ONE

INTRODUCTION

The set of models contained in this software allow for the determination of costs for major hub and drivetrain components of a wind turbine based on their masses and a few other select parameters. The software combines sources of information from several areas: The NREL Cost and Scaling Model [1] and related subsequent cost model development efforts, the Wind Partnerships for Advanced Component Technology (WindPACT) work that occurred between roughly 2002 to 2005 [2], and the University of Sunderland (the Sunderland Model) [3]. These mass-cost models use the data from the sources above to take the component mass and estimate the associated cost in a reference year and month. The component cost can then be scaled to a different year and month based on economic multipliers as done in [1].

INSTALLATION

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prerequisites

NumPy, SciPy

Download either masstocost.py-0.1.0.tar.gz or masstocost.py-0.1.0.zip, and uncompress/unpack it.

Install HubNacelleCST with the following command.

```
$ python setup.py install
```

To check if installation was successful run the unit tests for the NREL 5MW model

```
$ python test/test_masstocost.py
```

An 'OK' signifies that all the tests passed.

To access an HTML version of this documentation which contains further details and links to the source code, open docs/index.html.

TUTORIAL

As an example, let us simulate using masses for major wind turbine components for the NREL 5MW Reference Model [Jonkman2009] using the overall turbine cost model. The hub and drivetrain component masses must also be provided and are calculated from Sunderland Model [3].

The first step is to import the relevant files and set up the PPI indices based on the years of interest (reference and current).

```python
from turbine_costSE.src.turbine_costSE import TurbineCost
from turbine_costSE.src.config import *

# simple example of the turbine cost model

ref_yr  = 2002
ref_mon =    9
curr_yr = 2009
curr_mon =  12

ppi.ref_yr   = ref_yr
ppi.ref_mon  = ref_mon
```

The turbine cost model relies on the mass inputs of all major turbine components. These filter down to the individual component models through the rotor, nacelle and tower.

```python
# NREL 5 MW turbine component masses based on Sunderland model approach
bladeMass = 17650.67
hubMass = 31644.5
pitchSystemMass = 17004.0
spinnerMass = 1810.5

lssMass = 31257.3
bearingsMass = 9731.41
gearboxMass = 30237.60
hssMass = 1492.45
generatorMass = 16699.85
bedplateMass = 93090.6
yawSystemMass = 11878.24

towerMass = 434559.0
```

Next, we need to set additional inputs to the model. The blade number must be known to get the total cost for the blade set; the advanced Boolean for the blade must be set to select which mass-cost curve for the blade to use (normal or advanced blade). We set this to advanced to be in line with the FAST 5 MW reference model. The machine rating and boolean flags for onboard crane and offshore project must also be set. These are used in the determination of costs

for auxiliary system components. Finally, the drivetrain configuration (iDesign) is specified so that the proper gearbox and generator coefficients will be used. This should always be set to 1 for the current model.

```
# Additional non-mass cost model input variables
bladeNum = 3
advanced = True # use advanced blade mass-cost curve
machineRating = 5000.0
iDesign = 1 # conventional 3-stage geared drivetrain system
crane = True # onboard crane is present
offshore = True # turbine is for an offshore application
```

We can now create and evaluate the cost for the turbine and its components.

```
turbine = TurbineCost(bladeMass, bladeNum, hubMass, pitchSystemMass, spinnerMass, towerMass, lss
                      bearingsMass, gearboxMass, hssMass, generatorMass, bedplateMass, yawSystemM
                      machineRating, iDesign, offshore, curr_yr, curr_mon, crane, advanced)
```

We then print out the resulting cost values

```
print "Turbine cost is ${0:.2f} USD".format(turbine.cost)
print
print "Overall rotor cost with 3 advanced blades is ${0:.2f} USD".format(turbine.rotor.cost)
print "Advanced blade cost is ${0:.2f} USD".format(turbine.rotor.blade.cost)
print "Cost of 3 blades is ${0:.2f} USD".format(turbine.rotor.blade.cost * 3)
print "Hub cost is ${0:.2f} USD".format(turbine.rotor.hub.cost)
print "Pitch cost is ${0:.2f} USD".format(turbine.rotor.pitch.cost)
print "Spinner cost is ${0:.2f} USD".format(turbine.rotor.spinner.cost)
print
print "Overall nacelle cost is ${0:.2f} USD".format(turbine.nacelle.cost)
print "LSS cost is ${0:.2f} USD".format(turbine.nacelle.lss.cost)
print "Main bearings cost is ${0:.2f} USD".format(turbine.nacelle.bearings.cost)
print "Gearbox cost is ${0:.2f} USD".format(turbine.nacelle.gearbox.cost)
print "HSS cost is ${0:.2f} USD".format(turbine.nacelle.hss.cost)
print "Generator cost is ${0:.2f} USD".format(turbine.nacelle.generator.cost)
print "Bedplate cost is ${0:.2f} USD".format(turbine.nacelle.bedplate.cost)
print "Yaw system cost is ${0:.2f} USD".format(turbine.nacelle.yawsystem.cost)
print
print "Tower cost is ${0:.2f} USD".format(turbine.tower.cost)
```

The result is

```
>>> Turbine cost is $5315270.08 USD
>>>
>>> Overall rotor cost with 3 advanced blades is $1471019.77 USD
>>> Advanced blade cost is $251829.54 USD
>>> Cost of 3 blades is $755488.63 USD
>>> Hub cost is $173823.07 USD
>>> Pitch cost is $531016.46 USD
>>> Spinner cost is $10691.61 USD
>>>
>>> Overall nacelle cost is $2856229.57 USD
>>> LSS cost is $174104.10 USD
>>> Main bearings cost is $56228.71 USD
>>> Gearbox cost is $641045.88 USD
>>> HSS cost is $15161.40 USD
>>> Generator cost is $432991.21 USD
>>> Bedplate cost is $136836.34 USD
>>> Yaw system cost is $137375.05 USD
>>>
>>> Tower cost is $988020.74 USD
```

Note that the output for the individual nacelle components do not sum to the overall nacelle cost. There are additional costs in the overall nacelle assembly including the onboard crane, electronics and controls, HVAC, other miscellaneous hardware and the nacelle cover.

MODULE DOCUMENTATION

An HTML version of this documentation is available which is better formatted for reading the code documentation and contains hyperlinks to the source code.

This documentation covers turbine component mass-cost models for the full set of turbine components from the rotor to tower.

4.1 Component Cost Interface

The component cost objects in the mass-to-cost model set need only implement the __init__ method and set the cost attribute of the parent interface ComponentCost. The interface contains no methods that must be implemented.

4.2 Rotor Mass-Cost Models

Rotor mass-cost models include individual models for the blade, hub, pitch system and spinner components as well as combined model for the full hub system and the overall rotor.

4.2.1 BladeCost

Class Summary:

class turbine_costSE.src.rotor_costsSE.**BladeCost**(*bladeMass*, *curr_yr*, *curr_mon*, *advanced=True*)

    Initial computation of the costs for the wind turbine blade component.

        Parameters

            bladeMass : float

                blade mass [kg]

            curr_yr : int

                Project start year

            curr_mon : int

                Project start month

            advanced : bool

                boolean for advanced (using carbon) or basline (all fiberglass) blade

4.2.2 HubCost

Class Summary:

class `turbine_costSE.src.rotor_costsSE.`**`HubCost`** (*hubMass*, *curr_yr*, *curr_mon*)

Initial computation of the costs for the wind turbine hub component.

> **Parameters**
> **hubMass** : float
>
> > hub mass [kg]
>
> **curr_yr** : int
>
> > Project start year
>
> **curr_mon** : int
>
> > Project start month

4.2.3 PitchCost

Class Summary:

class `turbine_costSE.src.rotor_costsSE.`**`PitchCost`** (*pitchSystemMass*, *curr_yr*, *curr_mon*)

Initial computation of the costs for the wind turbine pitch system.

> **Parameters**
> **pitchSystemMass** : float
>
> > pitch system mass [kg]
>
> **curr_yr** : int
>
> > Project start year
>
> **curr_mon** : int
>
> > Project start month

4.2.4 SpinnerCost

Class Summary:

class `turbine_costSE.src.rotor_costsSE.`**`SpinnerCost`** (*spinnerMass*, *curr_yr*, *curr_mon*)

Initial computation of the costs for the wind turbine spinner component.

> **Parameters**
> **spinnerMass** : float
>
> > spinner mass [kg]
>
> **curr_yr** : int
>
> > Project start year
>
> **curr_mon** : int
>
> > Project start month

4.2.5 HubSystemCost

Class Summary:

class `turbine_costSE.src.rotor_costsSE.`**HubSystemCost**(*hubMass*, *pitchSystemMass*, *spinnerMass*, *curr_yr*, *curr_mon*)

    Initial computation of the costs for the wind turbine hub component.

        Parameters
            hubMass : float

                hub mass [kg]

            pitchSystemMass : float

                pitch system mass [kg]

            spinnerMass : float

                spinner mass [kg]

            curr_yr : int

                Project start year

            curr_mon : int

                Project start month

4.2.6 RotorCost

Class Summary:

class `turbine_costSE.src.rotor_costsSE.`**RotorCost**(*bladeMass*, *bladeNum*, *hubMass*, *pitchSystemMass*, *spinnerMass*, *curr_yr*, *curr_mon*, *advanced=True*)

    Initial computation of the costs for the wind turbine hub component.

        Parameters
            bladeMass : float

                blade mass [kg]

            bladeNum : int

                Number of blades on rotor

            hubMass : float

                hub mass [kg]

            pitchSystemMass : float

                pitch system mass [kg]

            spinnerMass : float

                spinner mass [kg]

            curr_yr : int

                Project start year

            curr_mon : int

Project start month

advanced : bool

   boolean for advanced (using carbon) or basline (all fiberglass) blade

4.3 Nacelle Mass-Cost Models

Nacelle mass-cost models include individual models for the low speed shaft, main bearing set, gearbox, high speed shaft and brake, generator, bedplate and yaw system as well as an overall nacelle cost model which includes power electronics, overall mainframe, controls, cables, HVAC and nacelle cover.

4.3.1 LowSpeedShaftCost

Class Summary:

class `turbine_costSE.src.nacelle_costsSE.`**`LowSpeedShaftCost`**(*lssMass*, *curr_yr*, *curr_mon*)

   Initial computation of the costs for the wind turbine low speed shaft component.

   Parameters
   lssMass : float

      lss mass [kg]

   curr_yr : int

      Project start year

   curr_mon : int

      Project start month

`update_cost` (*lssMass*, *curr_yr*, *curr_mon*)

   Computes the costs for the wind turbine low speed shaft component. Component costs are based on mass vs. cost relationships derived from drivetrain component cost and mass data of the NREL cost and scaling model.

   Parameters
   lssMass : float

      lss mass [kg]

   curr_yr : int

      Project start year

   curr_mon : int

      Project start month

4.3.2 MainBearingsCost

Class Summary:

class `turbine_costSE.src.nacelle_costsSE.`**`MainBearingsCost`**(*bearingsMass*, *curr_yr*, *curr_mon*)

   Initial computation of the costs for the wind turbine maing bearings.

Parameters
    bearingsMass : float

        bearing mass [kg]

    curr_yr : int

        Project start year

    curr_mon : int

        Project start month

4.3.3 GearboxCost

Class Summary:

class `turbine_costSE.src.nacelle_costsSE.`**`GearboxCost`**(*gearboxMass*, *iDesign*, *curr_yr*, *curr_mon*)

    Initial computation of the costs for the wind turbine gearbox component.

    Parameters
        gearboxMass : float

            gearbox mass [kg]

        iDesign : int

            machine configuration 1 conventional, 2 medium speed, 3 multi-gen, 4 direct-drive

        curr_yr : int

            Project start year

        curr_mon : int

            Project start month

4.3.4 HighSpeedShaftCost

Class Summary:

class `turbine_costSE.src.nacelle_costsSE.`**`HighSpeedShaftCost`**(*mechBrakeMass*, *curr_yr*, *curr_mon*)

    Initial computation of the costs for the wind turbine mechanical brake and HSS component.

    Parameters
        mechBrakeMass : float

            mechBrake mass [kg]

        curr_yr : int

            Project start year

        curr_mon : int

            Project start month

4.3.5 GeneratorCost

Class Summary:

class `turbine_costSE.src.nacelle_costsSE.`**`GeneratorCost`**(*generatorMass*,   *iDesign*,   *curr_yr*, *curr_mon*)

    Initial computation of the costs for the wind turbine generator component.

        Parameters

            generatorMass : float

                generator mass [kg]

            iDesign : int

                machine configuration 1 conventional, 2 medium speed, 3 multi-gen, 4 direct-drive

            curr_yr : int

                Project start year

            curr_mon : int

                Project start month

4.3.6 BedplateCost

Class Summary:

class `turbine_costSE.src.nacelle_costsSE.`**`BedplateCost`**(*bedplateMass*,   *curr_yr*,   *curr_mon*)

    Initial computation of the costs for the wind turbine bedplate component.

        Parameters

            bedplateMass : float

                bedplate mass [kg]

            curr_yr : int

                 Project start year

            curr_mon : int

                Project start month

4.3.7 YawSystemCost

Class Summary:

class `turbine_costSE.src.nacelle_costsSE.`**`YawSystemCost`**(*yawSystemMass*,   *curr_yr*,   *curr_mon*)

    Initial computation of the costs for the wind turbine yaw system.

        Parameters

            yawSystemMass : float

                yawSystem mass [kg]

            curr_yr : int

Project start year

curr_mon : int

Project start month

4.3.8 NacelleSystemCost

Class Summary:

class `turbine_costSE.src.nacelle_costsSE.`**`NacelleSystemCost`**(*lssMass, bearings-Mass, gearboxMass, mechBrakeMass, generatorMass, bedplateMass, yawSystemMass, machineRating, iDesign, offshore, curr_yr, curr_mon, crane=False*)

Initial computation of the costs for the wind turbine gearbox component.

Parameters

lssMass : float

Low speed shaft mass [kg]

bearingsMass : float

bearing mass [kg]

gearboxMass : float

Gearbox mass [kg]

mechBrakeMass : float

High speed shaft mass [kg]

bedplateMass : float

Bedplate mass [kg]

yawSystemMass : float

Yaw system mass [kg]

MachineRating : float

Machine rating for turbine [kW]

iDesign : int

machine configuration 1 conventional, 2 medium speed, 3 multi-gen, 4 direct-drive

offshore : bool

boolean true if it is offshore

curr_yr : int

Project start year

curr_mon : int

Project start month

crane : bool

> boolean for crane present on-board

4.4 Tower Mass-Cost Model

Tower mass-cost models include the mass to cost model of the tower component.

4.4.1 TowerCost

Class Summary:

class `turbine_costSE.src.tower_costSE.`**`TowerCost`**(*towerMass*, *curr_yr*, *curr_mon*)
> Initial computation of the costs for the wind turbine tower component.

> > **Parameters**
> > **towerMass** : float
> >
> > > mass [kg] of the wind turbine tower
> >
> > **curr_yr** : int
> >
> > > Project start year
> >
> > **curr_mon** : int
> >
> > > Project start month

4.5 Overall Turbine Mass-Cost Model

Turbine mass-cost models take mass for all major components of the turbine and compute overall turbine cost.

4.5.1 TurbineCost

Class Summary:

class `turbine_costSE.src.turbine_costSE.`**`TurbineCost`**(*bladeMass*, *bladeNum*, *hubMass*, *pitchSystemMass*, *spinnerMass*, *towerMass*, *lssMass*, *bearingsMass*, *gearboxMass*, *hssMass*, *generatorMass*, *bedplateMass*, *yawSystemMass*, *machineRating*, *iDesign*, *offshore*, *curr_yr*, *curr_mon*, *crane*, *advanced*)

> Initial computation of the costs for the wind turbine.

> > **Parameters**
> > **bladeMass** : float
> >
> > > blade mass [kg]
> >
> > **bladeNum** : int
> >
> > > Number of blades on rotor

hubMass : float

　　hub mass [kg]

pitchSystemMass : float

　　pitch system mass [kg]

spinnerMass : float

　　spinner mass [kg]

lssMass : float

　　Low speed shaft mass [kg]

bearingsMass : float

　　bearing mass [kg]

gearboxMass : float

　　Gearbox mass [kg]

mechBrakeMass : float

　　High speed shaft mass [kg]

bedplateMass : float

　　Bedplate mass [kg]

yawSystemMass : float

　　Yaw system mass [kg]

MachineRating : float

　　Machine rating for turbine [kW]

iDesign : int

　　machine configuration 1 conventional, 2 medium speed, 3 multi-gen, 4 direct-drive

offshore : bool

　　boolean true if it is offshore

towerMass : float

　　mass [kg] of the wind turbine tower

curr_yr : int

　　Project start year

curr_mon : int

　　Project start month

crane : bool

　　boolean for crane present on-board

advanced : bool

　　boolean for advanced (using carbon) or basline (all fiberglass) blade

4.6 PPI Index Calculations

All of the above mass-cost models use a Price Producer Indices (PPIs) to scale the costs from a reference year and month (typically September 2002). The PPI class is imported by all the above models through the config file.

4.6.1 PPI

Class Summary:

class turbine_costSE.src.csmPPI.**PPI** (*ref_yr*, *ref_mon*, *curr_yr*, *curr_mon*, *debug=0*)
Initialize the PPI class for calculation of PPI indices given a referene year/month and current year/month.

> **Parameters**
> **ref_yr** : int
>
> > reference PPI year
>
> **ref_mon** : int
>
> > reference PPI month
>
> **curr_yr** : int
>
> > current PPI year
>
> **curr_mon** : int
>
> > current PPI month

compute (*escCode*, *debug=0*)
Returns the cost escalator for escData object 'escCode', using reference and current yr/mon values.

> **Parameters**
> **escCode** : object
>
> > codes for different PPI data
>
> **Returns**
> **esc** : float
>
> > cost escalator for a particular PPI from reference year/month to current year month

THEORY

The theory for the models in this software are based directly on the work described in references [1], [2], [3], [4], and [5]. This section provides an overview of the development of these simple cost models for the major hub and drivetrain components.

The NREL Cost and Scaling Model [1] provides a simple cost and sizing tool to estimate wind turbine component masses and costs based on a small number of input parameters such as rotor diameter, hub height and rated power. The model was developed over several results following the Wind Partnerships for Advanced Component Technology (WindPACT) work that occurred between roughly 2002 to 2005 [2]. The original form of the cost model was based on an earlier model from 1993 out of the University of Sunderland (the Sunderland Model) [3]. The Sunderland Model created a set of wind turbine models to estimate the mass and cost of all major wind turbine components including: blade, hub system [hub, pitch system, and nose cone], nacelle [low speed shaft, main bearings, gearbox, high speed shaft/mechanical brake, generator, variable speed electronics, electrical cabling, mainframe [bedplate, platforms and railings, base hardware, and crane], HVAC system, controls, and nacelle cover], and tower. The Sunderland model was based on a set of semi-empirical models for each component which estimated design loads at the rotor, propagated these loads through the entire system, and used the loads to estimate the size of each component calibrated to data on actual turbines in the field during that time. Cost estimates were then made on a per weight basis using a multiplier again based on field data or industry sources.

To arrive at the NREL Cost and Scaling Model, the WindPACT studies began in many cases with the Sunderland model and updated the results with new coefficients or, in some cases, with entirely new cost equations based on curve fits of key design parameters (rotor diameter, etc) to the results of detailed design studies [4]. In addition, the WindPACT work established estimates of costs associated with balance of station and operations and maintenance for a fictitious wind plant in North Dakota which led to an overall cost of energy model for a wind plant. The key cost of energy equation for a wind plant is given in the NREL Cost and Scaling Model [1] as:

$$COE = (FCR * (BOS + TCC))/AEP + (LLC + LRC + (1 - tr) * OM)/AEP$$

where COE in this equation is a simple estimate of a wind plant cost of energy, FCR is the fixed charge rate for the project, BOS are the total balance of station costs for the project, TCC are the total turbine capital costs for the project, AEP is the annual energy production for the project, LLC are the annual land-lease costs, LRC is the levelized replacement cost for major part replacement, tr is the tax rate, and OM are the annual operations and maintenance costs which are tax deductible.

While the NREL Cost and Scaling Model improved the overall cost estimation for larger turbines on the order of 1 MW+, it abstracted away from the engineering analysis foundations of the original Sunderland model. This is depicted in the below figure where it can be seen that the engineering-analysis has been replaced by a series of curve fits which relate a small number of design parameters to mass and cost estimates for major wind turbine components.

The resulting NREL Cost and Scaling Model allows for a variety of interesting analyses including scaling of conventional technology from under a MW to 5 MW+, assessing impact of trends in input factors for materials and labor on wind plant cost of energy, etc. However, it does not preserve the underlying engineering relationships of the original Sunderland model and thus loses some fidelity of assessing how design changes may impact system costs.
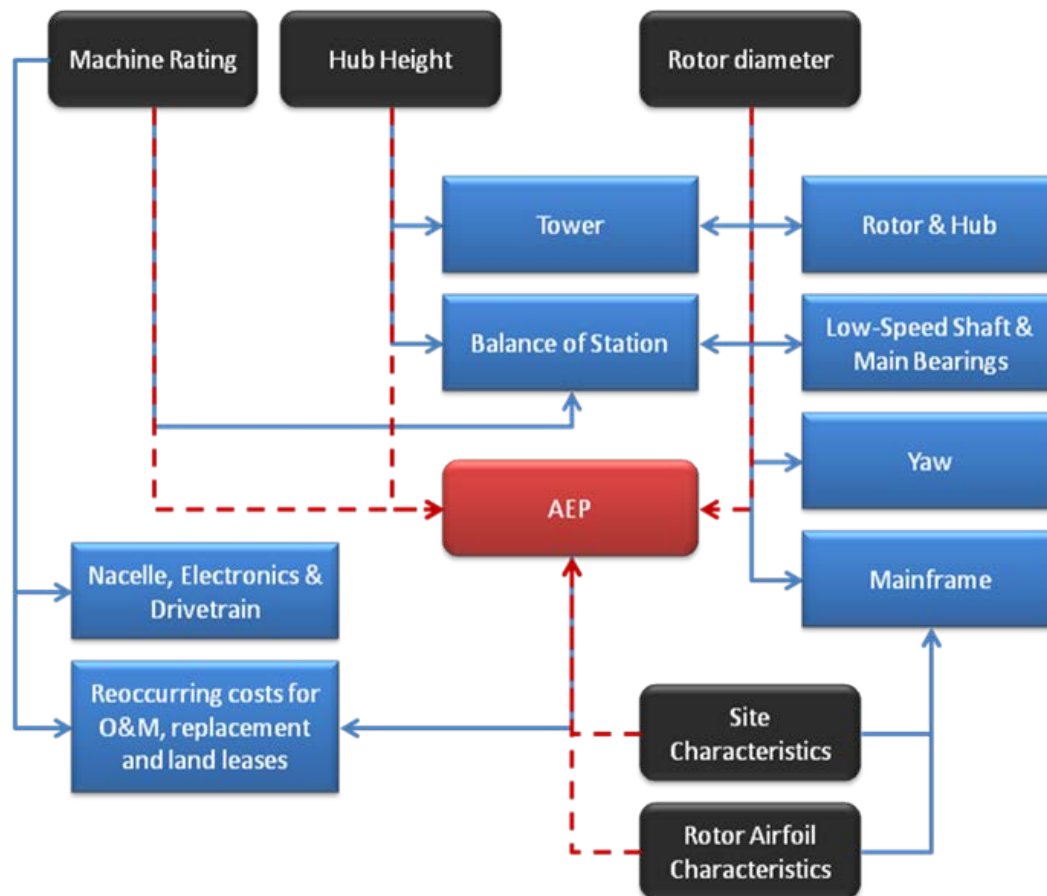
Figure 5.1: NREL Cost and Scaling Model Key Input-Output Relationships.

The goal of the development of the following set of models for the hub and nacelle are to return to the mass-based component cost calculations of the original Sunderland Model. A mass-cost model is developed for each of the major hub and drivetrain component. These use the NREL Cost and Scaling Model data to estimate relationships that can then be scaled based on economic multipliers as done in [1]. Details of the models are described next.

5.1 Turbine Component Mass-Cost Models

A set of models based on the NREL Cost and Scaling model data have been developed to produce relationships of mass-to-cost for all major wind turbine components [1]. These in many cases supplant the NREL Cost and Scaling model cost equations for wind turbine components which are often based on a small selection of design parameters such as rotor diameter, hub height and rated power. The set of wind turbine mass-to-cost models developed include the components: blade, hub system [hub, pitch system, and nose cone], nacelle [low speed shaft, main bearings, gearbox, high speed shaft/mechanical brake, generator, variable speed electronics, electrical cabling, mainframe [bedplate, platforms and railings, base hardware, and crane], HVAC system, controls, and nacelle cover], and tower. In addition, a mass-to-cost model for offshore monopile foundations has been established based on the new NREL Balance of Station Model [2]. This section will describe the mass-to-cost models each of the major wind turbine components.

Blades: The new NREL blades mass-cost model is based on the data of the NREL Cost and Scaling Model which was acquired via the WindPACT design studies efforts [3]. The data for the blade costs in particular stem from the "WindPACT Turbine Rotor Design Study" [4] as well as the "Cost Study for Large Wind Turbine Blades: WindPACT Blade System Design Studies" [6]. The equation for blade costs includes both materials and manufacturing. The NREL Cost and Scaling Model has built in escalators to update labor and material input cost factors based on cost trends over time. The model here is reduced to a cost model relationship dependent only on mass as is consistent with the full set of mass-to-cost models. A graph of the relationships for mass-to-cost from the WindPACT study data based on 2002 USD is shown below.

Hub System:

The cost model for the hub and spinner components are already based on a mass-to-cost relationship and so no adaptation is needed. For the pitch system, a new mass-to-cost relationship based on the WindPACT study [4] appendix C for bearing data. The costs are escalated as described in the NREL Cost and Scaling Model.

The mass-cost model for the pitch system was built using the equation as presented on the above figure mutliplied by a factor of 2.28 to account for the pitch system housing as was done in the NREL Cost and Scaling Model.

Drivetrain and Nacelle:

The major components of the low-speed shaft, gearbox, yaw drive and mainframe were adapted to a mass-cost relationship based on data from the WindPACT study [4]. The relationship for the main bearings was already mass-based though it had to be divided by a factor of 4 to account for the change in mass estimates from the Sunderland Model. The relationship for the mechanical brake was an inverse mass-to-cost relationship where the mass was derived by cost by a division of 10 [2]. This was adapted to a multiplier of 10 for the mass-cost model. The generator cost model is as described in [3] but the costs were updated to the mass-cost relationship of $65/kg as described in [4]. Mass-cost models for rest of the nacelle components could not be made since there is either a lack of data on individual masses and/or costs for such components. All costs are escalated as described in the NREL Cost and Scaling Model.

The mass-cost models for the components above were built using the equations as presented in the above figures.

Tower:

The NREL tower mass-cost model is identical to the NREL Cost and Scaling Model tower cost model since the model was already based on a mass-to-cost relationship.

Foundation:

The new NREL foundation mass-cost model is based on the new NREL Offshore Balance of Station Model [7]. While the model software can be used directly to calculate foundation costs for a variety of offshore configurations, it also calculates the mass of those foundations. It desirable for a number of analyses to determine the monopile mass directly
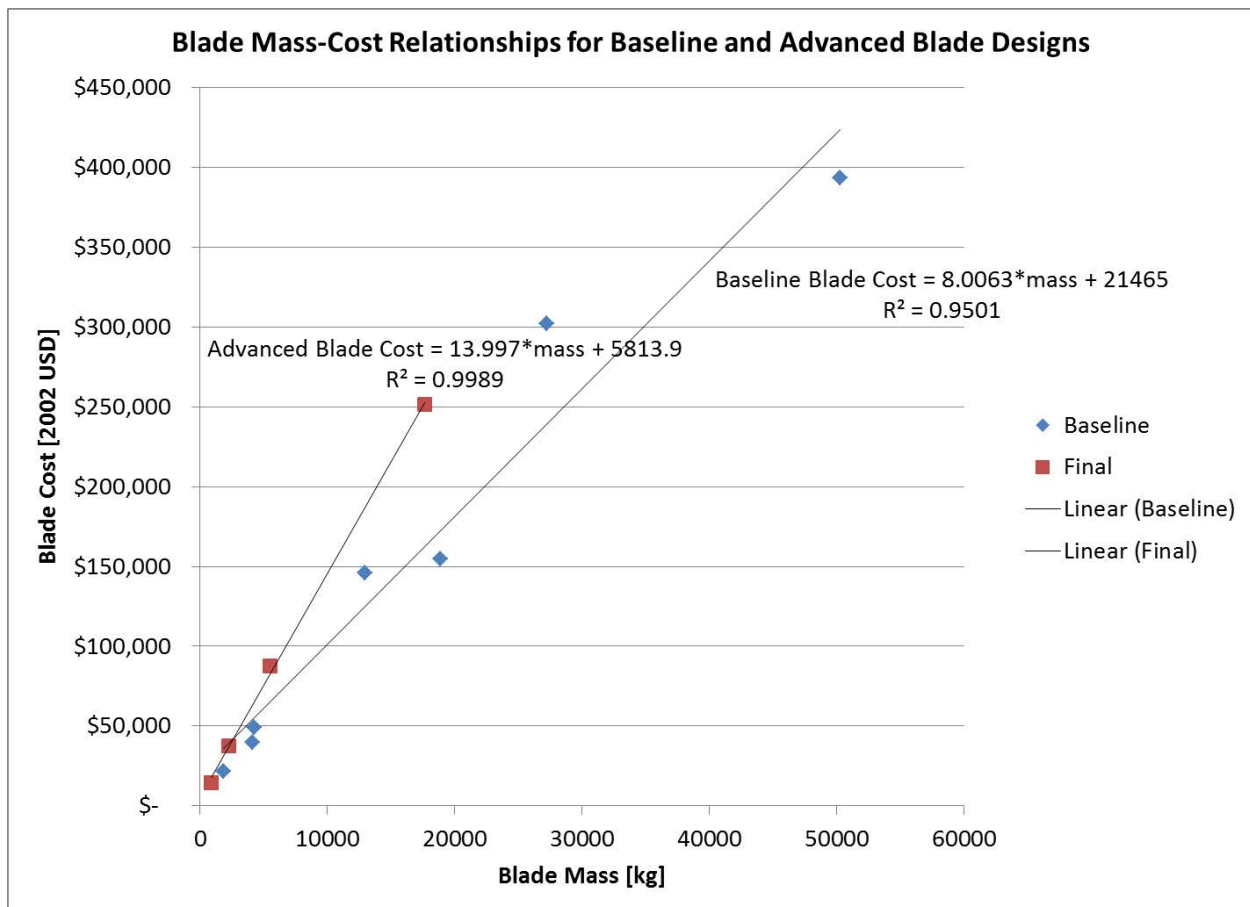
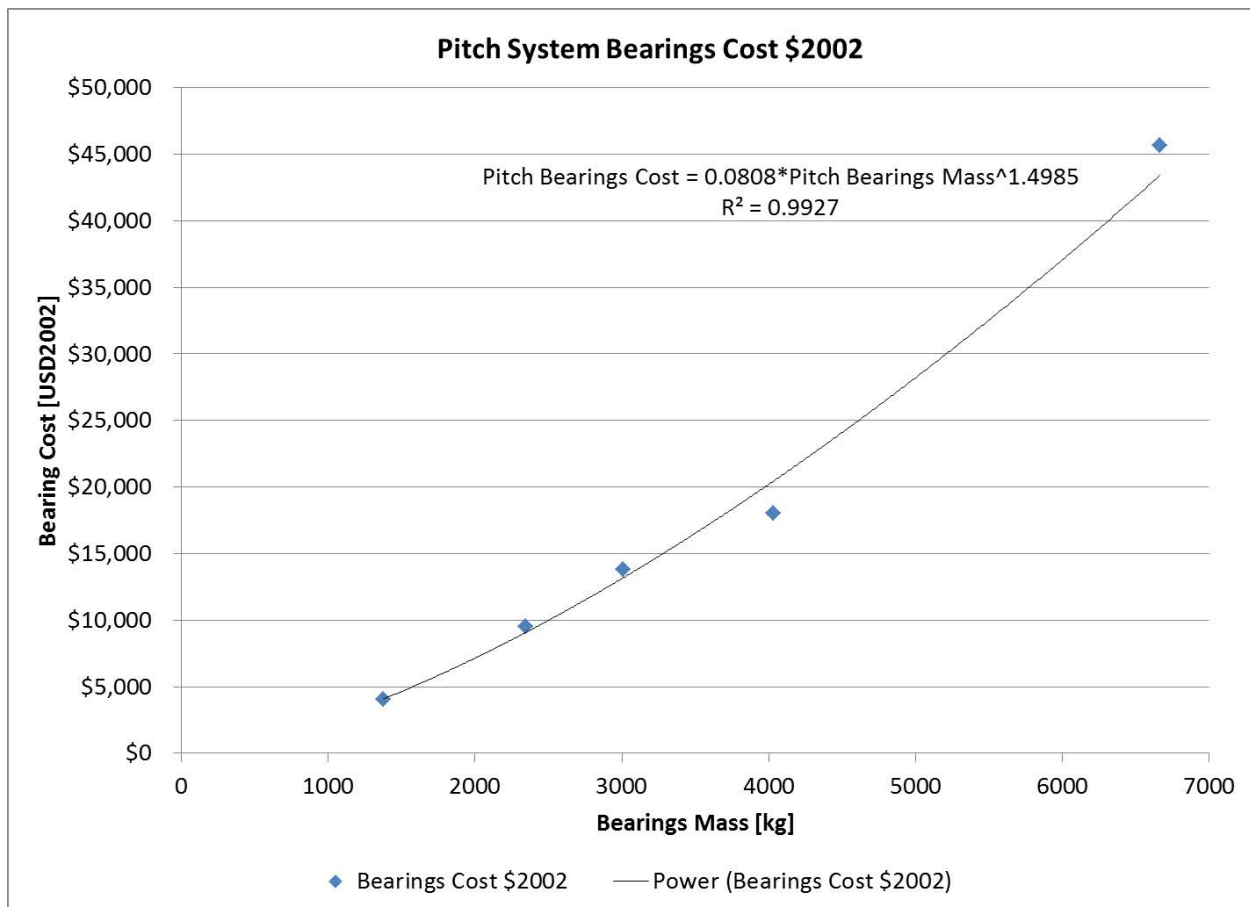Figure 5.2: Blade mass-cost relationship based on NREL Cost and Scaling Model.

Figure 5.3: Pitch system mass-cost relationship based on NREL Cost and Scaling Model.
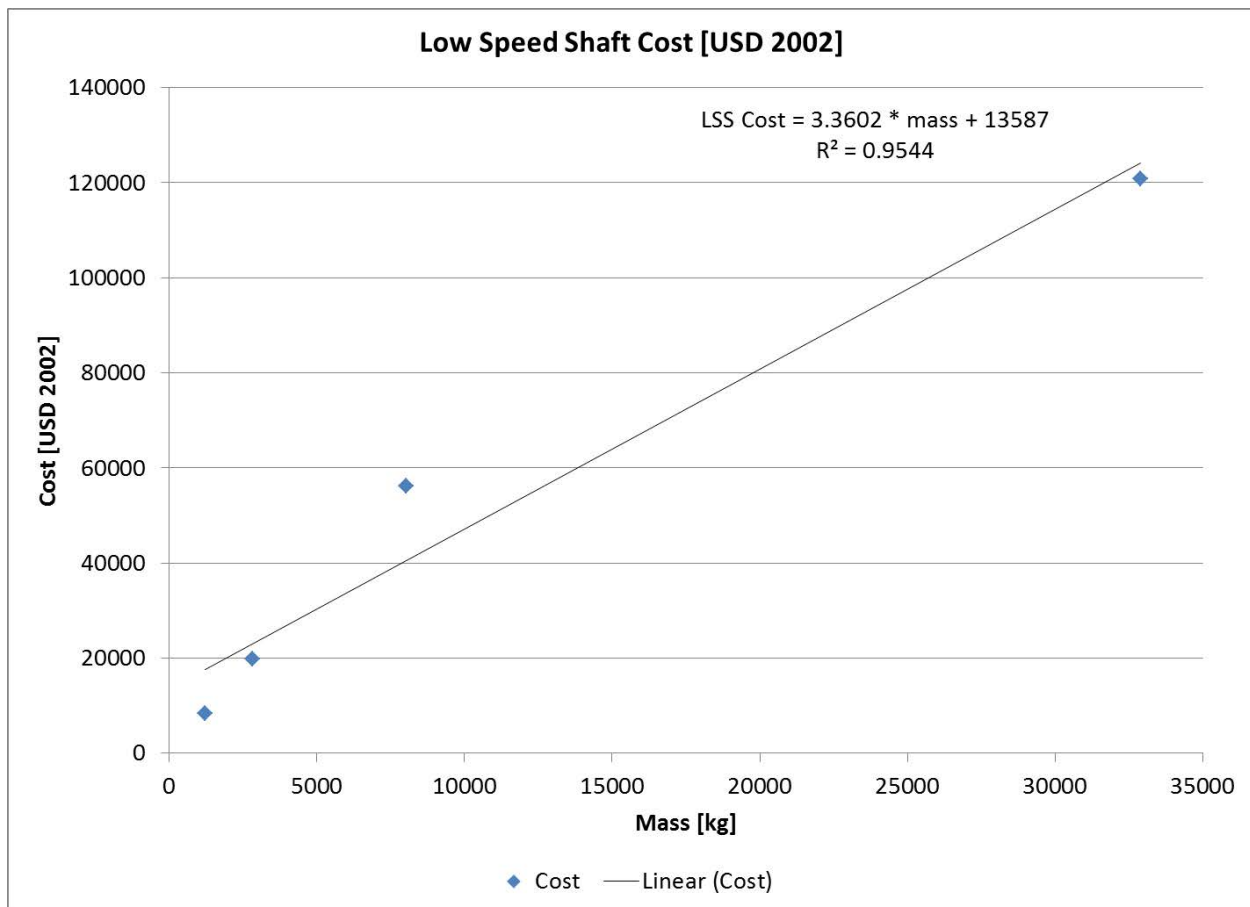
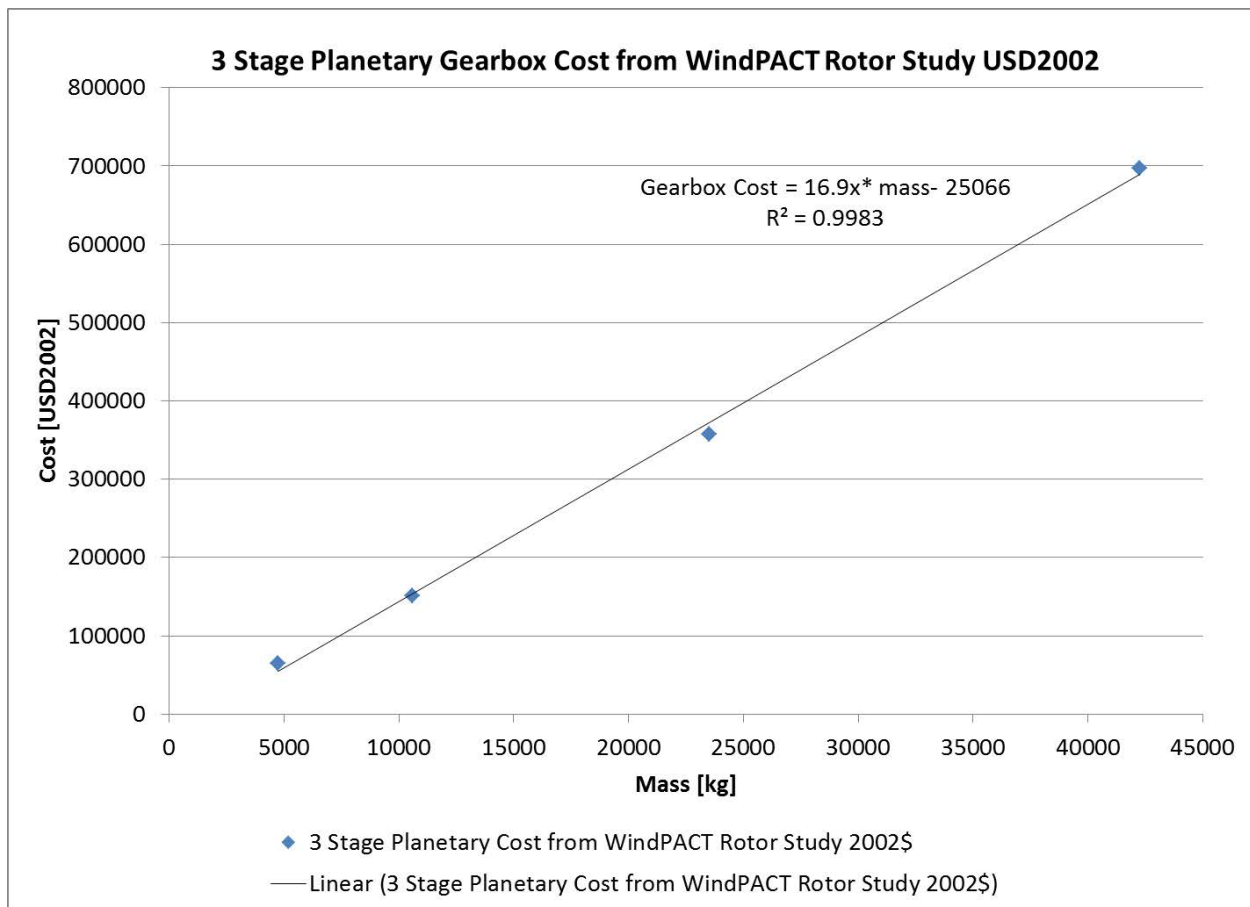Figure 5.4: LSS mass-cost relationship based on NREL Cost and Scaling Model.

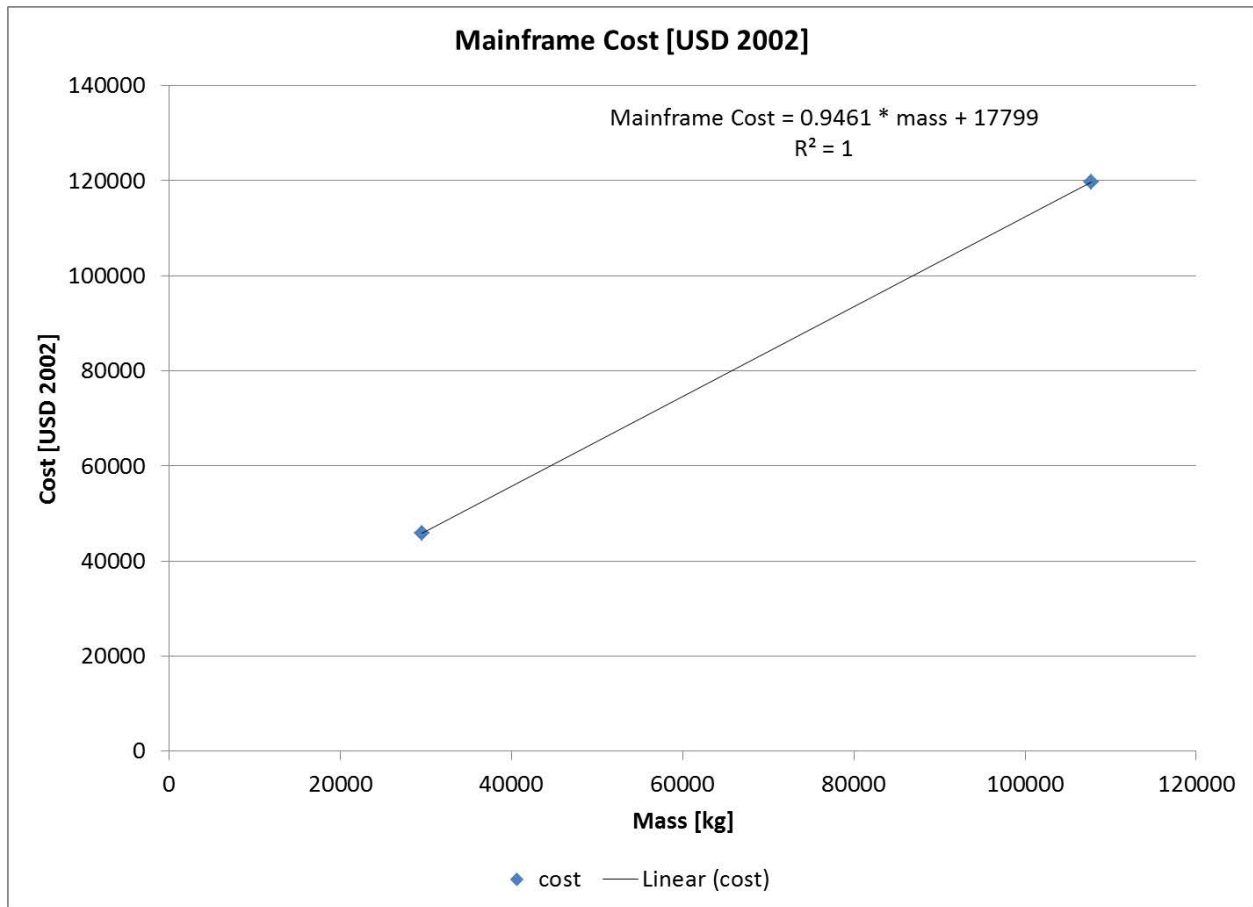Figure 5.5: Gearbox mass-cost relationship based on NREL Cost and Scaling Model.

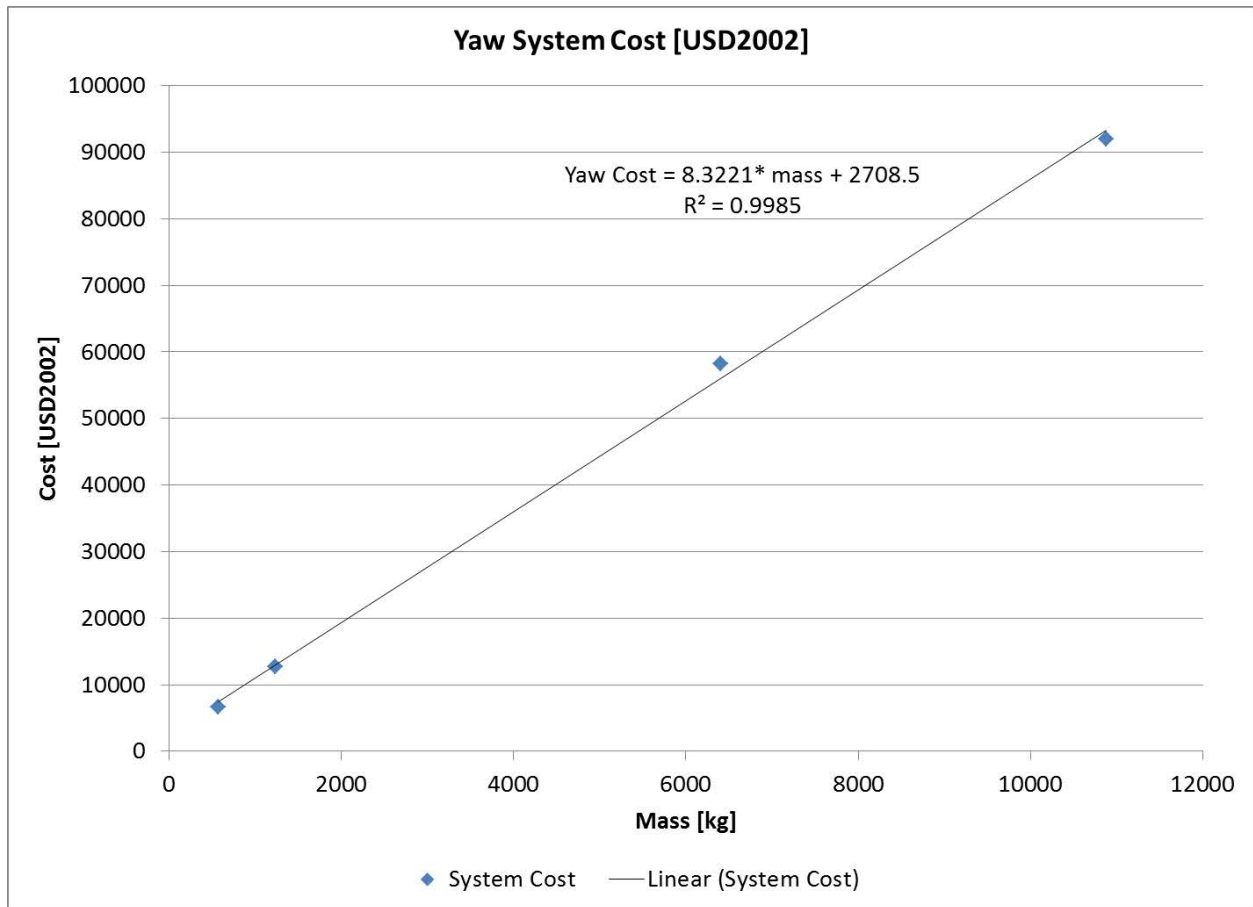Figure 5.6: Mainframe mass-cost relationship based on NREL Cost and Scaling Model.

Figure 5.7: Yaw system mass-cost relationship based on NREL Cost and Scaling Model.

via an engineering-analysis model. Thus, this model extracts the foundation cost model (as described in [7]) so that it can calculate the cost of a monopile foundation directly from the supplied mass of the monopile and transition pieces. Note that this model is only valid for a monopile type of foundation. If this model is used in conjunction with the NREL Offshore Balance of Station Model, care must be taken not to double count the foundation cost.

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