2_emissions_vec_kg[i],
                0,
                __FILE__,
                __LINE__
            );

            testFloatEquals(
                test_diesel_ptr->CO_emissions_vec_kg[i],
                0,
                __FILE__,
                __LINE__
            );

            testFloatEquals(
                test_diesel_ptr->NOx_emissions_vec_kg[i],
                0,
                __FILE__,
                __LINE__
            );

            testFloatEquals(
                test_diesel_ptr->SOx_emissions_vec_kg[i],
                0,
                __FILE__,
                __LINE__
            );

            testFloatEquals(
                test_diesel_ptr->CH4_emissions_vec_kg[i],
                0,
                __FILE__,
                __LINE__
            );

            testFloatEquals(
                test_diesel_ptr->PM_emissions_vec_kg[i],
                0,
                __FILE__,
                __LINE__
            );
        }
    }

    return;
}   /* testFuelConsumptionEmissions_Diesel() */
```

#### 5.57.2.9 testFuelLookup_Diesel()

```
void testFuelLookup_Diesel (
            Combustion * test_diesel_lookup_ptr )
```

Function to test that fuel consumption lookup (i.e., interpolation) is returning the expected values.

**Parameters**

| | |
|---|---|
| *test_diesel_lookup_ptr* | A Combustion pointer to the test Diesel object using fuel consumption lookup. |

```
{
    std::vector<double> load_ratio_vec = {
        0,
        0.170812859791767,
        0.322739274162545,
        0.369750203682042,
        0.443532869135929,
        0.471567864244626,
        0.536513734479662,
```

```
        0.586125806988674,
        0.601101175455075,
        0.658356862575221,
        0.70576929893201,
        0.784069734739331,
        0.805765927542453,
        0.884747873186048,
        0.930870496062112,
        0.979415217694769,
        1
    };

    std::vector<double> expected_fuel_consumption_vec_L = {
        4.68079520372916,
        8.35159603357656,
        11.7422361561399,
        12.9931187917615,
        14.8786636301325,
        15.5746957307243,
        17.1419229487141,
        18.3041866133728,
        18.6530540913696,
        19.9569217633299,
        21.012354614584,
        22.7142305879957,
        23.1916726441968,
        24.8602332554707,
        25.8172124624032,
        26.8256741279932,
        27.254952
    };

    for (size_t i = 0; i < load_ratio_vec.size(); i++) {
        testFloatEquals(
            test_diesel_lookup_ptr->getFuelConsumptionL(
                1, load_ratio_vec[i] * test_diesel_lookup_ptr->capacity_kW
            ),
            expected_fuel_consumption_vec_L[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testFuelLookup_Diesel() */
```

### 5.57.2.10 testMinimumLoadRatioConstraint_Diesel()

```
void testMinimumLoadRatioConstraint_Diesel (
            Combustion * test_diesel_ptr )
```

Test to check that the minimum load ratio constraint is active and behaving as expected.

**Parameters**

| | |
|---|---|
| *test_diesel_ptr* | A Combustion pointer to the test Diesel object. |

```
{
    testFloatEquals(
        test_diesel_ptr->requestProductionkW(
            0,
            1,
            0.5 * ((Diesel*)test_diesel_ptr)->minimum_load_ratio *
                test_diesel_ptr->capacity_kW
        ),
        ((Diesel*)test_diesel_ptr)->minimum_load_ratio * test_diesel_ptr->capacity_kW,
        __FILE__,
        __LINE__
    );

    return;
}   /* testMinimumLoadRatioConstraint_Diesel() */
```

#### 5.57.2.11 testMinimumRuntimeConstraint_Diesel()

```
void testMinimumRuntimeConstraint_Diesel (
            Combustion * test_diesel_ptr )
```

Function to check that the minimum runtime constraint is active and behaving as expected.

**Parameters**

| | |
|---|---|
| *test_diesel_ptr* | A Combustion pointer to the test Diesel object. |

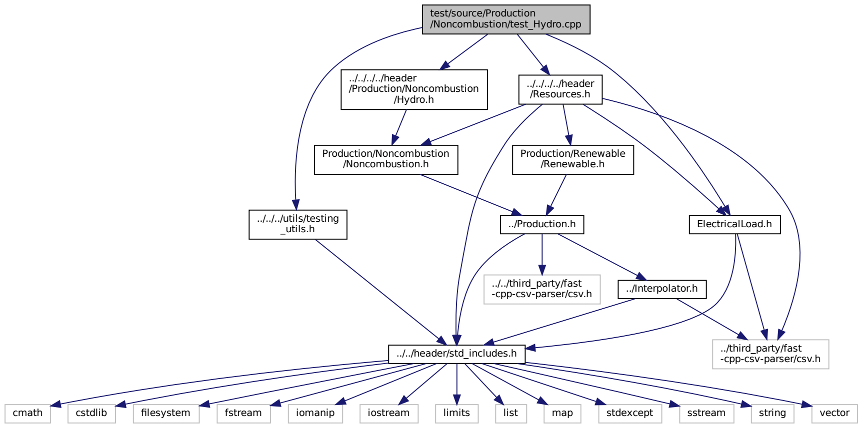
```
{
    std::vector<double> load_vec_kW = {
        1, 1, 0, 1, 0, 0, 1, 1, 1, 0, 1, 1,
        1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0,
        1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1,
        1, 0, 0, 0, 1, 1, 1, 0, 1, 1, 0, 0
    };

    std::vector<bool> expected_is_running_vec = {
        1, 1, 1, 1, 0, 0, 1, 1, 1, 1, 1, 1,
        1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 1,
        1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1,
        1, 1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 0
    };

    for (int i = 0; i < 48; i++) {
        testFloatEquals(
            test_diesel_ptr->is_running_vec[i],
            expected_is_running_vec[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testMinimumRuntimeConstraint_Diesel() */
```

## 5.58 test/source/Production/Noncombustion/test_Hydro.cpp File Reference

Testing suite for Hydro class.

```
#include "../../../utils/testing_utils.h"
#include "../../../../header/Resources.h"
#include "../../../../header/ElectricalLoad.h"
#include "../../../../header/Production/Noncombustion/Hydro.h"
```

Include dependency graph for test_Hydro.cpp:




## Functions

- Noncombustion ∗ testConstruct_Hydro (HydroInputs hydro_inputs, std::vector< double > ∗time_vec_hrs_←ptr)

  *A function to construct a Hydro object and spot check some post-construction attributes.*
- void testEfficiencyInterpolation_Hydro (Noncombustion ∗test_hydro_ptr)

  *Function to test that the generator and turbine efficiency maps are being initialized as expected, and that efficiency interpolation is returning the expected values.*
- void testCommit_Hydro (Noncombustion ∗test_hydro_ptr, Resources ∗test_resources_ptr)
- int main (int argc, char ∗∗argv)

## 5.58.1 Detailed Description

Testing suite for Hydro class.

A suite of tests for the Hydro class.

## 5.58.2 Function Documentation

### 5.58.2.1 main()

```
int main (
            int argc,
            char ** argv )
```

```
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Production <-- Noncombustion <-- Hydro");

    #ifdef _WIN32
```

```
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    std::vector<double> time_vec_hrs (8760, 0);
    for (size_t i = 0; i < time_vec_hrs.size(); i++) {
        time_vec_hrs[i] = i;
    }

    std::string path_2_electrical_load_time_series =
        "data/test/electrical_load/electrical_load_generic_peak-500kW_1yr_dt-1hr.csv";

    ElectricalLoad* test_electrical_load_ptr =
        new ElectricalLoad(path_2_electrical_load_time_series);

    Resources* test_resources_ptr = new Resources();

    HydroInputs hydro_inputs;
    int hydro_resource_key = 0;

    hydro_inputs.reservoir_capacity_m3 = 10000;
    hydro_inputs.resource_key = hydro_resource_key;

    Noncombustion* test_hydro_ptr = testConstruct_Hydro(hydro_inputs, &time_vec_hrs);

    std::string path_2_hydro_resource_data =
        "data/test/resources/hydro_inflow_peak-20000m3hr_1yr_dt-1hr.csv";

    test_resources_ptr->addResource(
        NoncombustionType::HYDRO,
        path_2_hydro_resource_data,
        hydro_resource_key,
        test_electrical_load_ptr
    );


    try {
        testEfficiencyInterpolation_Hydro(test_hydro_ptr);
        testCommit_Hydro(test_hydro_ptr, test_resources_ptr);
    }


    catch (...) {
        delete test_electrical_load_ptr;
        delete test_resources_ptr;
        delete test_hydro_ptr;

        printGold(" ... ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_electrical_load_ptr;
    delete test_resources_ptr;
    delete test_hydro_ptr;

    printGold(" ... ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;

}   /* main() */
```

### 5.58.2.2 testCommit_Hydro()

void testCommit_Hydro (
    Noncombustion * *test_hydro_ptr*,
    Resources * *test_resources_ptr* )

```
{
    double load_kW = 100 * (double)rand() / RAND_MAX;
    double production_kW = 0;

    for (int i = 0; i < 8760; i++) {
        production_kW = test_hydro_ptr->requestProductionkW(
            i,
```

```
                1,
                load_kW,
                test_resources_ptr->resource_map_1D[test_hydro_ptr->resource_key][i]
            );

            load_kW = test_hydro_ptr->commit(
                i,
                1,
                production_kW,
                load_kW,
                test_resources_ptr->resource_map_1D[test_hydro_ptr->resource_key][i]
            );

            testGreaterThanOrEqualTo(
                test_hydro_ptr->production_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testLessThanOrEqualTo(
                test_hydro_ptr->production_vec_kW[i],
                test_hydro_ptr->capacity_kW,
                __FILE__,
                __LINE__
            );

            testFloatEquals(
                test_hydro_ptr->production_vec_kW[i] -
                test_hydro_ptr->dispatch_vec_kW[i] -
                test_hydro_ptr->curtailment_vec_kW[i] -
                test_hydro_ptr->storage_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThanOrEqualTo(
                ((Hydro*)test_hydro_ptr)->turbine_flow_vec_m3hr[i],
                0,
                __FILE__,
                __LINE__
            );

            testLessThanOrEqualTo(
                ((Hydro*)test_hydro_ptr)->turbine_flow_vec_m3hr[i],
                ((Hydro*)test_hydro_ptr)->maximum_flow_m3hr,
                __FILE__,
                __LINE__
            );

            testGreaterThanOrEqualTo(
                ((Hydro*)test_hydro_ptr)->stored_volume_vec_m3[i],
                0,
                __FILE__,
                __LINE__
            );

            testLessThanOrEqualTo(
                ((Hydro*)test_hydro_ptr)->stored_volume_vec_m3[i],
                ((Hydro*)test_hydro_ptr)->reservoir_capacity_m3,
                __FILE__,
                __LINE__
            );
        }

        return;
}   /* testCommit_Hydro() */
```

### 5.58.2.3 testConstruct_Hydro()

```
Hydro *Noncombustion * testConstruct_Hydro (
            HydroInputs hydro_inputs,
            std::vector< double > * time_vec_hrs_ptr )
```

A function to construct a Hydro object and spot check some post-construction attributes.

**Returns**

A Noncombustion pointer to a test Hydro object.

```
{
    Noncombustion* test_hydro_ptr =  new Hydro(
        8760,
        1,
        hydro_inputs,
        time_vec_hrs_ptr
    );

    testTruth(
        not hydro_inputs.noncombustion_inputs.production_inputs.print_flag,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_hydro_ptr->n_points,
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_hydro_ptr->type,
        NoncombustionType :: HYDRO,
        __FILE__,
        __LINE__
    );

    testTruth(
        test_hydro_ptr->type_str == "HYDRO",
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((Hydro*)test_hydro_ptr)->turbine_type,
        HydroTurbineType :: HYDRO_TURBINE_PELTON,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((Hydro*)test_hydro_ptr)->reservoir_capacity_m3,
        10000,
        __FILE__,
        __LINE__
    );

    return test_hydro_ptr;
}   /* testConstruct_Hydro() */
```

### 5.58.2.4 testEfficiencyInterpolation_Hydro()

```
void testEfficiencyInterpolation_Hydro (
        Noncombustion * test_hydro_ptr )
```

Function to test that the generator and turbine efficiency maps are being initialized as expected, and that efficiency interpolation is returning the expected values.

**Parameters**

| | |
|---|---|
| *test_hydro_ptr* | A Noncombustion pointer to the test Hydro object. |

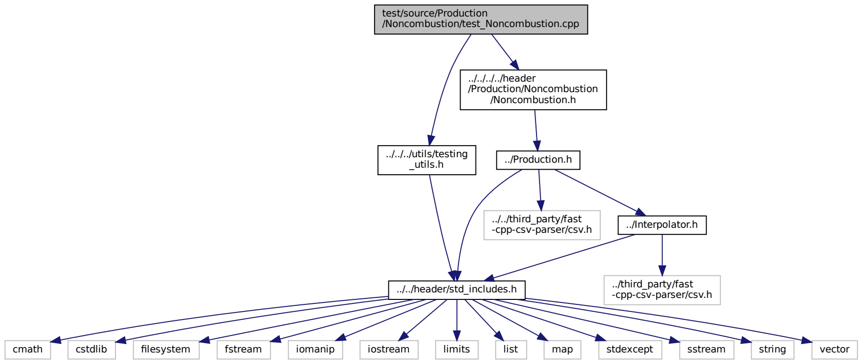
```
{
    std::vector<double> expected_gen_power_ratios = {
        0,    0.1, 0.2,  0.3, 0.4, 0.5,
        0.6, 0.7, 0.75, 0.8, 0.9, 1
    };

    std::vector<double> expected_gen_efficiencies = {
```

```
        0.000, 0.800, 0.900, 0.913,
        0.925, 0.943, 0.947, 0.950,
        0.953, 0.954, 0.956, 0.958
    };

    double query = 0;
    for (size_t i = 0; i < expected_gen_power_ratios.size(); i++) {
        testFloatEquals(
            test_hydro_ptr->interpolator.interp_map_1D[
                HydroInterpKeys :: GENERATOR_EFFICIENCY_INTERP_KEY
            ].x_vec[i],
            expected_gen_power_ratios[i],
            __FILE__,
            __LINE__
        );

        testFloatEquals(
            test_hydro_ptr->interpolator.interp_map_1D[
                HydroInterpKeys :: GENERATOR_EFFICIENCY_INTERP_KEY
            ].y_vec[i],
            expected_gen_efficiencies[i],
            __FILE__,
            __LINE__
        );

        if (i < expected_gen_power_ratios.size() - 1) {
            query = expected_gen_power_ratios[i] + ((double)rand() / RAND_MAX) *
                (expected_gen_power_ratios[i + 1] - expected_gen_power_ratios[i]);

            test_hydro_ptr->interpolator.interp1D(
                HydroInterpKeys :: GENERATOR_EFFICIENCY_INTERP_KEY,
                query
            );
        }
    }

    std::vector<double> expected_turb_power_ratios = {
        0,   0.1, 0.2, 0.3, 0.4,
        0.5, 0.6, 0.7, 0.8, 0.9,
        1
    };

    std::vector<double> expected_turb_efficiencies = {
        0.000, 0.780, 0.855, 0.875, 0.890,
        0.900, 0.908, 0.913, 0.918, 0.908,
        0.880
    };

    for (size_t i = 0; i < expected_turb_power_ratios.size(); i++) {
        testFloatEquals(
            test_hydro_ptr->interpolator.interp_map_1D[
                HydroInterpKeys :: TURBINE_EFFICIENCY_INTERP_KEY
            ].x_vec[i],
            expected_turb_power_ratios[i],
            __FILE__,
            __LINE__
        );

        testFloatEquals(
            test_hydro_ptr->interpolator.interp_map_1D[
                HydroInterpKeys :: TURBINE_EFFICIENCY_INTERP_KEY
            ].y_vec[i],
            expected_turb_efficiencies[i],
            __FILE__,
            __LINE__
        );

        if (i < expected_turb_power_ratios.size() - 1) {
            query = expected_turb_power_ratios[i] + ((double)rand() / RAND_MAX) *
                (expected_turb_power_ratios[i + 1] - expected_turb_power_ratios[i]);

            test_hydro_ptr->interpolator.interp1D(
                HydroInterpKeys :: TURBINE_EFFICIENCY_INTERP_KEY,
                query
            );
        }
    }

    return;
}   /* testEfficiencyInterpolation_Hydro() */
```

## 5.59 test/source/Production/Noncombustion/test_Noncombustion.cpp File Reference

Testing suite for Noncombustion class.

```
#include "../../../utils/testing_utils.h"
#include "../../../../header/Production/Noncombustion/Noncombustion.h"
```
Include dependency graph for test_Noncombustion.cpp:




### Functions

- Noncombustion ∗ testConstruct_Noncombustion (std::vector< double > ∗time_vec_hrs_ptr)

    *A function to construct a Noncombustion object and spot check some post-construction attributes.*
- int main (int argc, char ∗∗argv)

### 5.59.1 Detailed Description

Testing suite for Noncombustion class.

A suite of tests for the Noncombustion class.

### 5.59.2 Function Documentation

#### 5.59.2.1 main()

```
int main (
            int argc,
            char ** argv )
```

```
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Production <-- Noncombustion");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    std::vector<double> time_vec_hrs (8760, 0);
    for (size_t i = 0; i < time_vec_hrs.size(); i++) {
        time_vec_hrs[i] = i;
    }

    Noncombustion* test_noncombustion_ptr = testConstruct_Noncombustion(&time_vec_hrs);


    try {
        //...
    }


    catch (...) {
        delete test_noncombustion_ptr;

        printGold(" ............. ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_noncombustion_ptr;

    printGold(" ............. ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;

}   /* main() */
```

#### 5.59.2.2 testConstruct_Noncombustion()

```
Noncombustion * testConstruct_Noncombustion (
            std::vector< double > * time_vec_hrs_ptr )
```

A function to construct a Noncombustion object and spot check some post-construction attributes.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

**Returns**

A pointer to a test Noncombustion object.

```
{
    NoncombustionInputs noncombustion_inputs;

```

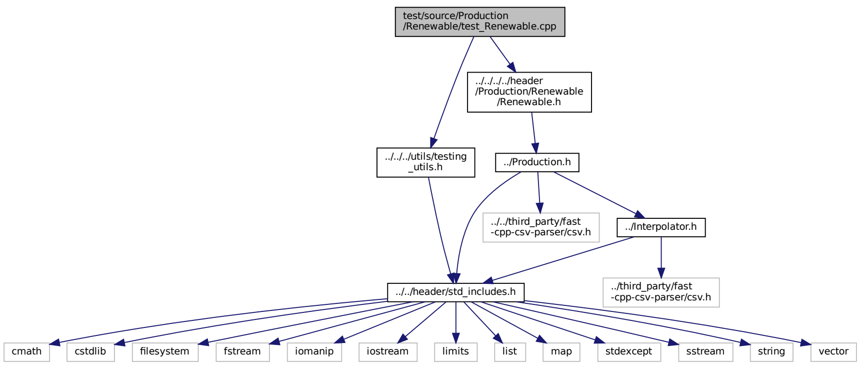
```
    Noncombustion* test_noncombustion_ptr =
        new Noncombustion(
            8760,
            1,
            noncombustion_inputs,
            time_vec_hrs_ptr
        );

    testTruth(
        not noncombustion_inputs.production_inputs.print_flag,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_noncombustion_ptr->n_points,
        8760,
        __FILE__,
        __LINE__
    );

    return test_noncombustion_ptr;
}   /* testConstruct_Noncombustion() */
```

## 5.60 test/source/Production/Renewable/test_Renewable.cpp File Reference

Testing suite for Renewable class.

```
#include "../../../utils/testing_utils.h"
#include "../../../../header/Production/Renewable/Renewable.h"
```

Include dependency graph for test_Renewable.cpp:




### Functions

- Renewable ∗ testConstruct_Renewable (std::vector< double > ∗time_vec_hrs_ptr)

  *A function to construct a Renewable object and spot check some post-construction attributes.*
- int main (int argc, char ∗∗argv)

### 5.60.1 Detailed Description

Testing suite for Renewable class.

A suite of tests for the Renewable class.

## 5.60.2 Function Documentation

### 5.60.2.1 main()

```
int main (
        int argc,
        char ** argv )
```

```
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Production <-- Renewable");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    std::vector<double> time_vec_hrs (8760, 0);
    for (size_t i = 0; i < time_vec_hrs.size(); i++) {
        time_vec_hrs[i] = i;
    }

    Renewable* test_renewable_ptr = testConstruct_Renewable(&time_vec_hrs);


    try {
        //...
    }


    catch (...) {
        delete test_renewable_ptr;

        printGold(" ................. ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_renewable_ptr;

    printGold(" ................. ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;

}   /* main() */
```

### 5.60.2.2 testConstruct_Renewable()

```
Renewable * testConstruct_Renewable (
        std::vector< double > * time_vec_hrs_ptr )
```

A function to construct a Renewable object and spot check some post-construction attributes.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

**Returns**

A pointer to a test Renewable object.

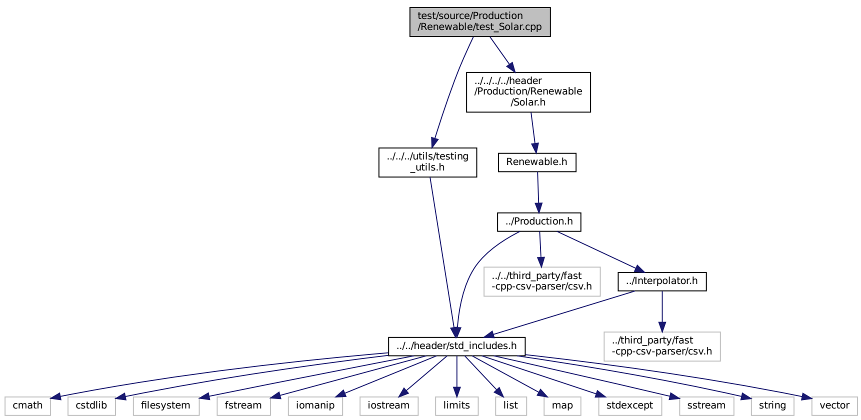
```
{
    RenewableInputs renewable_inputs;

    Renewable* test_renewable_ptr = new Renewable(
        8760,
        1,
        renewable_inputs,
        time_vec_hrs_ptr
    );

    testTruth(
        not renewable_inputs.production_inputs.print_flag,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_renewable_ptr->n_points,
        8760,
        __FILE__,
        __LINE__
    );

    return test_renewable_ptr;
}   /* testConstruct_Renewable() */
```

## 5.61 test/source/Production/Renewable/test_Solar.cpp File Reference

Testing suite for Solar class.

```
#include "../../../utils/testing_utils.h"
#include "../../../../header/Production/Renewable/Solar.h"
```

Include dependency graph for test_Solar.cpp:




### Functions

- Renewable * testConstruct_Solar (std::vector< double > *time_vec_hrs_ptr)

    *A function to construct a Solar object and spot check some post-construction attributes.*
- void testBadConstruct_Solar (std::vector< double > *time_vec_hrs_ptr)

    *Function to test the trying to construct a Solar object given bad inputs is being handled as expected.*
- void testProductionOverride_Solar (std::string path_2_normalized_production_time_series, std::vector< double > *time_vec_hrs_ptr)

*Function to test that normalized production data is being read in correctly, and that the associated production override feature is behaving as expected.*

- void testDetailed_Solar (void)
- void testProductionConstraint_Solar (Renewable ∗test_solar_ptr)

  *Function to test that the production constraint is active and behaving as expected.*
- void testCommit_Solar (Renewable ∗test_solar_ptr)

  *Function to test if the commit method is working as expected, by checking some post-call attributes of the test Solar object. Uses a randomized resource input.*
- void testEconomics_Solar (Renewable ∗test_solar_ptr)
- int main (int argc, char ∗∗argv)

## 5.61.1 Detailed Description

Testing suite for Solar class.

A suite of tests for the Solar class.

## 5.61.2 Function Documentation

### 5.61.2.1 main()

```
int main (
        int argc,
        char ** argv )
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Production <-- Renewable <-- Solar");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    std::vector<double> time_vec_hrs (8760, 0);
    for (size_t i = 0; i < time_vec_hrs.size(); i++) {
        time_vec_hrs[i] = i;
    }

    Renewable* test_solar_ptr = testConstruct_Solar(&time_vec_hrs);


    try {
        testBadConstruct_Solar(&time_vec_hrs);

        std::string path_2_normalized_production_time_series =
            "data/test/normalized_production/normalized_solar_production.csv";

        testProductionOverride_Solar(
            path_2_normalized_production_time_series,
            &time_vec_hrs
        );

        testDetailed_Solar();

        testProductionConstraint_Solar(test_solar_ptr);

        testCommit_Solar(test_solar_ptr);
        testEconomics_Solar(test_solar_ptr);
```

```
    }


    catch (...) {
        delete test_solar_ptr;

        printGold(" ....... ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_solar_ptr;

    printGold(" ....... ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;

}   /* main() */
```

#### 5.61.2.2 testBadConstruct_Solar()

```
void testBadConstruct_Solar (
            std::vector< double > * time_vec_hrs_ptr )
```

Function to test the trying to construct a Solar object given bad inputs is being handled as expected.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
{
    bool error_flag = true;

    try {
        SolarInputs bad_solar_inputs;
        bad_solar_inputs.derating = -1;

        Solar bad_solar(8760, 1, bad_solar_inputs, time_vec_hrs_ptr);

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    return;
}   /* testBadConstruct_Solar() */
```

#### 5.61.2.3 testCommit_Solar()

```
void testCommit_Solar (
            Renewable * test_solar_ptr )
```

Function to test if the commit method is working as expected, by checking some post-call attributes of the test Solar object. Uses a randomized resource input.

**Parameters**

| | |
|---|---|
| *test_solar_ptr* | A Renewable pointer to the test Solar object. |

```
{
    std::vector<double> dt_vec_hrs (48, 1);

    std::vector<double> load_vec_kW = {
        1, 1, 0, 1, 0, 0, 1, 1, 1, 0, 1, 1,
        1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0,
        1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1,
        1, 0, 0, 0, 1, 1, 1, 0, 1, 1, 0, 0
    };

    double load_kW = 0;
    double production_kW = 0;
    double roll = 0;
    double solar_resource_kWm2 = 0;

    for (int i = 0; i < 48; i++) {
        roll = (double)rand() / RAND_MAX;

        solar_resource_kWm2 = roll;

        roll = (double)rand() / RAND_MAX;

        if (roll <= 0.1) {
            solar_resource_kWm2 = 0;
        }

        else if (roll >= 0.95) {
            solar_resource_kWm2 = 1.25;
        }

        roll = (double)rand() / RAND_MAX;

        if (roll >= 0.95) {
            roll = 1.25;
        }

        load_vec_kW[i] *= roll * test_solar_ptr->capacity_kW;
        load_kW = load_vec_kW[i];

        production_kW = test_solar_ptr->computeProductionkW(
            i,
            dt_vec_hrs[i],
            solar_resource_kWm2
        );

        load_kW = test_solar_ptr->commit(
            i,
            dt_vec_hrs[i],
            production_kW,
            load_kW
        );

        // is running (or not) as expected
        if (solar_resource_kWm2 > 0) {
            testTruth(
                test_solar_ptr->is_running,
                __FILE__,
                __LINE__
            );
        }

        else {
            testTruth(
                not test_solar_ptr->is_running,
                __FILE__,
                __LINE__
            );
        }

        // load_kW <= load_vec_kW (i.e., after vs before)
        testLessThanOrEqualTo(
            load_kW,
            load_vec_kW[i],
            __FILE__,
            __LINE__
        );

        // production = dispatch + storage + curtailment
        testFloatEquals(
            test_solar_ptr->production_vec_kW[i] -
            test_solar_ptr->dispatch_vec_kW[i] -
            test_solar_ptr->storage_vec_kW[i] -
            test_solar_ptr->curtailment_vec_kW[i],
            0,
            __FILE__,
            __LINE__
        );
```

```
        // capacity constraint
        if (solar_resource_kWm2 > 1) {
            testFloatEquals(
                test_solar_ptr->production_vec_kW[i],
                test_solar_ptr->capacity_kW,
                __FILE__,
                __LINE__
            );
        }
    }

    return;
}   /* testCommit_Solar() */
```

#### 5.61.2.4 testConstruct_Solar()

```
Renewable * testConstruct_Solar (
            std::vector< double > * time_vec_hrs_ptr )
```

A function to construct a Solar object and spot check some post-construction attributes.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

**Returns**

A Renewable pointer to a test Solar object.

```
{
    SolarInputs solar_inputs;

    Renewable* test_solar_ptr = new Solar(
        8760,
        1,
        solar_inputs,
        time_vec_hrs_ptr
    );

    testTruth(
        not solar_inputs.renewable_inputs.production_inputs.print_flag,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_solar_ptr->n_points,
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_solar_ptr->type,
        RenewableType :: SOLAR,
        __FILE__,
        __LINE__
    );

    testTruth(
        test_solar_ptr->type_str == "SOLAR",
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_solar_ptr->capital_cost,
        350118.723363,
        __FILE__,
        __LINE__
    );
```

```

    testFloatEquals(
        test_solar_ptr->operation_maintenance_cost_kWh,
        0.01,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_solar_ptr->firmness_factor,
        0.2,
        __FILE__,
        __LINE__
    );

    return test_solar_ptr;
}   /* testConstruct_Solar() */
```

### 5.61.2.5 testDetailed_Solar()

```
void testDetailed_Solar (
            void )
{
    // init time and solar resource vectors
    std::vector<double> time_vec_hrs = {
        0,
        1,
        2,
        3,
        4,
        5,
        6,
        7,
        8,
        9,
        10,
        11,
        12,
        13,
        14,
        15,
        16,
        17,
        18,
        19,
        20,
        21,
        22,
        23
    };

    std::vector<double> solar_resource_vec_kWm2 = {
        0,
        0,
        0,
        0,
        0,
        0,
        8.51702662684015E-05,
        0.000348341567045,
        0.00213793728593,
        0.004099863613322,
        0.000997135230553,
        0.009534527624657,
        0.022927996790616,
        0.0136071715294,
        0.002535134127751,
        0.005206897515821,
        0.005627658648597,
        0.000701186722215,
        0.00017119827089,
        0,
        0,
        0,
        0,
        0
    };

    // init expected results (simple and detailed)
```

```
    std::vector<double> expected_simple_production_vec_kW = {
        0,
        0,
        0,
        0,
        0,
        0,
        0.00681362130147212,
        0.0278673253636,
        0.1710349828744,
        0.32798908906576,
        0.07977081844424,
        0.7627622099725601,
        1.83423974324928,
        1.088573722352,
        0.20281073022008,
        0.41655180126568,
        0.45021269188776,
        0.0560949377772,
        0.0136958616712,
        0,
        0,
        0,
        0,
        0
    };

    std::vector<double> expected_detailed_production_vec_kW = {
        0,
        0,
        0,
        0,
        0,
        0,
        0.007338124437333107,
        0.03001323298400045,
        0.1842098680357352,
        0.3532627387497894,
        0.085919752082476,
        0.8215778242841695,
        1.975723895381408,
        1.17256966118828,
        0.2184652818009985,
        0.4487156859620408,
        0.4849877212456633,
        0.06042929047364313,
        0.01475448450756636,
        0,
        0,
        0,
        0,
        0
    };

    // init Solar (simple)
    SolarInputs solar_inputs;

    Solar test_solar_simple(
        time_vec_hrs.size(),
        1,
        solar_inputs,
        &time_vec_hrs
    );

    // init Solar (detailed)
    solar_inputs.power_model = SolarPowerProductionModel :: SOLAR_POWER_DETAILED;

    solar_inputs.julian_day = 8766;
    solar_inputs.latitude_deg = 50;
    solar_inputs.longitude_deg = -125;
    solar_inputs.panel_azimuth_deg = 180;
    solar_inputs.panel_tilt_deg = 30;
    solar_inputs.albedo_ground_reflectance = 0.5;

    Solar test_solar_detailed(
        time_vec_hrs.size(),
        1,
        solar_inputs,
        &time_vec_hrs
    );

    // test simple production
    double production_kW = 0;

    for (size_t i = 0; i < time_vec_hrs.size(); i++) {
        production_kW = test_solar_simple.computeProductionkW(
            i, 1, solar_resource_vec_kWm2[i]
```

```
        );

        test_solar_simple.commit(
            i, 1, production_kW, 100
        );

        testFloatEquals(
            production_kW,
            expected_simple_production_vec_kW[i],
            __FILE__,
            __LINE__
        );
    }

    // test detailed production
    for (size_t i = 0; i < time_vec_hrs.size(); i++) {
        production_kW = test_solar_detailed.computeProductionkW(
            i, 1, solar_resource_vec_kWm2[i]
        );

        test_solar_detailed.commit(
            i, 1, production_kW, 100
        );

        testFloatEquals(
            production_kW,
            expected_detailed_production_vec_kW[i],
            __FILE__,
            __LINE__
        );
    }

}   /* testDetailed_Solar() */
```

### 5.61.2.6 testEconomics_Solar()

```
void testEconomics_Solar (
            Renewable * test_solar_ptr )
```

```
{
    for (int i = 0; i < 48; i++) {
        // resource, O&M > 0 whenever solar is running (i.e., producing)
        if (test_solar_ptr->is_running_vec[i]) {
            testGreaterThan(
                test_solar_ptr->operation_maintenance_cost_vec[i],
                0,
                __FILE__,
                __LINE__
            );
        }

        // resource, O&M = 0 whenever solar is not running (i.e., not producing)
        else {
            testFloatEquals(
                test_solar_ptr->operation_maintenance_cost_vec[i],
                0,
                __FILE__,
                __LINE__
            );
        }
    }

    return;
}   /* testEconomics_Solar() */
```

### 5.61.2.7 testProductionConstraint_Solar()

```
void testProductionConstraint_Solar (
            Renewable * test_solar_ptr )
```

Function to test that the production constraint is active and behaving as expected.

**Parameters**

| | |
|---|---|
| *test_solar_ptr* | A Renewable pointer to the test Solar object. |

```
{
    testFloatEquals(
        test_solar_ptr->computeProductionkW(0, 1, 2),
        100,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_solar_ptr->computeProductionkW(0, 1, -1),
        0,
        __FILE__,
        __LINE__
    );

    return;
}   /* testProductionConstraint_Solar() */
```

#### 5.61.2.8 testProductionOverride_Solar()

```
void testProductionOverride_Solar (
            std::string path_2_normalized_production_time_series,
            std::vector< double > * time_vec_hrs_ptr )
```

Function to test that normalized production data is being read in correctly, and that the associated production override feature is behaving as expected.

**Parameters**

| | |
|---|---|
| *path_2_normalized_production_time_series* | A path (either relative or absolute) to the given normalized production time series data. |
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
{
    SolarInputs solar_inputs;

    solar_inputs.renewable_inputs.production_inputs.path_2_normalized_production_time_series =
        path_2_normalized_production_time_series;

    Solar test_solar_override(
        time_vec_hrs_ptr->size(),
        1,
        solar_inputs,
        time_vec_hrs_ptr
    );


    std::vector<double> expected_normalized_production_vec = {
        0.916955708517556,
        0.90947506148393,
        0.38425267564517,
        0.191510884037643,
        0.803361391862077,
        0.261511294927198,
        0.221944653883198,
        0.858495335855501,
        0.0162863861443092,
        0.774345409915512,
        0.354898664149867,
        0.11158009453439,
        0.191670176408956,
        0.0149072402795702,
        0.30174228469322,
        0.0815062957850151,
        0.776404660266821,
        0.207069187162109,
```

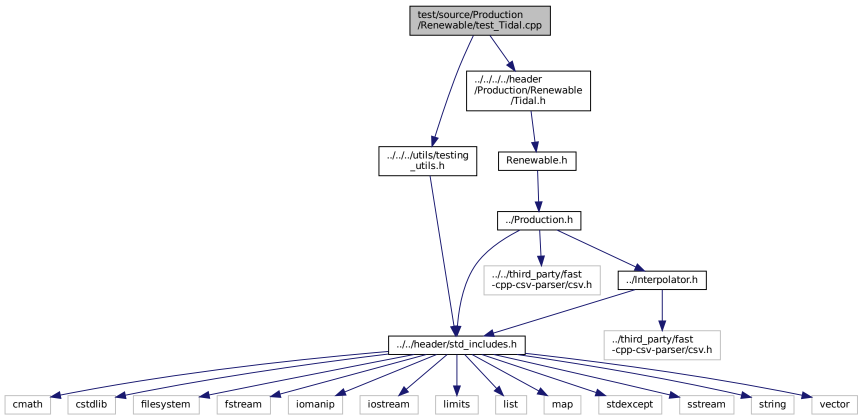
```
        0.518926216750454,
        0.148538109788597,
        0.443035200791027,
        0.62119079547209,
        0.270792717524391,
        0.761074879460849,
        0.0545251308358993,
        0.0895417089500092,
        0.21787190761933,
        0.834403724509682,
        0.908807953036246,
        0.815888965292123,
        0.416663215314571,
        0.523649705576525,
        0.490890480401437,
        0.28317138282312,
        0.877382682055847,
        0.14972090597986,
        0.480161632646382,
        0.0655830129932816,
        0.41802666403448,
        0.48692477737368,
        0.275957323208066,
        0.228651250718341,
        0.574371311550247,
        0.251872481275769,
        0.802697508767121,
        0.00130607304363551,
        0.481240172488057,
        0.702527508293784
    };

    for (size_t i = 0; i < expected_normalized_production_vec.size(); i++) {
        testFloatEquals(
            test_solar_override.normalized_production_vec[i],
            expected_normalized_production_vec[i],
            __FILE__,
            __LINE__
        );

        testFloatEquals(
            test_solar_override.computeProductionkW(i, rand(), rand()),
            test_solar_override.capacity_kW * expected_normalized_production_vec[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testProductionOverride_Solar() */
```

## 5.62 test/source/Production/Renewable/test_Tidal.cpp File Reference

Testing suite for Tidal class.

```
#include "../../../utils/testing_utils.h"
#include "../../../../header/Production/Renewable/Tidal.h"
```

Include dependency graph for test_Tidal.cpp:




## Functions

- Renewable ∗ testConstruct_Tidal (std::vector< double > ∗time_vec_hrs_ptr)

    *A function to construct a Tidal object and spot check some post-construction attributes.*
- void testBadConstruct_Tidal (std::vector< double > ∗time_vec_hrs_ptr)

    *Function to test the trying to construct a Tidal object given bad inputs is being handled as expected.*
- void testProductionConstraint_Tidal (Renewable ∗test_tidal_ptr)

    *Function to test that the production constraint is active and behaving as expected.*
- void testCommit_Tidal (Renewable ∗test_tidal_ptr)

    *Function to test if the commit method is working as expected, by checking some post-call attributes of the test Tidal object. Uses a randomized resource input.*
- void testEconomics_Tidal (Renewable ∗test_tidal_ptr)
- int main (int argc, char ∗∗argv)

### 5.62.1 Detailed Description

Testing suite for Tidal class.

A suite of tests for the Tidal class.

### 5.62.2 Function Documentation

#### 5.62.2.1 main()

```
int main (
        int argc,
        char ** argv )
```

```
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Production <-- Renewable <-- Tidal");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    std::vector<double> time_vec_hrs (8760, 0);
    for (size_t i = 0; i < time_vec_hrs.size(); i++) {
        time_vec_hrs[i] = i;
    }

    Renewable* test_tidal_ptr = testConstruct_Tidal(&time_vec_hrs);


    try {
        testBadConstruct_Tidal(&time_vec_hrs);

        testProductionConstraint_Tidal(test_tidal_ptr);

        testCommit_Tidal(test_tidal_ptr);
        testEconomics_Tidal(test_tidal_ptr);
    }


    catch (...) {
        delete test_tidal_ptr;

        printGold(" ....... ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_tidal_ptr;

    printGold(" ....... ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;

}   /* main() */
```

#### 5.62.2.2 testBadConstruct_Tidal()

```
void testBadConstruct_Tidal (
        std::vector< double > * time_vec_hrs_ptr )
```

Function to test the trying to construct a Tidal object given bad inputs is being handled as expected.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
{
    bool error_flag = true;

    try {
        TidalInputs bad_tidal_inputs;
```

```
        bad_tidal_inputs.design_speed_ms = -1;

        Tidal bad_tidal(8760, 1, bad_tidal_inputs, time_vec_hrs_ptr);

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    return;
}   /* testBadConstruct_Tidal() */
```

#### 5.62.2.3 testCommit_Tidal()

```
void testCommit_Tidal (
            Renewable * test_tidal_ptr )
```

Function to test if the commit method is working as expected, by checking some post-call attributes of the test Tidal object. Uses a randomized resource input.

**Parameters**

| | |
|---|---|
| *test_tidal_ptr* | A Renewable pointer to the test Tidal object. |

```
{
    std::vector<double> dt_vec_hrs (48, 1);

    std::vector<double> load_vec_kW = {
        1, 1, 0, 1, 0, 0, 1, 1, 1, 0, 1, 1,
        1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0,
        1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1,
        1, 0, 0, 0, 1, 1, 1, 0, 1, 1, 0, 0
    };

    double load_kW = 0;
    double production_kW = 0;
    double roll = 0;
    double tidal_resource_ms = 0;

    for (int i = 0; i < 48; i++) {
        roll = (double)rand() / RAND_MAX;

        tidal_resource_ms = roll * ((Tidal*)test_tidal_ptr)->design_speed_ms;

        roll = (double)rand() / RAND_MAX;

        if (roll <= 0.1) {
            tidal_resource_ms = 0;
        }

        else if (roll >= 0.95) {
            tidal_resource_ms = 3 * ((Tidal*)test_tidal_ptr)->design_speed_ms;
        }

        roll = (double)rand() / RAND_MAX;

        if (roll >= 0.95) {
            roll = 1.25;
        }

        load_vec_kW[i] *= roll * test_tidal_ptr->capacity_kW;
        load_kW = load_vec_kW[i];

        production_kW = test_tidal_ptr->computeProductionkW(
            i,
            dt_vec_hrs[i],
            tidal_resource_ms
        );

        load_kW = test_tidal_ptr->commit(
            i,
```

```
            dt_vec_hrs[i],
            production_kW,
            load_kW
        );

        // is running (or not) as expected
        if (production_kW > 0) {
            testTruth(
                test_tidal_ptr->is_running,
                __FILE__,
                __LINE__
            );
        }

        else {
            testTruth(
                not test_tidal_ptr->is_running,
                __FILE__,
                __LINE__
            );
        }

        // load_kW <= load_vec_kW (i.e., after vs before)
        testLessThanOrEqualTo(
            load_kW,
            load_vec_kW[i],
            __FILE__,
            __LINE__
        );

        // production = dispatch + storage + curtailment
        testFloatEquals(
            test_tidal_ptr->production_vec_kW[i] -
            test_tidal_ptr->dispatch_vec_kW[i] -
            test_tidal_ptr->storage_vec_kW[i] -
            test_tidal_ptr->curtailment_vec_kW[i],
            0,
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testCommit_Tidal() */
```

#### 5.62.2.4 testConstruct_Tidal()

Renewable * testConstruct_Tidal (
    std::vector< double > * *time_vec_hrs_ptr* )

A function to construct a Tidal object and spot check some post-construction attributes.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

**Returns**

A Renewable pointer to a test Tidal object.

```
{
    TidalInputs tidal_inputs;

    Renewable* test_tidal_ptr = new Tidal(8760, 1, tidal_inputs, time_vec_hrs_ptr);

    testTruth(
        not tidal_inputs.renewable_inputs.production_inputs.print_flag,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
```

```
        test_tidal_ptr->n_points,
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_tidal_ptr->type,
        RenewableType :: TIDAL,
        __FILE__,
        __LINE__
    );

    testTruth(
        test_tidal_ptr->type_str == "TIDAL",
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_tidal_ptr->capital_cost,
        500237.446725,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_tidal_ptr->operation_maintenance_cost_kWh,
        0.069905,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_tidal_ptr->firmness_factor,
        0.8,
        __FILE__,
        __LINE__
    );

    return test_tidal_ptr;
}   /* testConstruct_Tidal() */
```

#### 5.62.2.5 testEconomics_Tidal()

```
void testEconomics_Tidal (
            Renewable * test_tidal_ptr )
{
    for (int i = 0; i < 48; i++) {
        // resource, O&M > 0 whenever tidal is running (i.e., producing)
        if (test_tidal_ptr->is_running_vec[i]) {
            testGreaterThan(
                test_tidal_ptr->operation_maintenance_cost_vec[i],
                0,
                __FILE__,
                __LINE__
            );
        }

        // resource, O&M = 0 whenever tidal is not running (i.e., not producing)
        else {
            testFloatEquals(
                test_tidal_ptr->operation_maintenance_cost_vec[i],
                0,
                __FILE__,
                __LINE__
            );
        }
    }

    return;
}   /* testEconomics_Tidal() */
```

#### 5.62.2.6 testProductionConstraint_Tidal()

```
void testProductionConstraint_Tidal (
            Renewable * test_tidal_ptr )
```

Function to test that the production constraint is active and behaving as expected.

**Parameters**

| | |
|---|---|
| *test_tidal_ptr* | A Renewable pointer to the test Tidal object. |

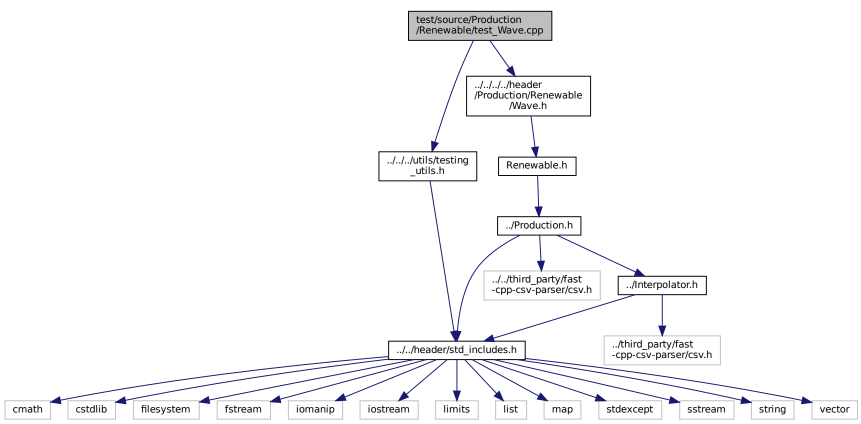
```
{
    testFloatEquals(
        test_tidal_ptr->computeProductionkW(0, 1, 1e6),
        0,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_tidal_ptr->computeProductionkW(
            0,
            1,
            ((Tidal*)test_tidal_ptr)->design_speed_ms
        ),
        test_tidal_ptr->capacity_kW,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_tidal_ptr->computeProductionkW(0, 1, -1),
        0,
        __FILE__,
        __LINE__
    );

    return;
}   /* testProductionConstraint_Tidal() */
```

## 5.63 test/source/Production/Renewable/test_Wave.cpp File Reference

Testing suite for Wave class.

```
#include "../../../utils/testing_utils.h"
#include "../../../../header/Production/Renewable/Wave.h"
```

Include dependency graph for test_Wave.cpp:



## Functions

- Renewable ∗ testConstruct_Wave (std::vector< double > ∗time_vec_hrs_ptr)

  *A function to construct a Wave object and spot check some post-construction attributes.*
- Renewable ∗ testConstructLookup_Wave (std::vector< double > ∗time_vec_hrs_ptr)

  *A function to construct a Wave object using production lookup.*
- void testBadConstruct_Wave (std::vector< double > ∗time_vec_hrs_ptr)

  *Function to test the trying to construct a Wave object given bad inputs is being handled as expected.*
- void testProductionConstraint_Wave (Renewable ∗test_wave_ptr)

  *Function to test that the production constraint is active and behaving as expected.*
- void testCommit_Wave (Renewable ∗test_wave_ptr)

  *Function to test if the commit method is working as expected, by checking some post-call attributes of the test Wave object. Uses a randomized resource input.*
- void testEconomics_Wave (Renewable ∗test_wave_ptr)
- void testProductionLookup_Wave (Renewable ∗test_wave_lookup_ptr)

  *Function to test that production lookup (i.e., interpolation) is returning the expected values.*
- int main (int argc, char ∗∗argv)

## 5.63.1 Detailed Description

Testing suite for Wave class.

A suite of tests for the Wave class.

## 5.63.2 Function Documentation

### 5.63.2.1 main()

```
int main (
        int argc,
        char ** argv )
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Production <-- Renewable <-- Wave");

    #ifdef _WIN32
        std::cout << std::endl;
    #endif

    srand(time(NULL));


    std::vector<double> time_vec_hrs (8760, 0);
    for (size_t i = 0; i < time_vec_hrs.size(); i++) {
        time_vec_hrs[i] = i;
    }

    Renewable* test_wave_ptr = testConstruct_Wave(&time_vec_hrs);
    Renewable* test_wave_lookup_ptr = testConstructLookup_Wave(&time_vec_hrs);


    try {
        testBadConstruct_Wave(&time_vec_hrs);

        testProductionConstraint_Wave(test_wave_ptr);
```

```
        testCommit_Wave(test_wave_ptr);
        testEconomics_Wave(test_wave_ptr);

        testProductionLookup_Wave(test_wave_lookup_ptr);
    }


    catch (...) {
        delete test_wave_ptr;
        delete test_wave_lookup_ptr;

        printGold(" ........ ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_wave_ptr;
    delete test_wave_lookup_ptr;

    printGold(" ........ ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;

}   /* main() */
```

#### 5.63.2.2 testBadConstruct_Wave()

```
void testBadConstruct_Wave (
            std::vector< double > * time_vec_hrs_ptr )
```

Function to test the trying to construct a Wave object given bad inputs is being handled as expected.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
{
    bool error_flag = true;

    try {
        WaveInputs bad_wave_inputs;
        bad_wave_inputs.design_significant_wave_height_m = -1;

        Wave bad_wave(8760, 1, bad_wave_inputs, time_vec_hrs_ptr);

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    return;
}   /* testBadConstruct_Wave() */
```

#### 5.63.2.3 testCommit_Wave()

```
void testCommit_Wave (
            Renewable * test_wave_ptr )
```

Function to test if the commit method is working as expected, by checking some post-call attributes of the test Wave object. Uses a randomized resource input.

#### Parameters

| | |
|---|---|
| *test_wave_ptr* | A Renewable pointer to the test Wave object. |

```
{
    std::vector<double> dt_vec_hrs (48, 1);

    std::vector<double> load_vec_kW = {
        1, 1, 0, 1, 0, 0, 1, 1, 1, 0, 1, 1,
        1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0,
        1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1,
        1, 0, 0, 0, 1, 1, 1, 0, 1, 1, 0, 0
    };

    double load_kW = 0;
    double production_kW = 0;
    double roll = 0;
    double significant_wave_height_m = 0;
    double energy_period_s = 0;

    for (int i = 0; i < 48; i++) {
        roll = (double)rand() / RAND_MAX;

        if (roll <= 0.05) {
            roll = 0;
        }

        significant_wave_height_m = roll *
            ((Wave*)test_wave_ptr)->design_significant_wave_height_m;

        roll = (double)rand() / RAND_MAX;

        if (roll <= 0.05) {
            roll = 0;
        }

        energy_period_s = roll * ((Wave*)test_wave_ptr)->design_energy_period_s;

        roll = (double)rand() / RAND_MAX;

        if (roll >= 0.95) {
            roll = 1.25;
        }

        load_vec_kW[i] *= roll * test_wave_ptr->capacity_kW;
        load_kW = load_vec_kW[i];

        production_kW = test_wave_ptr->computeProductionkW(
            i,
            dt_vec_hrs[i],
            significant_wave_height_m,
            energy_period_s
        );

        load_kW = test_wave_ptr->commit(
            i,
            dt_vec_hrs[i],
            production_kW,
            load_kW
        );

        // is running (or not) as expected
        if (production_kW > 0) {
            testTruth(
                test_wave_ptr->is_running,
                __FILE__,
                __LINE__
            );
        }

        else {
            testTruth(
                not test_wave_ptr->is_running,
                __FILE__,
                __LINE__
            );
        }

        // load_kW <= load_vec_kW (i.e., after vs before)
        testLessThanOrEqualTo(
            load_kW,
            load_vec_kW[i],
            __FILE__,
            __LINE__
        );

```

```
        // production = dispatch + storage + curtailment
        testFloatEquals(
            test_wave_ptr->production_vec_kW[i] -
            test_wave_ptr->dispatch_vec_kW[i] -
            test_wave_ptr->storage_vec_kW[i] -
            test_wave_ptr->curtailment_vec_kW[i],
            0,
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testCommit_Wave() */
```

#### 5.63.2.4 testConstruct_Wave()

Renewable * testConstruct_Wave (
    std::vector< double > * *time_vec_hrs_ptr* )

A function to construct a Wave object and spot check some post-construction attributes.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

**Returns**

A Renewable pointer to a test Wave object.

```
{
    WaveInputs wave_inputs;

    Renewable* test_wave_ptr = new Wave(8760, 1, wave_inputs, time_vec_hrs_ptr);

    testTruth(
        not wave_inputs.renewable_inputs.production_inputs.print_flag,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_wave_ptr->n_points,
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_wave_ptr->type,
        RenewableType :: WAVE,
        __FILE__,
        __LINE__
    );

    testTruth(
        test_wave_ptr->type_str == "WAVE",
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_wave_ptr->capital_cost,
        850831.063539,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_wave_ptr->operation_maintenance_cost_kWh,
        0.069905,
        __FILE__,
```

```
        __LINE__
    );

    testFloatEquals(
        test_wave_ptr->firmness_factor,
        0.8,
        __FILE__,
        __LINE__
    );

    return test_wave_ptr;
}   /* testConstruct_Wave() */
```

### 5.63.2.5 testConstructLookup_Wave()

```
Renewable * testConstructLookup_Wave (
        std::vector< double > * time_vec_hrs_ptr )
```

A function to construct a Wave object using production lookup.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

**Returns**

A Renewable pointer to a test Wave object.

```
{
    WaveInputs wave_inputs;

    wave_inputs.power_model = WavePowerProductionModel :: WAVE_POWER_LOOKUP;
    wave_inputs.path_2_normalized_performance_matrix =
        "data/test/interpolation/wave_energy_converter_normalized_performance_matrix.csv";

    Renewable* test_wave_lookup_ptr = new Wave(8760, 1, wave_inputs, time_vec_hrs_ptr);

    return test_wave_lookup_ptr;
}   /* testConstructLookup_Wave() */
```

### 5.63.2.6 testEconomics_Wave()

```
void testEconomics_Wave (
        Renewable * test_wave_ptr )
{
    for (int i = 0; i < 48; i++) {
        // resource, O&M > 0 whenever wave is running (i.e., producing)
        if (test_wave_ptr->is_running_vec[i]) {
            testGreaterThan(
                test_wave_ptr->operation_maintenance_cost_vec[i],
                0,
                __FILE__,
                __LINE__
            );
        }

        // resource, O&M = 0 whenever wave is not running (i.e., not producing)
        else {
            testFloatEquals(
                test_wave_ptr->operation_maintenance_cost_vec[i],
                0,
                __FILE__,
                __LINE__
```

```
            );
        }
    }

    return;
}   /* testEconomics_Wave() */
```

#### 5.63.2.7 testProductionConstraint_Wave()

```
void testProductionConstraint_Wave (
            Renewable * test_wave_ptr )
```

Function to test that the production constraint is active and behaving as expected.

**Parameters**

| | |
|---|---|
| *test_wave_ptr* | A Renewable pointer to the test Wave object. |

```
{
    testFloatEquals(
        test_wave_ptr->computeProductionkW(0, 1, 0, rand()),
        0,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_wave_ptr->computeProductionkW(0, 1, rand(), 0),
        0,
        __FILE__,
        __LINE__
    );

    return;
}   /* testProductionConstraint_Wave() */
```

#### 5.63.2.8 testProductionLookup_Wave()

```
void testProductionLookup_Wave (
            Renewable * test_wave_lookup_ptr )
```

Function to test that production lookup (i.e., interpolation) is returning the expected values.

**Parameters**

| | |
|---|---|
| *test_wave_lookup_ptr* | A Renewable pointer to the test Wave object using production lookup. |

```
{
    std::vector<double> significant_wave_height_vec_m = {
        0.389211848822208,
        0.836477431896843,
        1.52738334015579,
        1.92640601114508,
        2.27297317532019,
        2.87416589636605,
        3.72275770908175,
        3.95063175885536,
        4.68097139867404,
        4.97775020449812,
        5.55184219980547,
        6.06566629451658,
        6.27927876785062,
```

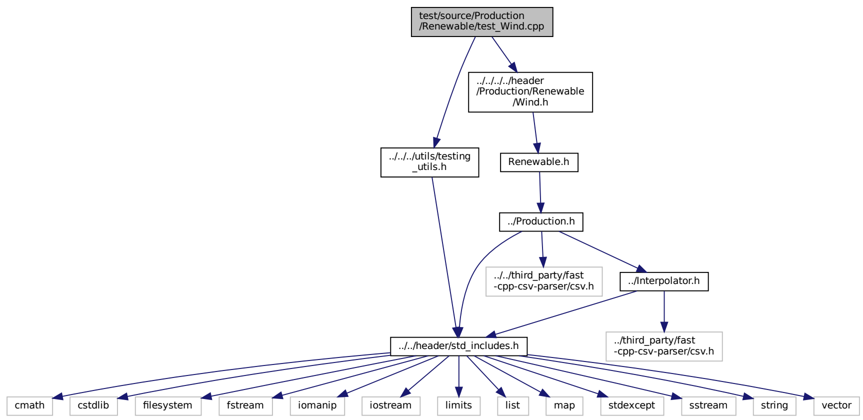
```
        6.96218133671013,
        7.51754442460228
    };

    std::vector<double> energy_period_vec_s = {
        5.45741899698926,
        6.00101329139007,
        7.50567689404182,
        8.77681262912881,
        9.45143678206774,
        10.7767876462885,
        11.4795760857165,
        12.9430684577599,
        13.303544885703,
        14.5069863517863,
        15.1487890438045,
        16.086524049077,
        17.176609978648,
        18.4155153740256,
        19.1704554940162
    };

    std::vector<std::vector<double>> expected_normalized_performance_matrix = {
    {0.0337204906738533,0.145056406036013,0.334677248806653,0.441674658936075,0.533295755691263,0.68807895676592,0.89961488
    {0.0310681846933292,0.135425896595439,0.324045598153363,0.430214268249038,0.520985043044784,0.673879556322479,0.8820580
    {0.0237266281076604,0.108768742207538,0.294617294841705,0.398492020763049,0.486909112828702,0.63457575706117,0.8334608
    {0.0175245009938255,0.0862488504001753,0.269756343931147,0.371693152028768,0.458121859300634,0.601372013927032,0.79240
    {0.0142328739589644,0.0742969694833995,0.256562003243255,0.357470308928265,0.442843729679424,0.583749940636223,0.77061
    {0.0077662203173173,0.0508165832074184,0.230640709501637,0.329528443353471,0.41282867283787,0.549130026772199,0.727811
    {0.00433717405958826,0.0383657337957315,0.21689552996585,0.314711823368423,0.396912710109449,0.530772265145106,0.70511
    {0.000102358416923608,0.0210697053701168,0.188272456115393,0.283857573197153,0.363769179652786,0.492543912767949,0.657
    {0,0.0196038727057393,0.181222235960193,0.276257786480759,0.355605514643888,0.483127792688125,0.646203044346932,0.6855
    {0,0.0157252942367668,0.157685253727545,0.250886090139653,0.328351324840186,0.451692313207986,0.607334650020078,0.6442
    {0,0.0136568246246201,0.145132837191606,0.23735520935175,0.313816498778623,0.43492757979648,0.586605897674033,0.622265
    {0,0.0106345930466366,0.12679255826648,0.217585300741544,0.292579730277991,0.410432703770651,0.556319211544087,0.59010
    {0,0.00712134879261874,0.10547259059088,0.194603435839713,0.267892689267542,0.381958220518761,0.52111194060085,0.55272
    {0,0.00312847342058727,0.0812420026472571,0.168484067035528,0.239835352250276,0.349596376397684,0.481098142839729,0.51
    {0,0.00103256269522045,0.0673448574082101,0.152567953107312,0.222738316872545,0.329876344040866,0.456715311514779,0.48
    };

    for (size_t i = 0; i < energy_period_vec_s.size(); i++) {
        for (size_t j = 0; j < significant_wave_height_vec_m.size(); j++) {
            testFloatEquals(
                test_wave_lookup_ptr->computeProductionkW(
                    0,
                    1,
                    significant_wave_height_vec_m[j],
                    energy_period_vec_s[i]
                ),
                expected_normalized_performance_matrix[i][j] *
                test_wave_lookup_ptr->capacity_kW,
                __FILE__,
                __LINE__
            );
        }
    }

    return;
}   /* testProductionLookup_Wave() */
```

## 5.64 test/source/Production/Renewable/test_Wind.cpp File Reference

Testing suite for Wind class.

```
#include "../../../utils/testing_utils.h"
#include "../../../../header/Production/Renewable/Wind.h"
```

Include dependency graph for test_Wind.cpp:




## Functions

- Renewable ∗ testConstruct_Wind (std::vector< double > ∗time_vec_hrs_ptr)

    *A function to construct a Wind object and spot check some post-construction attributes.*
- void testBadConstruct_Wind (std::vector< double > ∗time_vec_hrs_ptr)

    *Function to test the trying to construct a Wind object given bad inputs is being handled as expected.*
- void testProductionConstraint_Wind (Renewable ∗test_wind_ptr)

    *Function to test that the production constraint is active and behaving as expected.*
- void testCommit_Wind (Renewable ∗test_wind_ptr)

    *Function to test if the commit method is working as expected, by checking some post-call attributes of the test Wind object. Uses a randomized resource input.*
- void testEconomics_Wind (Renewable ∗test_wind_ptr)
- int main (int argc, char ∗∗argv)

### 5.64.1 Detailed Description

Testing suite for Wind class.

A suite of tests for the Wind class.

### 5.64.2 Function Documentation

#### 5.64.2.1 main()

```
int main (
            int argc,
            char ** argv )
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Production <-- Renewable <-- Wind");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    std::vector<double> time_vec_hrs (8760, 0);
    for (size_t i = 0; i < time_vec_hrs.size(); i++) {
        time_vec_hrs[i] = i;
    }

    Renewable* test_wind_ptr = testConstruct_Wind(&time_vec_hrs);


    try {
        testBadConstruct_Wind(&time_vec_hrs);

        testProductionConstraint_Wind(test_wind_ptr);

        testCommit_Wind(test_wind_ptr);
        testEconomics_Wind(test_wind_ptr);
    }


    catch (...) {
        delete test_wind_ptr;

        printGold(" ........ ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_wind_ptr;

    printGold(" ........ ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;

}   /* main() */
```

#### 5.64.2.2 testBadConstruct_Wind()

```
void testBadConstruct_Wind (
            std::vector< double > * time_vec_hrs_ptr )
```

Function to test the trying to construct a Wind object given bad inputs is being handled as expected.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
{
    bool error_flag = true;

    try {
        WindInputs bad_wind_inputs;
```

```
        bad_wind_inputs.design_speed_ms = -1;

        Wind bad_wind(8760, 1, bad_wind_inputs, time_vec_hrs_ptr);

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    return;
}   /* testBadConstruct_Wind() */
```

### 5.64.2.3 testCommit_Wind()

```
void testCommit_Wind (
              Renewable * test_wind_ptr )
```

Function to test if the commit method is working as expected, by checking some post-call attributes of the test Wind object. Uses a randomized resource input.

**Parameters**

| | |
|---|---|
| *test_wind_ptr* | A Renewable pointer to the test Wind object. |

```
{
    std::vector<double> dt_vec_hrs (48, 1);

    std::vector<double> load_vec_kW = {
        1, 1, 0, 1, 0, 0, 1, 1, 1, 0, 1, 1,
        1, 1, 1, 0, 0, 0, 0, 0, 0, 1, 1, 0,
        1, 1, 1, 1, 1, 0, 1, 1, 1, 1, 0, 1,
        1, 0, 0, 0, 1, 1, 1, 0, 1, 1, 0, 0
    };

    double load_kW = 0;
    double production_kW = 0;
    double roll = 0;
    double wind_resource_ms = 0;

    for (int i = 0; i < 48; i++) {
        roll = (double)rand() / RAND_MAX;

        wind_resource_ms = roll * ((Wind*)test_wind_ptr)->design_speed_ms;

        roll = (double)rand() / RAND_MAX;

        if (roll <= 0.1) {
            wind_resource_ms = 0;
        }

        else if (roll >= 0.95) {
            wind_resource_ms = 3 * ((Wind*)test_wind_ptr)->design_speed_ms;
        }

        roll = (double)rand() / RAND_MAX;

        if (roll >= 0.95) {
            roll = 1.25;
        }

        load_vec_kW[i] *= roll * test_wind_ptr->capacity_kW;
        load_kW = load_vec_kW[i];

        production_kW = test_wind_ptr->computeProductionkW(
            i,
            dt_vec_hrs[i],
            wind_resource_ms
        );

        load_kW = test_wind_ptr->commit(
            i,
```

```
            dt_vec_hrs[i],
            production_kW,
            load_kW
        );

        // is running (or not) as expected
        if (production_kW > 0) {
            testTruth(
                test_wind_ptr->is_running,
                __FILE__,
                __LINE__
            );
        }

        else {
            testTruth(
                not test_wind_ptr->is_running,
                __FILE__,
                __LINE__
            );
        }

        // load_kW <= load_vec_kW (i.e., after vs before)
        testLessThanOrEqualTo(
            load_kW,
            load_vec_kW[i],
            __FILE__,
            __LINE__
        );

        // production = dispatch + storage + curtailment
        testFloatEquals(
            test_wind_ptr->production_vec_kW[i] -
            test_wind_ptr->dispatch_vec_kW[i] -
            test_wind_ptr->storage_vec_kW[i] -
            test_wind_ptr->curtailment_vec_kW[i],
            0,
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testCommit_Wind() */
```

#### 5.64.2.4 testConstruct_Wind()

```
Renewable * testConstruct_Wind (
              std::vector< double > * time_vec_hrs_ptr )
```

A function to construct a Wind object and spot check some post-construction attributes.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

**Returns**

A Renewable pointer to a test Wind object.

```
{
    WindInputs wind_inputs;

    Renewable* test_wind_ptr = new Wind(8760, 1, wind_inputs, time_vec_hrs_ptr);

    testTruth(
        not wind_inputs.renewable_inputs.production_inputs.print_flag,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
```

```
        test_wind_ptr->n_points,
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_wind_ptr->type,
        RenewableType :: WIND,
        __FILE__,
        __LINE__
    );

    testTruth(
        test_wind_ptr->type_str == "WIND",
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_wind_ptr->capital_cost,
        450356.170088,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_wind_ptr->operation_maintenance_cost_kWh,
        0.034953,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_wind_ptr->firmness_factor,
        0.5,
        __FILE__,
        __LINE__
    );

    return test_wind_ptr;
}   /* testConstruct_Wind() */
```

#### 5.64.2.5 testEconomics_Wind()

void testEconomics_Wind (
    Renewable * *test_wind_ptr* )

```
{
    for (int i = 0; i < 48; i++) {
        // resource, O&M > 0 whenever wind is running (i.e., producing)
        if (test_wind_ptr->is_running_vec[i]) {
            testGreaterThan(
                test_wind_ptr->operation_maintenance_cost_vec[i],
                0,
                __FILE__,
                __LINE__
            );
        }

        // resource, O&M = 0 whenever wind is not running (i.e., not producing)
        else {
            testFloatEquals(
                test_wind_ptr->operation_maintenance_cost_vec[i],
                0,
                __FILE__,
                __LINE__
            );
        }
    }

    return;
}   /* testEconomics_Wind() */
```

#### 5.64.2.6 testProductionConstraint_Wind()

```
void testProductionConstraint_Wind (
            Renewable * test_wind_ptr )
```

Function to test that the production constraint is active and behaving as expected.

**Parameters**

| | |
|---|---|
| *test_wind_ptr* | A Renewable pointer to the test Wind object. |

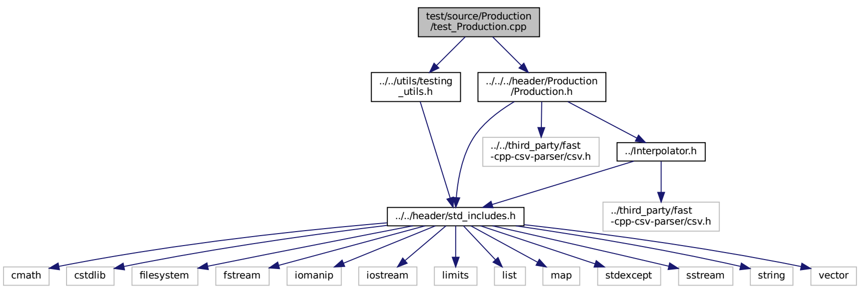
```
{
    testFloatEquals(
        test_wind_ptr->computeProductionkW(0, 1, 1e6),
        0,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_wind_ptr->computeProductionkW(
            0,
            1,
            ((Wind*)test_wind_ptr)->design_speed_ms
        ),
        test_wind_ptr->capacity_kW,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_wind_ptr->computeProductionkW(0, 1, -1),
        0,
        __FILE__,
        __LINE__
    );

    return;
}   /* testProductionConstraint_Wind() */
```

## 5.65 test/source/Production/test_Production.cpp File Reference

Testing suite for Production class.

```
#include "../../utils/testing_utils.h"
#include "../../../header/Production/Production.h"
```

Include dependency graph for test_Production.cpp:



## Functions

- Production ∗ testConstruct_Production (std::vector< double > ∗time_vec_hrs_ptr)

    *A function to construct a Production object and spot check some post-construction attributes.*
- void testBadConstruct_Production (std::vector< double > ∗time_vec_hrs_ptr)

    *Function to test the trying to construct a Production object given bad inputs is being handled as expected.*
- int main (int argc, char ∗∗argv)

## 5.65.1 Detailed Description

Testing suite for Production class.

A suite of tests for the Production class.

## 5.65.2 Function Documentation

### 5.65.2.1 main()

```
int main (
            int argc,
            char ** argv )
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Production");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    std::vector<double> time_vec_hrs (8760, 0);
    for (size_t i = 0; i < time_vec_hrs.size(); i++) {
        time_vec_hrs[i] = i;
    }

    Production* test_production_ptr = testConstruct_Production(&time_vec_hrs);


    try {
        testBadConstruct_Production(&time_vec_hrs);
    }


    catch (...) {
        delete test_production_ptr;

        printGold(" .............................. ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_production_ptr;

    printGold(" .............................. ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;

}   /* main() */
```

#### 5.65.2.2 testBadConstruct_Production()

```
void testBadConstruct_Production (
            std::vector< double > * time_vec_hrs_ptr )
```

Function to test the trying to construct a Production object given bad inputs is being handled as expected.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

```
{
    bool error_flag = true;

    try {
        ProductionInputs production_inputs;

        Production bad_production(0, 1, production_inputs, time_vec_hrs_ptr);

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    return;
}   /* testBadConstruct_Production() */
```

#### 5.65.2.3 testConstruct_Production()

```
Production * testConstruct_Production (
            std::vector< double > * time_vec_hrs_ptr )
```

A function to construct a Production object and spot check some post-construction attributes.

**Parameters**

| | |
|---|---|
| *time_vec_hrs_ptr* | A pointer to the vector containing the modelling time series. |

**Returns**

A pointer to a test Production object.

```
{
    ProductionInputs production_inputs;

    Production* test_production_ptr = new Production(
        8760,
        1,
        production_inputs,
        time_vec_hrs_ptr
    );

    testTruth(
        not production_inputs.print_flag,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        production_inputs.nominal_inflation_annual,
        0.02,
        __FILE__,
```

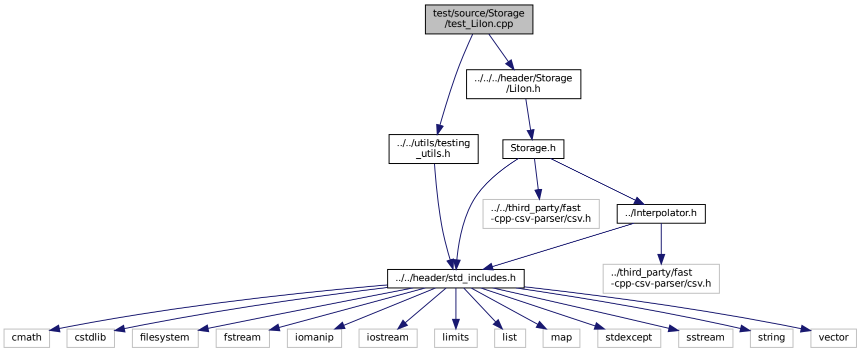
```
        __LINE__
    );

    testFloatEquals(
        production_inputs.nominal_discount_annual,
        0.04,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_production_ptr->n_points,
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_production_ptr->capacity_kW,
        100,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_production_ptr->real_discount_annual,
        0.0196078431372549,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_production_ptr->production_vec_kW.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_production_ptr->dispatch_vec_kW.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_production_ptr->storage_vec_kW.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_production_ptr->curtailment_vec_kW.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_production_ptr->capital_cost_vec.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_production_ptr->operation_maintenance_cost_vec.size(),
        8760,
        __FILE__,
        __LINE__
    );

    return test_production_ptr;
}   /* testConstruct_Production() */
```

## 5.66 test/source/Storage/test_LiIon.cpp File Reference

Testing suite for LiIon class.

```
#include "../../utils/testing_utils.h"
#include "../../../header/Storage/LiIon.h"
```

Include dependency graph for test_LiIon.cpp:




## Functions

- Storage ∗ testConstruct_LiIon (void)

  *A function to construct a LiIon object and spot check some post-construction attributes.*
- void testBadConstruct_LiIon (void)

  *Function to test the trying to construct a LiIon object given bad inputs is being handled as expected.*
- void testCommitCharge_LiIon (Storage ∗test_liion_ptr)

  *A function to test commitCharge() and ensure that its impact on acceptable and available power is as expected.*
- void testCommitDischarge_LiIon (Storage ∗test_liion_ptr)

  *A function to test commitDischarge() and ensure that its impact on acceptable and available power is as expected.*
- int main (int argc, char ∗∗argv)

## 5.66.1 Detailed Description

Testing suite for LiIon class.

A suite of tests for the LiIon class.

## 5.66.2 Function Documentation

#### 5.66.2.1 main()

```
int main (
        int argc,
        char ** argv )
```

```
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Storage <-- LiIon");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    Storage* test_liion_ptr = testConstruct_LiIon();


    try {
        testBadConstruct_LiIon();

        testCommitCharge_LiIon(test_liion_ptr);
        testCommitDischarge_LiIon(test_liion_ptr);
    }


    catch (...) {
        delete test_liion_ptr;

        printGold(" ........................ ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_liion_ptr;

    printGold(" ........................ ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;

}   /* main() */
```

#### 5.66.2.2 testBadConstruct_LiIon()

```
void testBadConstruct_LiIon (
        void )
```

Function to test the trying to construct a LiIon object given bad inputs is being handled as expected.

```
{
    bool error_flag = true;

    try {
        LiIonInputs bad_liion_inputs;
        bad_liion_inputs.min_SOC = -1;

        LiIon bad_liion(8760, 1, bad_liion_inputs);

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    return;
}   /* testBadConstruct_LiIon() */
```

### 5.66.2.3 testCommitCharge_LiIon()

```
void testCommitCharge_LiIon (
            Storage * test_liion_ptr )
```

A function to test commitCharge() and ensure that its impact on acceptable and available power is as expected.

**Parameters**

| | |
|---|---|
| *test_liion_ptr* | A Storage pointer to a test LiIon object. |

```
{
    double dt_hrs = 1;

    testFloatEquals(
        test_liion_ptr->getAvailablekW(dt_hrs),
        100,    // hits power capacity constraint
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_liion_ptr->getAcceptablekW(dt_hrs),
        100,    // hits power capacity constraint
        __FILE__,
        __LINE__
    );

    test_liion_ptr->power_kW = 1e6; // as if a massive amount of power is already flowing in

    testFloatEquals(
        test_liion_ptr->getAvailablekW(dt_hrs),
        0,    // is already hitting power capacity constraint
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_liion_ptr->getAcceptablekW(dt_hrs),
        0,    // is already hitting power capacity constraint
        __FILE__,
        __LINE__
    );

    test_liion_ptr->commitCharge(0, dt_hrs, 100);

    testFloatEquals(
        test_liion_ptr->power_kW,
        0,
        __FILE__,
        __LINE__
    );

    return;
}   /* testCommitCharge_LiIon() */
```

### 5.66.2.4 testCommitDischarge_LiIon()

```
void testCommitDischarge_LiIon (
            Storage * test_liion_ptr )
```

A function to test commitDischarge() and ensure that its impact on acceptable and available power is as expected.

**Parameters**

| | |
|---|---|
| *test_liion_ptr* | A Storage pointer to a test LiIon object. |

```
{
```

```
    double dt_hrs = 1;
    double load_kW = 100;

    testFloatEquals(
        test_liion_ptr->getAvailablekW(dt_hrs),
        100,    // hits power capacity constraint
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_liion_ptr->getAcceptablekW(dt_hrs),
        100,    // hits power capacity constraint
        __FILE__,
        __LINE__
    );

    test_liion_ptr->power_kW = 1e6; // as if a massive amount of power is already flowing out

    testFloatEquals(
        test_liion_ptr->getAvailablekW(dt_hrs),
        0,    // is already hitting power capacity constraint
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_liion_ptr->getAcceptablekW(dt_hrs),
        0,    // is already hitting power capacity constraint
        __FILE__,
        __LINE__
    );

    load_kW = test_liion_ptr->commitDischarge(0, dt_hrs, 100, load_kW);

    testFloatEquals(
        load_kW,
        0,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_liion_ptr->power_kW,
        0,
        __FILE__,
        __LINE__
    );

    return;
}   /* testCommitDischarge_LiIon() */
```

#### 5.66.2.5 testConstruct_LiIon()

```
Storage * testConstruct_LiIon (
            void )
```

A function to construct a LiIon object and spot check some post-construction attributes.

**Returns**

A Storage pointer to a test LiIon object.

```
{
    LiIonInputs liion_inputs;

    Storage* test_liion_ptr = new LiIon(8760, 1, liion_inputs);

    testTruth(
        test_liion_ptr->type_str == "LIION",
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((LiIon*)test_liion_ptr)->init_SOC,
```

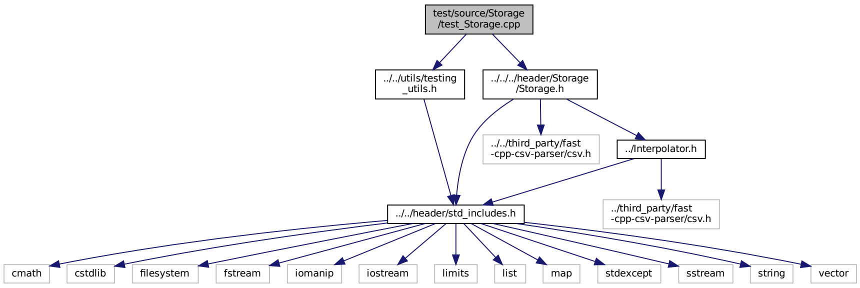
```
        0.5,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((LiIon*)test_liion_ptr)->min_SOC,
        0.15,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((LiIon*)test_liion_ptr)->hysteresis_SOC,
        0.5,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((LiIon*)test_liion_ptr)->max_SOC,
        0.9,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((LiIon*)test_liion_ptr)->charging_efficiency,
        0.9,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((LiIon*)test_liion_ptr)->discharging_efficiency,
        0.9,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((LiIon*)test_liion_ptr)->replace_SOH,
        0.8,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((LiIon*)test_liion_ptr)->power_kW,
        0,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        ((LiIon*)test_liion_ptr)->SOH_vec.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testTruth(
        not ((LiIon*)test_liion_ptr)->power_degradation_flag,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_liion_ptr->energy_capacity_kWh,
        ((LiIon*)test_liion_ptr)->dynamic_energy_capacity_kWh,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_liion_ptr->power_capacity_kW,
        ((LiIon*)test_liion_ptr)->dynamic_power_capacity_kW,
        __FILE__,
        __LINE__
    );

    return test_liion_ptr;
}   /* testConstruct_LiIon() */
```

## 5.67 test/source/Storage/test_Storage.cpp File Reference

Testing suite for Storage class.

```
#include "../../utils/testing_utils.h"
#include "../../../header/Storage/Storage.h"
```

Include dependency graph for test_Storage.cpp:




### Functions

- Storage ∗ testConstruct_Storage (void)
  
  *A function to construct a Storage object and spot check some post-construction attributes.*
- void testBadConstruct_Storage (void)
  
  *Function to test the trying to construct a Storage object given bad inputs is being handled as expected.*
- int main (int argc, char ∗∗argv)

### 5.67.1 Detailed Description

Testing suite for Storage class.

A suite of tests for the Storage class.

### 5.67.2 Function Documentation

#### 5.67.2.1 main()

```
int main (
            int argc,
            char ** argv )
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Storage");

    #ifdef _WIN32
        std::cout « std::endl;
```

```
    #endif

    srand(time(NULL));


    Storage* test_storage_ptr = testConstruct_Storage();


    try {
        testBadConstruct_Storage();
    }


    catch (...) {
        delete test_storage_ptr;

        printGold(" .................................. ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_storage_ptr;

    printGold(" .................................. ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;

}   /* main() */
```

#### 5.67.2.2 testBadConstruct_Storage()

```
void testBadConstruct_Storage (
            void   )
```

Function to test the trying to construct a Storage object given bad inputs is being handled as expected.

```
{
    bool error_flag = true;

    try {
        StorageInputs bad_storage_inputs;
        bad_storage_inputs.energy_capacity_kWh = 0;

        Storage bad_storage(8760, 1, bad_storage_inputs);

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    return;
}   /* testBadConstruct_Storage() */
```

#### 5.67.2.3 testConstruct_Storage()

```
Storage * testConstruct_Storage (
            void   )
```

A function to construct a Storage object and spot check some post-construction attributes.

**Returns**

A Renewable pointer to a test Storage object.

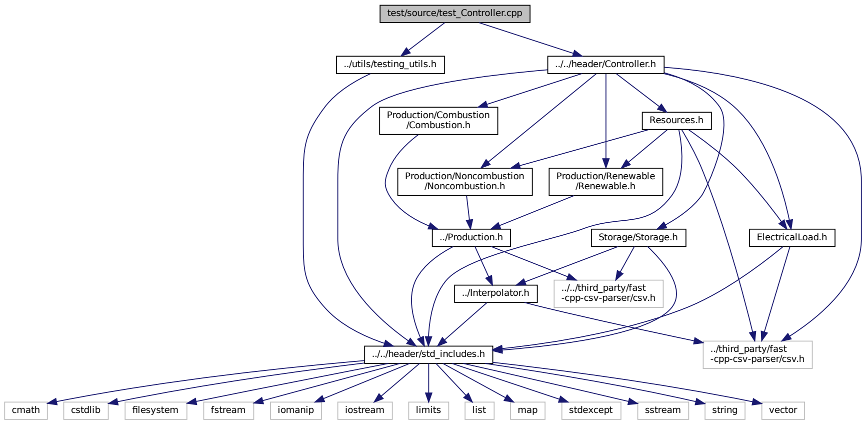
```
{
    StorageInputs storage_inputs;

    Storage* test_storage_ptr = new Storage(8760, 1, storage_inputs);

    testFloatEquals(
        test_storage_ptr->power_capacity_kW,
        100,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_storage_ptr->energy_capacity_kWh,
        1000,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_storage_ptr->charge_vec_kWh.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_storage_ptr->charging_power_vec_kW.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_storage_ptr->discharging_power_vec_kW.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_storage_ptr->capital_cost_vec.size(),
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_storage_ptr->operation_maintenance_cost_vec.size(),
        8760,
        __FILE__,
        __LINE__
    );

    return test_storage_ptr;
}   /* testConstruct_Storage() */
```

## 5.68 test/source/test_Controller.cpp File Reference

Testing suite for Controller class.

```
#include "../utils/testing_utils.h"
#include "../../header/Controller.h"
```

Include dependency graph for test_Controller.cpp:




## Functions

- Controller ∗ testConstruct_Controller (void)

    *A function to construct a Controller object.*
- int main (int argc, char ∗∗argv)

### 5.68.1 Detailed Description

Testing suite for Controller class.

A suite of tests for the Controller class.

### 5.68.2 Function Documentation

#### 5.68.2.1 main()

```
int main (
            int argc,
            char ** argv )
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Controller");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    Controller* test_controller_ptr = testConstruct_Controller();

```

```

    try {
        //...
    }


    catch (...) {
        delete test_controller_ptr;

         printGold(" .............................. ");
         printRed("FAIL");
         std::cout « std::endl;
         throw;
     }


     delete test_controller_ptr;

     printGold(" .............................. ");
     printGreen("PASS");
     std::cout « std::endl;
     return 0;
}    /* main() */
```

#### 5.68.2.2 testConstruct_Controller()

```
Controller * testConstruct_Controller (
              void )
```

A function to construct a Controller object.

**Returns**

A pointer to a test Controller object.

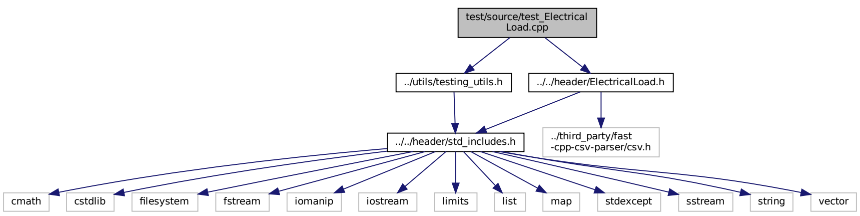
```
{
    Controller* test_controller_ptr = new Controller();

    return test_controller_ptr;
}   /* testConstruct_Controller() */
```

## 5.69 test/source/test_ElectricalLoad.cpp File Reference

Testing suite for ElectricalLoad class.

```
#include "../utils/testing_utils.h"
#include "../../header/ElectricalLoad.h"
```

Include dependency graph for test_ElectricalLoad.cpp:



## Functions

- ElectricalLoad ∗ testConstruct_ElectricalLoad (void)

    *A function to construct an ElectricalLoad object.*
- void testPostConstructionAttributes_ElectricalLoad (ElectricalLoad ∗test_electrical_load_ptr)

    *A function to check the values of various post-construction attributes.*
- void testDataRead_ElectricalLoad (ElectricalLoad ∗test_electrical_load_ptr)

    *A function to check the values read into the test ElectricalLoad object.*
- int main (int argc, char ∗∗argv)

### 5.69.1 Detailed Description

Testing suite for ElectricalLoad class.

A suite of tests for the ElectricalLoad class.

### 5.69.2 Function Documentation

#### 5.69.2.1 main()

```
int main (
            int argc,
            char ** argv )
```

```
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting ElectricalLoad");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    ElectricalLoad* test_electrical_load_ptr = testConstruct_ElectricalLoad();


    try {
        testPostConstructionAttributes_ElectricalLoad(test_electrical_load_ptr);
        testDataRead_ElectricalLoad(test_electrical_load_ptr);
    }


    catch (...) {
        delete test_electrical_load_ptr;

        printGold(" .......................... ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_electrical_load_ptr;

    printGold(" .......................... ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;
}   /* main() */
```

#### 5.69.2.2 testConstruct_ElectricalLoad()

```
ElectricalLoad * testConstruct_ElectricalLoad (
            void )
```

A function to construct an ElectricalLoad object.

**Returns**

A pointer to a test ElectricalLoad object.

```
{
    std::string path_2_electrical_load_time_series =
        "data/test/electrical_load/electrical_load_generic_peak-500kW_1yr_dt-1hr.csv";

    ElectricalLoad* test_electrical_load_ptr =
        new ElectricalLoad(path_2_electrical_load_time_series);

    testTruth(
        test_electrical_load_ptr->path_2_electrical_load_time_series ==
        path_2_electrical_load_time_series,
        __FILE__,
        __LINE__
    );

    return test_electrical_load_ptr;
}   /* testConstruct_ElectricalLoad() */
```

#### 5.69.2.3 testDataRead_ElectricalLoad()

```
void testDataRead_ElectricalLoad (
            ElectricalLoad * test_electrical_load_ptr )
```

A function to check the values read into the test ElectricalLoad object.

**Parameters**

| | |
|---|---|
| *test_electrical_load_ptr* | A pointer to the test ElectricalLoad object. |

```
{
    std::vector<double> expected_dt_vec_hrs (48, 1);

    std::vector<double> expected_time_vec_hrs = {
         0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11,
        12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23,
        24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35,
        36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47
    };

    std::vector<double> expected_load_vec_kW = {
        360.253836463674,
        355.171277826775,
        353.776453532298,
        353.75405737934,
        346.592867404975,
        340.132411175118,
        337.354867340578,
        340.644115618736,
        363.639028500678,
        378.787797779238,
        372.215798201712,
        395.093925731298,
        402.325427142659,
        386.907725462306,
        380.709170928091,
        372.062070914977,
        372.328646856954,
        391.841444284136,
        394.029351759596,
```

```
        383.369407765254,
        381.093099675206,
        382.604158946193,
        390.744843709034,
        383.13949492437,
        368.150393976985,
        364.629744480226,
        363.572736804082,
        359.854924202248,
        355.207590170267,
        349.094656012401,
        354.365935871597,
        343.380608328546,
        404.673065729266,
        486.296896820126,
        480.225974100847,
        457.318764401085,
        418.177339948609,
        414.399018364126,
        409.678420185754,
        404.768766016563,
        401.699589920585,
        402.44339040654,
        398.138372541906,
        396.010498627646,
        390.165117432277,
        375.850429417013,
        365.567100746484,
        365.429624610923
    };

    for (int i = 0; i < 48; i++) {
        testFloatEquals(
            test_electrical_load_ptr->dt_vec_hrs[i],
            expected_dt_vec_hrs[i],
            __FILE__,
            __LINE__
        );

        testFloatEquals(
            test_electrical_load_ptr->time_vec_hrs[i],
            expected_time_vec_hrs[i],
            __FILE__,
            __LINE__
        );

        testFloatEquals(
            test_electrical_load_ptr->load_vec_kW[i],
            expected_load_vec_kW[i],
            __FILE__,
            __LINE__
        );

    }

    return;
}   /* testDataRead_ElectricalLoad() */
```

#### 5.69.2.4 testPostConstructionAttributes_ElectricalLoad()

```
void testPostConstructionAttributes_ElectricalLoad (
            ElectricalLoad * test_electrical_load_ptr )
```

A function to check the values of various post-construction attributes.

**Parameters**

| | |
|---|---|
| *test_electrical_load_ptr* | A pointer to the test ElectricalLoad object. |

```
{
    testFloatEquals(
        test_electrical_load_ptr->n_points,
        8760,
        __FILE__,
        __LINE__
```

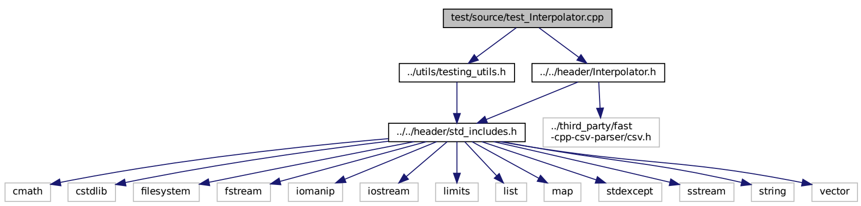
```
    );

    testFloatEquals(
        test_electrical_load_ptr->n_years,
        0.999886,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_electrical_load_ptr->min_load_kW,
        82.1211213927802,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_electrical_load_ptr->mean_load_kW,
        258.373472633202,
        __FILE__,
        __LINE__
    );


    testFloatEquals(
        test_electrical_load_ptr->max_load_kW,
        500,
        __FILE__,
        __LINE__
    );

    return;
}   /* testPostConstructionAttributes_ElectricalLoad() */
```

## 5.70 test/source/test_Interpolator.cpp File Reference

Testing suite for Interpolator class.

```
#include "../utils/testing_utils.h"
#include "../../header/Interpolator.h"
```

Include dependency graph for test_Interpolator.cpp:




### Functions

- Interpolator ∗ testConstruct_Interpolator (void)

    *A function to construct an Interpolator object.*

- void testDataRead1D_Interpolator (Interpolator ∗test_interpolator_ptr, int data_key_1D, std::string path_2←_data_1D)

    *A function to check the 1D data values read into the Interpolator object.*

- void testBadIndexing1D_Interpolator (Interpolator ∗test_interpolator_ptr, int data_key_bad)

    *A function to check if bad key errors are being handled properly.*

- void testInvalidInterpolation1D_Interpolator (Interpolator ∗test_interpolator_ptr, int data_key_1D)

    *Function to check if attempting to interpolate outside the given 1D data domain is handled properly.*

- void testInterpolation1D_Interpolator (Interpolator ∗test_interpolator_ptr, int data_key_1D)

    *Function to check that the Interpolator object is returning the expected 1D interpolation values.*
- void testDataRead2D_Interpolator (Interpolator ∗test_interpolator_ptr, int data_key_2D, std::string path_2↩_data_2D)

    *A function to check the 2D data values read into the Interpolator object.*
- void testInvalidInterpolation2D_Interpolator (Interpolator ∗test_interpolator_ptr, int data_key_2D)

    *Function to check if attempting to interpolate outside the given 2D data domain is handled properly.*
- void testInterpolation2D_Interpolator (Interpolator ∗test_interpolator_ptr, int data_key_2D)

    *Function to check that the Interpolator object is returning the expected 2D interpolation values.*
- int main (int argc, char ∗∗argv)

## 5.70.1 Detailed Description

Testing suite for Interpolator class.

A suite of tests for the Interpolator class.

## 5.70.2 Function Documentation

### 5.70.2.1 main()

```
int main (
            int argc,
            char ** argv )
```

```
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\n\tTesting Interpolator");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    Interpolator* test_interpolator_ptr = testConstruct_Interpolator();


    try {
        int data_key_1D = 1;
        std::string path_2_data_1D =
            "data/test/interpolation/diesel_fuel_curve.csv";

        testDataRead1D_Interpolator(test_interpolator_ptr, data_key_1D, path_2_data_1D);
        testBadIndexing1D_Interpolator(test_interpolator_ptr, -99);
        testInvalidInterpolation1D_Interpolator(test_interpolator_ptr, data_key_1D);
        testInterpolation1D_Interpolator(test_interpolator_ptr, data_key_1D);


        int data_key_2D = 2;
        std::string path_2_data_2D =
            "data/test/interpolation/wave_energy_converter_normalized_performance_matrix.csv";

        testDataRead2D_Interpolator(test_interpolator_ptr, data_key_2D, path_2_data_2D);
        testInvalidInterpolation2D_Interpolator(test_interpolator_ptr, data_key_2D);
        testInterpolation2D_Interpolator(test_interpolator_ptr, data_key_2D);
    }


```

```
    catch (...) {
        delete test_interpolator_ptr;

        printGold(" ............................ ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_interpolator_ptr;

    printGold(" ............................ ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;
}   /* main() */
```

### 5.70.2.2 testBadIndexing1D_Interpolator()

```
void testBadIndexing1D_Interpolator (
            Interpolator * test_interpolator_ptr,
            int data_key_bad )
```

A function to check if bad key errors are being handled properly.

**Parameters**

| | |
|---|---|
| *test_interpolator_ptr* | A pointer to the test Interpolator object. |
| *data_key_bad* | A key used to index into the Interpolator object. |

```
{
    bool error_flag = true;

    try {
        test_interpolator_ptr->interp1D(data_key_bad, 0);
        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    return;
}   /* testBadIndexing1D_Interpolator() */
```

### 5.70.2.3 testConstruct_Interpolator()

```
Interpolator * testConstruct_Interpolator (
            void )
```

A function to construct an Interpolator object.

**Returns**

A pointer to a test Interpolator object.

```
{
    Interpolator* test_interpolator_ptr = new Interpolator();

    return test_interpolator_ptr;
}   /* testConstruct_Interpolator() */
```

#### 5.70.2.4 testDataRead1D_Interpolator()

```
void testDataRead1D_Interpolator (
            Interpolator * test_interpolator_ptr,
            int data_key,
            std::string path_2_data_1D )
```

A function to check the 1D data values read into the Interpolator object.

**Parameters**

| | |
|---|---|
| *test_interpolator_ptr* | A pointer to the test Interpolator object. |
| *data_key_1D* | A key used to index into the Interpolator object. |
| *path_2_data_1D* | A path (either relative or absolute) to the interpolation data. |

```
{
    test_interpolator_ptr->addData1D(data_key_1D, path_2_data_1D);

    testTruth(
        test_interpolator_ptr->path_map_1D[data_key_1D] == path_2_data_1D,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_interpolator_ptr->interp_map_1D[data_key_1D].n_points,
        16,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_interpolator_ptr->interp_map_1D[data_key_1D].x_vec.size(),
        16,
        __FILE__,
        __LINE__
    );

    std::vector<double> expected_x_vec = {
        0,
        0.3,
        0.35,
        0.4,
        0.45,
        0.5,
        0.55,
        0.6,
        0.65,
        0.7,
        0.75,
        0.8,
        0.85,
        0.9,
        0.95,
        1
    };

    std::vector<double> expected_y_vec = {
        4.68079520372916,
        11.1278522361839,
        12.4787834830748,
        13.7808847600209,
        15.0417468303382,
        16.277263,
        17.4612831516442,
        18.6279054806525,
        19.7698039220515,
        20.8893499214868,
        21.955378,
        23.0690535155297,
        24.1323614374927,
        25.1797231192866,
        26.2122451458747,
        27.254952
    };

    for (int i = 0; i < test_interpolator_ptr->interp_map_1D[data_key_1D].n_points; i++) {
        testFloatEquals(
```

```
            test_interpolator_ptr->interp_map_1D[data_key_1D].x_vec[i],
            expected_x_vec[i],
            __FILE__,
            __LINE__
        );

        testFloatEquals(
            test_interpolator_ptr->interp_map_1D[data_key_1D].y_vec[i],
            expected_y_vec[i],
            __FILE__,
            __LINE__
        );
    }

    testFloatEquals(
        test_interpolator_ptr->interp_map_1D[data_key_1D].min_x,
        expected_x_vec[0],
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_interpolator_ptr->interp_map_1D[data_key_1D].max_x,
        expected_x_vec[expected_x_vec.size() - 1],
        __FILE__,
        __LINE__
    );

    return;
}   /* testDataRead1D_Interpolator() */
```

### 5.70.2.5 testDataRead2D_Interpolator()

```
void testDataRead2D_Interpolator (
            Interpolator * test_interpolator_ptr,
            int data_key,
            std::string path_2_data_2D )
```

A function to check the 2D data values read into the Interpolator object.

**Parameters**

| | |
|---|---|
| *test_interpolator_ptr* | A pointer to the test Interpolator object. |
| *data_key_2D* | A key used to index into the Interpolator object. |
| *path_2_data_2D* | A path (either relative or absolute) to the interpolation data. |

```
{
    test_interpolator_ptr->addData2D(data_key_2D, path_2_data_2D);

    testTruth(
        test_interpolator_ptr->path_map_2D[data_key_2D] == path_2_data_2D,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_interpolator_ptr->interp_map_2D[data_key_2D].n_rows,
        16,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_interpolator_ptr->interp_map_2D[data_key_2D].n_cols,
        16,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_interpolator_ptr->interp_map_2D[data_key_2D].x_vec.size(),
        16,
```

```
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_interpolator_ptr->interp_map_2D[data_key_2D].y_vec.size(),
        16,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_interpolator_ptr->interp_map_2D[data_key_2D].z_matrix.size(),
        16,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_interpolator_ptr->interp_map_2D[data_key_2D].z_matrix[0].size(),
        16,
        __FILE__,
        __LINE__
    );

    std::vector<double> expected_x_vec = {
        0.25, 0.75, 1.25, 1.75, 2.25, 2.75, 3.25, 3.75, 4.25, 4.75, 5.25, 5.75, 6.25, 6.75, 7.25, 7.75
    };

    std::vector <double> expected_y_vec = {
        5,
        6,
        7,
        8,
        9,
        10,
        11,
        12,
        13,
        14,
        15,
        16,
        17,
        18,
        19,
        20
    };

    for (int i = 0; i < test_interpolator_ptr->interp_map_2D[data_key_2D].n_cols; i++) {
        testFloatEquals(
            test_interpolator_ptr->interp_map_2D[data_key_2D].x_vec[i],
            expected_x_vec[i],
            __FILE__,
            __LINE__
        );
    }

    for (int i = 0; i < test_interpolator_ptr->interp_map_2D[data_key_2D].n_rows; i++) {
        testFloatEquals(
            test_interpolator_ptr->interp_map_2D[data_key_2D].y_vec[i],
            expected_y_vec[i],
            __FILE__,
            __LINE__
        );
    }

    testFloatEquals(
        test_interpolator_ptr->interp_map_2D[data_key_2D].min_x,
        expected_x_vec[0],
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_interpolator_ptr->interp_map_2D[data_key_2D].max_x,
        expected_x_vec[expected_x_vec.size() - 1],
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_interpolator_ptr->interp_map_2D[data_key_2D].min_y,
        expected_y_vec[0],
        __FILE__,
        __LINE__
    );

```

```
    testFloatEquals(
        test_interpolator_ptr->interp_map_2D[data_key_2D].max_y,
        expected_y_vec[expected_y_vec.size() - 1],
        __FILE__,
        __LINE__
    );

    std::vector<std::vector<double» expected_z_matrix = {
        {0, 0.129128125, 0.268078125, 0.404253125, 0.537653125, 0.668278125, 0.796128125, 0.921203125, 1, 1, 1, 0, 0, 0, 0, 0},
        {0, 0.11160375, 0.24944375, 0.38395375, 0.51513375, 0.64298375, 0.76750375, 0.88869375, 1, 1, 1, 1, 1, 1, 1, 1},
        {0, 0.094079375, 0.230809375, 0.363654375, 0.492614375, 0.617689375, 0.738879375, 0.856184375, 0.969604375, 1, 1, 1, 1, 1, 1, 1},
        {0, 0.076555, 0.212175, 0.343355, 0.470095, 0.592395, 0.710255, 0.823675, 0.932655, 1, 1, 1, 1, 1, 1, 1},
        {0, 0.059030625, 0.193540625, 0.323055625, 0.447575625, 0.567100625, 0.681630625, 0.791165625, 0.895705625, 0.995250625, 1, 1, 1, 1, 1, 1},
        {0, 0.04150625, 0.17490625, 0.30275625, 0.42505625, 0.54180625, 0.65300625, 0.75865625, 0.85875625, 0.95330625, 1, 1, 1, 1, 1, 1},
        {0, 0.023981875, 0.156271875, 0.282456875, 0.402536875, 0.516511875, 0.624381875, 0.726146875, 0.821806875, 0.911361875, 0.994811875, 1, 1, 1, 1, 1},
        {0, 0.0064575, 0.1376375, 0.2621575, 0.3800175, 0.4912175, 0.5957575, 0.6936375, 0.7848575, 0.8694175, 0.9473175, 1, 1, 1, 1, 1},
        {0, 0, 0.119003125, 0.241858125, 0.357498125, 0.465923125, 0.567133125, 0.661128125, 0.747908125, 0.827473125, 0.899823125, 0.964958125, 1, 1, 1, 1},
        {0, 0, 0.10036875, 0.22155875, 0.33497875, 0.44062875, 0.53850875, 0.62861875, 0.71095875, 0.78552875, 0.85232875, 0.91135875, 0.96261875, 1, 1, 1},
        {0, 0, 0.081734375, 0.201259375, 0.312459375, 0.415334375, 0.509884375, 0.596109375, 0.674009375, 0.743584375, 0.804834375, 0.857759375, 0.902359375, 0.938634375, 0.966584375, 0.986209375},
        {0, 0, 0.0631, 0.18096, 0.28994, 0.39004, 0.48126, 0.5636, 0.63706, 0.70164, 0.75734, 0.80416, 0.8421, 0.87116, 0.89134, 0.90264},
        {0, 0, 0.044465625, 0.160660625, 0.267420625, 0.364745625, 0.452635625, 0.531090625, 0.600110625, 0.659695625, 0.709845625, 0.750560625, 0.781840625, 0.803685624999999, 0.816095625, 0.819070625},
        {0, 0, 0.02583125, 0.14036125, 0.24490125, 0.33945125, 0.42401125, 0.49858125, 0.56316125, 0.61775125, 0.66235125, 0.69696125, 0.72158125, 0.73621125, 0.74085125, 0.73550125},
        {0, 0, 0.007196875, 0.120061875, 0.222381875, 0.314156875, 0.395386875, 0.466071875, 0.526211875, 0.575806875, 0.614856875, 0.643361875, 0.661321875, 0.668736875, 0.665606875, 0.651931875},
        {0, 0, 0, 0.0997625, 0.1998625, 0.2888625, 0.3667625, 0.4335625, 0.4892625, 0.5338625, 0.5673625, 0.5897625, 0.6010625, 0.6012625, 0.5903625, 0.5683625}
    };

    for (int i = 0; i < test_interpolator_ptr->interp_map_2D[data_key_2D].n_rows; i++) {
        for (int j = 0; j < test_interpolator_ptr->interp_map_2D[data_key_2D].n_cols; j++) {
            testFloatEquals(
                test_interpolator_ptr->interp_map_2D[data_key_2D].z_matrix[i][j],
                expected_z_matrix[i][j],
                __FILE__,
                __LINE__
            );
        }
    }

    return;
}   /* testDataRead2D_Interpolator() */
```

### 5.70.2.6 testInterpolation1D_Interpolator()

```
void testInterpolation1D_Interpolator (
        Interpolator * test_interpolator_ptr,
        int data_key_1D )
```

Function to check that the Interpolator object is returning the expected 1D interpolation values.

**Parameters**

| | |
|---|---|
| *test_interpolator_ptr* | A pointer to the test Interpolator object. |
| *data_key_1D* | A key used to index into the Interpolator object. |

```
{
    std::vector<double> interp_x_vec = {
```

```
        0,
        0.170812859791767,
        0.322739274162545,
        0.369750203682042,
        0.443532869135929,
        0.471567864244626,
        0.536513734479662,
        0.586125806988674,
        0.601101175455075,
        0.658356862575221,
        0.70576929893201,
        0.784069734739331,
        0.805765927542453,
        0.884747873186048,
        0.930870496062112,
        0.979415217694769,
        1
    };

    std::vector<double> expected_interp_y_vec = {
        4.68079520372916,
        8.35159603357656,
        11.7422361561399,
        12.9931187917615,
        14.8786636301325,
        15.5746957307243,
        17.1419229487141,
        18.3041866133728,
        18.6530540913696,
        19.9569217633299,
        21.012354614584,
        22.7142305879957,
        23.1916726441968,
        24.8602332554707,
        25.8172124624032,
        26.8256741279932,
        27.254952
    };

    for (size_t i = 0; i < interp_x_vec.size(); i++) {
        testFloatEquals(
            test_interpolator_ptr->interp1D(data_key_1D, interp_x_vec[i]),
            expected_interp_y_vec[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testInterpolation1D_Interpolator() */
```

### 5.70.2.7 testInterpolation2D_Interpolator()

```
void testInterpolation2D_Interpolator (
            Interpolator * test_interpolator_ptr,
            int data_key_2D )
```

Function to check that the Interpolator object is returning the expected 2D interpolation values.

**Parameters**

| | |
|---|---|
| *test_interpolator_ptr* | A pointer to the test Interpolator object. |
| *data_key_2D* | A key used to index into the Interpolator object. |

```
{
    std::vector<double> interp_x_vec = {
        0.389211848822208,
        0.836477431896843,
        1.52738334015579,
        1.92640601114508,
        2.27297317532019,
        2.87416589636605,
        3.72275770908175,
        3.95063175885536,
```

```
        4.68097139867404,
        4.97775020449812,
        5.55184219980547,
        6.06566629451658,
        6.27927876785062,
        6.96218133671013,
        7.51754442460228
    };

    std::vector<double> interp_y_vec = {
        5.45741899698926,
        6.00101329139007,
        7.50567689404182,
        8.77681262912881,
        9.45143678206774,
        10.7767876462885,
        11.4795760857165,
        12.9430684577599,
        13.303544885703,
        14.5069863517863,
        15.1487890438045,
        16.086524049077,
        17.176609978648,
        18.4155153740256,
        19.1704554940162
    };

    std::vector<std::vector<double» expected_interp_z_matrix = {
   {0.0337204906738533,0.145056406036013,0.334677248806653,0.441674658936075,0.533295755691263,0.68807895676592,0.8996148
   {0.0310681846933292,0.135425896595439,0.324045598153363,0.430214268249038,0.520985043044784,0.673879556322479,0.882058
   {0.0237266281076604,0.108768742207538,0.294617294841705,0.398492020763049,0.486909112828702,0.63457575706117,0.8334608
   {0.0175245009938255,0.0862488504001753,0.269756343931147,0.371693152028768,0.458121859300634,0.601372013927032,0.79240
   {0.0142328739589644,0.0742969694833995,0.256562003243255,0.357470308928265,0.442843729679424,0.583749940636223,0.77061
   {0.0077662203173173,0.0508165832074184,0.230640709501637,0.329528443353471,0.41282867283787,0.549130026772199,0.727811
   {0.00433717405958826,0.0383657337957315,0.21689552996585,0.314711823368423,0.396912710109449,0.530772265145106,0.70511
   {0.000102358416923608,0.0210697053701168,0.188272456115393,0.283857573197153,0.363769179652786,0.492543912767949,0.657
   {0,0.0196038727057393,0.181222235960193,0.276257786480759,0.355605514643888,0.483127792688125,0.646203044346932,0.6855
   {0,0.0157252942367668,0.157685253727545,0.250886090139653,0.328351324840186,0.451692313207986,0.607334650020078,0.6442
   {0,0.0136568246246201,0.145132837191606,0.23735520935175,0.313816498778623,0.43492757979648,0.586605897674033,0.622265
   {0,0.0106345930466366,0.12679255826648,0.217585300741544,0.292579730277991,0.410432703770651,0.556319211544087,0.59010
   {0,0.00712134879261874,0.10547259059088,0.194603435839713,0.267892689267542,0.381958220518761,0.52111194060085,0.55272
   {0,0.00312847342058727,0.0812420026472571,0.168484067035528,0.239835352250276,0.349596376397684,0.481098142839729,0.51
   {0,0.00103256269522045,0.0673448574082101,0.152567953107312,0.222738316872545,0.329876344040866,0.456715311514779,0.48
    };

    for (size_t i = 0; i < interp_y_vec.size(); i++) {
        for (size_t j = 0; j < interp_x_vec.size(); j++) {
            testFloatEquals(
                test_interpolator_ptr->interp2D(data_key_2D, interp_x_vec[j], interp_y_vec[i]),
                expected_interp_z_matrix[i][j],
                __FILE__,
                __LINE__
            );
        }
    }

    return;
}   /* testInterpolation2D_Interpolator() */
```

#### 5.70.2.8 testInvalidInterpolation1D_Interpolator()

```
void testInvalidInterpolation1D_Interpolator (
        Interpolator * test_interpolator_ptr,
        int data_key_1D )
```

Function to check if attempting to interpolate outside the given 1D data domain is handled properly.

**Parameters**

| | |
|---|---|
| *test_interpolator_ptr* | A pointer to the test Interpolator object. |
| *data_key_1D* | A key used to index into the Interpolator object. |

```
{
    bool error_flag = true;

    try {
        test_interpolator_ptr->interp1D(data_key_1D, -1);
        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    try {
        test_interpolator_ptr->interp1D(data_key_1D, 2);
        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    try {
        test_interpolator_ptr->interp1D(data_key_1D, 0 - FLOAT_TOLERANCE);
        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    try {
        test_interpolator_ptr->interp1D(data_key_1D, 1 + FLOAT_TOLERANCE);
        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    return;
}   /* testInvalidInterpolation1D_Interpolator() */
```

### 5.70.2.9 testInvalidInterpolation2D_Interpolator()

```
void testInvalidInterpolation2D_Interpolator (
            Interpolator * test_interpolator_ptr,
            int data_key_2D )
```

Function to check if attempting to interpolate outside the given 2D data domain is handled properly.

**Parameters**

| | |
|---|---|
| *test_interpolator_ptr* | A pointer to the test Interpolator object. |
| *data_key_2D* | A key used to index into the Interpolator object. |

```
{
    bool error_flag = true;

    try {
        test_interpolator_ptr->interp2D(data_key_2D, -1, 6);
        error_flag = false;
    } catch (...) {
```

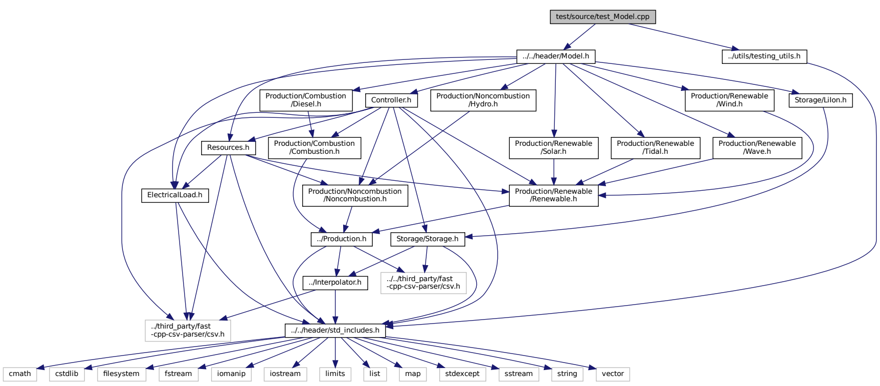
```
            // Task failed successfully! =P
        }
        if (not error_flag) {
            expectedErrorNotDetected(__FILE__, __LINE__);
        }

        try {
            test_interpolator_ptr->interp2D(data_key_2D, 99, 6);
            error_flag = false;
        } catch (...) {
            // Task failed successfully! =P
        }
        if (not error_flag) {
            expectedErrorNotDetected(__FILE__, __LINE__);
        }

        try {
            test_interpolator_ptr->interp2D(data_key_2D, 0.75, -1);
            error_flag = false;
        } catch (...) {
            // Task failed successfully! =P
        }
        if (not error_flag) {
            expectedErrorNotDetected(__FILE__, __LINE__);
        }

        try {
            test_interpolator_ptr->interp2D(data_key_2D, 0.75, 99);
            error_flag = false;
        } catch (...) {
            // Task failed successfully! =P
        }
        if (not error_flag) {
            expectedErrorNotDetected(__FILE__, __LINE__);
        }

        return;
}   /* testInvalidInterpolation2D_Interpolator() */
```

## 5.71 test/source/test_Model.cpp File Reference

Testing suite for Model class.

```
#include "../utils/testing_utils.h"
#include "../../header/Model.h"
```

Include dependency graph for test_Model.cpp:




### Functions

- Model * testConstruct_Model (ModelInputs test_model_inputs)
- void testBadConstruct_Model (void)

*Function to check if passing bad ModelInputs to the Model constructor is handled appropriately.*

- void testPostConstructionAttributes_Model (Model ∗test_model_ptr)

  *A function to check the values of various post-construction attributes.*
- void testElectricalLoadData_Model (Model ∗test_model_ptr)

  *Function to check the values read into the ElectricalLoad component of the test Model object.*
- void testAddSolarResource_Model (Model ∗test_model_ptr, std::string path_2_solar_resource_data, int solar_resource_key)

  *Function to test adding a solar resource and then check the values read into the Resources component of the test Model object.*
- void testAddTidalResource_Model (Model ∗test_model_ptr, std::string path_2_tidal_resource_data, int tidal↩_resource_key)

  *Function to test adding a tidal resource and then check the values read into the Resources component of the test Model object.*
- void testAddWaveResource_Model (Model ∗test_model_ptr, std::string path_2_wave_resource_data, int wave_resource_key)

  *Function to test adding a wave resource and then check the values read into the Resources component of the test Model object.*
- void testAddWindResource_Model (Model ∗test_model_ptr, std::string path_2_wind_resource_data, int wind_resource_key)

  *Function to test adding a wind resource and then check the values read into the Resources component of the test Model object.*
- void testAddHydroResource_Model (Model ∗test_model_ptr, std::string path_2_hydro_resource_data, int hydro_resource_key)

  *Function to test adding a hydro resource and then check the values read into the Resources component of the test Model object.*
- void testAddHydro_Model (Model ∗test_model_ptr, int hydro_resource_key)

  *Function to test adding a hydroelectric asset to the test Model object, and then spot check some post-add attributes.*
- void testAddDiesel_Model (Model ∗test_model_ptr)

  *Function to test adding a suite of diesel generators to the test Model object, and then spot check some post-add attributes.*
- void testAddSolar_Model (Model ∗test_model_ptr, int solar_resource_key)

  *Function to test adding a solar PV array to the test Model object and then spot check some post-add attributes.*
- void testAddSolar_productionOverride_Model (Model ∗test_model_ptr, std::string path_2_normalized_↩production_time_series)

  *Function to test adding a solar PV array to the test Model object using the production override feature, and then spot check some post-add attributes.*
- void testAddTidal_Model (Model ∗test_model_ptr, int tidal_resource_key)

  *Function to test adding a tidal turbine to the test Model object and then spot check some post-add attributes.*
- void testAddWave_Model (Model ∗test_model_ptr, int wave_resource_key)

  *Function to test adding a wave energy converter to the test Model object and then spot check some post-add attributes.*
- void testAddWind_Model (Model ∗test_model_ptr, int wind_resource_key)

  *Function to test adding a wind turbine to the test Model object and then spot check some post-add attributes.*
- void testAddLiIon_Model (Model ∗test_model_ptr)

  *Function to test adding a lithium ion battery energy storage system to the test Model object and then spot check some post-add attributes.*
- void testLoadBalance_Model (Model ∗test_model_ptr)

  *Function to check that the post-run load data is as expected. That is, the added renewable, production, and storage assets are handled by the Controller as expected.*
- void testOperatingReserve_Model (Model ∗test_model_ptr)

  *Function to check that the post-run state is consistent with the intended operating reserve (or "spinning reserve") logic.*
- void testEconomics_Model (Model ∗test_model_ptr)

  *Function to check that the modelled economic metrics are $>$ 0.*

- void testFuelConsumptionEmissions_Model (Model *test_model_ptr)

    *Function to check that the modelled fuel consumption and emissions are > 0.*
- int main (int argc, char **argv)

## 5.71.1 Detailed Description

Testing suite for Model class.

A suite of tests for the Model class.

## 5.71.2 Function Documentation

### 5.71.2.1 main()

```
int main (
        int argc,
        char ** argv )
```

```
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Model");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    std::cout « std::flush;

    srand(time(NULL));


    std::string path_2_electrical_load_time_series =
        "data/test/electrical_load/electrical_load_generic_peak-500kW_1yr_dt-1hr.csv";

    ModelInputs test_model_inputs;
    test_model_inputs.path_2_electrical_load_time_series =
        path_2_electrical_load_time_series;

    Model* test_model_ptr = testConstruct_Model(test_model_inputs);


    try {
        testBadConstruct_Model();
        testPostConstructionAttributes_Model(test_model_ptr);
        testElectricalLoadData_Model(test_model_ptr);


        int solar_resource_key = 0;
        std::string path_2_solar_resource_data =
            "data/test/resources/solar_GHI_peak-1kWm2_1yr_dt-1hr.csv";

        testAddSolarResource_Model(
            test_model_ptr,
            path_2_solar_resource_data,
            solar_resource_key
        );


        int tidal_resource_key = 1;
        std::string path_2_tidal_resource_data =
            "data/test/resources/tidal_speed_peak-3ms_1yr_dt-1hr.csv";

        testAddTidalResource_Model(
            test_model_ptr,
            path_2_tidal_resource_data,
```

```
            tidal_resource_key
        );


        int wave_resource_key = 2;
        std::string path_2_wave_resource_data =
            "data/test/resources/waves_H_s_peak-8m_T_e_peak-15s_1yr_dt-1hr.csv";

        testAddWaveResource_Model(
            test_model_ptr,
            path_2_wave_resource_data,
            wave_resource_key
        );


        int wind_resource_key = 3;
        std::string path_2_wind_resource_data =
            "data/test/resources/wind_speed_peak-25ms_1yr_dt-1hr.csv";

        testAddWindResource_Model(
            test_model_ptr,
            path_2_wind_resource_data,
            wind_resource_key
        );


        int hydro_resource_key = 4;
        std::string path_2_hydro_resource_data =
            "data/test/resources/hydro_inflow_peak-20000m3hr_1yr_dt-1hr.csv";

        testAddHydroResource_Model(
            test_model_ptr,
            path_2_hydro_resource_data,
            hydro_resource_key
        );


        std::string path_2_normalized_production_time_series =
                "data/test/normalized_production/normalized_solar_production.csv";

        // looping solely for the sake of profiling (also tests reset(), which is
        // needed for wrapping PGMcpp in an optimizer)
        int n_times = 1000;
        for (int i = 0; i < n_times; i++) {
            test_model_ptr->reset();

            testAddHydro_Model(test_model_ptr, hydro_resource_key);
            testAddDiesel_Model(test_model_ptr);
            testAddSolar_Model(test_model_ptr, solar_resource_key);

            testAddSolar_productionOverride_Model(
                test_model_ptr,
                path_2_normalized_production_time_series
            );

            testAddTidal_Model(test_model_ptr, tidal_resource_key);
            testAddWave_Model(test_model_ptr, wave_resource_key);
            testAddWind_Model(test_model_ptr, wind_resource_key);

            testAddLiIon_Model(test_model_ptr);

            test_model_ptr->run();
        }


        testLoadBalance_Model(test_model_ptr);
        testOperatingReserve_Model(test_model_ptr);
        testEconomics_Model(test_model_ptr);
        testFuelConsumptionEmissions_Model(test_model_ptr);

        test_model_ptr->writeResults("test/test_results/");
    }


    catch (...) {
        delete test_model_ptr;

        printGold(" .................................... ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_model_ptr;

    printGold(" .................................... ");
```

```
    printGreen("PASS");
    std::cout « std::endl;
    return 0;
}   /* main() */
```

#### 5.71.2.2 testAddDiesel_Model()

```
void testAddDiesel_Model (
            Model * test_model_ptr )
```

Function to test adding a suite of diesel generators to the test Model object, and then spot check some post-add attributes.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |

```
{
    DieselInputs diesel_inputs;
    diesel_inputs.combustion_inputs.production_inputs.capacity_kW = 100;
    diesel_inputs.combustion_inputs.production_inputs.is_sunk = true;

    test_model_ptr->addDiesel(diesel_inputs);

    testFloatEquals(
        test_model_ptr->combustion_ptr_vec.size(),
        1,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->combustion_ptr_vec[0]->type,
        CombustionType :: DIESEL,
        __FILE__,
        __LINE__
    );

    diesel_inputs.combustion_inputs.production_inputs.capacity_kW = 150;

    test_model_ptr->addDiesel(diesel_inputs);

    diesel_inputs.combustion_inputs.production_inputs.capacity_kW = 250;

    test_model_ptr->addDiesel(diesel_inputs);

    testFloatEquals(
        test_model_ptr->combustion_ptr_vec.size(),
        3,
        __FILE__,
        __LINE__
    );

    std::vector<int> expected_diesel_capacity_vec_kW = {100, 150, 250};

    for (int i = 0; i < 3; i++) {
        testFloatEquals(
            test_model_ptr->combustion_ptr_vec[i]->capacity_kW,
            expected_diesel_capacity_vec_kW[i],
            __FILE__,
            __LINE__
        );
    }

    diesel_inputs.combustion_inputs.production_inputs.capacity_kW = 100;

    for (int i = 0; i < 2 * ((double)rand() / RAND_MAX); i++) {
        test_model_ptr->addDiesel(diesel_inputs);
    }

    return;
}   /* testAddDiesel_Model() */
```

#### 5.71.2.3 testAddHydro_Model()

```
void testAddHydro_Model (
            Model * test_model_ptr,
            int hydro_resource_key )
```

Function to test adding a hydroelectric asset to the test Model object, and then spot check some post-add attributes.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |
| *hydro_resource_key* | A key used to index into the Resources component of the test Model object. |

```
{
    HydroInputs hydro_inputs;
    hydro_inputs.noncombustion_inputs.production_inputs.capacity_kW = 300;
    hydro_inputs.reservoir_capacity_m3 = 100000;
    hydro_inputs.init_reservoir_state = 0.5;
    hydro_inputs.noncombustion_inputs.production_inputs.is_sunk = true;
    hydro_inputs.resource_key = hydro_resource_key;

    test_model_ptr->addHydro(hydro_inputs);

    testFloatEquals(
        test_model_ptr->noncombustion_ptr_vec.size(),
        1,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->noncombustion_ptr_vec[0]->type,
        NoncombustionType :: HYDRO,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->noncombustion_ptr_vec[0]->resource_key,
        hydro_resource_key,
        __FILE__,
        __LINE__
    );

    return;
}   /* testAddHydro_Model() */
```

#### 5.71.2.4 testAddHydroResource_Model()

```
void testAddHydroResource_Model (
            Model * test_model_ptr,
            std::string path_2_hydro_resource_data,
            int hydro_resource_key )
```

Function to test adding a hydro resource and then check the values read into the Resources component of the test Model object.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |
| *path_2_hydro_resource_data* | A path (either relative or absolute) to the hydro resource data. |
| *hydro_resource_key* | A key used to index into the Resources component of the test Model object. |

```
{
```

```
    test_model_ptr->addResource(
        NoncombustionType :: HYDRO,
        path_2_hydro_resource_data,
        hydro_resource_key
    );

    std::vector<double> expected_hydro_resource_vec_ms = {
        2167.91531556942,
        2046.58261560569,
        2007.85941123153,
        2000.11477247929,
        1917.50527264453,
        1963.97311577093,
        1908.46985899809,
        1886.5267112678,
        1965.26388854254,
        1953.64692935289,
        2084.01504296306,
        2272.46796101188,
        2520.29645627096,
        2715.203242423,
        2720.36633563203,
        3130.83228077221,
        3289.59741021591,
        3981.45195965772,
        5295.45929491303,
        7084.47124360523,
        7709.20557708454,
        7436.85238642936,
        7235.49173429668,
        6710.14695517339,
        6015.71085806577,
        5279.97001316337,
        4877.24870889801,
        4421.60569340303,
        3919.49483690424,
        3498.70270322341,
        3274.10813058883,
        3147.61233529349,
        2904.94693324343,
        2805.55738101,
        2418.32535637171,
        2398.96375630723,
        2260.85100182222,
        2157.58912702878,
        2019.47637254377,
        1913.63295220712,
        1863.29279076589,
        1748.41395678279,
        1695.49224555317,
        1599.97501375715,
        1559.96103873397,
        1505.74855473274,
        1438.62833664765,
        1384.41585476901
    };

    for (size_t i = 0; i < expected_hydro_resource_vec_ms.size(); i++) {
        testFloatEquals(
            test_model_ptr->resources.resource_map_1D[hydro_resource_key][i],
            expected_hydro_resource_vec_ms[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testAddHydroResource_Model() */
```

### 5.71.2.5 testAddLiIon_Model()

```
void testAddLiIon_Model (
        Model * test_model_ptr )
```

Function to test adding a lithium ion battery energy storage system to the test Model object and then spot check some post-add attributes.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |

```
{
    LiIonInputs liion_inputs;

    test_model_ptr->addLiIon(liion_inputs);

    testFloatEquals(
        test_model_ptr->storage_ptr_vec.size(),
        1,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->storage_ptr_vec[0]->type,
        StorageType :: LIION,
        __FILE__,
        __LINE__
    );

    return;
}   /* testAddLiIon_Model() */
```

#### 5.71.2.6 testAddSolar_Model()

```
void testAddSolar_Model (
            Model * test_model_ptr,
            int solar_resource_key )
```

Function to test adding a solar PV array to the test Model object and then spot check some post-add attributes.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |
| *solar_resource_key* | A key used to index into the Resources component of the test Model object. |

```
{
    SolarInputs solar_inputs;
    solar_inputs.resource_key = solar_resource_key;

    test_model_ptr->addSolar(solar_inputs);

    testFloatEquals(
        test_model_ptr->renewable_ptr_vec.size(),
        1,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->renewable_ptr_vec[0]->type,
        RenewableType :: SOLAR,
        __FILE__,
        __LINE__
    );

    return;
}   /* testAddSolar_Model() */
```

#### 5.71.2.7 testAddSolar_productionOverride_Model()

```
void testAddSolar_productionOverride_Model (
```

```
Model * test_model_ptr,
std::string path_2_normalized_production_time_series )
```

Function to test adding a solar PV array to the test Model object using the production override feature, and then spot check some post-add attributes.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |
| *path_2_normalized_production_time_series* | A path (either relative or absolute) to the given normalized production time series data. |

```
{
    SolarInputs solar_inputs;
    solar_inputs.renewable_inputs.production_inputs.path_2_normalized_production_time_series =
        path_2_normalized_production_time_series;

    test_model_ptr->addSolar(solar_inputs);

    testFloatEquals(
        test_model_ptr->renewable_ptr_vec.size(),
        2,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->renewable_ptr_vec[1]->type,
        RenewableType :: SOLAR,
        __FILE__,
        __LINE__
    );

    testTruth(
        test_model_ptr->renewable_ptr_vec[1]->normalized_production_series_given,
        __FILE__,
        __LINE__
    );

    testTruth(
        test_model_ptr->renewable_ptr_vec[1]->path_2_normalized_production_time_series ==
        path_2_normalized_production_time_series,
        __FILE__,
        __LINE__
    );

    return;
}   /* testAddSolar_productionOverride_Model() */
```

#### 5.71.2.8 testAddSolarResource_Model()

```
void testAddSolarResource_Model (
            Model * test_model_ptr,
            std::string path_2_solar_resource_data,
            int solar_resource_key )
```

Function to test adding a solar resource and then check the values read into the Resources component of the test Model object.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |
| *path_2_solar_resource_data* | A path (either relative or absolute) to the solar resource data. |
| *solar_resource_key* | A key used to index into the Resources component of the test Model object. |

```
{
    test_model_ptr->addResource(
        RenewableType :: SOLAR,
        path_2_solar_resource_data,
        solar_resource_key
    );

    std::vector<double> expected_solar_resource_vec_kWm2 = {
        0,
        0,
        0,
        0,
        0,
        0,
        8.51702662684015E-05,
        0.000348341567045,
        0.00213793728593,
        0.004099863613322,
        0.000997135230553,
        0.009534527624657,
        0.022927996790616,
        0.0136071715294,
        0.002535134127751,
        0.005206897515821,
        0.005627658648597,
        0.000701186722215,
        0.00017119827089,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0.000141055102242,
        0.00084525014743,
        0.024893647822702,
        0.091245556190749,
        0.158722176731637,
        0.152859680515876,
        0.149922903895116,
        0.13049996570866,
        0.03081254222795,
        0.001218928911125,
        0.000206092647423,
        0,
        0,
        0,
        0,
        0,
        0
    };

    for (size_t i = 0; i < expected_solar_resource_vec_kWm2.size(); i++) {
        testFloatEquals(
            test_model_ptr->resources.resource_map_1D[solar_resource_key][i],
            expected_solar_resource_vec_kWm2[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testAddSolarResource_Model() */
```

### 5.71.2.9 testAddTidal_Model()

```
void testAddTidal_Model (
            Model * test_model_ptr,
            int tidal_resource_key )
```

Function to test adding a tidal turbine to the test Model object and then spot check some post-add attributes.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |
| *tidal_resource_key* | A key used to index into the Resources component of the test Model object. |

```
{
    TidalInputs tidal_inputs;
    tidal_inputs.resource_key = tidal_resource_key;

    test_model_ptr->addTidal(tidal_inputs);

    testFloatEquals(
        test_model_ptr->renewable_ptr_vec.size(),
        3,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->renewable_ptr_vec[2]->type,
        RenewableType :: TIDAL,
        __FILE__,
        __LINE__
    );

    return;
}   /* testAddTidal_Model() */
```

#### 5.71.2.10 testAddTidalResource_Model()

```
void testAddTidalResource_Model (
            Model * test_model_ptr,
            std::string path_2_tidal_resource_data,
            int tidal_resource_key )
```

Function to test adding a tidal resource and then check the values read into the Resources component of the test Model object.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |
| *path_2_tidal_resource_data* | A path (either relative or absolute) to the tidal resource data. |
| *tidal_resource_key* | A key used to index into the Resources component of the test Model object. |

```
{
    test_model_ptr->addResource(
        RenewableType :: TIDAL,
        path_2_tidal_resource_data,
        tidal_resource_key
    );

    std::vector<double> expected_tidal_resource_vec_ms = {
        0.347439913040533,
        0.770545522195602,
        0.731352084836198,
        0.293389814389542,
        0.209959110813115,
        0.610609623896497,
        1.78067162013604,
        2.53522775118089,
        2.75966627832024,
        2.52101111143895,
        2.05389330201031,
        1.3461515862445,
        0.28909254878384,
        0.897754086048563,
        1.71406453837407,
        1.85047408742869,
        1.71507908595979,
```

```
        1.33540349705416,
        0.434586143463003,
        0.500623815700637,
        1.37172172646733,
        1.68294125491228,
        1.56101300975417,
        1.04925834219412,
        0.211395463930223,
        1.03720048903385,
        1.85059536356448,
        1.85203242794517,
        1.4091471616277,
        0.767776539039899,
        0.251464906990961,
        1.47018469375652,
        2.36260493698197,
        2.46653750048625,
        2.12851908739291,
        1.62783753197988,
        0.734594890957439,
        0.441886297300355,
        1.6574418350918,
        2.0684558286637,
        1.87717416992136,
        1.58871262337931,
        1.03451227609235,
        0.193371305159817,
        0.976400122458815,
        1.6583227369707,
        1.76690616570953,
        1.54801328553115
    };

    for (size_t i = 0; i < expected_tidal_resource_vec_ms.size(); i++) {
        testFloatEquals(
            test_model_ptr->resources.resource_map_1D[tidal_resource_key][i],
            expected_tidal_resource_vec_ms[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testAddTidalResource_Model() */
```

### 5.71.2.11 testAddWave_Model()

```
void testAddWave_Model (
            Model * test_model_ptr,
            int wave_resource_key )
```

Function to test adding a wave energy converter to the test Model object and then spot check some post-add attributes.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |
| *wave_resource_key* | A key used to index into the Resources component of the test Model object. |

```
{
    WaveInputs wave_inputs;
    wave_inputs.resource_key = wave_resource_key;

    test_model_ptr->addWave(wave_inputs);

    testFloatEquals(
        test_model_ptr->renewable_ptr_vec.size(),
        4,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
```

```
        test_model_ptr->renewable_ptr_vec[3]->type,
        RenewableType :: WAVE,
        __FILE__,
        __LINE__
    );

    return;
}   /* testAddWave_Model() */
```

#### 5.71.2.12 testAddWaveResource_Model()

```
void testAddWaveResource_Model (
            Model * test_model_ptr,
            std::string path_2_wave_resource_data,
            int wave_resource_key )
```

Function to test adding a wave resource and then check the values read into the Resources component of the test Model object.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |
| *path_2_wave_resource_data* | A path (either relative or absolute) to the wave resource data. |
| *wave_resource_key* | A key used to index into the Resources component of the test Model object. |

```
{
    test_model_ptr->addResource(
        RenewableType :: WAVE,
        path_2_wave_resource_data,
        wave_resource_key
    );

    std::vector<double> expected_significant_wave_height_vec_m = {
        4.26175222125028,
        4.25020976167872,
        4.25656524330349,
        4.27193854786718,
        4.28744955711233,
        4.29421815278154,
        4.2839937266082,
        4.25716982457976,
        4.22419391611483,
        4.19588925217606,
        4.17338788587412,
        4.14672746914214,
        4.10560041173665,
        4.05074966447193,
        3.9953696962433,
        3.95316976150866,
        3.92771018142378,
        3.91129562488595,
        3.89558312094911,
        3.87861093931749,
        3.86538307240754,
        3.86108961027929,
        3.86459448853189,
        3.86796474016882,
        3.86357412779993,
        3.85554872014731,
        3.86044266668675,
        3.89445961915999,
        3.95554798115731,
        4.02265508610476,
        4.07419587011404,
        4.10314247143958,
        4.11738045085928,
        4.12554995596708,
        4.12923992001675,
        4.1229292327442,
        4.10123955307441,
        4.06748827895363,
        4.0336230651344,
```

```
        4.01134236393876,
        4.00136570034559,
        3.99368787690411,
        3.97820924247644,
        3.95369335178055,
        3.92742545608532,
        3.90683362771686,
        3.89331520944006,
        3.88256045801583
    };

    std::vector<double> expected_energy_period_vec_s = {
        10.4456008226821,
        10.4614151137651,
        10.4462827795433,
        10.4127692097884,
        10.3734397942723,
        10.3408599227669,
        10.32637292093,
        10.3245412676322,
        10.310409818185,
        10.2589529840966,
        10.1728100603103,
        10.0862908658929,
        10.03480243813,
        10.023673635806,
        10.0243418565116,
        10.0063487117653,
        9.96050302286607,
        9.9011999635568,
        9.84451822125472,
        9.79726875879626,
        9.75614594835158,
        9.7173447961368,
        9.68342904390577,
        9.66380508567062,
        9.6674009575699,
        9.68927134575103,
        9.70979984863046,
        9.70967357906908,
        9.68983025704562,
        9.6722855524805,
        9.67973599910003,
        9.71977125328293,
        9.78450442291421,
        9.86532355233449,
        9.96158937600019,
        10.0807018356507,
        10.2291022504937,
        10.39458528356,
        10.5464393581004,
        10.6553277500484,
        10.7245553190084,
        10.7893127285064,
        10.8846512240849,
        11.0148158739075,
        11.1544325654719,
        11.2772785848343,
        11.3744362756187,
        11.4533643503183
    };

    for (size_t i = 0; i < expected_energy_period_vec_s.size(); i++) {
        testFloatEquals(
            test_model_ptr->resources.resource_map_2D[wave_resource_key][i][0],
            expected_significant_wave_height_vec_m[i],
            __FILE__,
            __LINE__
        );

        testFloatEquals(
            test_model_ptr->resources.resource_map_2D[wave_resource_key][i][1],
            expected_energy_period_vec_s[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testAddWaveResource_Model() */
```

#### 5.71.2.13 testAddWind_Model()

```
void testAddWind_Model (
        Model * test_model_ptr,
        int wind_resource_key )
```

Function to test adding a wind turbine to the test Model object and then spot check some post-add attributes.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |
| *wind_resource_key* | A key used to index into the Resources component of the test Model object. |

```
{
    WindInputs wind_inputs;
    wind_inputs.resource_key = wind_resource_key;

    test_model_ptr->addWind(wind_inputs);

    testFloatEquals(
        test_model_ptr->renewable_ptr_vec.size(),
        5,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->renewable_ptr_vec[4]->type,
        RenewableType :: WIND,
        __FILE__,
        __LINE__
    );

    return;
}   /* testAddWind_Model() */
```

#### 5.71.2.14 testAddWindResource_Model()

```
void testAddWindResource_Model (
        Model * test_model_ptr,
        std::string path_2_wind_resource_data,
        int wind_resource_key )
```

Function to test adding a wind resource and then check the values read into the Resources component of the test Model object.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |
| *path_2_wind_resource_data* | A path (either relative or absolute) to the wind resource data. |
| *wind_resource_key* | A key used to index into the Resources component of the test Model object. |

```
{
    test_model_ptr->addResource(
        RenewableType :: WIND,
        path_2_wind_resource_data,
        wind_resource_key
    );

    std::vector<double> expected_wind_resource_vec_ms = {
        6.88566688469997,
        5.02177105466549,
        3.74211715899568,
        5.67169579985362,
```

```
        4.90670669971858,
        4.29586955031368,
        7.41155377205065,
        10.2243290476943,
        13.1258696725555,
        13.7016198628274,
        16.2481482330233,
        16.5096744355418,
        13.4354482206162,
        14.0129230731609,
        14.5554549260515,
        13.4454539065912,
        13.3447169512094,
        11.7372615098554,
        12.7200070078013,
        10.6421127908149,
        6.09869498990661,
        5.66355596602321,
        4.97316966910831,
        3.48937138360567,
        2.15917470979169,
        1.29061103587027,
        3.43475751425219,
        4.11706326260927,
        4.28905275747408,
        5.75850263196241,
        8.98293663055264,
        11.7069822941315,
        12.4031987075858,
        15.4096570910089,
        16.6210843829552,
        13.3421219142573,
        15.2112831900548,
        18.350864533037,
        15.8751799822971,
        15.3921198799796,
        15.9729192868434,
        12.4728950178772,
        10.177050481096,
        10.7342247355551,
        8.98846695631389,
        4.14671169124739,
        3.17256452697149,
        3.40036336968628
    };

    for (size_t i = 0; i < expected_wind_resource_vec_ms.size(); i++) {
        testFloatEquals(
            test_model_ptr->resources.resource_map_1D[wind_resource_key][i],
            expected_wind_resource_vec_ms[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testAddWindResource_Model() */
```

### 5.71.2.15 testBadConstruct_Model()

```
void testBadConstruct_Model (
        void )
```

Function to check if passing bad ModelInputs to the Model constructor is handled appropriately.

```
{
    bool error_flag = true;

    try {
        ModelInputs bad_model_inputs;   // path_2_electrical_load_time_series left empty

        Model bad_model(bad_model_inputs);

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
```

```
    }

    try {
        ModelInputs bad_model_inputs;
        bad_model_inputs.path_2_electrical_load_time_series =
            "data/test/electrical_load/bad_path_";
        bad_model_inputs.path_2_electrical_load_time_series += std::to_string(rand());
        bad_model_inputs.path_2_electrical_load_time_series += ".csv";

        Model bad_model(bad_model_inputs);

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    return;
}
```

#### 5.71.2.16 testConstruct_Model()

```
Model* testConstruct_Model (
            ModelInputs test_model_inputs )
```

```
{
    Model* test_model_ptr = new Model(test_model_inputs);

    testTruth(
        test_model_ptr->electrical_load.path_2_electrical_load_time_series ==
        test_model_inputs.path_2_electrical_load_time_series,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->controller.load_operating_reserve_factor,
        0.2,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->controller.max_operating_reserve_factor,
        1,
        __FILE__,
        __LINE__
    );

    return test_model_ptr;
}   /* testConstruct_Model() */
```

#### 5.71.2.17 testEconomics_Model()

```
void testEconomics_Model (
            Model * test_model_ptr )
```

Function to check that the modelled economic metrics are $>0$.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |

```
{
    testGreaterThan(
```

```
        test_model_ptr->net_present_cost,
        0,
        __FILE__,
        __LINE__
    );

    testGreaterThan(
        test_model_ptr->levellized_cost_of_energy_kWh,
        0,
        __FILE__,
        __LINE__
    );

    return;
}   /* testEconomics_Model() */
```

#### 5.71.2.18 testElectricalLoadData_Model()

```
void testElectricalLoadData_Model (
            Model * test_model_ptr )
```

Function to check the values read into the ElectricalLoad component of the test Model object.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |

```
{
    std::vector<double> expected_dt_vec_hrs (48, 1);

    std::vector<double> expected_time_vec_hrs = {
         0,  1,  2,  3,  4,  5,  6,  7,  8,  9, 10, 11,
        12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23,
        24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35,
        36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47
    };

    std::vector<double> expected_load_vec_kW = {
        360.253836463674,
        355.171277826775,
        353.776453532298,
        353.75405737934,
        346.592867404975,
        340.132411175118,
        337.354867340578,
        340.644115618736,
        363.639028500678,
        378.787797779238,
        372.215798201712,
        395.093925731298,
        402.325427142659,
        386.907725462306,
        380.709170928091,
        372.062070914977,
        372.328646856954,
        391.841444284136,
        394.029351759596,
        383.369407765254,
        381.093099675206,
        382.604158946193,
        390.744843709034,
        383.13949492437,
        368.150393976985,
        364.629744480226,
        363.572736804082,
        359.854924202248,
        355.207590170267,
        349.094656012401,
        354.365935871597,
        343.380608328546,
        404.673065729266,
        486.296896820126,
        480.225974100847,
        457.318764401085,
        418.177339948609,
```

```
        414.399018364126,
        409.678420185754,
        404.768766016563,
        401.699589920585,
        402.44339040654,
        398.138372541906,
        396.010498627646,
        390.165117432277,
        375.850429417013,
        365.567100746484,
        365.429624610923
    };

    for (int i = 0; i < 48; i++) {
        testFloatEquals(
            test_model_ptr->electrical_load.dt_vec_hrs[i],
            expected_dt_vec_hrs[i],
            __FILE__,
            __LINE__
        );

        testFloatEquals(
            test_model_ptr->electrical_load.time_vec_hrs[i],
            expected_time_vec_hrs[i],
            __FILE__,
            __LINE__
        );

        testFloatEquals(
            test_model_ptr->electrical_load.load_vec_kW[i],
            expected_load_vec_kW[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testElectricalLoadData_Model() */
```

#### 5.71.2.19 testFuelConsumptionEmissions_Model()

```
void testFuelConsumptionEmissions_Model (
            Model * test_model_ptr )
```

Function to check that the modelled fuel consumption and emissions are $>$ 0.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |

```
{
    testGreaterThan(
        test_model_ptr->total_fuel_consumed_L,
        0,
        __FILE__,
        __LINE__
    );

    testGreaterThan(
        test_model_ptr->total_emissions.CO2_kg,
        0,
        __FILE__,
        __LINE__
    );

    testGreaterThan(
        test_model_ptr->total_emissions.CO_kg,
        0,
        __FILE__,
        __LINE__
    );

    testGreaterThan(
        test_model_ptr->total_emissions.NOx_kg,
        0,
```

```
        __FILE__,
        __LINE__
    );

    testGreaterThan(
        test_model_ptr->total_emissions.SOx_kg,
        0,
        __FILE__,
        __LINE__
    );

    testGreaterThan(
        test_model_ptr->total_emissions.CH4_kg,
        0,
        __FILE__,
        __LINE__
    );

    testGreaterThan(
        test_model_ptr->total_emissions.PM_kg,
        0,
        __FILE__,
        __LINE__
    );

    return;
}   /* testFuelConsumptionEmissions_Model() */
```

### 5.71.2.20 testLoadBalance_Model()

```
void testLoadBalance_Model (
            Model * test_model_ptr )
```

Function to check that the post-run load data is as expected. That is, the added renewable, production, and storage assets are handled by the Controller as expected.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |

```
{
    double load_kW = 0;

    Combustion* combustion_ptr;
    Noncombustion* noncombustion_ptr;
    Renewable* renewable_ptr;
    Storage* storage_ptr;

    for (int i = 0; i < test_model_ptr->electrical_load.n_points; i++) {
        testLessThanOrEqualTo(
            test_model_ptr->controller.net_load_vec_kW[i],
            test_model_ptr->electrical_load.max_load_kW,
            __FILE__,
            __LINE__
        );

        load_kW = test_model_ptr->electrical_load.load_vec_kW[i];

        for (size_t j = 0; j < test_model_ptr->combustion_ptr_vec.size(); j++) {
            combustion_ptr = test_model_ptr->combustion_ptr_vec[j];

            testGreaterThanOrEqualTo(
                combustion_ptr->production_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThanOrEqualTo(
                combustion_ptr->dispatch_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );
```

```
            testGreaterThanOrEqualTo(
                combustion_ptr->curtailment_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThanOrEqualTo(
                combustion_ptr->storage_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testFloatEquals(
                combustion_ptr->production_vec_kW[i] -
                combustion_ptr->dispatch_vec_kW[i] -
                combustion_ptr->curtailment_vec_kW[i] -
                combustion_ptr->storage_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            load_kW -= combustion_ptr->dispatch_vec_kW[i];
        }

        for (size_t j = 0; j < test_model_ptr->noncombustion_ptr_vec.size(); j++) {
            noncombustion_ptr = test_model_ptr->noncombustion_ptr_vec[j];

            testGreaterThanOrEqualTo(
                noncombustion_ptr->production_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThanOrEqualTo(
                noncombustion_ptr->dispatch_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThanOrEqualTo(
                noncombustion_ptr->curtailment_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThanOrEqualTo(
                noncombustion_ptr->storage_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testFloatEquals(
                noncombustion_ptr->production_vec_kW[i] -
                noncombustion_ptr->dispatch_vec_kW[i] -
                noncombustion_ptr->curtailment_vec_kW[i] -
                noncombustion_ptr->storage_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            load_kW -= noncombustion_ptr->dispatch_vec_kW[i];
        }

        for (size_t j = 0; j < test_model_ptr->renewable_ptr_vec.size(); j++) {
            renewable_ptr = test_model_ptr->renewable_ptr_vec[j];

            testGreaterThanOrEqualTo(
                renewable_ptr->production_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThanOrEqualTo(
                renewable_ptr->dispatch_vec_kW[i],
                0,
                __FILE__,
                __LINE__
```

```
            );

            testGreaterThanOrEqualTo(
                renewable_ptr->curtailment_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThanOrEqualTo(
                renewable_ptr->storage_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testFloatEquals(
                renewable_ptr->production_vec_kW[i] -
                renewable_ptr->dispatch_vec_kW[i] -
                renewable_ptr->curtailment_vec_kW[i] -
                renewable_ptr->storage_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            load_kW -= renewable_ptr->dispatch_vec_kW[i];
        }

        for (size_t j = 0; j < test_model_ptr->storage_ptr_vec.size(); j++) {
            storage_ptr = test_model_ptr->storage_ptr_vec[j];

            testGreaterThanOrEqualTo(
                storage_ptr->charging_power_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testGreaterThanOrEqualTo(
                storage_ptr->discharging_power_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );

            testTruth(
                not (
                    storage_ptr->charging_power_vec_kW[i] > 0 and
                    storage_ptr->discharging_power_vec_kW[i] > 0
                ),
                __FILE__,
                __LINE__
            );

            load_kW -= storage_ptr->discharging_power_vec_kW[i];
        }

        testLessThanOrEqualTo(
            load_kW,
            1e-6,
            __FILE__,
            __LINE__
        );

        testLessThanOrEqualTo(
            test_model_ptr->controller.missed_load_vec_kW[i],
            0,
            __FILE__,
            __LINE__
        );
    }

    testFloatEquals(
        test_model_ptr->total_dispatch_discharge_kWh,
        2263351.62026685,
        __FILE__,
        __LINE__
    );

    return;
}   /* testLoadBalance_Model() */
```

#### 5.71.2.21 testOperatingReserve_Model()

```
void testOperatingReserve_Model (
            Model * test_model_ptr )
```

Function to check that the post-run state is consistent with the intended operating reserve (or "spinning reserve") logic.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |

```
{
    double load_kW = 0;
    double operating_reserve_kW = 0;

    Combustion* combustion_ptr;
    Noncombustion* noncombustion_ptr;
    Renewable* renewable_ptr;
    Storage* storage_ptr;

    for (int i = 0; i < test_model_ptr->electrical_load.n_points; i++) {
        //  1. compute operating reserve
        load_kW = test_model_ptr->electrical_load.load_vec_kW[i];

        operating_reserve_kW =
            test_model_ptr->controller.load_operating_reserve_factor * load_kW;

        for (size_t j = 0; j < test_model_ptr->renewable_ptr_vec.size(); j++) {
            renewable_ptr = test_model_ptr->renewable_ptr_vec[j];

            operating_reserve_kW += (1 - renewable_ptr->firmness_factor) *
                renewable_ptr->production_vec_kW[i];

            testGreaterThanOrEqualTo(
                renewable_ptr->production_vec_kW[i],
                0,
                __FILE__,
                __LINE__
            );
        }

        if (
            operating_reserve_kW >
                test_model_ptr->controller.max_operating_reserve_factor * load_kW
        ) {
            operating_reserve_kW =
                test_model_ptr->controller.max_operating_reserve_factor * load_kW;
        }

        testGreaterThanOrEqualTo(
            operating_reserve_kW,
            0,
            __FILE__,
            __LINE__
        );

        //  2. deduct Storage discharge from operating reserve
        for (size_t j = 0; j < test_model_ptr->storage_ptr_vec.size(); j++) {
            storage_ptr = test_model_ptr->storage_ptr_vec[j];

            operating_reserve_kW -= storage_ptr->discharging_power_vec_kW[i];
        }

        //  3. deduct Noncombustion dispatch from operating reserve
        for (size_t j = 0; j < test_model_ptr->noncombustion_ptr_vec.size(); j++) {
            noncombustion_ptr = test_model_ptr->noncombustion_ptr_vec[j];

            operating_reserve_kW -= noncombustion_ptr->dispatch_vec_kW[i];
        }

        //  4. deduct Combustion dispatch from operating reserve
        for (size_t j = 0; j < test_model_ptr->combustion_ptr_vec.size(); j++) {
            combustion_ptr = test_model_ptr->combustion_ptr_vec[j];

            operating_reserve_kW -= combustion_ptr->dispatch_vec_kW[i];
        }

        //  5. assert remaining operating reserve is zero (+/- tolerance)
        testLessThanOrEqualTo(
```

```
            operating_reserve_kW,
            1e-6,
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testOperatingReserve_Model() */
```

#### 5.71.2.22 testPostConstructionAttributes_Model()

```
void testPostConstructionAttributes_Model (
            Model * test_model_ptr )
```

A function to check the values of various post-construction attributes.

**Parameters**

| | |
|---|---|
| *test_model_ptr* | A pointer to the test Model object. |

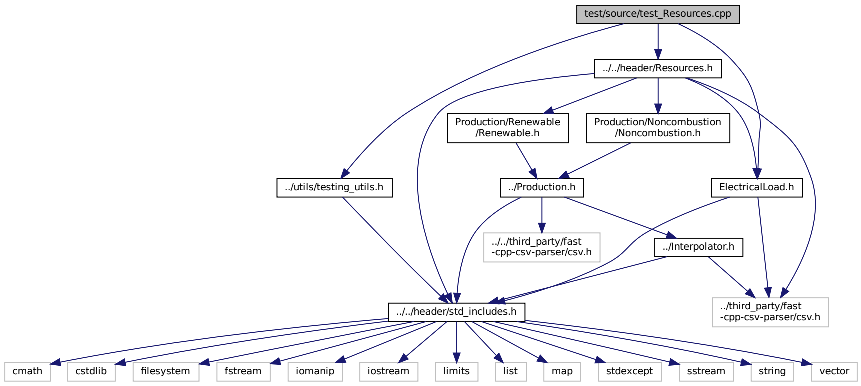
```
{
    testFloatEquals(
        test_model_ptr->electrical_load.n_points,
        8760,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->electrical_load.n_years,
        0.999886,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->electrical_load.min_load_kW,
        82.1211213927802,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_model_ptr->electrical_load.mean_load_kW,
        258.373472633202,
        __FILE__,
        __LINE__
    );


    testFloatEquals(
        test_model_ptr->electrical_load.max_load_kW,
        500,
        __FILE__,
        __LINE__
    );

    return;
}   /* testPostConstructionAttributes_Model() */
```

## 5.72 test/source/test_Resources.cpp File Reference

Testing suite for Resources class.

```
#include "../utils/testing_utils.h"
#include "../../header/Resources.h"
```

`#include "../../header/ElectricalLoad.h"`
Include dependency graph for test_Resources.cpp:




## Functions

- Resources ∗ testConstruct_Resources (void)

    *A function to construct a Resources object and spot check some post-construction attributes.*
- void testAddSolarResource_Resources (Resources ∗test_resources_ptr, ElectricalLoad ∗test_electrical_load_ptr, std::string path_2_solar_resource_data, int solar_resource_key)

    *Function to test adding a solar resource and then check the values read into the test Resources object.*
- void testBadAdd_Resources (Resources ∗test_resources_ptr, ElectricalLoad ∗test_electrical_load_ptr, std::string path_2_solar_resource_data, int solar_resource_key)

    *Function to test that trying to add bad resource data is being handled as expected.*
- void testAddTidalResource_Resources (Resources ∗test_resources_ptr, ElectricalLoad ∗test_electrical_load_ptr, std::string path_2_tidal_resource_data, int tidal_resource_key)

    *Function to test adding a tidal resource and then check the values read into the test Resources object.*
- void testAddWaveResource_Resources (Resources ∗test_resources_ptr, ElectricalLoad ∗test_electrical_load_ptr, std::string path_2_wave_resource_data, int wave_resource_key)

    *Function to test adding a wave resource and then check the values read into the test Resources object.*
- void testAddWindResource_Resources (Resources ∗test_resources_ptr, ElectricalLoad ∗test_electrical_load_ptr, std::string path_2_wind_resource_data, int wind_resource_key)

    *Function to test adding a wind resource and then check the values read into the test Resources object.*
- void testAddHydroResource_Resources (Resources ∗test_resources_ptr, ElectricalLoad ∗test_electrical_load_ptr, std::string path_2_hydro_resource_data, int hydro_resource_key)

    *Function to test adding a hydro resource and then check the values read into the test Resources object.*
- int main (int argc, char ∗∗argv)

## 5.72.1 Detailed Description

Testing suite for Resources class.

A suite of tests for the Resources class.

## 5.72.2 Function Documentation

#### 5.72.2.1 main()

```
int main (
            int argc,
            char ** argv )
```

```
{
    #ifdef _WIN32
        activateVirtualTerminal();
    #endif  /* _WIN32 */

    printGold("\tTesting Resources");

    #ifdef _WIN32
        std::cout « std::endl;
    #endif

    srand(time(NULL));


    std::string path_2_electrical_load_time_series =
        "data/test/electrical_load/electrical_load_generic_peak-500kW_1yr_dt-1hr.csv";

    ElectricalLoad* test_electrical_load_ptr =
        new ElectricalLoad(path_2_electrical_load_time_series);

    Resources* test_resources_ptr = testConstruct_Resources();


    try {
        int solar_resource_key = 0;
        std::string path_2_solar_resource_data =
            "data/test/resources/solar_GHI_peak-1kWm2_1yr_dt-1hr.csv";

        testAddSolarResource_Resources(
            test_resources_ptr,
            test_electrical_load_ptr,
            path_2_solar_resource_data,
            solar_resource_key
        );

        testBadAdd_Resources(
            test_resources_ptr,
            test_electrical_load_ptr,
            path_2_solar_resource_data,
            solar_resource_key
        );


        int tidal_resource_key = 1;
        std::string path_2_tidal_resource_data =
            "data/test/resources/tidal_speed_peak-3ms_1yr_dt-1hr.csv";

        testAddTidalResource_Resources(
            test_resources_ptr,
            test_electrical_load_ptr,
            path_2_tidal_resource_data,
            tidal_resource_key
        );


        int wave_resource_key = 2;
        std::string path_2_wave_resource_data =
            "data/test/resources/waves_H_s_peak-8m_T_e_peak-15s_1yr_dt-1hr.csv";

        testAddWaveResource_Resources(
            test_resources_ptr,
            test_electrical_load_ptr,
            path_2_wave_resource_data,
            wave_resource_key
        );


        int wind_resource_key = 3;
        std::string path_2_wind_resource_data =
            "data/test/resources/wind_speed_peak-25ms_1yr_dt-1hr.csv";

        testAddWindResource_Resources(
            test_resources_ptr,
            test_electrical_load_ptr,
            path_2_wind_resource_data,
            wind_resource_key
        );


        int hydro_resource_key = 4;
```

```
        std::string path_2_hydro_resource_data =
            "data/test/resources/hydro_inflow_peak-20000m3hr_1yr_dt-1hr.csv";

        testAddHydroResource_Resources(
            test_resources_ptr,
            test_electrical_load_ptr,
            path_2_hydro_resource_data,
            hydro_resource_key
        );
    }


    catch (...) {
        delete test_electrical_load_ptr;
        delete test_resources_ptr;

        printGold(" ................................ ");
        printRed("FAIL");
        std::cout « std::endl;
        throw;
    }


    delete test_electrical_load_ptr;
    delete test_resources_ptr;

    printGold(" ................................ ");
    printGreen("PASS");
    std::cout « std::endl;
    return 0;
}   /* main() */
```

### 5.72.2.2 testAddHydroResource_Resources()

```
void testAddHydroResource_Resources (
            Resources * test_resources_ptr,
            ElectricalLoad * test_electrical_load_ptr,
            std::string path_2_hydro_resource_data,
            int hydro_resource_key )
```

Function to test adding a hydro resource and then check the values read into the test Resources object.

**Parameters**

| | |
|---|---|
| *test_resources_ptr* | A pointer to the test Resources object. |
| *test_electrical_load_ptr* | A pointer to the test ElectricalLoad object. |
| *path_2_hydro_resource_data* | A path (either relative or absolute) to the hydro resource data. |
| *hydro_resource_key* | A key used to index into the Resources component of the test Resources object. |

```
{
    test_resources_ptr->addResource(
        NoncombustionType::HYDRO,
        path_2_hydro_resource_data,
        hydro_resource_key,
        test_electrical_load_ptr
    );

    std::vector<double> expected_hydro_resource_vec_m3hr = {
        2167.91531556942,
        2046.58261560569,
        2007.85941123153,
        2000.11477247929,
        1917.50527264453,
        1963.97311577093,
        1908.46985899809,
        1886.5267112678,
        1965.26388854254,
        1953.64692935289,
        2084.01504296306,
        2272.46796101188,
        2520.29645627096,
```

```
        2715.203242423,
        2720.36633563203,
        3130.83228077221,
        3289.59741021591,
        3981.45195965772,
        5295.45929491303,
        7084.47124360523,
        7709.20557708454,
        7436.85238642936,
        7235.49173429668,
        6710.14695517339,
        6015.71085806577,
        5279.97001316337,
        4877.24870889801,
        4421.60569340303,
        3919.49483690424,
        3498.70270322341,
        3274.10813058883,
        3147.61233529349,
        2904.94693324343,
        2805.55738101,
        2418.32535637171,
        2398.96375630723,
        2260.85100182222,
        2157.58912702878,
        2019.47637254377,
        1913.63295220712,
        1863.29279076589,
        1748.41395678279,
        1695.49224555317,
        1599.97501375715,
        1559.96103873397,
        1505.74855473274,
        1438.62833664765,
        1384.41585476901
    };

    for (size_t i = 0; i < expected_hydro_resource_vec_m3hr.size(); i++) {
        testFloatEquals(
            test_resources_ptr->resource_map_1D[hydro_resource_key][i],
            expected_hydro_resource_vec_m3hr[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testAddHydroResource_Resources() */
```

#### 5.72.2.3 testAddSolarResource_Resources()

```
void testAddSolarResource_Resources (
            Resources * test_resources_ptr,
            ElectricalLoad * test_electrical_load_ptr,
            std::string path_2_solar_resource_data,
            int solar_resource_key )
```

Function to test adding a solar resource and then check the values read into the test Resources object.

**Parameters**

| | |
|---|---|
| *test_resources_ptr* | A pointer to the test Resources object. |
| *test_electrical_load_ptr* | A pointer to the test ElectricalLoad object. |
| *path_2_solar_resource_data* | A path (either relative or absolute) to the solar resource data. |
| *solar_resource_key* | A key used to index into the Resources component of the test Resources object. |

```
{
    test_resources_ptr->addResource(
        RenewableType::SOLAR,
        path_2_solar_resource_data,
        solar_resource_key,
```

```
        test_electrical_load_ptr
    );

    std::vector<double> expected_solar_resource_vec_kWm2 = {
        0,
        0,
        0,
        0,
        0,
        0,
        8.51702662684015E-05,
        0.000348341567045,
        0.00213793728593,
        0.004099863613322,
        0.000997135230553,
        0.009534527624657,
        0.022927996790616,
        0.0136071715294,
        0.002535134127751,
        0.005206897515821,
        0.005627658648597,
        0.000701186722215,
        0.00017119827089,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0,
        0.000141055102242,
        0.00084525014743,
        0.024893647822702,
        0.091245556190749,
        0.158722176731637,
        0.152859680515876,
        0.149922903895116,
        0.13049996570866,
        0.03081254222795,
        0.001218928911125,
        0.000206092647423,
        0,
        0,
        0,
        0,
        0,
        0
    };

    for (size_t i = 0; i < expected_solar_resource_vec_kWm2.size(); i++) {
        testFloatEquals(
            test_resources_ptr->resource_map_1D[solar_resource_key][i],
            expected_solar_resource_vec_kWm2[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testAddSolarResource_Resources() */
```

#### 5.72.2.4 testAddTidalResource_Resources()

```
void testAddTidalResource_Resources (
            Resources * test_resources_ptr,
            ElectricalLoad * test_electrical_load_ptr,
            std::string path_2_tidal_resource_data,
            int tidal_resource_key )
```

Function to test adding a tidal resource and then check the values read into the test Resources object.

**Parameters**

| | |
|---|---|
| *test_resources_ptr* | A pointer to the test Resources object. |
| *test_electrical_load_ptr* | A pointer to the test ElectricalLoad object. |
| *path_2_tidal_resource_data* | A path (either relative or absolute) to the tidal resource data. |
| *tidal_resource_key* | A key used to index into the Resources component of the test Resources object. |

```
{
    test_resources_ptr->addResource(
        RenewableType::TIDAL,
        path_2_tidal_resource_data,
        tidal_resource_key,
        test_electrical_load_ptr
    );

    std::vector<double> expected_tidal_resource_vec_ms = {
        0.347439913040533,
        0.770545522195602,
        0.731352084836198,
        0.293389814389542,
        0.209959110813115,
        0.610609623896497,
        1.78067162013604,
        2.53522775118089,
        2.75966627832024,
        2.52101111143895,
        2.05389330201031,
        1.3461515862445,
        0.28909254878384,
        0.897754086048563,
        1.71406453837407,
        1.85047408742869,
        1.71507908595979,
        1.33540349705416,
        0.434586143463003,
        0.500623815700637,
        1.37172172646733,
        1.68294125491228,
        1.56101300975417,
        1.04925834219412,
        0.211395463930223,
        1.03720048903385,
        1.85059536356448,
        1.85203242794517,
        1.4091471616277,
        0.767776539039899,
        0.251464906990961,
        1.47018469375652,
        2.36260493698197,
        2.46653750048625,
        2.12851908739291,
        1.62783753197988,
        0.734594890957439,
        0.441886297300355,
        1.6574418350918,
        2.0684558286637,
        1.87717416992136,
        1.58871262337931,
        1.03451227609235,
        0.193371305159817,
        0.976400122458815,
        1.6583227369707,
        1.76690616570953,
        1.54801328553115
    };

    for (size_t i = 0; i < expected_tidal_resource_vec_ms.size(); i++) {
        testFloatEquals(
            test_resources_ptr->resource_map_1D[tidal_resource_key][i],
            expected_tidal_resource_vec_ms[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testAddTidalResource_Resources() */
```

#### 5.72.2.5 testAddWaveResource_Resources()

```
void testAddWaveResource_Resources (
            Resources * test_resources_ptr,
            ElectricalLoad * test_electrical_load_ptr,
            std::string path_2_wave_resource_data,
            int wave_resource_key )
```

Function to test adding a wave resource and then check the values read into the test Resources object.

**Parameters**

| | |
|---|---|
| *test_resources_ptr* | A pointer to the test Resources object. |
| *test_electrical_load_ptr* | A pointer to the test ElectricalLoad object. |
| *path_2_wave_resource_data* | A path (either relative or absolute) to the wave resource data. |
| *wave_resource_key* | A key used to index into the Resources component of the test Resources object. |

```
{
    test_resources_ptr->addResource(
        RenewableType::WAVE,
        path_2_wave_resource_data,
        wave_resource_key,
        test_electrical_load_ptr
    );

    std::vector<double> expected_significant_wave_height_vec_m = {
        4.26175222125028,
        4.25020976167872,
        4.25656524330349,
        4.27193854786718,
        4.28744955711233,
        4.29421815278154,
        4.2839937266082,
        4.25716982457976,
        4.22419391611483,
        4.19588925217606,
        4.17338788587412,
        4.14672746914214,
        4.10560041173665,
        4.05074966447193,
        3.9953696962433,
        3.95316976150866,
        3.92771018142378,
        3.91129562488595,
        3.89558312094911,
        3.87861093931749,
        3.86538307240754,
        3.86108961027929,
        3.86459448853189,
        3.86796474016882,
        3.86357412779993,
        3.85554872014731,
        3.86044266668675,
        3.89445961915999,
        3.95554798115731,
        4.02265508610476,
        4.07419587011404,
        4.10314247143958,
        4.11738045085928,
        4.12554995596708,
        4.12923992001675,
        4.1229292327442,
        4.10123955307441,
        4.06748827895363,
        4.0336230651344,
        4.01134236393876,
        4.00136570034559,
        3.99368787690411,
        3.97820924247644,
        3.95369335178055,
        3.92742545608532,
        3.90683362771686,
        3.89331520944006,
        3.88256045801583
    };

    std::vector<double> expected_energy_period_vec_s = {
```

```
        10.4456008226821,
        10.4614151137651,
        10.4462827795433,
        10.4127692097884,
        10.3734397942723,
        10.3408599227669,
        10.32637292093,
        10.3245412676322,
        10.310409818185,
        10.2589529840966,
        10.1728100603103,
        10.0862908658929,
        10.03480243813,
        10.023673635806,
        10.0243418565116,
        10.0063487117653,
        9.96050302286607,
        9.9011999635568,
        9.84451822125472,
        9.79726875879626,
        9.75614594835158,
        9.7173447961368,
        9.68342904390577,
        9.66380508567062,
        9.6674009575699,
        9.68927134575103,
        9.70979984863046,
        9.70967357906908,
        9.68983025704562,
        9.6722855524805,
        9.67973599910003,
        9.71977125328293,
        9.78450442291421,
        9.86532355233449,
        9.96158937600019,
        10.0807018356507,
        10.2291022504937,
        10.39458528356,
        10.5464393581004,
        10.6553277500484,
        10.7245553190084,
        10.7893127285064,
        10.8846512240849,
        11.0148158739075,
        11.1544325654719,
        11.2772785848343,
        11.3744362756187,
        11.4533643503183
    };

    for (size_t i = 0; i < expected_significant_wave_height_vec_m.size(); i++) {
        testFloatEquals(
            test_resources_ptr->resource_map_2D[wave_resource_key][i][0],
            expected_significant_wave_height_vec_m[i],
            __FILE__,
            __LINE__
        );

        testFloatEquals(
            test_resources_ptr->resource_map_2D[wave_resource_key][i][1],
            expected_energy_period_vec_s[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}   /* testAddWaveResource_Resources() */
```

#### 5.72.2.6 testAddWindResource_Resources()

```
void testAddWindResource_Resources (
            Resources * test_resources_ptr,
            ElectricalLoad * test_electrical_load_ptr,
            std::string path_2_wind_resource_data,
            int wind_resource_key )
```

Function to test adding a wind resource and then check the values read into the test Resources object.

**Parameters**

| | |
|---|---|
| *test_resources_ptr* | A pointer to the test Resources object. |
| *test_electrical_load_ptr* | A pointer to the test ElectricalLoad object. |
| *path_2_wind_resource_data* | A path (either relative or absolute) to the wind resource data. |
| *wind_resource_key* | A key used to index into the Resources component of the test Resources object. |

```
{
    test_resources_ptr->addResource(
        RenewableType::WIND,
        path_2_wind_resource_data,
        wind_resource_key,
        test_electrical_load_ptr
    );

    std::vector<double> expected_wind_resource_vec_ms = {
        6.88566688469997,
        5.02177105466549,
        3.74211715899568,
        5.67169579985362,
        4.90670669971858,
        4.29586955031368,
        7.41155377205065,
        10.2243290476943,
        13.1258696725555,
        13.7016198628274,
        16.2481482330233,
        16.5096744355418,
        13.4354482206162,
        14.0129230731609,
        14.5554549260515,
        13.4454539065912,
        13.3447169512094,
        11.7372615098554,
        12.7200070078013,
        10.6421127908149,
        6.09869498990661,
        5.66355596602321,
        4.97316966910831,
        3.48937138360567,
        2.15917470979169,
        1.29061103587027,
        3.43475751425219,
        4.11706326260927,
        4.28905275747408,
        5.75850263196241,
        8.98293663055264,
        11.7069822941315,
        12.4031987075858,
        15.4096570910089,
        16.6210843829552,
        13.3421219142573,
        15.2112831900548,
        18.350864533037,
        15.8751799822971,
        15.3921198799796,
        15.9729192868434,
        12.4728950178772,
        10.177050481096,
        10.7342247355551,
        8.98846695631389,
        4.14671169124739,
        3.17256452697149,
        3.40036336968628
    };

    for (size_t i = 0; i < expected_wind_resource_vec_ms.size(); i++) {
        testFloatEquals(
            test_resources_ptr->resource_map_1D[wind_resource_key][i],
            expected_wind_resource_vec_ms[i],
            __FILE__,
            __LINE__
        );
    }

    return;
}    /* testAddWindResource_Resources() */
```

#### 5.72.2.7 testBadAdd_Resources()

```
void testBadAdd_Resources (
            Resources * test_resources_ptr,
            ElectricalLoad * test_electrical_load_ptr,
            std::string path_2_solar_resource_data,
            int solar_resource_key )
```

Function to test that trying to add bad resource data is being handled as expected.

**Parameters**

| | |
|---|---|
| *test_resources_ptr* | A pointer to the test Resources object. |
| *test_electrical_load_ptr* | A pointer to the test ElectricalLoad object. |
| *path_2_solar_resource_data* | A path (either relative or absolute) to the given solar resource data. |
| *solar_resource_key* | A key for indexing into the test Resources object. |

```
{
    bool error_flag = true;

    try {
        test_resources_ptr->addResource(
            RenewableType::SOLAR,
            path_2_solar_resource_data,
            solar_resource_key,
            test_electrical_load_ptr
        );

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }


    try {
        std::string path_2_solar_resource_data_BAD_TIMES =
            "data/test/resources/solar_GHI_peak-1kWm2_1yr_dt-1hr_BAD_TIMES.csv";

        test_resources_ptr->addResource(
            RenewableType::SOLAR,
            path_2_solar_resource_data_BAD_TIMES,
            -1,
            test_electrical_load_ptr
        );

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }


    try {
        std::string path_2_solar_resource_data_BAD_LENGTH =
            "data/test/resources/solar_GHI_peak-1kWm2_1yr_dt-1hr_BAD_LENGTH.csv";

        test_resources_ptr->addResource(
            RenewableType::SOLAR,
            path_2_solar_resource_data_BAD_LENGTH,
            -2,
            test_electrical_load_ptr
        );

        error_flag = false;
    } catch (...) {
        // Task failed successfully! =P
    }
    if (not error_flag) {
        expectedErrorNotDetected(__FILE__, __LINE__);
    }

    return;
```

```
}   /* testBadAdd_Resources() */
```

#### 5.72.2.8 testConstruct_Resources()

```
Resources * testConstruct_Resources (
            void   )
```

A function to construct a Resources object and spot check some post-construction attributes.

**Returns**

A pointer to a test Resources object.

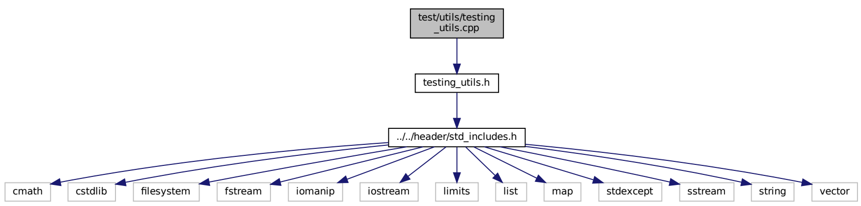
```
{
    Resources* test_resources_ptr = new Resources();

    testFloatEquals(
        test_resources_ptr->resource_map_1D.size(),
        0,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_resources_ptr->path_map_1D.size(),
        0,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_resources_ptr->resource_map_2D.size(),
        0,
        __FILE__,
        __LINE__
    );

    testFloatEquals(
        test_resources_ptr->path_map_2D.size(),
        0,
        __FILE__,
        __LINE__
    );

    return test_resources_ptr;
}   /* testConstruct_Resources() */
```

## 5.73 test/utils/testing_utils.cpp File Reference

Implementation file for various PGMcpp testing utilities.

`#include "testing_utils.h"`

Include dependency graph for testing_utils.cpp:



## Functions

- void printGreen (std::string input_str)

  *A function that sends green text to std::cout.*
- void printGold (std::string input_str)

  *A function that sends gold text to std::cout.*
- void printRed (std::string input_str)

  *A function that sends red text to std::cout.*
- void testFloatEquals (double x, double y, std::string file, int line)

  *Tests for the equality of two floating point numbers x and y (to within FLOAT_TOLERANCE).*
- void testGreaterThan (double x, double y, std::string file, int line)

  *Tests if $x > y$.*
- void testGreaterThanOrEqualTo (double x, double y, std::string file, int line)

  *Tests if $x >= y$.*
- void testLessThan (double x, double y, std::string file, int line)

  *Tests if $x < y$.*
- void testLessThanOrEqualTo (double x, double y, std::string file, int line)

  *Tests if $x <= y$.*
- void testTruth (bool statement, std::string file, int line)

  *Tests if the given statement is true.*
- void expectedErrorNotDetected (std::string file, int line)

  *A utility function to print out a meaningful error message whenever an expected error fails to be thrown/caught/detected.*

### 5.73.1 Detailed Description

Implementation file for various PGMcpp testing utilities.

This is a library of utility functions used throughout the various test suites.

### 5.73.2 Function Documentation

#### 5.73.2.1 expectedErrorNotDetected()

```
void expectedErrorNotDetected (
            std::string file,
            int line )
```

A utility function to print out a meaningful error message whenever an expected error fails to be thrown/caught/detected.

**Parameters**

| | |
|---|---|
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    std::string error_str = "\n ERROR  failed to throw expected error prior to line ";
    error_str += std::to_string(line);
```

```
    error_str += " of ";
    error_str += file;

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
    return;
}   /* expectedErrorNotDetected() */
```

#### 5.73.2.2 printGold()

```
void printGold (
              std::string input_str )
```

A function that sends gold text to std::cout.

**Parameters**

| | |
|---|---|
| *input_str* | The text of the string to be sent to std::cout. |

```
{
    std::cout « "\x1B[33m" « input_str « "\033[0m";
    return;
}   /* printGold() */
```

#### 5.73.2.3 printGreen()

```
void printGreen (
              std::string input_str )
```

A function that sends green text to std::cout.

**Parameters**

| | |
|---|---|
| *input_str* | The text of the string to be sent to std::cout. |

```
{
    std::cout « "\x1B[32m" « input_str « "\033[0m";
    return;
}   /* printGreen() */
```

#### 5.73.2.4 printRed()

```
void printRed (
              std::string input_str )
```

A function that sends red text to std::cout.

**Parameters**

| | |
|---|---|
| *input_str* | The text of the string to be sent to std::cout. |

```
{
    std::cout « "\x1B[31m" « input_str « "\033[0m";
    return;
}   /* printRed() */
```

#### 5.73.2.5 testFloatEquals()

```
void testFloatEquals (
            double x,
            double y,
            std::string file,
            int line )
```

Tests for the equality of two floating point numbers *x* and *y* (to within FLOAT_TOLERANCE).

**Parameters**

| | |
|---|---|
| *x* | The first of two numbers to test. |
| *y* | The second of two numbers to test. |
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    if (fabs(x - y) <= FLOAT_TOLERANCE) {
        return;
    }

    std::string error_str = "ERROR: testFloatEquals():\t in ";
    error_str += file;
    error_str += "\tline ";
    error_str += std::to_string(line);
    error_str += ":\t\n";
    error_str += std::to_string(x);
    error_str += " and ";
    error_str += std::to_string(y);
    error_str += " are not equal to within +/- ";
    error_str += std::to_string(FLOAT_TOLERANCE);
    error_str += "\n";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
    return;
}   /* testFloatEquals() */
```

#### 5.73.2.6 testGreaterThan()

```
void testGreaterThan (
            double x,
            double y,
            std::string file,
            int line )
```

Tests if x $>$ y.

**Parameters**

| | |
|---|---|
| *x* | The first of two numbers to test. |
| *y* | The second of two numbers to test. |
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    if (x > y) {
        return;
    }

    std::string error_str = "ERROR: testGreaterThan():\t in ";
    error_str += file;
    error_str += "\tline ";
    error_str += std::to_string(line);
    error_str += ":\t\n";
    error_str += std::to_string(x);
    error_str += " is not greater than ";
    error_str += std::to_string(y);
    error_str += "\n";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
    return;
}   /* testGreaterThan() */
```

### 5.73.2.7 testGreaterThanOrEqualTo()

```
void testGreaterThanOrEqualTo (
            double x,
            double y,
            std::string file,
            int line )
```

Tests if x >= y.

**Parameters**

| | |
|---|---|
| *x* | The first of two numbers to test. |
| *y* | The second of two numbers to test. |
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    if (x >= y) {
        return;
    }

    std::string error_str = "ERROR: testGreaterThanOrEqualTo():\t in ";
    error_str += file;
    error_str += "\tline ";
    error_str += std::to_string(line);
    error_str += ":\t\n";
    error_str += std::to_string(x);
    error_str += " is not greater than or equal to ";
    error_str += std::to_string(y);
    error_str += "\n";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
```

```
    return;
}   /* testGreaterThanOrEqualTo() */
```

#### 5.73.2.8 testLessThan()

```
void testLessThan (
            double x,
            double y,
            std::string file,
            int line )
```

Tests if x < y.

**Parameters**

| | |
|---|---|
| *x* | The first of two numbers to test. |
| *y* | The second of two numbers to test. |
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    if (x < y) {
        return;
    }

    std::string error_str = "ERROR: testLessThan():\t in ";
    error_str += file;
    error_str += "\tline ";
    error_str += std::to_string(line);
    error_str += ":\t\n";
    error_str += std::to_string(x);
    error_str += " is not less than ";
    error_str += std::to_string(y);
    error_str += "\n";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
    return;
}   /* testLessThan() */
```

#### 5.73.2.9 testLessThanOrEqualTo()

```
void testLessThanOrEqualTo (
            double x,
            double y,
            std::string file,
            int line )
```

Tests if x <= y.

**Parameters**

| | |
|---|---|
| *x* | The first of two numbers to test. |
| *y* | The second of two numbers to test. |
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    if (x <= y) {
        return;
    }

    std::string error_str = "ERROR: testLessThanOrEqualTo():\t in ";
    error_str += file;
    error_str += "\tline ";
    error_str += std::to_string(line);
    error_str += ":\t\n";
    error_str += std::to_string(x);
    error_str += " is not less than or equal to ";
    error_str += std::to_string(y);
    error_str += "\n";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
    return;
}   /* testLessThanOrEqualTo() */
```

#### 5.73.2.10 testTruth()

```
void testTruth (
            bool statement,
            std::string file,
            int line )
```

Tests if the given statement is true.

**Parameters**

| | |
|---|---|
| *statement* | The statement whose truth is to be tested ("1 == 0", for example). |
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

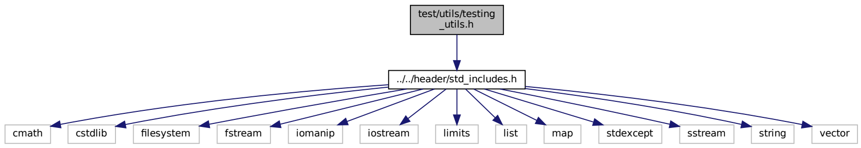
```
{
    if (statement) {
        return;
    }

    std::string error_str = "ERROR: testTruth():\t in ";
    error_str += file;
    error_str += "\tline ";
    error_str += std::to_string(line);
    error_str += ":\t\n";
    error_str += "Given statement is not true";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
    return;
}   /* testTruth() */
```

## 5.74 test/utils/testing_utils.h File Reference

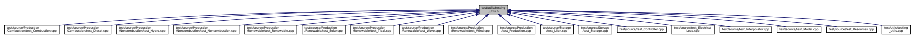
Header file for various PGMcpp testing utilities.

```
#include "../../header/std_includes.h"
```

Include dependency graph for testing_utils.h:




This graph shows which files directly or indirectly include this file:



## Macros

- #define FLOAT_TOLERANCE 1e-6

  *A tolerance for application to floating point equality tests.*

## Functions

- void printGreen (std::string)

  *A function that sends green text to std::cout.*
- void printGold (std::string)

  *A function that sends gold text to std::cout.*
- void printRed (std::string)

  *A function that sends red text to std::cout.*
- void testFloatEquals (double, double, std::string, int)

  *Tests for the equality of two floating point numbers x and y (to within FLOAT_TOLERANCE).*
- void testGreaterThan (double, double, std::string, int)

  *Tests if* $x > y$.
- void testGreaterThanOrEqualTo (double, double, std::string, int)

  *Tests if* $x >= y$.
- void testLessThan (double, double, std::string, int)

  *Tests if* $x < y$.
- void testLessThanOrEqualTo (double, double, std::string, int)

  *Tests if* $x <= y$.
- void testTruth (bool, std::string, int)

  *Tests if the given statement is true.*
- void expectedErrorNotDetected (std::string, int)

  *A utility function to print out a meaningful error message whenever an expected error fails to be thrown/caught/detected.*

### 5.74.1 Detailed Description

Header file for various PGMcpp testing utilities.

This is a library of utility functions used throughout the various test suites.

## 5.74.2 Macro Definition Documentation

### 5.74.2.1 FLOAT_TOLERANCE

```
#define FLOAT_TOLERANCE 1e-6
```

A tolerance for application to floating point equality tests.

## 5.74.3 Function Documentation

### 5.74.3.1 expectedErrorNotDetected()

```
void expectedErrorNotDetected (
            std::string file,
            int line )
```

A utility function to print out a meaningful error message whenever an expected error fails to be thrown/caught/detected.

**Parameters**

| | |
|---|---|
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    std::string error_str = "\n ERROR  failed to throw expected error prior to line ";
    error_str += std::to_string(line);
    error_str += " of ";
    error_str += file;

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
    return;
}   /* expectedErrorNotDetected() */
```

### 5.74.3.2 printGold()

```
void printGold (
            std::string input_str )
```

A function that sends gold text to std::cout.

**Parameters**

| | |
|---|---|
| *input_str* | The text of the string to be sent to std::cout. |

```
{
    std::cout « "\x1B[33m" « input_str « "\033[0m";
    return;
}   /* printGold() */
```

### 5.74.3.3 printGreen()

```
void printGreen (
            std::string input_str )
```

A function that sends green text to std::cout.

**Parameters**

| | |
|---|---|
| *input_str* | The text of the string to be sent to std::cout. |

```
{
    std::cout « "\x1B[32m" « input_str « "\033[0m";
    return;
}   /* printGreen() */
```

### 5.74.3.4 printRed()

```
void printRed (
            std::string input_str )
```

A function that sends red text to std::cout.

**Parameters**

| | |
|---|---|
| *input_str* | The text of the string to be sent to std::cout. |

```
{
    std::cout « "\x1B[31m" « input_str « "\033[0m";
    return;
}   /* printRed() */
```

### 5.74.3.5 testFloatEquals()

```
void testFloatEquals (
            double x,
            double y,
            std::string file,
            int line )
```

Tests for the equality of two floating point numbers *x* and *y* (to within FLOAT_TOLERANCE).

**Parameters**

| | |
|---|---|
| *x* | The first of two numbers to test. |

**Parameters**

| | |
|---|---|
| *y* | The second of two numbers to test. |
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    if (fabs(x - y) <= FLOAT_TOLERANCE) {
        return;
    }

    std::string error_str = "ERROR: testFloatEquals():\t in ";
    error_str += file;
    error_str += "\tline ";
    error_str += std::to_string(line);
    error_str += ":\t\n";
    error_str += std::to_string(x);
    error_str += " and ";
    error_str += std::to_string(y);
    error_str += " are not equal to within +/- ";
    error_str += std::to_string(FLOAT_TOLERANCE);
    error_str += "\n";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
    return;
}   /* testFloatEquals() */
```

### 5.74.3.6 testGreaterThan()

```
void testGreaterThan (
            double x,
            double y,
            std::string file,
            int line )
```

Tests if x $>$ y.

**Parameters**

| | |
|---|---|
| *x* | The first of two numbers to test. |
| *y* | The second of two numbers to test. |
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    if (x > y) {
        return;
    }

    std::string error_str = "ERROR: testGreaterThan():\t in ";
    error_str += file;
    error_str += "\tline ";
    error_str += std::to_string(line);
    error_str += ":\t\n";
    error_str += std::to_string(x);
    error_str += " is not greater than ";
    error_str += std::to_string(y);
    error_str += "\n";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

```

```
    throw std::runtime_error(error_str);
    return;
}   /* testGreaterThan() */
```

#### 5.74.3.7 testGreaterThanOrEqualTo()

```
void testGreaterThanOrEqualTo (
            double x,
            double y,
            std::string file,
            int line )
```

Tests if x >= y.

**Parameters**

| | |
|---|---|
| *x* | The first of two numbers to test. |
| *y* | The second of two numbers to test. |
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    if (x >= y) {
        return;
    }

    std::string error_str = "ERROR: testGreaterThanOrEqualTo():\t in ";
    error_str += file;
    error_str += "\tline ";
    error_str += std::to_string(line);
    error_str += ":\t\n";
    error_str += std::to_string(x);
    error_str += " is not greater than or equal to ";
    error_str += std::to_string(y);
    error_str += "\n";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
    return;
}   /* testGreaterThanOrEqualTo() */
```

#### 5.74.3.8 testLessThan()

```
void testLessThan (
            double x,
            double y,
            std::string file,
            int line )
```

Tests if x < y.

**Parameters**

| | |
|---|---|
| *x* | The first of two numbers to test. |
| *y* | The second of two numbers to test. |
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    if (x < y) {
        return;
    }

    std::string error_str = "ERROR: testLessThan():\t in ";
    error_str += file;
    error_str += "\tline ";
    error_str += std::to_string(line);
    error_str += ":\t\n";
    error_str += std::to_string(x);
    error_str += " is not less than ";
    error_str += std::to_string(y);
    error_str += "\n";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
    return;
}   /* testLessThan() */
```

#### 5.74.3.9 testLessThanOrEqualTo()

```
void testLessThanOrEqualTo (
            double x,
            double y,
            std::string file,
            int line )
```

Tests if x <= y.

**Parameters**

| | |
|---|---|
| *x* | The first of two numbers to test. |
| *y* | The second of two numbers to test. |
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    if (x <= y) {
        return;
    }

    std::string error_str = "ERROR: testLessThanOrEqualTo():\t in ";
    error_str += file;
    error_str += "\tline ";
    error_str += std::to_string(line);
    error_str += ":\t\n";
    error_str += std::to_string(x);
    error_str += " is not less than or equal to ";
    error_str += std::to_string(y);
    error_str += "\n";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
    return;
}   /* testLessThanOrEqualTo() */
```

#### 5.74.3.10 testTruth()

```
void testTruth (
```

```
bool statement,
std::string file,
int line )
```

Tests if the given statement is true.

**Parameters**

| | |
|---|---|
| *statement* | The statement whose truth is to be tested ("1 == 0", for example). |
| *file* | The file in which the test is applied (you should be able to just pass in "__FILE__"). |
| *line* | The line of the file in which the test is applied (you should be able to just pass in "__LINE__"). |

```
{
    if (statement) {
        return;
    }

    std::string error_str = "ERROR: testTruth():\t in ";
    error_str += file;
    error_str += "\tline ";
    error_str += std::to_string(line);
    error_str += ":\t\n";
    error_str += "Given statement is not true";

    #ifdef _WIN32
        std::cout « error_str « std::endl;
    #endif

    throw std::runtime_error(error_str);
    return;
}   /* testTruth() */
```

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