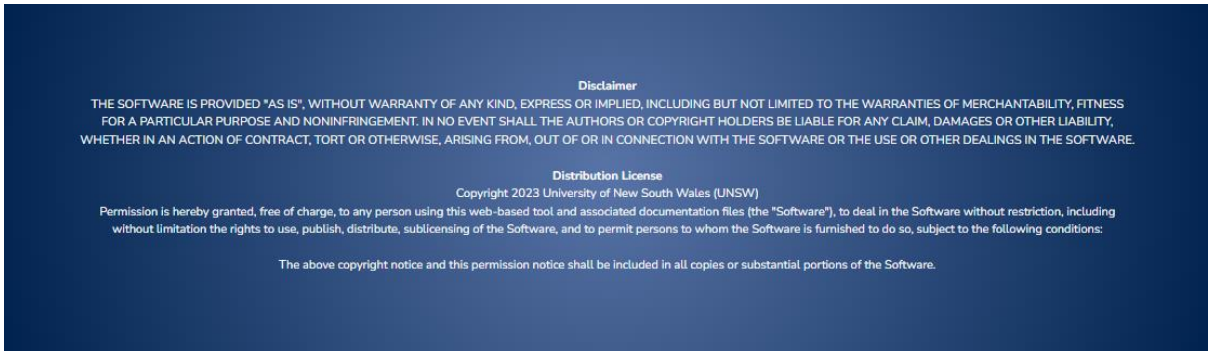
NSW Powerfuel Value Chain Tool

Documentation and tool navigation

Introductions:

The NSW Powerfuel Value Chain Tool is developed to investigate pathways to deploy Power-to-X technologies in NSW. Targeting a wide range of stakeholders, the tool can be used to evaluate the opportunity and potential costs of generating hydrogen and several key powerfuels (including ammonia) using renewable power sources across NSW. The key function of the tool is to calculate the levelised cost for hydrogen and other powerfuels, which users can then evaluate the feasibility and determine the potential for developing their own Power-to-X projects in various locations across NSW.

The tool consists of 4 main interfaces that users will interact with to build and assess projects, select location, select model, specify input parameters, and view modelled results. A walkthrough of these steps and additional information can be found in the sections that follow.



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1. Location and Model

1. **Select location:** The first interface that users will interact with after the landing page will be to select from the 22 available onshore and offshore zones corresponding to the desired site location within NSW. Each zone corresponds to unique set of annual solar and wind generation profiles which will be used to model project performance. These data sets are preloaded into the tool and will be updated from time to time. (Note: Offshore zones correspond to offshore wind power generation and transmission to an onshore powerfuel facility.)
2. **Start Project Design:** Once a zone has been selected a location summary will appear with key information about the locations in the zone as well as the average solar and wind power generation capacity factors. If desired the user can click away from the location summary to select a different location. Once satisfied, select 'Start Project Design' to choose the selected location and move to the next step.
3. **Select Powerfuel Pathway:** The next step is to choose from the list of powerfuels available (currently hydrogen, ammonia, methanol, or methane) to specify the pathway that will be modelled.
4. **Design tool ribbon:** Navigate back to this map at any time by clicking on the design tool ribbon on the left side of the tool interface.

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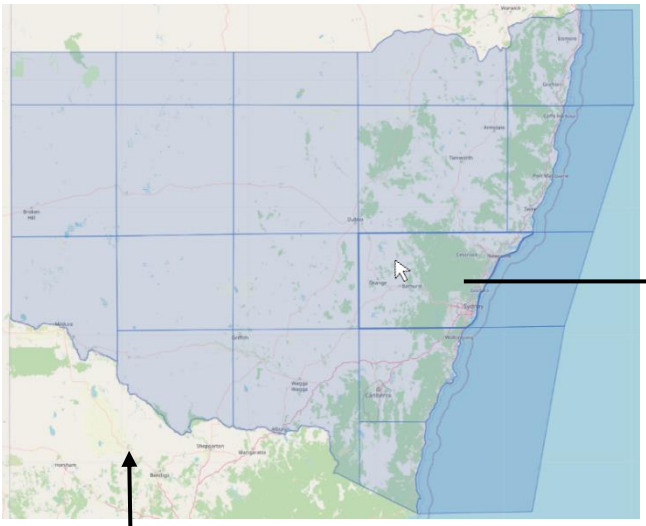

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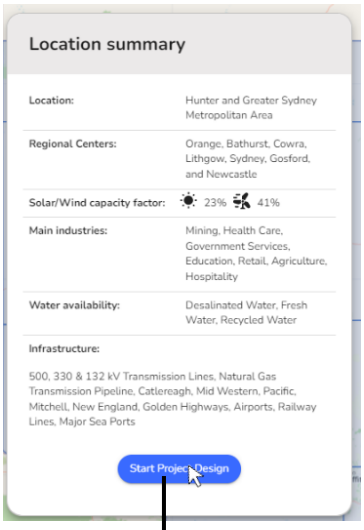

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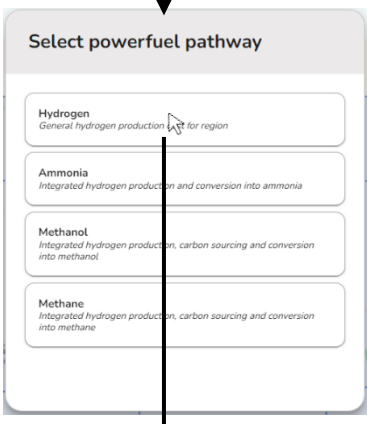

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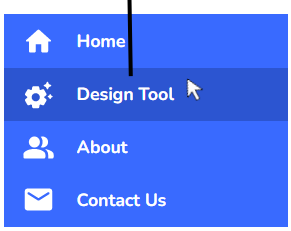
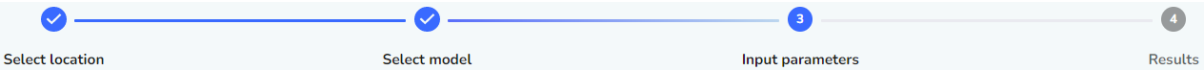
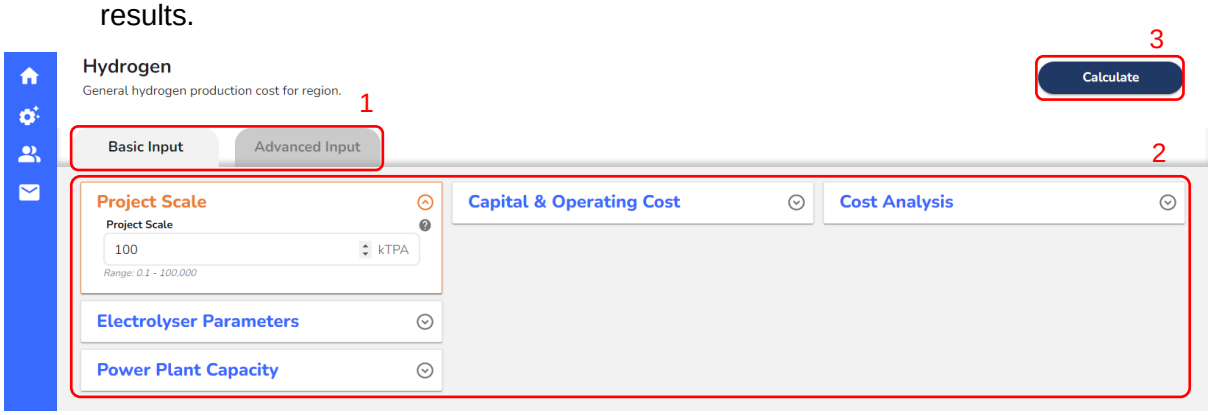




2. Input Parameters

The model building interface will allow the user to define and customize project operating and costing parameters.

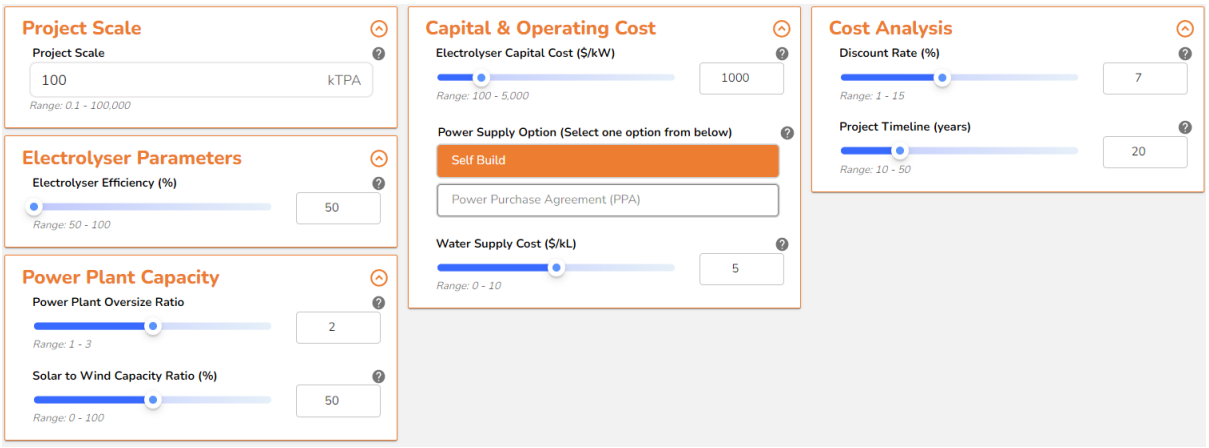
1. On this interface there is a choice between basic and advanced model inputs.
2. Both Basic and advanced pages contain collapsible menus the different groups of parameters and selections that can be specified. Default values are predefined for key inputs. However, we strongly recommend for users to review all parameters and to input their own to obtain relevant and tailored results.
3. Once all inputs have been defined, the 'Calculate' button can be selected to generate results.



2.1. Hydrogen

2.1.1. Basic Inputs

The basic model input page has been designed using simple inputs and sliders to build and evaluate a project easily and quickly.



Project scale: Specify the hydrogen production rate in thousand ton/yr (kTPA). Renewable energy and electrolyser units will be scaled automatically to match this nameplate production rate.

Electrolyser Efficiency: A slider to specify electrolyser energy efficiency relative to the theoretical minimum of 39.4 kWh/kg of H_2 produced.

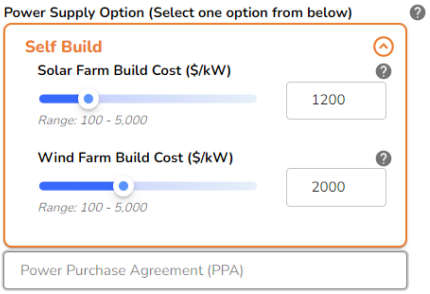
Power Plant Oversize Ratio: A slider to adjust the ratio of powerplant capacity oversizing relative to the electrolyser capacity in MW, e.g., choosing 3 results in the powerplant full load capacity (MW) being 3 times that of the electrolyser full load capacity (MW). This is an important configurational choice, which affects the achieved electrolyser capacity factor and thus the electrolyser and powerplant sizing required to meet the specified hydrogen production rate. Note: Higher powerplant oversizing will lower the required electrolyser capacity to meet the same hydrogen production rate.

Solar to Wind Ratio: Split of solar and wind farm share in the power capacity from solar only at 100% to wind only at 0%.

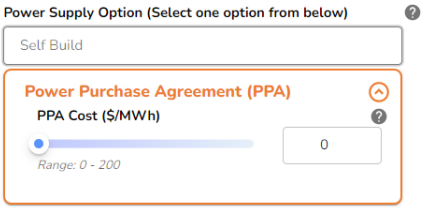
Electrolyser Capital Cost: Capital cost of electrolyser per kW including the equipment and installation costs.

Power Supply option: Select 'Self Build' for cases in which a new power plant is built in conjunction with electrolyser. Select PPA if there is a grid connection to a power supplier.

- Self Build selected:
  Solar Farm Build Cost: Capital cost of solar farm per kW including the equipment and installation costs.
  Wind Farm Build Cost: Capital cost of wind farm per kW including the equipment and installation costs.



- Power Purchase Agreement (PPA) selected:
  PPA Cost: Cost of PPA per MWh including electricity consumption and transmission/grid usage charges.



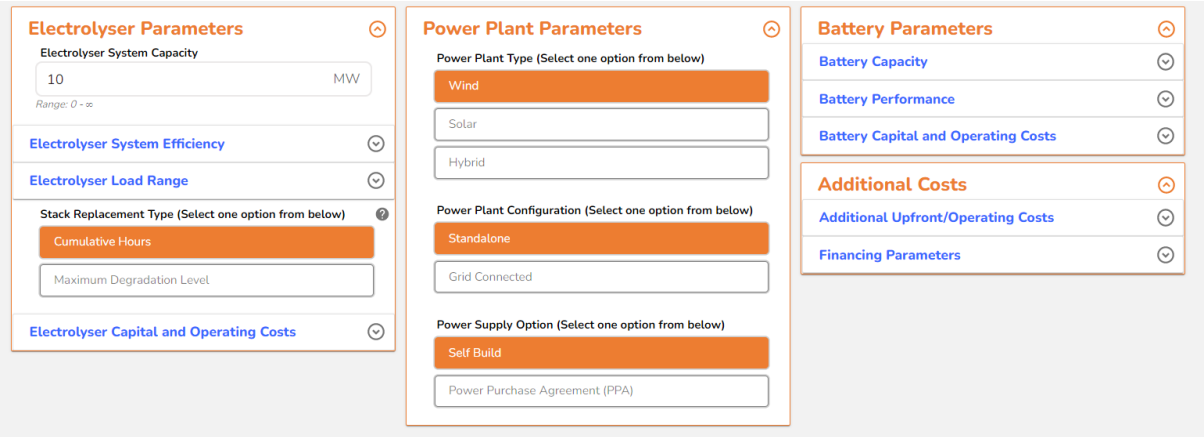
Water Supply Cost: Wholesale cost of water supply per kL.

Discount rate: Required rate of return based on similar investments.

Project timeline: Length of time that project is operational in years.

2.1.2. Advanced Inputs

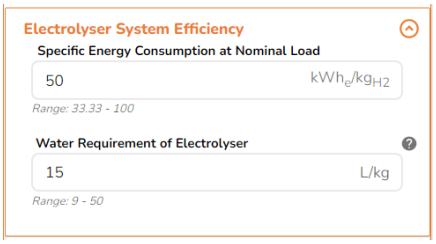
The advanced version of the inputs page allows for more detailed specification of operational and economic parameters.



Electrolyser parameters:

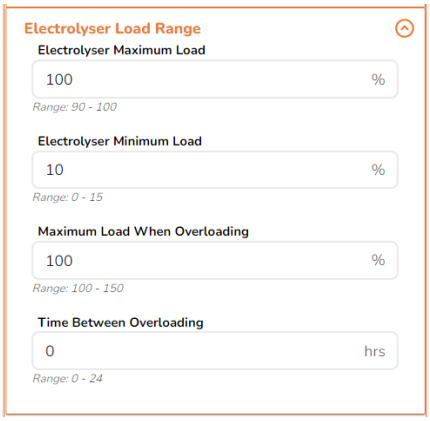
Electrolyser System Capacity: Specify the electrolyser system rated capacity in MW.

Electrolyser System Efficiency:



- **Specific Energy Consumption at Nominal Load:** Specify the specific energy consumption of the electrolyser unit kWh of electricity per kg of hydrogen product.
- **Water Requirement of Electrolyser:** Water consumed per kg of hydrogen produced - independent of load.

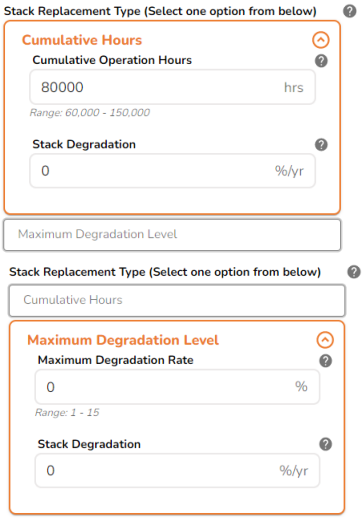
Electrolyser Load Range:



- **Electrolyser Maximum Load:** Maximum normal operating electrolyser loading as a percentage of the rated electrolyser capacity.
- **Electrolyser Minimum Load:** Minimum normal operating electrolyser loading as a percentage of the rated electrolyser capacity.
- **Maximum Load When Overloading:** Maximum operating electrolyser loading as a percentage of the rated electrolyser capacity during overloading. Overloading is a temporary boost in production rate past the rated capacity.
- **Time between overloading:** Minimum required cooldown time between overloading events.

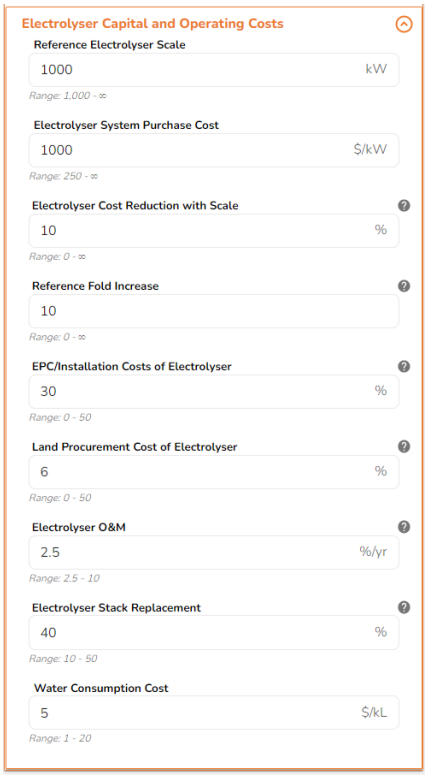
Stack Replacement Type: Select between electrolyser stack replacement methods. Select “Cumulative Hours” to replace the stack when it exceeds a threshold lifetime operational hours. Select “Maximum Degradation Level” to replace the stack once it degrades past a threshold percentage of the original production rate.

- Cumulative Hours Selected:
  Cumulative Operating Hours: Cumulative hours of operation before stack replacement is due.
  Stack Degradation: Decrease in stack productivity per year as a percentage of the original production rate.



- Maximum Degradation Level selected:
  Maximum degradation rate: Maximum allowable cumulative degradation as a percentage of original production rate before the stack must be replaced.
  Stack Degradation: Decrease in stack productivity per year as a percentage of the original production rate.

Electrolyser Capital and Operating Costs:



- **Reference Electrolyser Scale:** Scale in kW of reference electrolyser system for economies of scale.
- **Electrolyser System Purchase Cost:** Cost of reference electrolyser system per kW of capacity.
- **Electrolyser Cost Reduction with Scale:** Cost reduction due to economies of scale per specified fold increase.
- **Reference Fold Increase:** Cost reduction occurs for every specified fold increase in capacity vs. reference scale.
- **EPC/Installation Costs of Electrolyser:** Costs for engineering, procurement and installation of the electrolyser as a percentage of electrolyser CAPEX.
- **Land Procurement Cost of Electrolyser:** Land Procurement Cost of Electrolyser as a percentage of electrolyser CAPEX.
- **Electrolyser O&M:** Annual electrolyser operating and maintenance costs as a percentage of CAPEX, excluding energy consumption.
- **Electrolyser Stack Replacement:** Cost of electrolyser stack replacement as a percentage of electrolyser CAPEX.
- **Water Consumption Cost:** Wholesale cost of water supply per kL.

Power plant Parameters:

Power Plant Type: Select between Wind only, solar only or hybrid wind and solar power generation.

- **Power Plant Capacity:** Select Power Plant capacity in MW or as a ratio of electrolyser capacity.
    - **Nominal Capacity:** Specify the wind farm and/or solar farm capacity in MW.
    - **Oversize Ratio:** Specify the ratio of powerplant capacity relative to the electrolyser capacity in MW/MW, e.g., choosing 3 results in the powerplant full load capacity (MW) being 3 times that of the electrolyser full load capacity (MW). This is an important configurational choice, which affects the achieved electrolyser capacity factor and thus the achieved hydrogen production rate. Note: Higher powerplant oversizing will lower the required electrolyser capacity to meet the same hydrogen production rate.
- **Wind Degradation rate:** Decrease in wind farm productivity per year as a percentage of the original power generation capacity.
- **Solar Degradation rate:** Decrease in solar farm productivity per year as a percentage of the original power generation capacity.

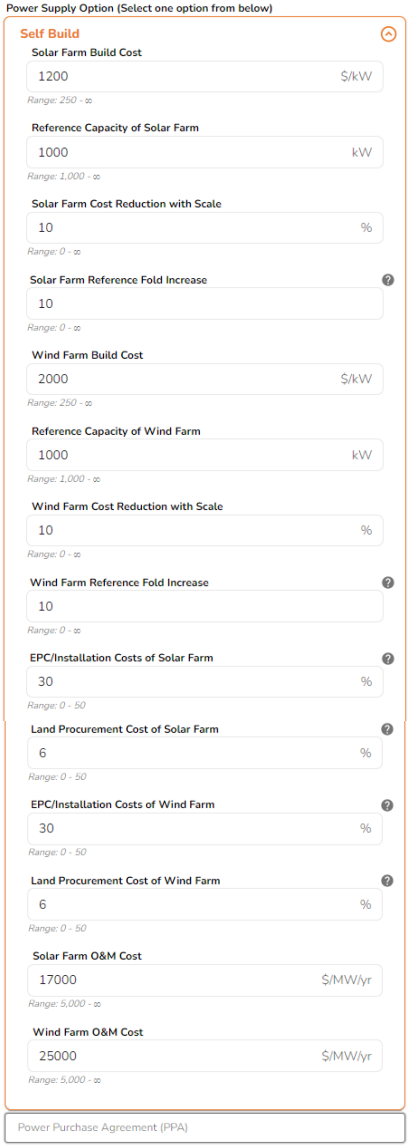
Power Plant Configuration: Select between standalone power plant configuration without a grid connection, or a grid/network connected configuration.

- **Grid Connected selected:**
  Grid Connection Costs: Capital cost for transmission connection.
  Grid Usage Charges: Any additional charges for using grid services, e.g. Transmission Use of System (TUOS) Charges.

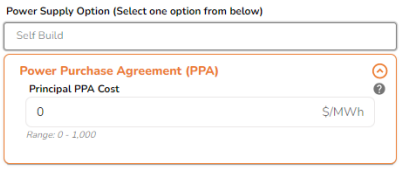
Power Supply Option: Select ‘Self Build’ for cases in which a new power plant is built in conjunction with electrolyser. Select PPA if there is a grid connection to a power supplier.

Self-Build Selected:

- **Solar/Wind Farm Build Cost:** Cost of reference solar/wind farm per kW of capacity.
- **Reference Solar/Wind Farm Capacity:** Scale in kW of reference electrolyser system for economies of scale.
- **Solar Farm Cost Reduction with Scale:** Cost reduction due to economies of scale per specified fold increase.
- **Reference Fold Increase:** Cost reduction occurs for every specified fold increase in capacity vs. reference scale.
- **EPC/Installation Costs of Solar/Wind Farm:** Costs for engineering, procurement and installation of the solar/wind farm as a percentage of solar/wind farm CAPEX.
- **Land Procurement Cost of Solar/Wind Farm:** Land Procurement Cost of solar/wind farm as a percentage of solar/wind farm CAPEX.
- **Solar/Wind Farm O&M Costs:** Annual Solar/Wind farm operating and maintenance costs per MW of installed capacity.



Power Purchase Agreement PPA: Fixed price for electricity bought from the grid per MWh.



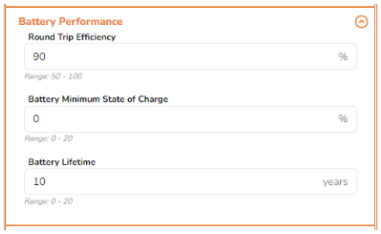
Battery Parameters

Battery Capacity:

- **Battery Rated Power:** Rated power capacity of the battery. Sets a limit on how much the battery can charge/ discharge instantaneously.
- **Battery Storage Duration:** Battery storage capacity in terms of hours at rated power discharge.

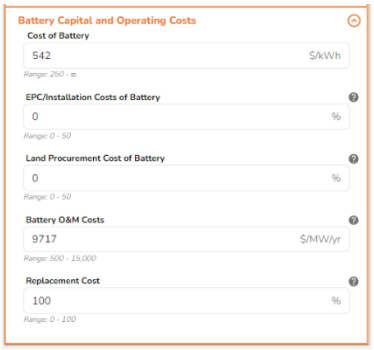
Battery Performance:

- **Round Trip Efficiency:** Overall Energy efficiency of battery charge discharge cycle.
- **Battery Minimum State of Charge:** Minimum battery charge level.
- **Battery Lifetime:** Time until battery is due for replacement.



Battery Capital and operating Costs:

- **Cost of Battery:** Battery capital cost per kWh of storage capacity.
- **EPC/Installation Costs of Battery:** Costs for engineering, procurement and installation of the battery as a percentage of battery CAPEX.
- **Land Procurement Cost of Battery:** Land procurement cost of battery as a percentage of battery CAPEX.
- **Battery O&M Costs:** Annual battery operating and maintenance costs per MW of installed capacity.
- **Replacement Cost:** Percentage of CAPEX. Cost of battery replacement is incurred as additional operating cost in each year the battery lifetime is reached.



<u>Additional Costs:</u>

Additional upfront/Operating Costs:

- **Additional Upfront Costs:** Any other additional costs to include as a once off in the Levelized cost of hydrogen LC_{H2} calculation.
- **Additional Annual Costs:** Any other additional costs to include as an annual cost in the LC_{H2} calculation.

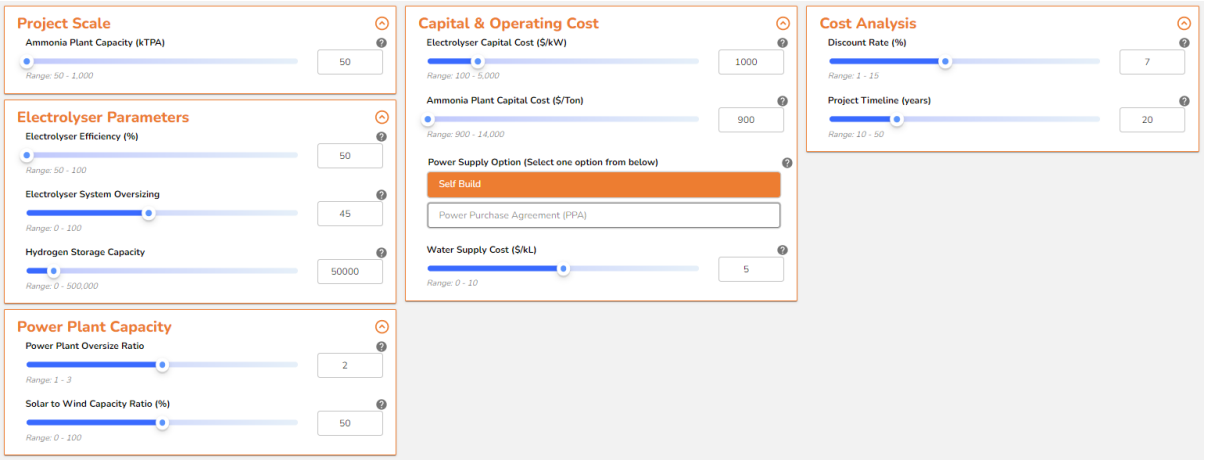
Financing Parameters:

- **Project Timeline:** Length of time that project is operational. Same for both power plant and electrolyser.
- **Discount rate:** Discount rate for NPV analysis and LC_{H2}. Required rate of return based on similar investments.

2.2. Ammonia

2.2.1. Basic Inputs

The basic model input page has been designed using simple inputs and sliders to build and evaluate a project easily and quickly.



Ammonia Plant Capacity: Specify the Ammonia production rate in thousand tons/yr (kTPA). Ammonia plant, renewable energy and electrolyser units will be scaled automatically to match this nameplate production rate.

Electrolyser Efficiency: A slider to specify electrolyser energy efficiency relative to the theoretical maximum of 39.4 kWh/kg of H_2 produced.

Electrolyser System Oversizing: Oversize the electrolyser to optimize hydrogen supply stability to match with storage and downstream demand profile.

Hydrogen Storage Capacity: Add hydrogen storage to improve ammonia production flexibility and reduce the strain of frequent ammonia plant start up and shutdown.

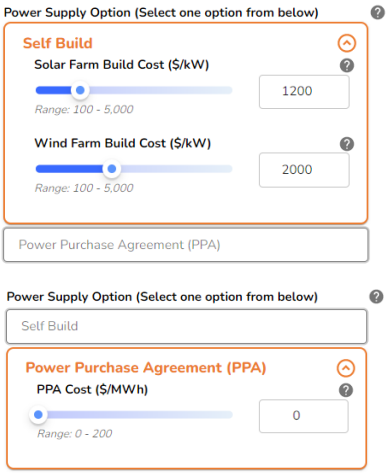
Power Plant Oversize Ratio: A slider to adjust the ratio of powerplant capacity oversizing relative to the electrolyser capacity in MW, e.g., choosing 3 results in the powerplant full load capacity (MW) being 3 times that of the electrolyser full load capacity (MW). This is an important configurational choice, which affects the achieved electrolyser capacity factor and thus the electrolyser and powerplant sizing required to meet the specified hydrogen production rate. Note: Higher powerplant oversizing will lower the required electrolyser capacity to meet the same hydrogen production rate.

Solar to Wind Ratio: Split of solar and wind farm share in the power capacity from solar only at 100% to wind only at 0%.

Electrolyser Capital Cost: Capital cost of electrolyser per kW including the equipment and installation costs.

Ammonia Plant Capital Cost: Capital cost of Ammonia plant per ton of nameplate production capacity. Includes Ammonia Synthesis Unit, Air Separation Unit and Ammonia Storage Unit Costs.

Power Supply option: Select 'Self Build' for cases in which a new power plant is built in conjunction with electrolyser. Select PPA if there is a grid connection to a power supplier.



- **Self Build selected:**
  Solar Farm Build Cost: Capital cost of solar farm per kW including the equipment and installation costs.
  Wind Farm Build Cost: Capital cost of wind farm per kW including the equipment and installation costs.
- **Power Purchase Agreement (PPA) selected:**
  PPA Cost: Cost of PPA per MWh including electricity consumption and transmission/grid usage charges.

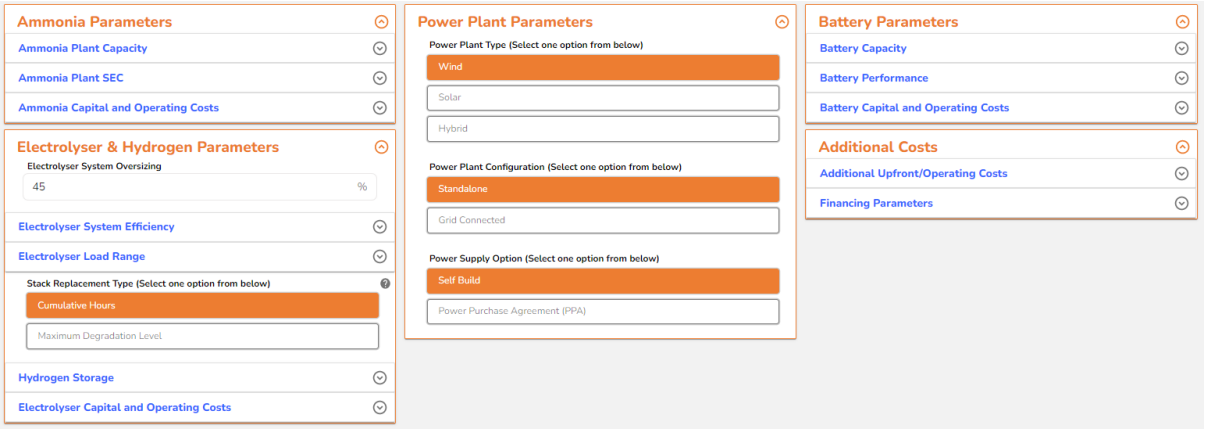
Water Supply Cost: Wholesale cost of water supply per kL.

Discount rate: Required rate of return based on similar investments.

Project timeline: Length of time that project is operational in years.

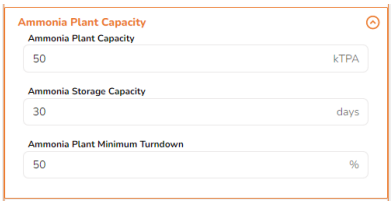
2.2.2. Advanced Inputs

The advanced version of the inputs page allows for more detailed specification of operational and economic parameters.



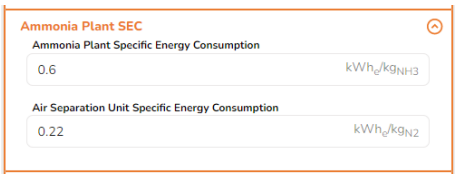
<u>Ammonia Parameters:</u>

Ammonia Plant Capacity:



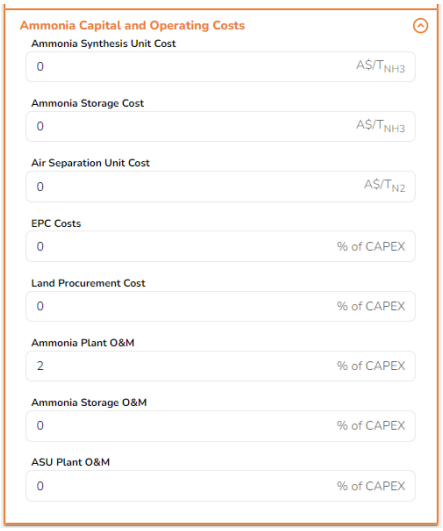
- **Ammonia Plant Capacity:** Specify the Ammonia production rate in thousand tons/yr (kTPA).
- **Ammonia Storage Capacity:** Onsite ammonia storage capacity in number of days' worth of production volume.
- **Ammonia Plant Minimum Turndown:** The degree to which the ammonia plant loading can be reduced as a percentage of nameplate plant capacity, e.g., 50% turndown means that the ammonia plant can operate within the range of 50% to 100% of the specified plant capacity.

Ammonia Plant SEC:



- **Ammonia Plant Specific Energy Consumption:** Specify the specific energy consumption of the ammonia plant kWh of electricity per kg of ammonia product.
- **Air Separation Unit Specific Energy Consumption:** Specify the specific energy consumption of the ammonia plant kWh of electricity per kg of nitrogen produced.

Ammonia Plant Capital and Operating Costs:

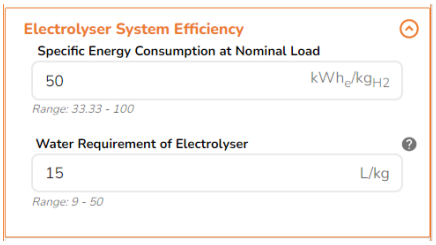


- **Ammonia Synthesis Unit Cost:** Specify the ammonia synthesis unit capital cost per ton of ammonia plant capacity.
- **Ammonia Storage Cost:** Specify cost of onsite ammonia storage per ton of storage capacity.
- **Air Separation Unit Cost:** Specify the ASU capital cost per ton of nitrogen plant capacity.
- **EPC Costs:** Engineering and procurement costs as a percentage of Ammonia CAPEX.
- **Land Procurement Cost:** Land procurement cost of battery as a percentage of Ammonia CAPEX.
- **Ammonia Plant O&M:** Annual Ammonia operating and maintenance costs as a percentage of ammonia plant CAPEX.
- **Ammonia Storage O&M:** Annual Ammonia operating and maintenance costs as a percentage of ammonia storage CAPEX.
- **ASU Plant O&M:** Annual Ammonia operating and maintenance costs as a percentage of ASU CAPEX.

<u>Electrolyser parameters:</u>

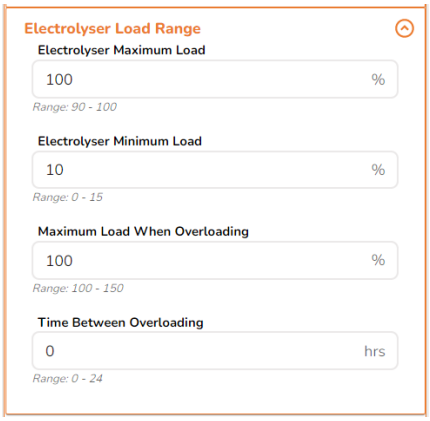
Electrolysis System Oversizing: Oversize the electrolyser to optimize hydrogen supply stability to match with storage and downstream demand profile.

Electrolyser System Efficiency:



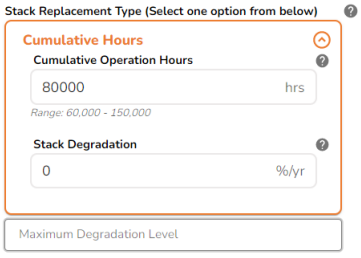
- **Specific Energy Consumption at Nominal Load:** Specify the specific energy consumption of the electrolyser unit kWh of electricity per kg of hydrogen product.
- **Water Requirement of Electrolyser:** Water consumed per kg of hydrogen produced - independent of load.

Electrolyser Load Range:

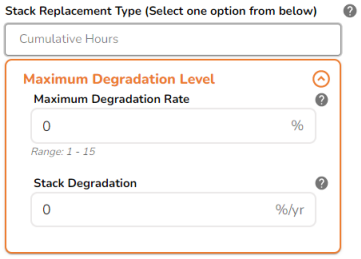


- **Electrolyser Maximum Load:** Maximum normal operating electrolyser loading as a percentage of the rated electrolyser capacity.
- **Electrolyser Minimum Load:** Minimum normal operating electrolyser loading as a percentage of the rated electrolyser capacity.
- **Maximum Load When Overloading:** Maximum operating electrolyser loading as a percentage of the rated electrolyser capacity during overloading. Overloading is a temporary boost in production rate past the rated capacity.
- **Time between overloading:** Minimum required cooldown time between overloading events.

Stack Replacement Type: Select between electrolyser stack replacement methods. Select "Cumulative Hours" to replace the stack when it exceeds a threshold lifetime operational hours. Select "Maximum Degradation Level" to replace the stack once it degrades past a threshold percentage of the original production rate.



- Cumulative Hours Selected:
  Cumulative Operating Hours: Cumulative hours of operation before stack replacement is due.
  Stack Degradation: Decrease in stack productivity per year as a percentage of the original production rate.

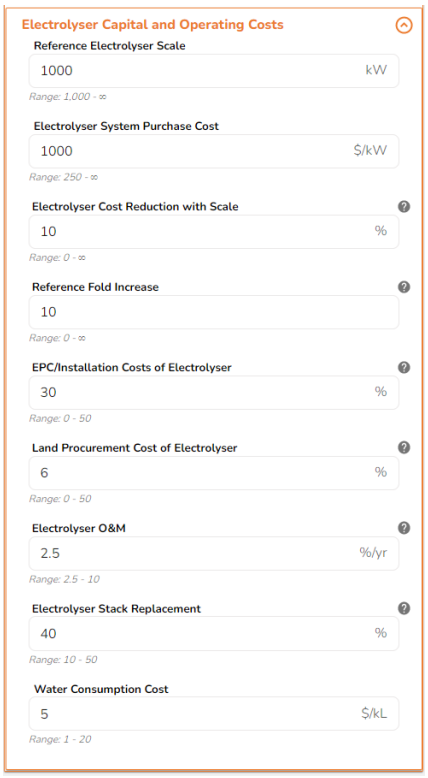


- Maximum Degradation Level selected:
  Maximum degradation rate: Maximum allowable cumulative degradation as a percentage of original production rate before the stack must be replaced.
  Stack Degradation: Decrease in stack productivity per year as a percentage of the original production rate.

Hydrogen Storage:

- **Hydrogen Storage Capacity:** Add hydrogen storage to improve ammonia production flexibility and reduce the strain of frequent ammonia plant start up and shutdown.
- **Minimum Hydrogen Storage:** Minimum hydrogen storage capacity as a percentage of total storage capacity. This determines the usable volume of the specified hydrogen storage capacity.

Electrolyser Capital and Operating Costs:



- **Reference Electrolyser Scale:** Scale in kW of reference electrolyser system for economies of scale.
- **Electrolyser System Purchase Cost:** Cost of reference electrolyser system per kW of capacity.
- **Electrolyser Cost Reduction with Scale:** Cost reduction due to economies of scale per specified fold increase.
- **Reference Fold Increase:** Cost reduction occurs for every specified fold increase in capacity vs. reference scale.
- **EPC/Installation Costs of Electrolyser:** Costs for engineering, procurement and installation of the electrolyser as a percentage of electrolyser CAPEX.
- **Land Procurement Cost of Electrolyser:** Land Procurement Cost of Electrolyser as a percentage of electrolyser CAPEX.
- **Electrolyser O&M:** Annual electrolyser operating and maintenance costs as a percentage of CAPEX, excluding energy consumption.
- **Electrolyser Stack Replacement:** Cost of electrolyser stack replacement as a percentage of electrolyser CAPEX.
- **Water Consumption Cost:** Wholesale cost of water supply per kL.

<u>Power plant Parameters:</u>

Power Plant Type: Select between Wind only, solar only or hybrid wind and solar power generation.

- **Power Plant Capacity:** Select power plant capacity as a ratio of electrolyser capacity.
    - **Oversize Ratio:** Specify the ratio of powerplant capacity relative to the electrolyser capacity in MW/MW, e.g., choosing 3 results in the powerplant full load capacity (MW) being 3 times that of the electrolyser full load capacity (MW). This is an important configurational choice, which affects the achieved electrolyser capacity factor and thus the achieved hydrogen production rate. Note: Higher powerplant oversizing will lower the required electrolyser capacity to meet the same hydrogen production rate.
- **Wind Degradation rate:** Decrease in wind farm productivity per year as a percentage of the original power generation capacity.
- **Solar Degradation rate:** Decrease in solar farm productivity per year as a percentage of the original power generation capacity.

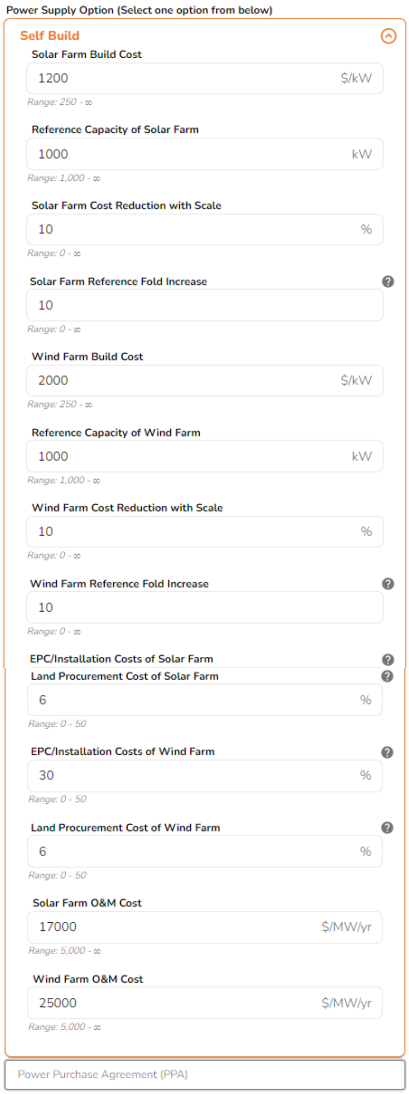
Power Plant Configuration: Select between standalone power plant configuration without a grid connection, or a grid connected configuration. Grid connected configurations make use of private or shared transmission networks to transmit power from an offsite renewable energy farm to the site of the project. With no offtake from fossil fuel power generation.

- Grid Connected selected:
  Grid Connection Costs: Capital cost for transmission connection.
  Grid Usage Charges: Any additional charges for using grid services, e.g. Transmission Use of System (TUOS) Charges.

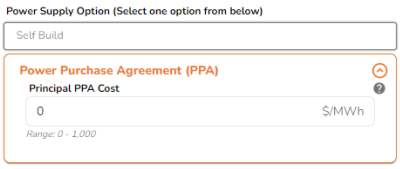
Power Supply Option: Select ‘Self Build’ for cases in which a new power plant is built in conjunction with electrolyser. Select PPA if there is a grid connection to a power supplier.

Self-Build Selected:

- **Solar/Wind Farm Build Cost:** Cost of reference solar/wind farm per kW of capacity.
- **Reference Solar/Wind Farm Capacity:** Scale in kW of reference electrolyser system for economies of scale.
- **Solar Farm Cost Reduction with Scale:** Cost reduction due to economies of scale per specified fold increase.
- **Reference Fold Increase:** Cost reduction occurs for every specified fold increase in capacity vs. reference scale.
- **EPC/Installation Costs of Solar/Wind Farm:** Costs for engineering, procurement and installation of the solar/wind farm as a percentage of solar/wind farm CAPEX.
- **Land Procurement Cost of Solar/Wind Farm:** Land Procurement Cost of solar/wind farm as a percentage of solar/wind farm CAPEX.
- **Solar/Wind Farm O&M Costs:** Annual Solar/Wind farm operating and maintenance costs per MW of installed capacity.



Power Purchase Agreement PPA: Fixed price for electricity bought from the grid per MWh.

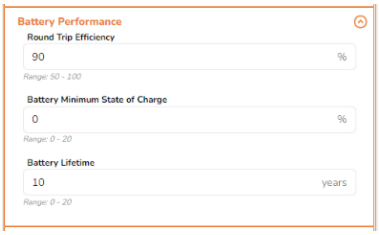


Battery Parameters

Battery Capacity:

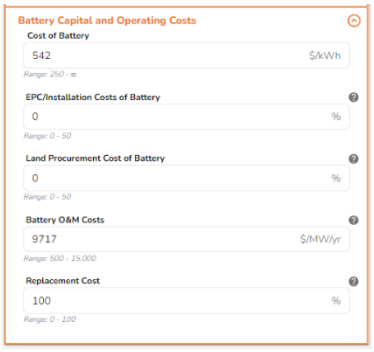
- **Battery Rated Power:** Rated power capacity of the battery. Sets a limit on how much the battery can charge/ discharge instantaneously.
- **Battery Storage Duration:** Battery storage capacity in terms of hours at rated power discharge.

Battery Performance:



- **Round Trip Efficiency:** Overall Energy efficiency of battery charge discharge cycle.
- **Battery Minimum State of Charge:** Minimum battery charge level.
- **Battery Lifetime:** Time until battery is due for replacement.

Battery Capital and operating Costs:



- **Cost of Battery:** Battery capital cost per kWh of storage capacity.
- **EPC/Installation Costs of Battery:** Costs for engineering, procurement and installation of the battery as a percentage of solar/wind farm CAPEX.
- **Land Procurement Cost of Battery:** Land procurement cost of battery as a percentage of solar/wind farm CAPEX.
- **Battery O&M Costs:** Annual battery operating and maintenance costs per MW of installed capacity.
- **Replacement Cost:** Percentage of CAPEX. Cost of battery replacement is incurred as additional operating cost in each year the battery lifetime is reached.

Additional Costs:

Additional upfront/Operating Costs:

- **Additional Upfront Costs:** Any other additional costs to include as a once off in the Levelized cost of hydrogen LC_{H2} calculation.
- **Additional Annual Costs:** Any other additional costs to include as an annual cost in the LC_{H2} calculation.

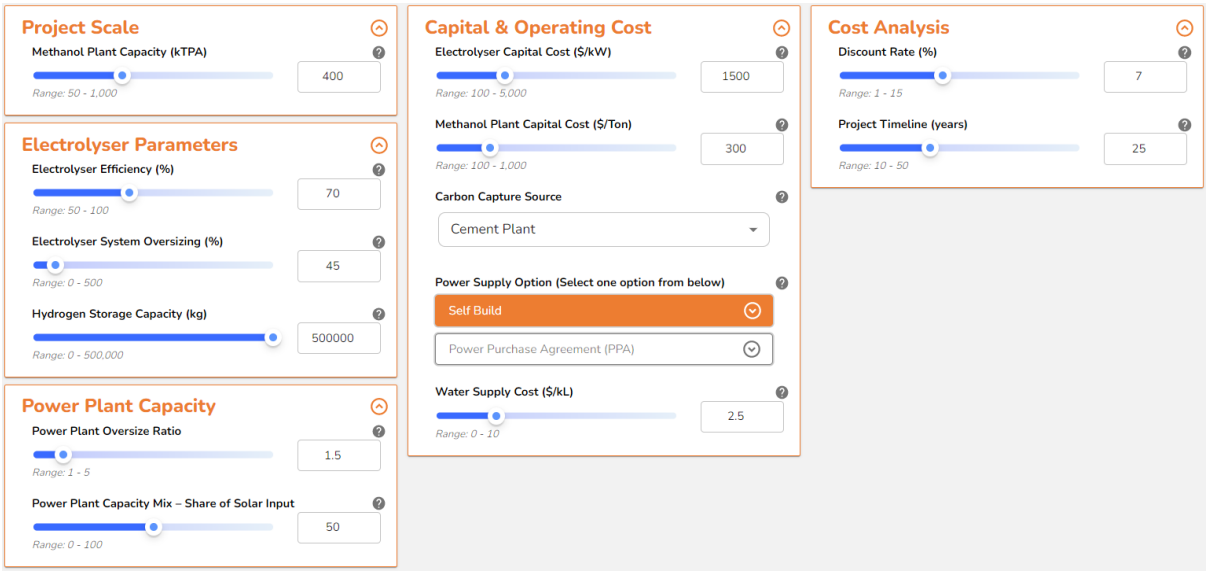
Financing Parameters:

- **Project Timeline:** Length of time that project is operational. Same for both power plant and electrolyser.
- **Discount rate:** Discount rate for NPV analysis and LC_{H2}. Required rate of return based on similar investments.

2.3. Methanol

2.3.1. Basic Inputs

The basic model input page has been designed using simple inputs and sliders to build and evaluate a project easily and quickly.



Methanol Plant Capacity: Specify the Methanol production rate in thousand tons/yr (kTPA). Methanol plant, Carbon capture plant, renewable energy, electrolyser and battery units will be scaled automatically to match this nameplate production rate.

Electrolyser Efficiency: A slider to specify electrolyser energy efficiency relative to the theoretical maximum of 39.4 kWh/kg of H_2 produced.

Electrolyser System Oversizing: Oversize the electrolyser to optimize hydrogen supply stability to match with storage and downstream demand profile.

Hydrogen Storage Capacity: Add hydrogen storage to improve Methanol production flexibility and reduce the strain of frequent Methanol plant start up and shutdown.

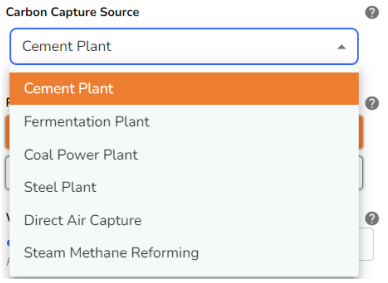
Power Plant Oversize Ratio: A slider to adjust the ratio of powerplant capacity oversizing relative to the electrolyser capacity in MW, e.g., choosing 3 results in the powerplant full load capacity (MW) being 3 times that of the electrolyser full load capacity (MW). This is an important configurational choice, which affects the achieved electrolyser capacity factor and thus the electrolyser and powerplant sizing required to meet the specified hydrogen production rate. Note: Higher powerplant oversizing will lower the required electrolyser capacity to meet the same hydrogen production rate.

Solar to Wind Ratio: Split of solar and wind farm share in the power capacity from solar only at 100% to wind only at 0%.

Electrolyser Capital Cost: Capital cost of electrolyser per kW including the equipment and installation costs.

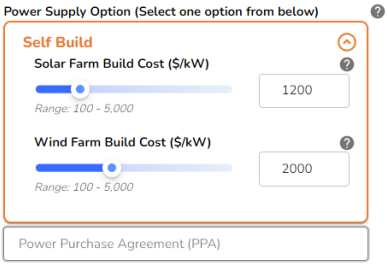
Methanol Plant Capital Cost: Capital cost of Methanol plant per ton of nameplate production capacity. Includes Methanol Synthesis process, Methanol Storage Unit Costs.

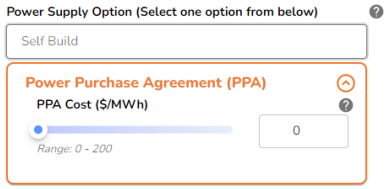
Carbon Capture Source: Select from a list of pre-set carbon capture sources including DAC – Direct Air capture, and flue gas from industrial sources including cement, steel, CO_2 by-product of fermentation, Coal fired power generation, and SMR – Steam methane reforming. Corresponding default specific energy consumption and capital cost, values will be assigned based on selection.



Power Supply option: Select 'Self Build' for cases in which a new power plant is built in conjunction with electrolyser. Select PPA if there is a grid connection to a power supplier.

- **Self Build selected:**
  Solar Farm Build Cost: Capital cost of solar farm per kW including the equipment and installation costs.
  Wind Farm Build Cost: Capital cost of wind farm per kW including the equipment and installation costs.
- **Power Purchase Agreement (PPA) selected:**
  PPA Cost: Cost of PPA per MWh including electricity consumption and transmission/grid usage charges.





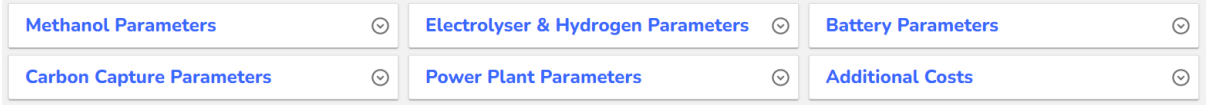
Water Supply Cost: Wholesale cost of water supply per kL.

Discount rate: Required rate of return based on similar investments.

Project timeline: Length of time that project is operational in years.

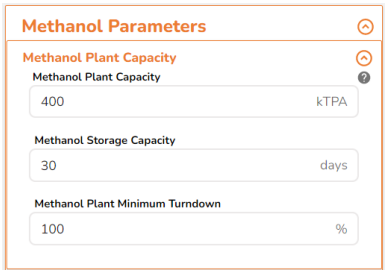
2.3.2. Advanced Inputs

The advanced version of the inputs page allows for more detailed specification of operational and economic parameters.



Methanol Parameters:

Methanol Plant Capacity:

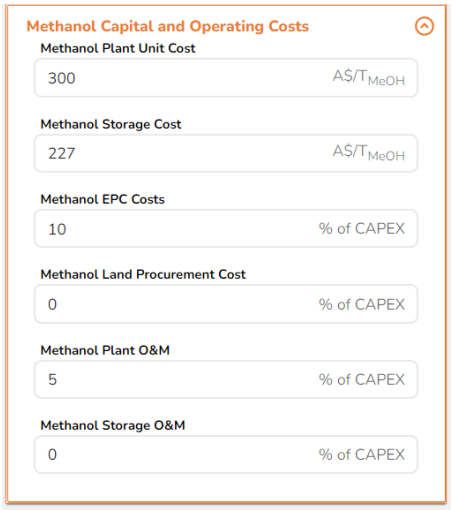


- **Methanol Plant Capacity:** Specify the Methanol production rate in thousand tons/yr (kTPA).
- **Methanol Storage Capacity:** Onsite Methanol storage capacity in number of days' worth of production volume.
- **Methanol Plant Minimum Turndown:** The degree to which the Methanol plant loading can be reduced as a percentage of nameplate plant capacity, e.g., 50% turndown means that the Methanol plant can operate within the range of 50% to 100% of the specified plant capacity.

Methanol Plant SEC:

- **Methanol Plant Specific Energy Consumption:** Specify the specific energy consumption of the Methanol plant kWh of electricity per kg of Methanol product.

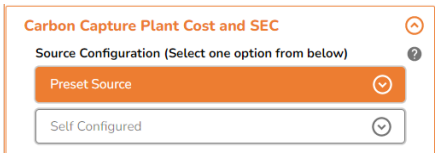
Methanol Plant Capital and Operating Costs:

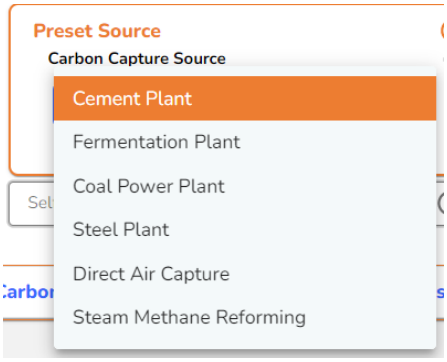


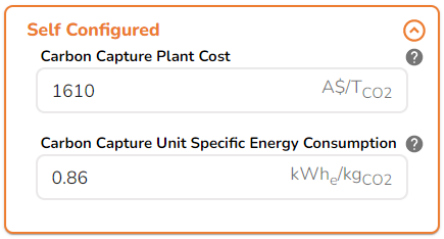
- **Methanol Synthesis Plant Cost:** Specify the Methanol synthesis unit capital cost per ton of Methanol plant capacity.
- **Methanol Storage Cost:** Specify cost of onsite Methanol storage per ton of storage capacity.
- **EPC Costs:** Engineering and procurement costs as a percentage of Methanol CAPEX.
- **Land Procurement Cost:** Land procurement cost of battery as a percentage of Methanol CAPEX.
- **Methanol Plant O&M:** Annual Methanol operating and maintenance costs as a percentage of Methanol plant CAPEX. Excluding energy costs which are accounted for by costing of the renewable energy plant.
- **Methanol Storage O&M:** Annual Methanol operating and maintenance costs as a percentage of Methanol storage CAPEX. Excluding energy costs which are accounted for by costing of the renewable energy plant.

<u>Carbon Capture Parameters:</u>

Carbon Capture Plant Cost and SEC:

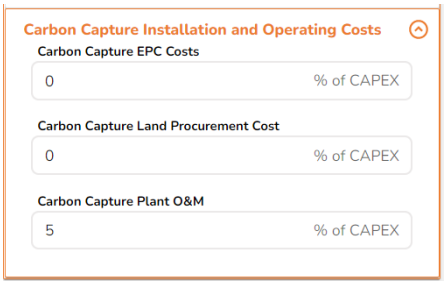






- **Pre-Set vs Self-Configured:** Select between pre-set options or providing custom carbon capture costing and energy consumption values.
- **Pre-Set Carbon Capture Source:** Select from a list of pre-set carbon capture sources including DAC – Direct Air capture, and flue gas from industrial sources including cement, steel, CO_2 by-product of fermentation, Coal fired power generation, and SMR – Steam methane reforming. Corresponding default specific energy consumption and capital cost, values will be assigned based on selection.
- **Self-Configured Carbon Capture Plant Cost:** Specify capital cost of carbon capture plant per ton of annual carbon capture capacity.
- **Self-Configured Carbon Capture SEC:** Specify the specific energy consumption of the carbon capture plant in kWh of electricity per kg of CO_2 captured.

Carbon Capture Installation and Operating Costs:

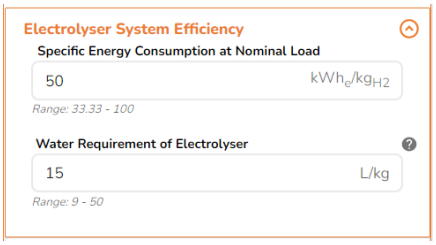


- **Carbon Capture EPC Costs:** Engineering and procurement costs as a percentage of Carbon Capture CAPEX.
- **Land Procurement Cost:** Land procurement cost of battery as a percentage of Carbon Capture CAPEX.
- **Carbon Capture Plant O&M:** Annual Carbon Capture Plant operating and maintenance costs as a percentage of Carbon Capture plant CAPEX. Excluding energy costs which are accounted for by costing of the renewable energy plant.

<u>Electrolyser parameters:</u>

Electrolysis System Oversizing: Oversize the electrolyser to optimize hydrogen supply stability to match with storage and downstream demand profile.

Electrolyser System Efficiency:



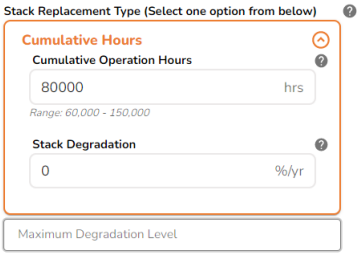
- **Specific Energy Consumption at Nominal Load:** Specify the specific energy consumption of the electrolyser unit kWh of electricity per kg of hydrogen product.
- **Water Requirement of Electrolyser:** Water consumed per kg of hydrogen produced - independent of load.

Electrolyser Load Range:

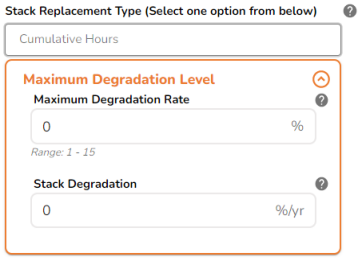
- **Electrolyser Maximum Load:** Maximum normal operating electrolyser loading as a percentage of the rated electrolyser capacity.
- **Electrolyser Minimum Load:** Minimum normal operating electrolyser loading as a percentage of the rated electrolyser capacity.

Stack Replacement Type: Select between electrolyser stack replacement methods. Select "Cumulative Hours" to replace the stack when it exceeds a threshold lifetime operational hours. Select "Maximum Degradation Level" to replace the stack once it degrades past a threshold percentage of the original production rate.

- Cumulative Hours Selected:
  Cumulative Operating Hours: Cumulative hours of operation before stack replacement is due.
  Stack Degradation: Decrease in stack productivity per year as a percentage of the original production rate.



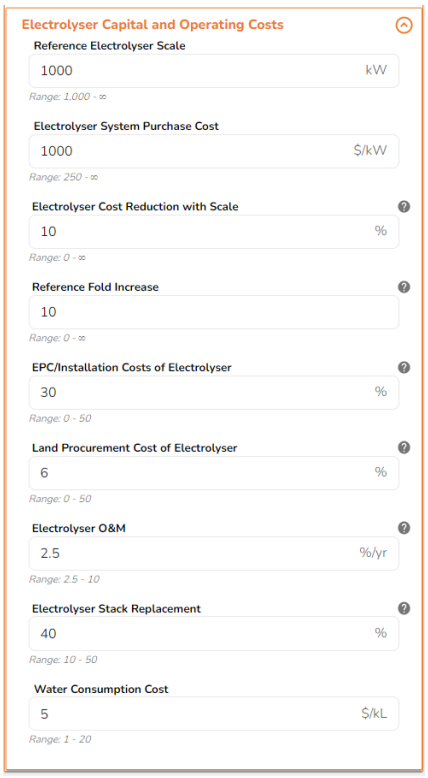
- Maximum Degradation Level selected:
  Maximum degradation rate: Maximum allowable cumulative degradation as a percentage of original production rate before the stack must be replaced.
  Stack Degradation: Decrease in stack productivity per year as a percentage of the original production rate.



Hydrogen Storage:

- **Hydrogen Storage Capacity:** Add hydrogen storage to improve methanol production flexibility and reduce the strain of frequent Methanol plant start up and shutdown.
- **Minimum Hydrogen Storage:** Minimum hydrogen storage capacity as a percentage of total storage capacity. This determines the usable volume of the specified hydrogen storage capacity.

Electrolyser Capital and Operating Costs:



- **Reference Electrolyser Scale:** Scale in kW of reference electrolyser system for economies of scale.
- **Electrolyser System Purchase Cost:** Cost of reference electrolyser system per kW of capacity.
- **Electrolyser Cost Reduction with Scale:** Cost reduction due to economies of scale per specified fold increase.
- **Reference Fold Increase:** Cost reduction occurs for every specified fold increase in capacity vs. reference scale.
- **EPC/Installation Costs of Electrolyser:** Costs for engineering, procurement and installation of the electrolyser as a percentage of electrolyser CAPEX.
- **Land Procurement Cost of Electrolyser:** Land Procurement Cost of Electrolyser as a percentage of electrolyser CAPEX.
- **Electrolyser O&M:** Annual electrolyser operating and maintenance costs as a percentage of CAPEX, excluding energy consumption.
- **Electrolyser Stack Replacement:** Cost of electrolyser stack replacement as a percentage of electrolyser CAPEX.
- **Water Consumption Cost:** Wholesale cost of water supply per kL.

<u>Power plant Parameters:</u>

Power Plant Type: Select between Wind only, solar only or hybrid wind and solar power generation.

- **Power Plant Capacity:** Select power plant capacity as a ratio of electrolyser capacity.
  - **Oversize Ratio:** Specify the ratio of powerplant capacity relative to the electrolyser capacity in MW/MW, e.g., choosing 3 results in the powerplant full load capacity (MW) being 3 times that of the electrolyser full load capacity (MW). This is an important configurational choice, which affects the achieved electrolyser capacity factor and thus the achieved hydrogen production rate. Note: Higher powerplant oversizing will lower the required electrolyser capacity to meet the same hydrogen production rate.
- **Wind Degradation rate:** Decrease in wind farm productivity per year as a percentage of the original power generation capacity.
- **Solar Degradation rate:** Decrease in solar farm productivity per year as a percentage of the original power generation capacity.
- **Power Plant Capacity Mix – Share of Solar Input**: Hybrid type only. Select the percentage of Solar in the total power plant installed capacity. Wind will make up the balance of the total installed capacity. E.g., Input 100% for solar only and 0% for wind only.

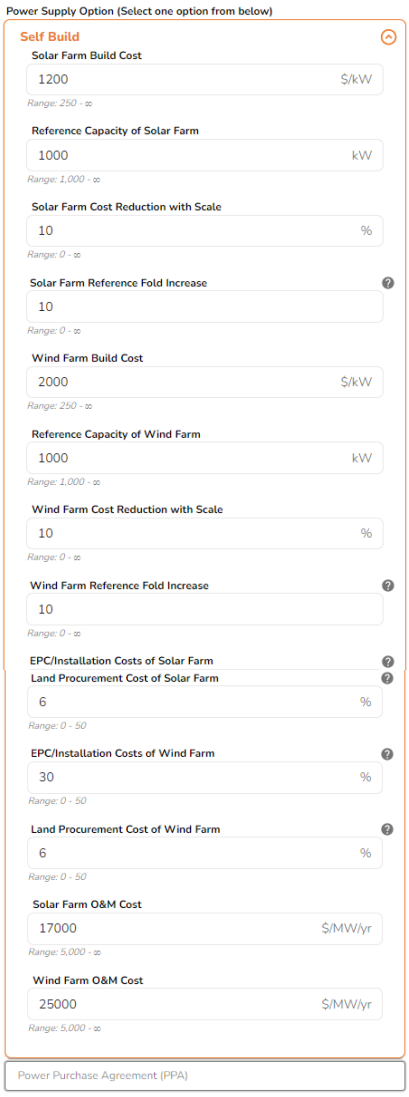
Power Plant Configuration: Select between standalone power plant configuration without a grid connection, or a grid connected configuration. Grid connected configurations make use of private or shared transmission networks to transmit power from an offsite renewable energy farm to the site of the project. With no offtake from fossil fuel power generation.

- Grid Connected selected:
  Grid Connection Costs: Capital cost for transmission connection.
  Grid Usage Charges: Any additional charges for using grid services, e.g. Transmission Use of System (TUOS) Charges.

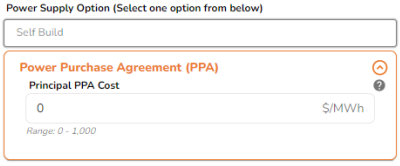
Power Supply Option: Select 'Self Build' for cases in which a new power plant is built in conjunction with electrolyser. Select PPA if there is a grid connection to a power supplier.

Self-Build Selected:

- **Solar/Wind Farm Build Cost:** Cost of reference solar/wind farm per kW of capacity.
- **Reference Solar/Wind Farm Capacity:** Scale in kW of reference electrolyser system for economies of scale.
- **Solar Farm Cost Reduction with Scale:** Cost reduction due to economies of scale per specified fold increase.
- **Reference Fold Increase:** Cost reduction occurs for every specified fold increase in capacity vs. reference scale.
- **EPC/Installation Costs of Solar/Wind Farm:** Costs for engineering, procurement and installation of the solar/wind farm as a percentage of solar/wind farm CAPEX.
- **Land Procurement Cost of Solar/Wind Farm:** Land Procurement Cost of solar/wind farm as a percentage of solar/wind farm CAPEX.
- **Solar/Wind Farm O&M Costs:** Annual Solar/Wind farm operating and maintenance costs per MW of installed capacity.



Power Purchase Agreement PPA: Fixed price for electricity bought from the grid per MWh.

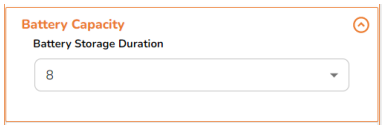


Battery Parameters

Battery Capacity:

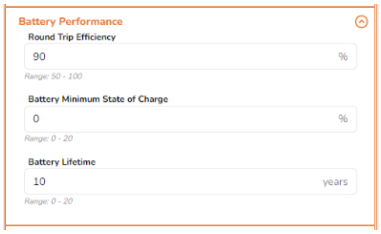
Battery storage was deemed to be an integral part of the Power to methanol pathway to provide backup utilities to the methanol and carbon capture facilities during periods of low power generation. Therefore, the battery storage capacity is automatically matched to the designed power demand of methanol and carbon capture plants. Depending on power generation profile, this can dramatically improve the modelled methanol plant capacity factor. To exclude battery storage from the plant design, select 0 hours for battery storage duration.

- **Battery Storage Duration:** Battery storage capacity in terms of hours at rated power discharge.



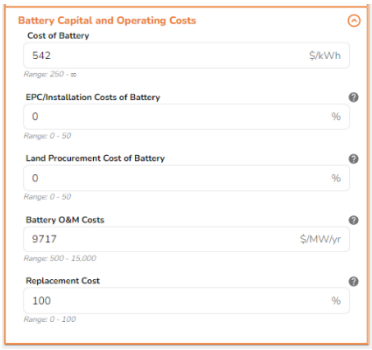
Battery Performance:

- **Round Trip Efficiency:** Overall Energy efficiency of battery charge discharge cycle.
- **Battery Minimum State of Charge:** Minimum battery charge level.
- **Battery Lifetime:** Time until battery is due for replacement.



Battery Capital and operating Costs:

- **Cost of Battery:** Battery capital cost per kWh of storage capacity.
- **EPC/Installation Costs of Battery:** Costs for engineering, procurement and installation of the battery as a percentage of solar/wind farm CAPEX.
- **Land Procurement Cost of Battery:** Land procurement cost of battery as a percentage of solar/wind farm CAPEX.
- **Battery O&M Costs:** Annual battery operating and maintenance costs per MW of installed capacity.
- **Replacement Cost:** Percentage of CAPEX. Cost of battery replacement is incurred as additional operating cost in each year the battery lifetime is reached.



Additional Costs:

Additional upfront/Operating Costs:

- **Additional Upfront Costs:** Any other additional costs to include as a once off in the Levelized cost of hydrogen LC_{H2} calculation.
- **Additional Annual Costs:** Any other additional costs to include as an annual cost in the LC_{H2} calculation.

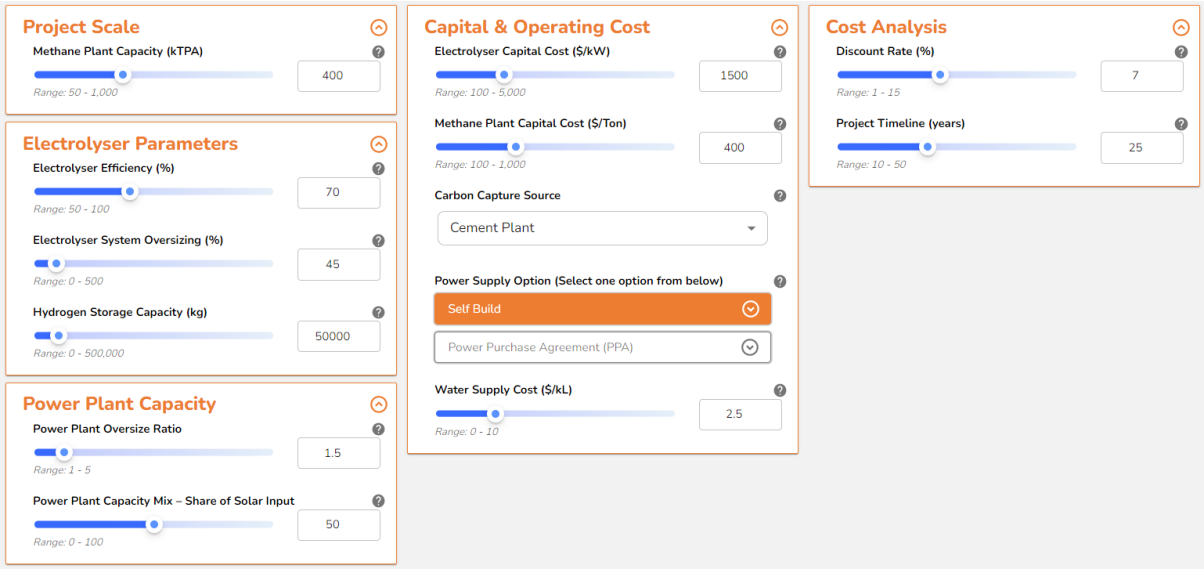
Financing Parameters:

- **Project Timeline:** Length of time that project is operational. Same for both power plant and electrolyser.
- **Discount rate:** Discount rate for NPV analysis and LC_{H2}. Required rate of return based on similar investments.

2.4. Methane

2.4.1. Basic Inputs

The basic model input page has been designed using simple inputs and sliders to build and evaluate a project easily and quickly.



Methane Plant Capacity: Specify the Methane production rate in thousand tons/yr (kTPA). Methane plant, Carbon capture plant, renewable energy, electrolyser and battery units will be scaled automatically to match this nameplate production rate.

Electrolyser Efficiency: A slider to specify electrolyser energy efficiency relative to the theoretical maximum of 39.4 kWh/kg of H_2 produced.

Electrolyser System Oversizing: Oversize the electrolyser to optimize hydrogen supply stability to match with storage and downstream demand profile.

Hydrogen Storage Capacity: Add hydrogen storage to improve Methane production flexibility and reduce the strain of frequent Methane plant start up and shutdown.

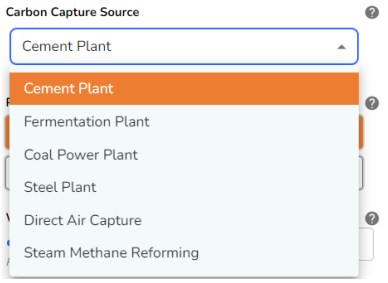
Power Plant Oversize Ratio: A slider to adjust the ratio of powerplant capacity oversizing relative to the electrolyser capacity in MW, e.g., choosing 3 results in the powerplant full load capacity (MW) being 3 times that of the electrolyser full load capacity (MW). This is an important configurational choice, which affects the achieved electrolyser capacity factor and thus the electrolyser and powerplant sizing required to meet the specified hydrogen production rate. Note: Higher powerplant oversizing will lower the required electrolyser capacity to meet the same hydrogen production rate.

Solar to Wind Ratio: Split of solar and wind farm share in the power capacity from solar only at 100% to wind only at 0%.

Electrolyser Capital Cost: Capital cost of electrolyser per kW including the equipment and installation costs.

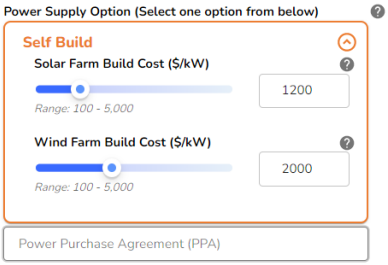
Methane Plant Capital Cost: Capital cost of Methane plant per ton of nameplate production capacity. Includes Methane Synthesis process, Methane Storage Unit Costs.

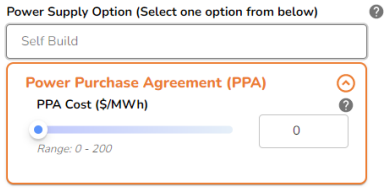
Carbon Capture Source: Select from a list of pre-set carbon capture sources including DAC – Direct Air capture, and flue gas from industrial sources including cement, steel, CO_2 by-product of fermentation, Coal fired power generation, and SMR – Steam methane reforming. Corresponding default specific energy consumption and capital cost, values will be assigned based on selection.



Power Supply option: Select 'Self Build' for cases in which a new power plant is built in conjunction with electrolyser. Select PPA if there is a grid connection to a power supplier.

- **Self-Build selected:**
  Solar Farm Build Cost: Capital cost of solar farm per kW including the equipment and installation costs.
  Wind Farm Build Cost: Capital cost of wind farm per kW including the equipment and installation costs.
- **Power Purchase Agreement (PPA) selected:**
  PPA Cost: Cost of PPA per MWh including electricity consumption and transmission/grid usage charges.





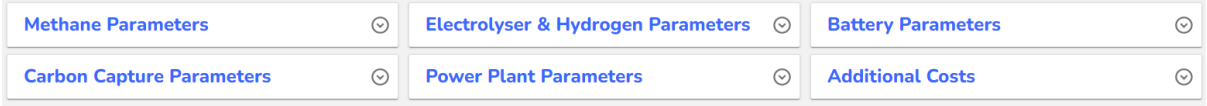
Water Supply Cost: Wholesale cost of water supply per kL.

Discount rate: Required rate of return based on similar investments.

Project timeline: Length of time that project is operational in years.

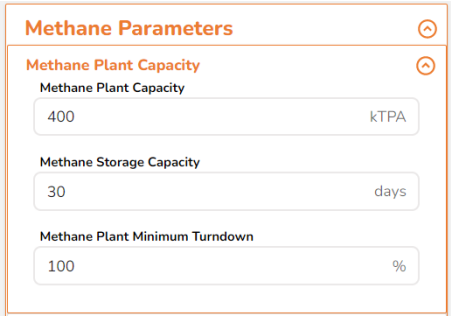
2.4.2. Advanced Inputs

The advanced version of the inputs page allows for more detailed specification of operational and economic parameters.



Methane Parameters:

Methane Plant Capacity:

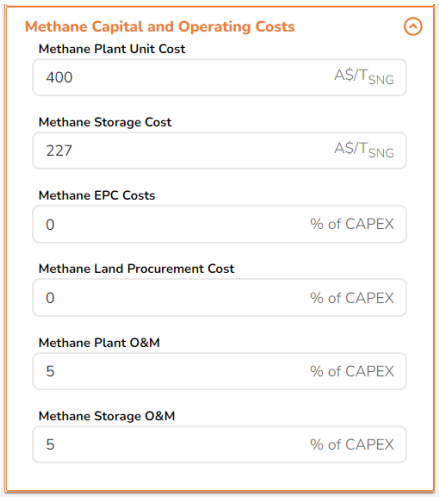


- **Methane Plant Capacity:** Specify the Methane production rate in thousand tons/yr (kTPA).
- **Methane Storage Capacity:** Onsite Methane storage capacity in number of days' worth of production volume.
- **Methane Plant Minimum Turndown:** The degree to which the Methane plant loading can be reduced as a percentage of nameplate plant capacity, e.g., 50% turndown means that the Methane plant can operate within the range of 50% to 100% of the specified plant capacity.

Methane Plant SEC:

- **Methane Plant Specific Energy Consumption:** Specify the specific energy consumption of the Methane plant kWh of electricity per kg of Methane product.

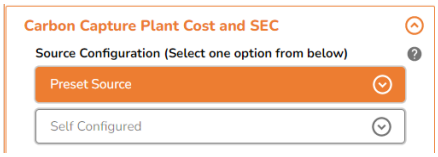
Methane Plant Capital and Operating Costs:

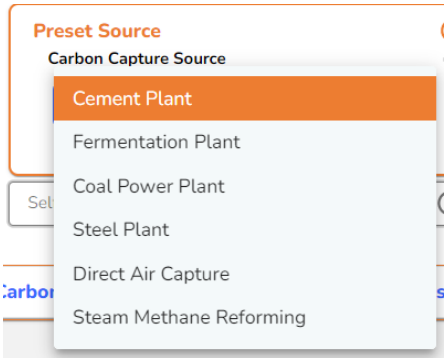


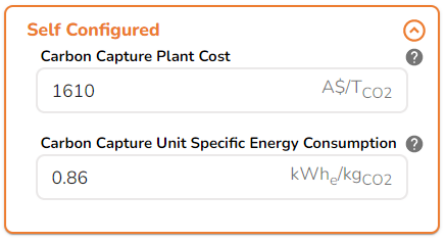
- **Methane Synthesis Plant Cost:** Specify the Methane synthesis unit capital cost per ton of Methane plant capacity.
- **Methane Storage Cost:** Specify cost of onsite Methane storage per ton of storage capacity.
- **EPC Costs:** Engineering and procurement costs as a percentage of Methane CAPEX.
- **Land Procurement Cost:** Land procurement cost of battery as a percentage of Methane CAPEX.
- **Methane Plant O&M:** Annual Methane operating and maintenance costs as a percentage of Methane plant CAPEX. Excluding energy costs which are accounted for by costing of the renewable energy plant.
- **Methane Storage O&M:** Annual Methane operating and maintenance costs as a percentage of Methane storage CAPEX. Excluding energy costs which are accounted for by costing of the renewable energy plant.

<u>Carbon Capture Parameters:</u>

Carbon Capture Plant Cost and SEC:

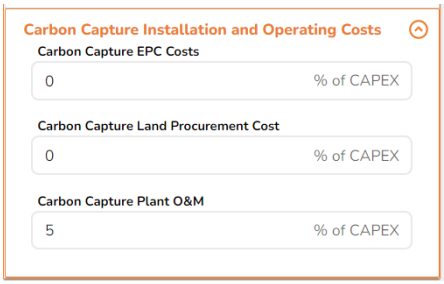






- **Pre-Set vs Self-Configured:** Select between pre-set options or providing custom carbon capture costing and energy consumption values.
- **Pre-Set Carbon Capture Source:** Select from a list of pre-set carbon capture sources including DAC – Direct Air capture, and flue gas from industrial sources including cement, steel, CO_2 by-product of fermentation, Coal fired power generation, and SMR – Steam methane reforming. Corresponding default specific energy consumption and capital cost, values will be assigned based on selection.
- **Self-Configured Carbon Capture Plant Cost:** Specify capital cost of carbon capture plant per ton of annual carbon capture capacity.
- **Self-Configured Carbon Capture SEC:** Specify the specific energy consumption of the carbon capture plant in kWh of electricity per kg of CO_2 captured.

Carbon Capture Installation and Operating Costs:

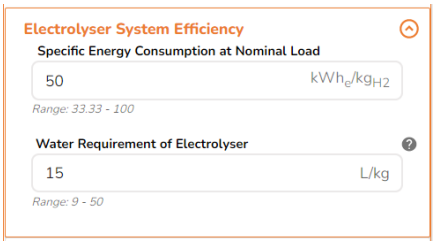


- **Carbon Capture EPC Costs:** Engineering and procurement costs as a percentage of Carbon Capture CAPEX.
- **Land Procurement Cost:** Land procurement cost of battery as a percentage of Carbon Capture CAPEX.
- **Carbon Capture Plant O&M:** Annual Carbon Capture Plant operating and maintenance costs as a percentage of Carbon Capture plant CAPEX. Excluding energy costs which are accounted for by costing of the renewable energy plant.

<u>Electrolyser parameters:</u>

Electrolysis System Oversizing: Oversize the electrolyser to optimize hydrogen supply stability to match with storage and downstream demand profile.

Electrolyser System Efficiency:



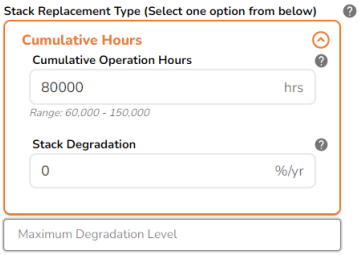
- **Specific Energy Consumption at Nominal Load:** Specify the specific energy consumption of the electrolyser unit kWh of electricity per kg of hydrogen product.
- **Water Requirement of Electrolyser:** Water consumed per kg of hydrogen produced - independent of load.

Electrolyser Load Range:

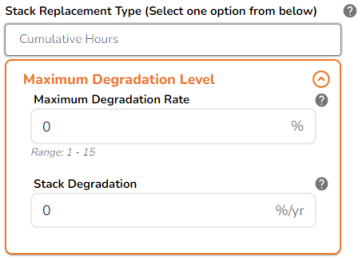
- **Electrolyser Maximum Load:** Maximum normal operating electrolyser loading as a percentage of the rated electrolyser capacity.
- **Electrolyser Minimum Load:** Minimum normal operating electrolyser loading as a percentage of the rated electrolyser capacity.

Stack Replacement Type: Select between electrolyser stack replacement methods. Select "Cumulative Hours" to replace the stack when it exceeds a threshold lifetime operational hours. Select "Maximum Degradation Level" to replace the stack once it degrades past a threshold percentage of the original production rate.

- Cumulative Hours Selected:
  Cumulative Operating Hours: Cumulative hours of operation before stack replacement is due.
  Stack Degradation: Decrease in stack productivity per year as a percentage of the original production rate.



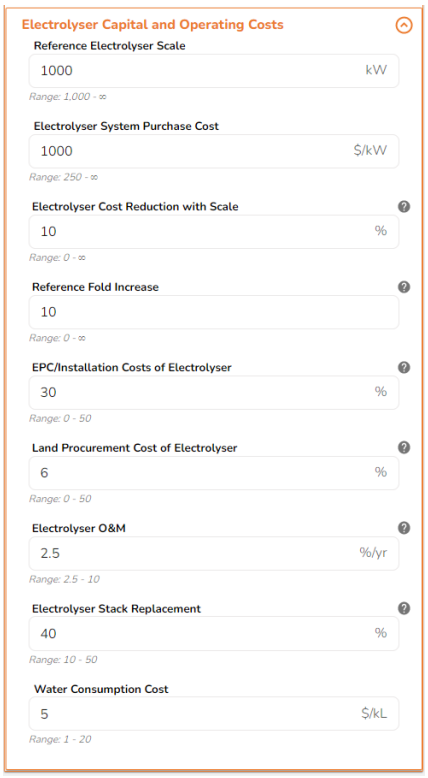
- Maximum Degradation Level selected:
  Maximum degradation rate: Maximum allowable cumulative degradation as a percentage of original production rate before the stack must be replaced.
  Stack Degradation: Decrease in stack productivity per year as a percentage of the original production rate.



Hydrogen Storage:

- **Hydrogen Storage Capacity:** Add hydrogen storage to improve Methane production flexibility and reduce the strain of frequent Methane plant start up and shutdown.
- **Minimum Hydrogen Storage:** Minimum hydrogen storage capacity as a percentage of total storage capacity. This determines the usable volume of the specified hydrogen storage capacity.

Electrolyser Capital and Operating Costs:



- **Reference Electrolyser Scale:** Scale in kW of reference electrolyser system for economies of scale.
- **Electrolyser System Purchase Cost:** Cost of reference electrolyser system per kW of capacity.
- **Electrolyser Cost Reduction with Scale:** Cost reduction due to economies of scale per specified fold increase.
- **Reference Fold Increase:** Cost reduction occurs for every specified fold increase in capacity vs. reference scale.
- **EPC/Installation Costs of Electrolyser:** Costs for engineering, procurement and installation of the electrolyser as a percentage of electrolyser CAPEX.
- **Land Procurement Cost of Electrolyser:** Land Procurement Cost of Electrolyser as a percentage of electrolyser CAPEX.
- **Electrolyser O&M:** Annual electrolyser operating and maintenance costs as a percentage of CAPEX, excluding energy consumption.
- **Electrolyser Stack Replacement:** Cost of electrolyser stack replacement as a percentage of electrolyser CAPEX.
- **Water Consumption Cost:** Wholesale cost of water supply per kL.

<u>Power plant Parameters:</u>

Power Plant Type: Select between Wind only, solar only or hybrid wind and solar power generation.

- **Power Plant Capacity:** Select power plant capacity as a ratio of electrolyser capacity.
  - **Oversize Ratio:** Specify the ratio of powerplant capacity relative to the electrolyser capacity in MW/MW, e.g., choosing 3 results in the powerplant full load capacity (MW) being 3 times that of the electrolyser full load capacity (MW). This is an important configurational choice, which affects the achieved electrolyser capacity factor and thus the achieved hydrogen production rate. Note: Higher powerplant oversizing will lower the required electrolyser capacity to meet the same hydrogen production rate.
- **Wind Degradation rate:** Decrease in wind farm productivity per year as a percentage of the original power generation capacity.
- **Solar Degradation rate:** Decrease in solar farm productivity per year as a percentage of the original power generation capacity.
- **Power Plant Capacity Mix – Share of Solar Input**: Hybrid type only. Select the percentage of Solar in the total power plant installed capacity. Wind will make up the balance of the total installed capacity. E.g., Input 100% for solar only and 0% for wind only.

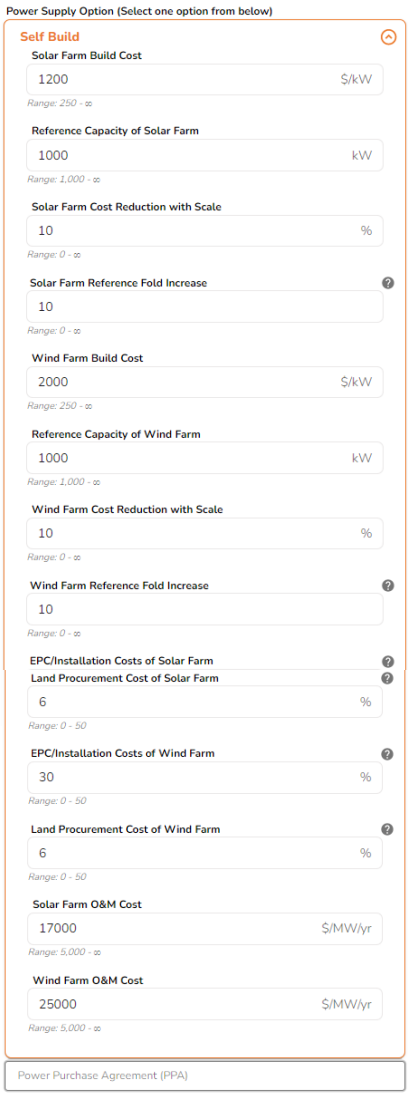
Power Plant Configuration: Select between standalone power plant configuration without a grid connection, or a grid connected configuration. Grid connected configurations make use of private or shared transmission networks to transmit power from an offsite renewable energy farm to the site of the project. With no offtake from fossil fuel power generation.

- Grid Connected selected:
  Grid Connection Costs: Capital cost for transmission connection.
  Grid Usage Charges: Any additional charges for using grid services, e.g. Transmission Use of System (TUOS) Charges.

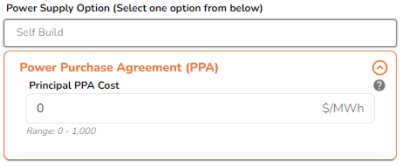
Power Supply Option: Select 'Self Build' for cases in which a new power plant is built in conjunction with electrolyser. Select PPA if there is a grid connection to a power supplier.

Self-Build Selected:

- **Solar/Wind Farm Build Cost:** Cost of reference solar/wind farm per kW of capacity.
- **Reference Solar/Wind Farm Capacity:** Scale in kW of reference electrolyser system for economies of scale.
- **Solar Farm Cost Reduction with Scale:** Cost reduction due to economies of scale per specified fold increase.
- **Reference Fold Increase:** Cost reduction occurs for every specified fold increase in capacity vs. reference scale.
- **EPC/Installation Costs of Solar/Wind Farm:** Costs for engineering, procurement and installation of the solar/wind farm as a percentage of solar/wind farm CAPEX.
- **Land Procurement Cost of Solar/Wind Farm:** Land Procurement Cost of solar/wind farm as a percentage of solar/wind farm CAPEX.
- **Solar/Wind Farm O&M Costs:** Annual Solar/Wind farm operating and maintenance costs per MW of installed capacity.



Power Purchase Agreement PPA: Fixed price for electricity bought from the grid per MWh.

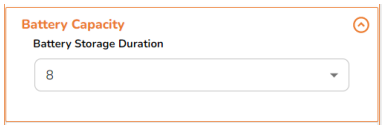


Battery Parameters

Battery Capacity:

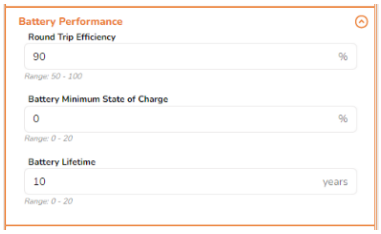
Battery storage was deemed to be an integral part of the Power to Methane pathway to provide backup utilities to the Methane and carbon capture facilities during periods of low power generation. Therefore, the battery storage capacity is automatically matched to the designed power demand of Methane and carbon capture plants. Depending on power generation profile, this can dramatically improve the modelled Methane plant capacity factor. To exclude battery storage from the plant design, select 0 hours for battery storage duration.

- **Battery Storage Duration:** Battery storage capacity in terms of hours at rated power discharge.



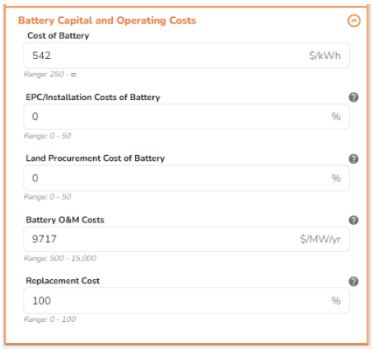
Battery Performance:

- **Round Trip Efficiency:** Overall Energy efficiency of battery charge discharge cycle.
- **Battery Minimum State of Charge:** Minimum battery charge level.
- **Battery Lifetime:** Time until battery is due for replacement.



Battery Capital and operating Costs:

- **Cost of Battery:** Battery capital cost per kWh of storage capacity.
- **EPC/Installation Costs of Battery:** Costs for engineering, procurement and installation of the battery as a percentage of solar/wind farm CAPEX.
- **Land Procurement Cost of Battery:** Land procurement cost of battery as a percentage of solar/wind farm CAPEX.
- **Battery O&M Costs:** Annual battery operating and maintenance costs per MW of installed capacity.
- **Replacement Cost:** Percentage of CAPEX. Cost of battery replacement is incurred as additional operating cost in each year the battery lifetime is reached.



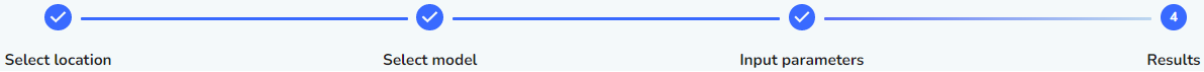
Additional Costs:

Additional upfront/Operating Costs:

- **Additional Upfront Costs:** Any other additional costs to include as a once off in the Levelized cost of hydrogen LC_{H2} calculation.
- **Additional Annual Costs:** Any other additional costs to include as an annual cost in the LC_{H2} calculation.

Financing Parameters:

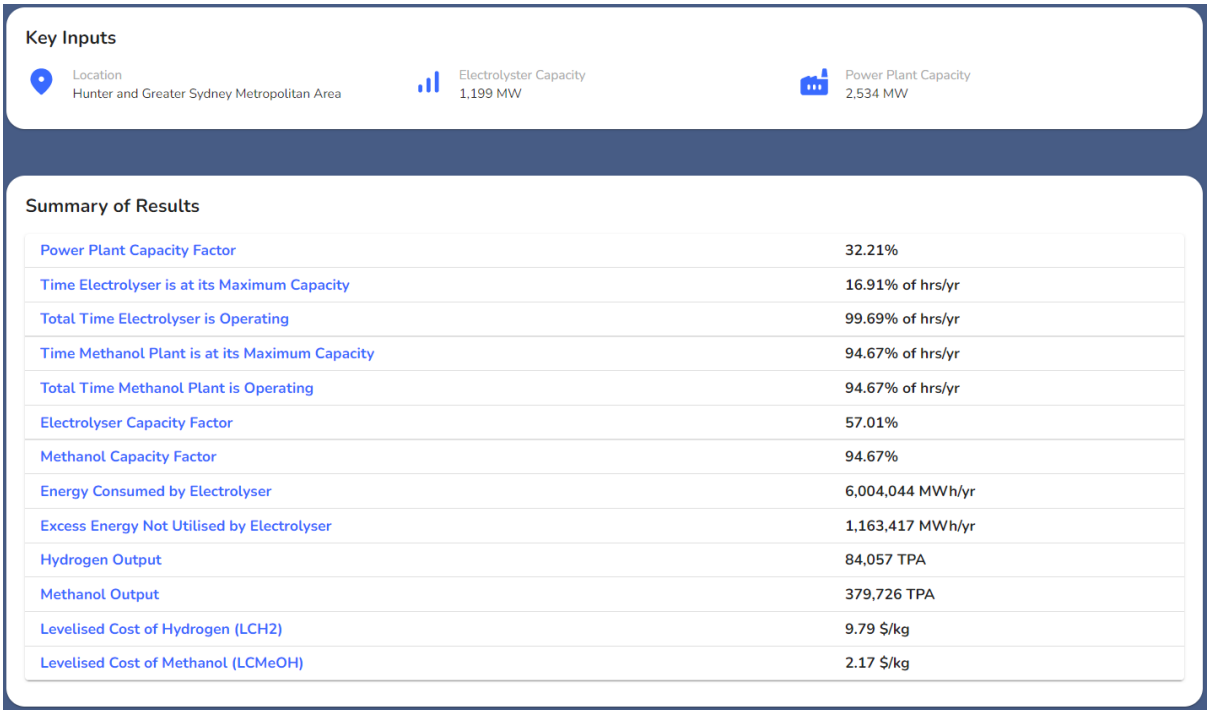
- **Project Timeline:** Length of time that project is operational. Same for both power plant and electrolyser.
- **Discount rate:** Discount rate for NPV analysis and LC_{H2}. Required rate of return based on similar investments.



3. Results

The results interface features a summary of key results for the modelled project, key inputs, and various charts of the project costs and performance.

3.1. Results Page



Key inputs:

- **Location:** Selected project location zone.
- **Electrolyser Capacity:** Scale of project electrolyser unit based on model inputs.
- **Power Plant Capacity:** Scale of project renewable energy farm capacity based on model inputs

Summary of Results:

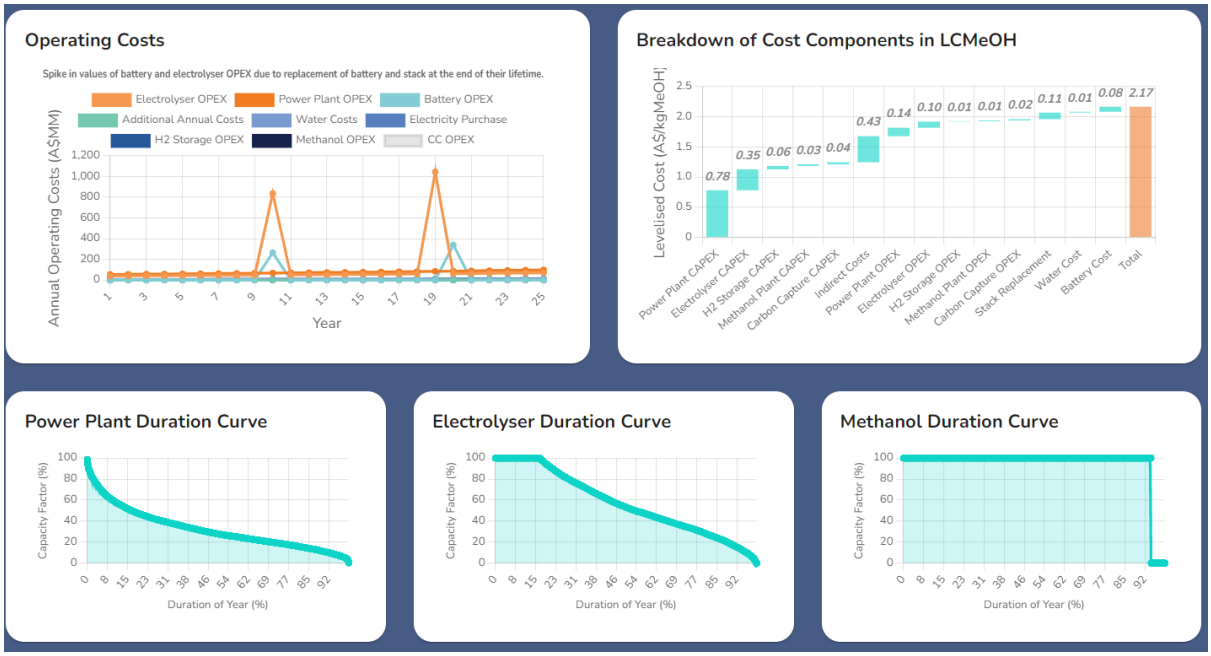
- **Power Plant Capacity Factor:** Average annual power plant capacity factor based on selected renewable energy zone profile and mix of solar and wind power generation. Capacity factor refers to the actual output as a percentage of the maximum possible output at constant full load operation.
- **Time Electrolyser is at its Maximum Capacity:** The modelled percentage of time that the electrolyser unit operates at maximum capacity. This is dependant on the selected zone, and sizing parameters of both the electrolyser and the power plant.
- **Total Time Electrolyser is Operating:** The modelled percentage of time that the electrolyser unit is operational. The electrolyser is not operational at times when the power supplied to the electrolyser unit is below the minimum electrolyser operating load.
- **Electrolyser capacity factor:** Average annual electrolyser capacity factor. Based on the chosen sizing parameters for the electrolyser, and powerplant units as well as the

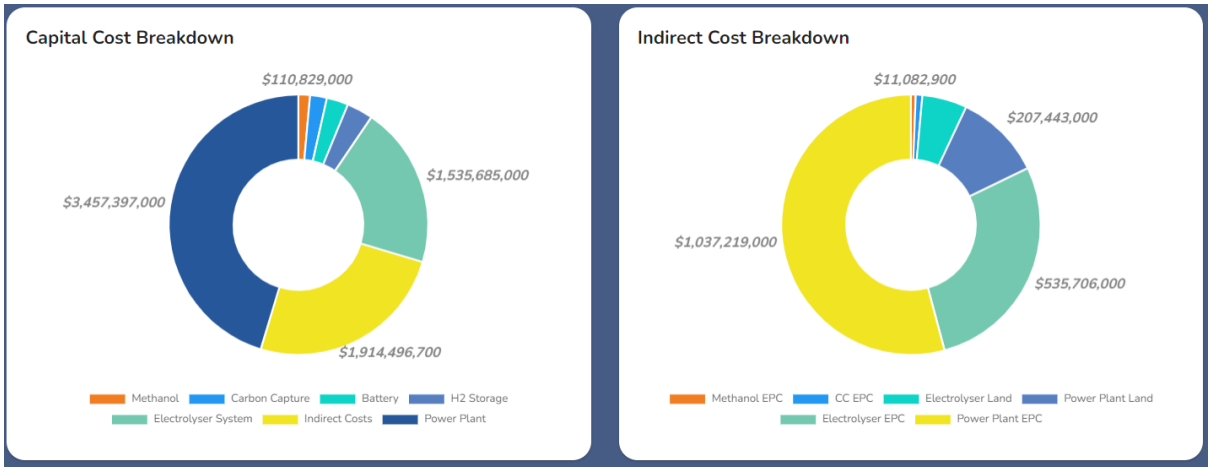
power generation profile corresponding to the chosen renewable energy zone. Capacity factor refers to the actual output as a percentage of the maximum possible output at constant full load operation.

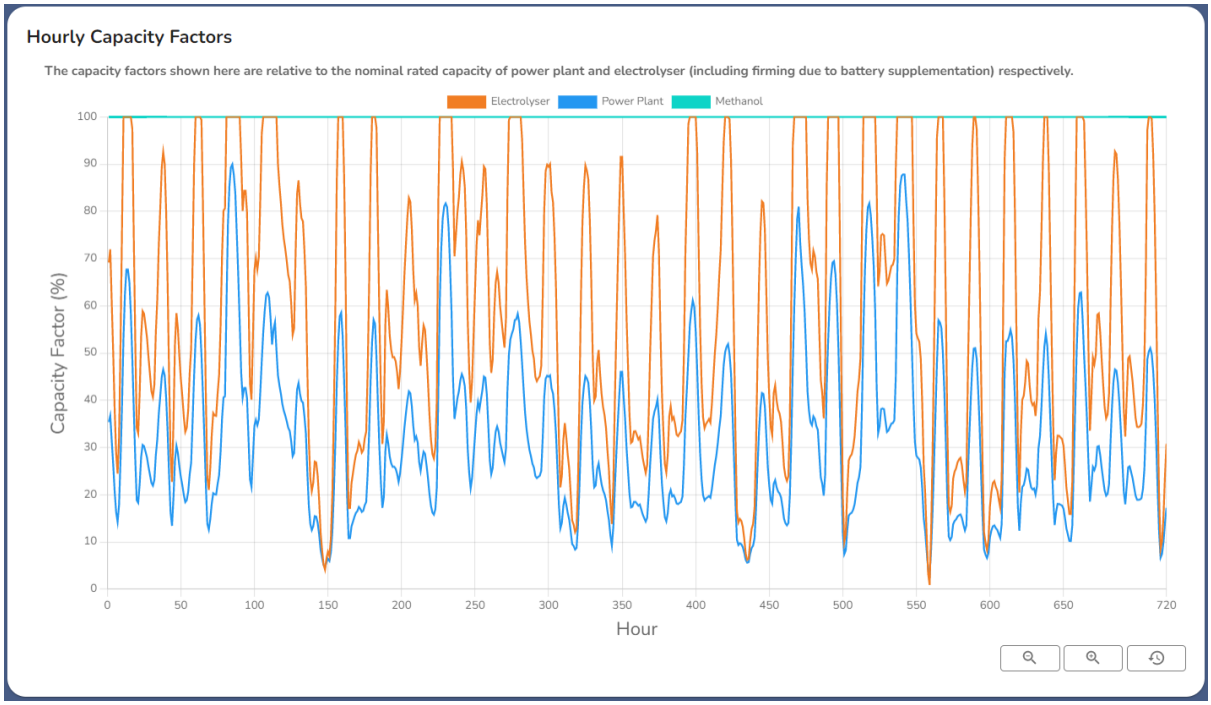
- **Energy Consumed by Electrolyser:** Modelled annual power consumption of the electrolyser unit.
- **Excess energy not utilized by electrolyser:** Curtailed or excess power generation that could not be utilized by the electrolyser unit during peaks due to oversizing of the power plant.
- **Hydrogen generation output:** The modelled annual hydrogen production in ton per year.
- **Powerfuel Output (Ammonia, Methanol, Methane):** The modelled annual powerfuel production in metric ton per year.
- **Levelised cost of product (Hydrogen, Ammonia, Methanol, Methane):** Levelised cost of product. This is the discounted cost of product over the project lifetime in A$ per kg.

Graphical Results:

- **Operating Costs:** Annual operating costs over the project lifetime. Spikes correlate to replacement costs of key units in a given year (Electrolyser stack, battery etc.).
- **Breakdown of cost Components in LCH2:** Waterfall breakdown of the levelized cost of hydrogen into key cost categories.
- **Duration Curves:** Ordered annual capacity factor data for each major section (Powerplant, electrolyser, powerfuel plant). This illustrates the proportion of time at different operating loads throughout the year (from 0 to 100% capacity factor).
- **Capital Cost Breakdown:** Pie chart of major capital costs.
- **Indirect Cost Breakdown:** Pie chart of indirect costs. (Engineering and procurement costs EPC, and Land costs of different plant sections)
- **Hourly Capacity Factors:** Simulated hourly plant capacity factors (Powerplant, Electrolyser, Powerfuels plant), scroll right to see different portions of the year. Use to inspect impact of configuration choices on plant operation.







4. Default Values

4.1. Hydrogen – Basic

Input Parameter	Default Value
Project Scale	15 KTPA
Electrolyser Efficiency	70%
Powerplant Oversize Ratio	1.5
Solar and Wind Mix	50%
Electrolyser Capital Cost	A$2000
Powerplant Build option	Self-Build
Solar Farm Build Cost	A$1200
Wind Farm Build Cost	A$2000
PPA Cost	A$60/MWh
Water Supply Cost	A$5/kL
Discount Rate	0.07
Project Timeline	15 Years

4.2. Hydrogen – Advanced

Input Category	Defaults
Electrolyser System Capacity	100 MW
Electrolyser Efficiency	
Electrolyser System Electricity Consumption at Nominal load (SEC at Nominal load)	50 kWh/kg
Water Requirement	15
Electrolyser Load Range	
Electrolyser Operation Range	100%
Electrolyser Overloading	10%
Maximum Load when overloading	100%
Time Between overloading	0
Electrolyser Stack Replacement	
Replacement Type	Cumulative
Cumulative Operation Hours	80000
Maximum Degradation Rate	10%
Stack Degradation	1%
Electrolyser Capital and Operating Cost	
Electrolyser System Purchase Cost	1500 $/kW
Reference Electrolyser Scale	1000 kW
Electrolyser cost reduction with scale	5%
Reference fold increase for economies of scale to occur	10
Electrolyser System Installation Costs	
EPC Costs	30%
Land Cost	6%
Electrolyser Operating Costs	
Electrolyser O&M	3%
Electrolyser Stack Replacement	40%
Water Consumption Cost	5 $/kL
Powerplant Configuration	Standalone
Powerplant Type	Hybrid
Oversize Ratio	1.5
Solar to Wind Capacity	50%
Powerplant Efficiency	
Powerplant Degradation Rate	1%
Powerplant Capital and Operating Costs	
Power supply option	Self-Build
Powerplant Equipment Costs	
Solar Farm Purchase Cost	A$1200/kW
Reference Solar Farm Scale	1000 kW
Solar Farm cost reduction with scale	5%
Reference fold increase for economies of scale to occur	10

Wind Farm Purchase Cost	A$2000/kW
Reference Wind Farm Scale	1000 kW
Wind Farm cost reduction with scale	5%
Reference fold increase for economies of scale to occur	10
Powerplant Installation Costs	
EPC/Installation Costs of Solar Farm	30%
Land Development Cost of Solar Farm	6%
EPC/Installation Costs of Wind Farm	30%
Land Development Cost of Wind Farm	6%
Powerplant Operating Costs	
Solar Farm O&M	17000 $/MWh/y
Wind Farm O&M	25000 $/MWh/y
PPA Costs	
PPA Costs	A$50/MWh
Grid Connection Costs	
Grid Connection Costs	A$1,000,000
Grid Usage Charges	A$10/MWh
Battery Capacity	
Battery Rated Power Capacity	0%
Battery Storage Duration	0%
Battery Performance	
Round Trip Efficiency	85%
Battery Minimum State of Charge	10%
Battery Maximum State of Charge	100%
Battery Lifetime	10
Battery Capital Costs	
Battery System Purchase Costs	A$1000/kWh
Battery System Installation Costs	0%
Battery System Land Costs	0%
Battery Operating Costs	
Battery O&M Costs	10,000 $/MWh/y
Battery Replacement Costs	100%
Additional Costs	
Additional Upfront Costs	0%
Additional Annual Costs	0%
Financing Parameters	
Project Timeline	15
Discount Rate	7%

4.3. Ammonia – Basic

Input Category	Default Values
Project Scale	50 KTPA
Electrolyser Parameter	
Electrolyser Efficiency	75%
Electrolyser Oversizing	45%
Hydrogen Storage	50000 kg
Powerplant Capacity	
Powerplant Oversizing	1.5
Solar and Wind Mix	50%
Capital and Operating Costs	
Ammonia Plant Capital Cost	A$900/Ton
Electrolyser Capital Cost	A$1500/kW
Powerplant Build option	
Build Powerplant	
Solar Farm Build Cost	A$1200/kW
Wind Farm Build Cost	A$1800/kW
Purchase Electricity via PPA	
PPA Cost	A$50/MWh
Water Supply Cost	A$5/kL
Cost Analysis	
Discount Rate	7%
Project Timeline	25 Years

4.4. Ammonia – Advanced

Input Category	Defaults
Ammonia Plant Capacity	50 kTPA
Ammonia Plant Specific Energy Consumption	
Ammonia Unit Specific Energy Consumption	0.4 kWh/kg
Air Separation Unit Specific Energy Consumption	0.2 kWh/kg
Ammonia Plant Load Range and Storage	
Minimum Turndown	33%
Duration of Ammonia Storage	30 Days
Ammonia Plant Capital and Operating Costs	
Capital Costs	
Ammonia Synthesis Unit Cost	A$400/t/a
Ammonia Storage Cost	A$100/t/a
Air Separation Unit Cost	A$200/t
Ammonia Plant Installation Costs	
EPC Costs	10%
Land Cost	0%
Operating Costs	
Ammonia Synthesis Unit Cost	2%
Ammonia Storage Cost	2%
Air Separation Unit Cost	2%
Electrolyser System Oversizing	45%

Minimum Hydrogen Storage	10%
Electrolyser Efficiency	
Electrolyser System Electricity Consumption at Nominal load (SEC at Nominal load)	50 kWh/kg
Water Requirement	15 L/kg
Electrolyser Load Range	
Electrolyser Operation Range	10 – 100%
Electrolyser Stack Replacement	
Replacement Type	Cumulative
Cumulative Operation Hours	80000
Maximum Degradation Rate	10%
Electrolyser Capital and Operating Cost	
Electrolyser Equipment Costs	
Electrolyser System Purchase Cost	1500 $/kW
Reference Electrolyser Scale	1000 kW
Electrolyser cost reduction with scale	10 %
Reference fold increase for economies of scale to occur	10
Hydrogen Storage Purchase Cost	A$500 / kg
Electrolyser System Installation Costs	
EPC Costs	30%
Land Cost	6%
Electrolyser Operating Costs	
Electrolyser O&M	2.5%
Hydrogen Storage O&M	2.00%
Electrolyser Stack Replacement	40%
Water Consumption Cost	5 $/kL
Powerplant Capacity	
Powerplant Configuration	Standalone
Powerplant Type	Hybrid
Powerplant Oversizing	1.5
Hybrid Mix	50%
Powerplant Efficiency	
Powerplant Degradation Rate	0%
Powerplant Capital and Operating Costs	
Power supply option	Self Build
Powerplant Equipment Costs	
Solar Farm Purchase Cost	1200 $/kW
Reference Solar Farm Scale	1000 kW
Solar Farm cost reduction with scale	10%
Reference fold increase for economies of scale to occur	10
Wind Farm Purchase Cost	2000 $/kW
Reference Wind Farm Scale	1000 kW
Wind Farm cost reduction with scale	10%
Reference fold increase for economies of scale to occur	10
Powerplant Installation Costs	
EPC/Installation Costs of Solar Farm	30%
Land Development Cost of Solar Farm	6%

EPC/Installation Costs of Wind Farm	30%
Land Development Cost of Wind Farm	6%
Powerplant Operating Costs	
Solar Farm O&M	17000 $/MW/yr
Wind Farm O&M	25000 $/MW/yr
PPA Costs	
PPA Costs	50 $/MWh
Grid Connection Costs	
Grid Connection Costs	$ 1000000
Grid Usage Charges	10 $/MWh
Battery Capacity	
Battery Rated Power Capacity	0
Battery Storage Duration	0
Battery Performance	
Round Trip Efficiency	85%
Battery Minimum State of Charge	10%
Battery Lifetime	10 yrs
Battery Capital and Operating Costs	
Battery System Equipment Costs	
Battery System Purchase Costs	380 $/kWh
Battery Systems Installation Costs	
Battery System Installation Costs EPC	0
Battery System Land Costs	0
Battery Operating Costs	
Battery O&M Costs	10000 $/MW/yr
Battery Replacement Costs	100%

4.5. Methanol – Basic

Input Category	**Default Values**
Project Scale	400 KTPA
Electrolyser Parameters	
Electrolyser Efficiency	70%
Electrolyser Oversizing	85%
Hydrogen Storage	500,000kg
Powerplant Capacity	
Powerplant Oversizing	100%
Solar and Wind Mix	50% solar
Backup power source	Battery
Capital and Operating Costs	
Methanol Plant Capital Cost	A$265/Ton
Carbon Capture Plant Cost	
DAC	A$ 1610 /t CO2/a
Cement	A$ 275 /t CO2/a
Steel	A$ 460 /t CO2/a
Coal	A$ 420 /t CO2/a
Fermentation CO_2	A$ 0 /t CO2/a
SMR	A$ 420 /t CO2/a

Electrolyser Capital Cost	A$1500/kW
Power plant Configuration Parameters	
Build Powerplant	Self Build
Solar Farm Build Cost	A$1200/kW
Wind Farm Build Cost	A$2000/kW
Battery Build Cost	A$380/kW
Purchase Electricity via PPA	
PPA Cost	A$65/MWh
Water Supply Cost	A$2.5/kL
Cost Analysis	
Discount Rate	7%
Project Timeline	25 years

4.6. Methanol – Advanced

Input Category	**Defaults**
Methanol Plant Parameters	
Methanol Plant Capacity	400 kTPA
Methanol Plant Specific Energy Consumption	
Methanol Unit Specific Energy Consumption	0.36 kWh/kg
Methanol Plant Load Range and Storage	
Minimum Turndown	100%
Duration of Methanol Storage	30 Days
Methanol Plant Capital and Operating Costs	
Capital Costs	
Methanol Synthesis Unit Cost	A$265 /t MeOH/a
Methanol Storage Cost	A$227 /t MeOH
Methanol Plant Installation Costs	
EPC Costs	0
Land Cost	0
Operating Costs	
Methanol Synthesis Unit Cost	5%
Methanol Storage Cost	0%
Carbon Capture Plant Parameters	
Carbon Capture Plant Source Type	Cement
Carbon Capture Plant Specific Energy Consumption	
Carbon capture plant Specific Energy Consumption	
DAC	1.535 kW/kg CO_2
Cement	0.78 kW/kg CO_2
Steel	0.78 kW/kg CO_2
Coal	0.86 kW/kg CO_2
Fermentation CO_2	0 kW/kg CO_2
SMR	0.78 kW/kg CO_2
Carbon Capture Plant Capital and Operating Costs	
Capital Costs	
Carbon Capture Plant Cost	
DAC	A$ 1610 /t CO2/a

Cement	A$ 275 /t CO2/a
Steel	A$ 460 /t CO2/a
Coal	A$ 420 /t CO2/a
Fermentation CO_2	A$ 0 /t CO2/a
SMR	A$ 420 /t CO2/a
Methanol Plant Installation Costs	
EPC Costs	0%
Land Cost	0%
Operating Costs	
Carbon Capture Plant Cost	5%
Electrolyser and Hydrogen Storage Parameter	
Electrolyser System Oversizing	85%
Minimum Hydrogen Storage	10%
Electrolyser Efficiency	
Electrolyser System Electricity Consumption at Nominal load (SEC at Nominal load)	50 kWh/kgH2
Water Requirement	25 L/kg h2
Electrolyser Load Range	
Electrolyser Operation Range	10% - 100%
Electrolyser Stack Replacement	
Replacement Type	Cumulative
Cumulative Operation Hours	80,000
Maximum Degradation Rate	10%
Electrolyser Capital and Operating Cost	
Electrolyser Equipment Costs	
Electrolyser System Purchase Cost	A$1500 /kW
Reference Electrolyser Scale	1000 kW
Electrolyser cost reduction with scale	10%
Reference fold increase for economies of scale to occur	10
Hydrogen Storage Purchase Cost	A$500/kg
Electrolyser System Installation Costs	
EPC Costs	30% of CAPEX
Land Cost	6% of Capex
Electrolyser Operating Costs	
Electrolyser O&M	2.5% of CAPEX
hydrogen Storage O&M	1.00%
Electrolyser Stack Replacement	40% of Capex
Water Consumption Cost	A$2.7/kL
Powerplant Parameters	
Powerplant Capacity	
Powerplant Configuration	Standalone
Powerplant Type	Hybrid
Powerplant Oversizing ratio	2
Hybrid Mix	50%:50%
Powerplant Efficiency	
Powerplant Degradation Rate	0%
Powerplant Capital and Operating Costs	
Power supply option	Self Build
Powerplant Equipment Costs	

Solar Farm Purchase Cost	1200 $/kW
Reference Solar Farm Scale	1000 kW
Solar Farm cost reduction with scale	10%
Reference fold increase for economies of scale to occur	10
Wind Farm Purchase Cost	2000 $/kW
Reference Wind Farm Scale	1000 kW
Wind Farm cost reduction with scale	10%
Reference fold increase for economies of scale to occur	10
Powerplant Installation Costs	
EPC/Installation Costs of Solar Farm	30%
Land Development Cost of Solar Farm	6%
EPC/Installation Costs of Wind Farm	30%
Land Development Cost of Wind Farm	6%
Powerplant Operating Costs	
Solar Farm O&M	17000 $/MW/yr
Wind Farm O&M	25000 $/MW/yr
PPA Costs	
PPA Costs	65 $/MWh
Grid Connection Costs	
Grid Connection Costs	$ 1000000
Grid Usage Charges	10 $/MWh
Battery Parameters	
Battery Capacity	
Battery Rated Power Capacity	"set to equal methanol and carbon capture plant instantaneous power demand"
Battery Storage Duration	8 hr
Battery Performance	
Round Trip Efficiency	85%
Battery Minimum State of Charge	0%
Battery Lifetime	10 yrs
Battery Capital and Operating Costs	
Battery System Equipment Costs	
Battery System Purchase Costs	A$380/kW
Battery Systems Installation Costs	
Battery System Installation Costs EPC	0
Battery System Land Costs	0
Battery Operating Costs	
Battery O&M Costs	10000 $/MW/yr
Battery Replacement Costs	100%
Cost Analysis	
Discount Rate	7%
Project Timeline	25 years

4.7. Methane – Basic

Input Category	Default Values
Project Scale	400 KTPA
Electrolyser Parameters	
Electrolyser Efficiency	70%
Electrolyser Oversizing	85%
Hydrogen Storage	500,000kg
Powerplant Capacity	
Powerplant Oversizing	100%
Solar and Wind Mix	50% solar
Backup power source	Battery
Capital and Operating Costs	
Methane Plant Capital Cost	A$400/Ton
Carbon Capture Capital Cost	
DAC	A$ 1610 /t CO2/a
Cement	A$ 275 /t CO2/a
Steel	A$ 460 /t CO2/a
Coal	A$ 420 /t CO2/a
Fermentation CO_2	A$ 0 /t CO2/a
SMR	A$ 420 /t CO2/a
Electrolyser Capital Cost	A$1500/kW
Power plant Configuration Parameters	
Build Powerplant	Self Build
Solar Farm Build Cost	A$1200/kW
Wind Farm Build Cost	A$2000/kW
Battery Build Cost	A$380/kW
Purchase Electricity via PPA	
PPA Cost	A$65/MWh
Water Supply Cost	A$2.5/kL
Cost Analysis	
Discount Rate	7%
Project Timeline	25 years

4.8. Methane – Advanced

Input Category	Defaults
Methane Plant Parameters	
Methane Plant Capacity	400 kTPA
Methane Plant Specific Energy Consumption	
Methane Unit Specific Energy Consumption	0.36 kWh/kg
Methane Plant Load Range and Storage	
Minimum Turndown	100%
Methane Plant Capital and Operating Costs	
Capital Costs	
Methane Synthesis Unit Cost	A$400/t MeOH/a
Methane Plant Installation Costs	
EPC Costs	0

Land Cost	0
Operating Costs	
Methane Synthesis Unit Cost	5%
Methane Storage Cost	0%
Carbon Capture Plant Parameters	
Carbon Capture Plant Source Type	Cement
Carbon Capture Plant Specific Energy Consumption	
Carbon capture plant Specific Energy Consumption	
DAC	1.535 kW/kg CO_2
Cement	0.78 kW/kg CO_2
Steel	0.78 kW/kg CO_2
Coal	0.86 kW/kg CO_2
Fermentation CO_2	0 kW/kg CO_2
SMR	0.78 kW/kg CO_2
Carbon Capture Plant Capital and Operating Costs	
Capital Costs	
Carbon Capture Plant Cost	
DAC	A$ 1610 /t CO2/a
Cement	A$ 275 /t CO2/a
Steel	A$ 460 /t CO2/a
Coal	A$ 420 /t CO2/a
Fermentation CO_2	A$ 0 /t CO2/a
SMR	A$ 420 /t CO2/a
Methane Plant Installation Costs	
EPC Costs	0%
Land Cost	0%
Operating Costs	
Carbon Capture Plant Cost	5%
Electrolyser and Hydrogen Storage Parameter	
Electrolyser System Oversizing	85%
Minimum Hydrogen Storage	10%
Electrolyser Efficiency	
Electrolyser System Electricity Consumption at Nominal load (SEC at Nominal load)	50 kWh/kgH2
Water Requirement	25 L/kg h2
Electrolyser Load Range	
Electrolyser Operation Range	10% - 100%
Electrolyser Stack Replacement	
Replacement Type	Cumulative
Cumulative Operation Hours	80,000
Maximum Degradation Rate	10%
Electrolyser Capital and Operating Cost	
Electrolyser Equipment Costs	
Electrolyser System Purchase Cost	A$1500 /kW
Reference Electrolyser Scale	1000 kW
Electrolyser cost reduction with scale	10%
Reference fold increase for economies of scale to occur	10
Hydrogen Storage Purchase Cost	A$500/kg

Electrolyser System Installation Costs	
EPC Costs	30% of CAPEX
Land Cost	6% of Capex
Electrolyser Operating Costs	
Electrolyser O&M	2.5% of CAPEX
hydrogen Storage O&M	1.00%
Electrolyser Stack Replacement	40% of Capex
Water Consumption Cost	A$2.7/kL
Powerplant Parameters	
Powerplant Capacity	
Powerplant Configuration	Standalone
Powerplant Type	Hybrid
Powerplant Oversizing ratio	2
Hybrid Mix	50%:50%
Powerplant Efficiency	
Powerplant Degradation Rate	0%
Powerplant Capital and Operating Costs	
Power supply option	Self Build
Powerplant Equipment Costs	
Solar Farm Purchase Cost	1200 $/kW
Reference Solar Farm Scale	1000 kW
Solar Farm cost reduction with scale	10%
Reference fold increase for economies of scale to occur	10
Wind Farm Purchase Cost	2000 $/kW
Reference Wind Farm Scale	1000 kW
Wind Farm cost reduction with scale	10%
Reference fold increase for economies of scale to occur	10
Powerplant Installation Costs	
EPC/Installation Costs of Solar Farm	30%
Land Development Cost of Solar Farm	6%
EPC/Installation Costs of Wind Farm	30%
Land Development Cost of Wind Farm	6%
Powerplant Operating Costs	
Solar Farm O&M	17000 $/MW/yr
Wind Farm O&M	25000 $/MW/yr
PPA Costs	
PPA Costs	65 $/MWh
Grid Connection Costs	
Grid Connection Costs	$ 1000000
Grid Usage Charges	10 $/MWh
Battery Parameters	
Battery Capacity	
Battery Rated Power Capacity	"set to equal Methane and carbon capture plant instantaneous power demand"
Battery Storage Duration	8 hr
Battery Performance	
Round Trip Efficiency	85%
Battery Minimum State of Charge	0%

Battery Lifetime	10 yrs
Battery Capital and Operating Costs	
Battery System Equipment Costs	
Battery System Purchase Costs	A$380/kW
Battery Systems Installation Costs	
Battery System Installation Costs EPC	0
Battery System Land Costs	0
Battery Operating Costs	
Battery O&M Costs	10000 $/MW/yr
Battery Replacement Costs	100%
Cost Analysis	
Discount Rate	7%
Project Timeline	25 years