2010 Resource Options Report

BC hydro

Appendix 7

Wind Cost Review Report

GL Garrad Hassan

UPDATED CAPITAL AND O&M COST ASSUMPTIONS FOR WIND POWER DEVELOPMENT IN BRITISH COLUMBIA

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REVISION HISTORY

Issue	Issue date	Summary
A	28.09.10	Original draft issue for discussion (electronic version only)
B	06.10.10	Updated with comments following Client questions.
C	07.10.10	Updated with comments on offshore projects following Client questions.
D	14.11.10	Updated following further Client questions
E	26.11.10	Final issue

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1 INTRODUCTION

In February 2008, GH provided BC Hydro with a report entitled "Assessment of the energy potential and estimated costs of wind energy in British Columbia" (GH reference 38094/OR/01 version E Final) (the "Report"). In the Report, GH undertook a high-level assessment of the potential energy that could likely be harnessed by wind power and also estimated the likely cost ranges of the power in different regions of the province. This report was used by the Client in their 2008 Long-Term Acquisition Plan (LTAP) filed with the BC Utilities Commission in 2008.

The Client is currently updating this planning process through the 2011 Integrated Resource Plan, which will be filed with the Government of British Columbia in November 2011. While BC Hydro has indicated that they intend to fulfil the energy assessment portion of the 2008 report on a project-specific basis with data acquired in a comprehensive wind data study completed in 2009, the Client would like GH to update the cost assumption portions of the Report with capital and O&M cost data which are reflective of 2010/2011 market conditions.

The Client has advised that the project assumptions of the Report will remain unchanged; therefore, GH shall consider the likely cost of development in the BC market based upon experience of recent project costs in the North American market, and will provide updated cost assumptions for the tables related to onshore and offshore cost assumptions that appear in Sections 3.1.1. and 3.1.2 of the Report. The data shall be provided for Base Case (average) and High Case for sensitivity testing.

In addition to the Client's request to update the cost tables of the Report, GH has been requested to provide an estimate of energy loss factors that are typically experienced at offshore wind farms and example costs for offshore wind farms in 5 m to 35 m water depth using monopile or jacket foundation technology.

2 ENERGY COST ASSESSMENT

It is important to note that capital and operations and maintenance (O&M) costs and can be expected to vary significantly for individual wind farm projects. GH has attempted to address this within the analysis through consideration of a sensitivity analysis of the range of costs. The data shall be provided for Base Case (average) and High Case for sensitivity testing. GH has not been requested to provide an updated cost estimate model.

2.1 ONSHORE COST ASSUMPTIONS

GH has considered the likely cost of wind farm development and construction in the BC market, based upon experience of onshore project costs in the North American market. This includes experience from due diligence on over 1,000 MW of onshore projects built in Canada between 2008 and 2010.

2.1.1 Onshore capital cost assumptions

The updated onshore capital cost assumptions are listed in the tables below in Canadian 2010 Dollars (000s). It should be noted that the grouping of costs of the various categories varies between wind farm developers. Since the issue of the Report, GH has noted that development costs are likely to vary within a large range, depending on the work that is required to bring the project to the point of construction. This has resulted in some wind farm developers including a large number of detailed individual cost categories or alternatively grouping CAPEX costs under generic categories. For example, site studies and investigations, energy assessment, land acquisition costs may be listed separately or grouped into one all encompassing 'Development' cost.

Table 2-1 presents general project development costs which could be included in the onshore construction table by some onshore wind project developers:

Category	Base	High	Comment
Development	$ 1,600	$ 3,800	Includes engineering design, investigation, land acquisition and site studies. It is noted that in British Columbia wind farms tend to be developed on Crown Land; however, it was not possible to exclude land acquisition from this cost range
Project SCADA	$ 300	$ 540	This cost range applies to third party SCADA which an Owner may choose to purchase. Typically the OEM SCADA is included in the TSA price.
Connection Charge	$ 1,520	$ 3,120	Dependent location of wind farm and Utility

Table 2-1: Project Development Costs (in CAN $ 000s)

Table 2-2 presents unit costs associated with onshore wind farms and normalised per wind turbine.

Category	Base	High	Comment
Project Management	$ 65	$ 115	1-3% of total CAPEX; dependent on contracting strategy
Turbine Transformer (pad mount)	$45	$60	Typically included in BoP contract unless turbine transformer is up tower (i.e. Vestas V90) in which case this cost would be included in the total TSA price.
Turbine Foundation	$ 350	$ 550	
Crane Pad and Laydown	$ 25	$ 90	
On-site collection system	$250	$380	
Roads (on site and public)	$ 110	$ 296	May include public road and reinstatement costs
Public Roads, Culverts, Reinstatement etc	$ 5	$ 75	Subset of Roads
Communication	$ 5	$ 30	

Table 2-2: Project Construction Costs (in CAN $,000s per Wind Turbine)

Table 2-3 presents financial costs associated with onshore wind farms normalised by MW capacity:

Category	Base	High	Comment
Substation	$ 78	$ 155	Costs will vary depending on the number of substations required for the project
Insurance	$ 5	$ 15	Typically between 1% and 3% of total construction cost
Advisers	$ 30	$ 70	This costs may be included under a generic 'development' cost category
Turbine (total TSA price)	$ 1,480	$ 1,990	Typically Siemens has included both transportation and installation in the TSA price. Other turbine manufacturers do not provide erection services. Transportation charges for OEMs, other than Siemens, typically include both sea and ground transportation to either a lay-down area or the actual turbine location. These costs are dictated in the TSA and often subject to negotiation.
Turbine Transport	$ 110	$ 200	If in addition to the TSA transportation scope i.e. a requirement to move the turbines from a lay-down yard to the actual turbine location
Turbine Installation	$ 50	$ 130	Per comments above, this cost would be reflected in the BoP contract.

Table 2-3: Project Financial Costs (in CAN $,000s per MW)

2.1.2 Summary of Onshore capital cost assumptions

As an overall guide, GH notes current data suggest a range of total project cost per MW between $2,400k (Base) and $3,100k (High).

2.1.3 Onshore O&M Cost assumptions

Table 2-4 presents financial costs associated with the operations and maintenance (O&M) of onshore wind farms normalised by MWh, and assumes that non routine maintenance starts in year two when the TSA warranty expires:

Category	Base	High	Comment
Maintenance and Service	$ 5.00	$ 7.15	
Non-Routine Maintenance and Service	$ 2.00	$ 9.00	Varies during warranty and post warranty life of project. Depending on issues arising with major components, the cost post warranty could be in the high range of 15k/MWh in some years.
Electrical Usage	$ 0.25	$ 0.60	
Management fees	$ 1.15	$ 3.5	
Insurance	$ 1.00	$ 1.40	
BoP Expenses	$ 1.45	$ 2.60	
Business Rates	$	$	Business rates vary depending on region
General Administration	$0.50	$ 1.55	
Use of System Charges (Transmission)			Dependent on location and Utility.
Bank fees			Determined by Financing Agreement
Land Payments	1%	3%	Cost is typically a percentage of revenue

Table 2-4: Operational cost assumptions (in CAN $ per MWh)

2.2 OFFSHORE CAPITAL COST ASSUMPTIONS

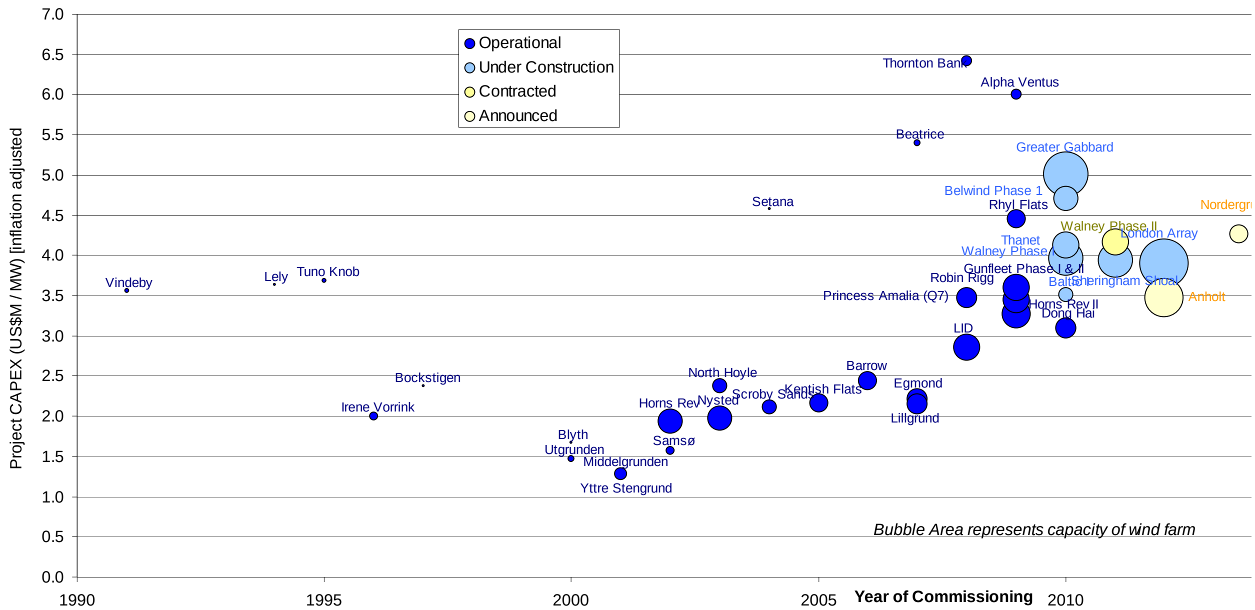
This section presents GH's current understanding of the costs associated with developing, constructing and operating offshore wind farms. It is predominantly based on European experience, where the overwhelming majority of projects to date are located.

Costs are based on a number of sources, the principal being GH's general knowledge of the industry gained through serving project developers, wind turbine manufacturers, investors and other interested parties for two decades now. This has provided the company with unparallel access to understanding the changes that have impacted the industry during this period. In particular, the information presented within this report is based on engineering work undertaken on a number of offshore wind farms, including all-encompassing FEED (Front End Engineering Design) studies, and previous cost studies, such as WindSpeed [2].

In addition, GH has undertaken Due Diligence on between thirty and forty offshore wind assignments over the last three years, predominantly in the pre-construction phase but including a handful of projects under construction or in operation, and a handful of offshore supply chain assignments. The work also covers all the main offshore wind regions of Northern Europe.

This knowledge has been distilled into a number of analysis tools and databases, which have been used to generate parts of this section of the report. However, plausibility checks have also been undertaken, confirming the propositions against original source information.

Figure 2-1 presents a historic record of how the CAPEX costs of offshore wind farms have varied over the last two decades. It is clear that there are significant drivers within and beyond the wind energy industry impacting costs.



Various public sources; converted to $ as per date of publication; adjusted for inflation CAN$

Figure 2-1: Offshore Wind Capital Costs

2.2.1 Offshore capital cost assumptions

The capital costs for offshore wind farms are presented in the set of tables below. This examination is based on:

- GH internal knowledge and experience from working on
  - due diligence of both offshore wind farms and offshore wind supply chain companies;
  - project engineering, such as foundation design, energy yield analyses, electrical studies;
  - offshore wind farm project management.
- Specific databases and tools, in particular
  - Offshore wind CAPEX database
  - Offshore wind farm cost model
    - Comprehensive cost model for offshore wind farms, based on commercial costs, interpolated through engineering analyses

Note that the format of the following set of tables is identical to that used for onshore wind costs presented above, however the distribution between items and project phase differs. For this reason, items have been broken down into sub-categories where it is felt this provides additional illumination.

Where necessary, the costs are based on a medium size of offshore wind farm with characteristics as per Table 2-5:

Parameter	Assumption	Comment
Wind Farm Capacity	100 - 500 MW	Medium sixed wind farm as per 2010
Distance to Shore	20km	Edge of the EEZ (Exclusive Economic Zone; this is the region beyond 12 nautical miles from the coast)
Grid Connection Technology	HVAC	HVDC used for some projected further from shore
Wind Turbine Capacity	Current Technology	i.e. broadly applicable for 3 – 5MW wind turbine models

Table 2-5: Offshore Wind Farm Assumptions

Table 2-6 presents general project development costs, including the substation costs, which could be included in the offshore construction table by some offshore wind project developers:

Category	Base	High	Comment
Development			
Project Development	$ 4,000	$ 10,000	Including planning application, stakeholder meetings, company internal costs etc.
Engineering Studies	$ 2,000	$ 3,000	Including Conceptual Design / FEED; detailed engineering assumed to be undertaken by contractors
Site Studies			
Meteorological Mast	$ 3,000	$ 5,000	Single seabed mounted, hub-height met mast
Environmental Surveys	$ 250	$ 1,000	Bird, mammals, benthos etc.
Geophysical Site Investigations	$ 500	$ 1,000	Bathymetry, sonar etc.
Geotechnical Site Investigations	$ 5,000	$ 20,000	Borehole, CPTs
Project SCADA	-	-	Included in wind turbine and substation CAPEX

Category	Base	High	Comment
Connection Charge	$ 0	$ 10,000 +	Dependent on country and location; under certain jurisdictions, grid connection is provided at no cost to the wind farm
Project Management	$ 20,000	$ 60,000	1-3% of total CAPEX; dependent on contracting strategy
Substation			
Offshore Substation Structure	$ 1,000	$ 10,000	Per substation: monopile / jacket
Offshore Substation Plant	-	-	See Table 2-7
Offshore Substation Installation	$ 500	$ 30,000	Per substation: support structure and topside
Onshore Substation	-	-	See Table 2-7

Table 2-6: Project Development Costs (in CAN $,000s)

Table 2-7 presents unit costs associated with the wind farm and normalised per MW.

Category	Base	High	Comment
Project Management			See Table 2-6
Turbine Transport			Included in procurement and installation
Turbine Installation	$ 200	$ 400	Historically highly volatile
Turbine Procurement	$ 2,000	$ 2,500	
Turbine Transformer			Included in procurement
Turbine Foundation			
Procurement	$ 1,000	$ 2,000	
Installation	$ 250	$ 500	Historically highly volatile
Crane Pad and Laydown			Not applicable offshore
Public Roads, Culverts, Reinstatement etc			Not applicable offshore
Communication			Included in procurement

Category	Base	High	Comment
Offshore Substation Plant	$ 50	$ 250	Dependent on grid code requirements, export cable length and export technology type: HVAC or HVDC in particular
Onshore Substation Plant	$ 10	$ 250	Dependent on grid code requirements, export cable length, export technology type: HVAC or HVDC, voltage of grid and connection in particular

Table 2-7: Project Construction Costs (in CAN $,000s per MW)

Table 2-8 presents financial costs associated with offshore wind farms:

Category	Base	High	Comment
Insurance	1.5%	2%	of total CAPEX
Advisers			Negligible in projects of this size
Turbine			See Table 2-7 above

Table 2-8: Project Financial Costs

Finally Table 2-9 presents cable procurement and installation costs:

Category	Base	High	Comment
Site Roads			Not applicable offshore
On-site collection (array cables)			
Array Cable Procurement	$250	$350	Assuming 33kV
Array Cable Installation	$500	$750	

Category	Base	High	Comment
Transmission Line (export cable)			
Offshore Cable Procurement	$700	$1,000	Dependent on capacity and voltage
Offshore Cable Installation	$600	$900	
Onshore Cable Procurement	$400	$500	
Onshore Cable Installation	$300	$400	

Table 2-9: Project Construction Costs (in CAN $,000s per km)

2.2.2 Offshore O&M cost assumptions

Offshore wind farm operational costs have experienced similar rises as the CAPEX shown in Figure 2-1, however there is limited data in the public domain. Certainly, the relatively low OPEX costs contracted for the first Round 1 wind farms off the British coast are no longer being achieved and hence cannot be considered as evidence.

Category	Base	High	Comment
All Maintenance (Routine and Non-Routine)	$ 75,000	$ 150,000	Per MW (annual); including non-routine; dependent on distance to shore, wave climate, turbine size and wind farm O&M strategy amongst other factors
	$ 20	$ 30	Equivalent per MWh value (rounded); dependent on energy yield
Non-Routine Maintenance			In the order of 50% of total maintenance, however higher if routine maintenance schedule is insufficient
Electrical Usage	0.5%	1%	Of generation, higher if wind farm suffers from poor availability
Management fees			As onshore
Insurance	0.7%	1%	Of income; alternatively self insurance may be an option for many large wind farm owners
BoP Expenses			Included in Wind Farm Routine and Non-Routine Maintenance
Business Rates			Generally not applicable for offshore wind farm
General Administration			As onshore
Use of System Charges			As onshore

Category	Base	High	Comment
Bank fees			As onshore
Land Payments			Generally not applicable, the Crown Estate in the United Kingdom being an exception

Table 2-10: Operational cost assumptions (CAN $ or %)

2.2.3 Typical loss factors for offshore wind farms

Table 2-11 presents energy loss factors that are typically experienced at European offshore wind farms. Note that wake array losses and wind turbine availability losses are typically higher than for onshore wind farms.

Category	Base	High	Comment
Wake array losses	10%	15%	
Neighbouring Wind Farm losses	0%	5%	Dependent on presence and distance to neighbouring wind farms; higher figure if neighbours directly adjacent
Electrical System Losses			
Array cable losses	1%		
Offshore transformer losses	1%		Not applicable if metering takes place offshore
Export cable losses	1%		Not applicable if metering takes place offshore
Wind Turbine Availability losses	6%	10%	Wide range has been recorded at offshore wind farms
Balance of Plant Availability losses	1%	3%	Dependent on levels of redundancy of offshore transformer and export cable
Blade contamination ./ performance degradation	0.5%		
High Wind hysterises	0.5%		
Project power Consumption	0.5%	1%	

Table 2-11: Typical Loss Factors for Offshore Wind Farms

2.2.4 Cost escalation factor based on water depth

In terms of offshore wind turbine foundation technology, Figure 2.1 shows that one type of technology has dominated: the monopile, and will continue to do so for the immediate years. Use of monopile is restricted to smaller turbines models in shallow waters, however that envelop covers the majority of the most promising projects currently under development. The deeper waters of the further reaches of the German Bight as well as the United Kingdom Round 3 projects are likely tor require jacket foundations, or similar, with an associated increase in cost. It may be possible to extend the envelop range for monopiles further, however costs will remain significant and the principal advantage will be a simple, easy to fabricate, and relatively low risk technology, the current grout connection issue notwithstanding.

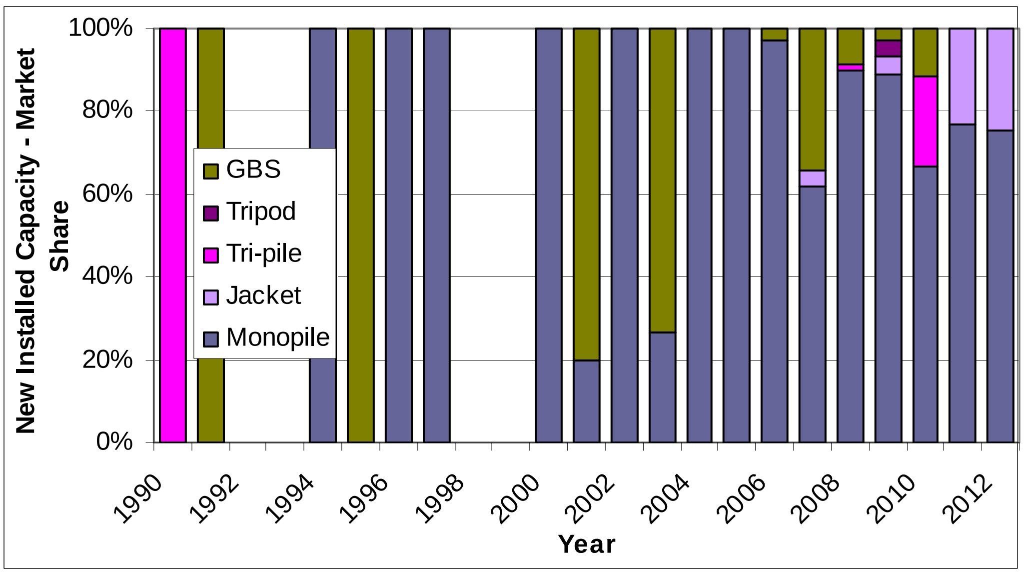
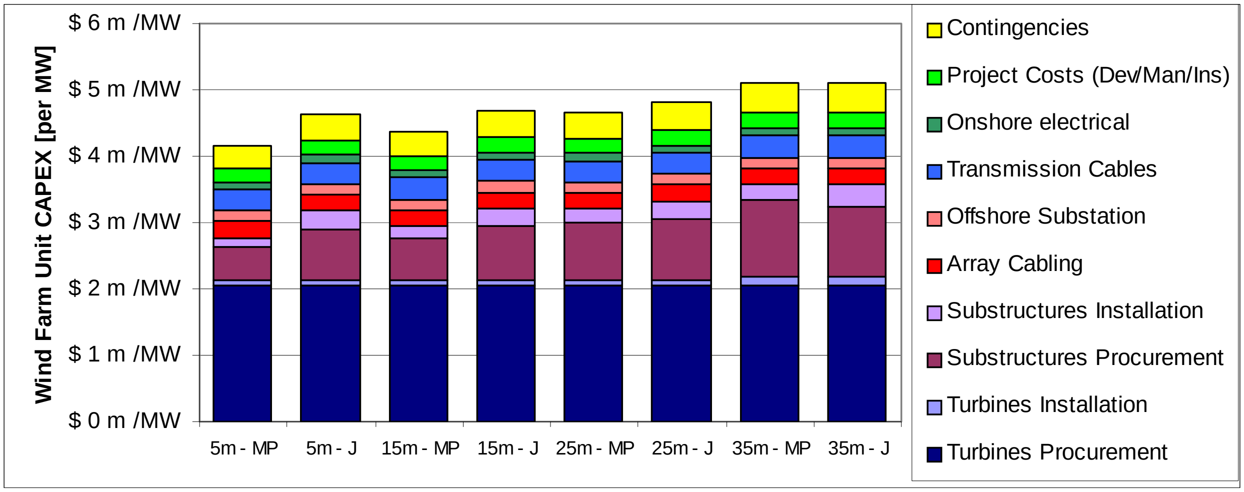


Figure 2-2: Evolvement of Offshore Wind Farm Technology Deployed – Foundations

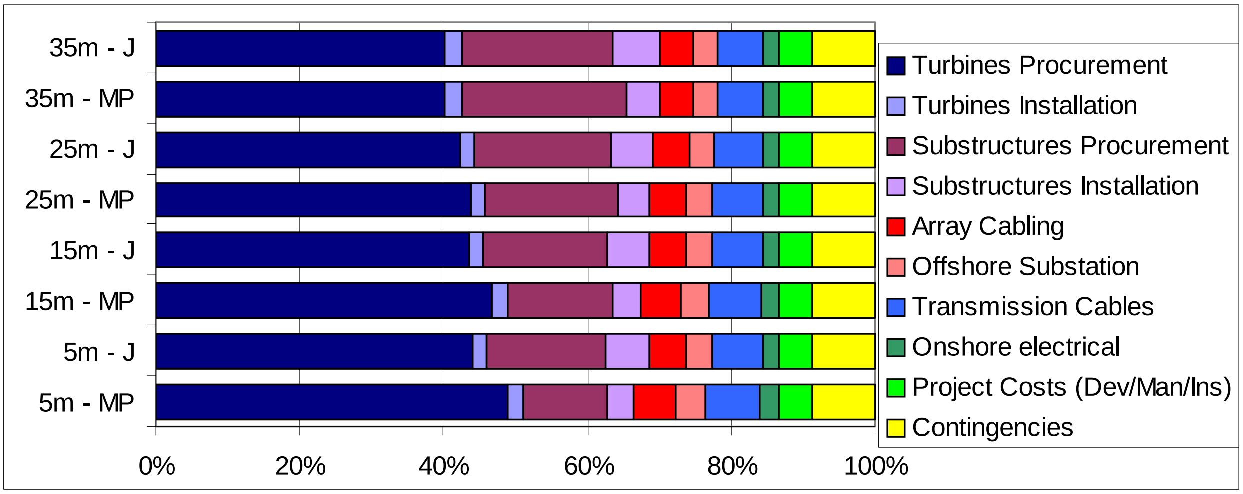
The following Figure 2-3 presents example costs for offshore wind farms in 5 m to 35 m water depth using monopile or jacket foundation technology. The cross-over between lowest cost option based on the assumptions within this scenario is apparently at 35m water depth but this is highly sensitive to wind turbine model, ground conditions and appetite and confidence of foundation fabricator to win and deliver the work. The charts are generated by GH's Offshore Wind Farm Cost Model but can be considered broadly representative of the current climate.



MP = monopile; J = jacket; water depth from 5 m through to 35 m CAN$

Figure 2-3: Offshore Wind Capital Costs – Monopiles and Jackets in Increasing Water Depth

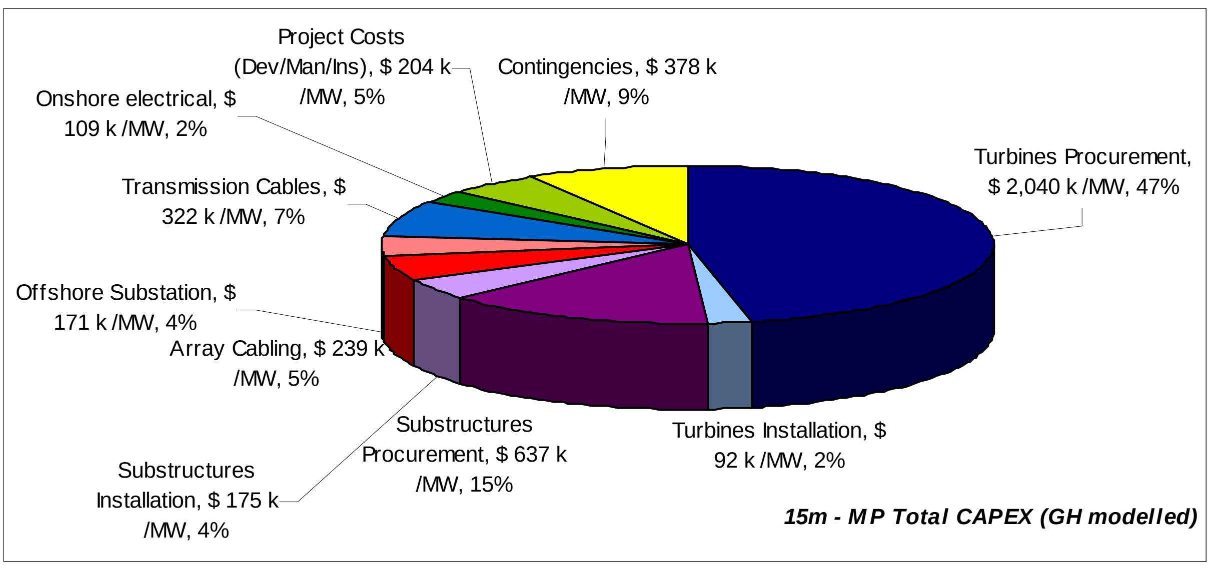
Figure 2.3 presents the same information as Figure 2.2, however in terms of percentage, to show the increasing importance of foundation costs in deeper waters. If the deeper waters coincide with stronger winds, this increased cost may be mitigated by increased income from higher generation, however in general the stronger winds further offshore will be sufficient to mitigate the higher transmission system costs to a certain extent but will not be sufficient to mitigate the higher foundation costs as well, hence additional support may be necessary, with examples including offshore grid connection provided by transmission system operator (TSO) or adjustment to the tariff depending on the project characteristics.



MP = monopile; J = jacket; water depth from 5 m through to 35 m

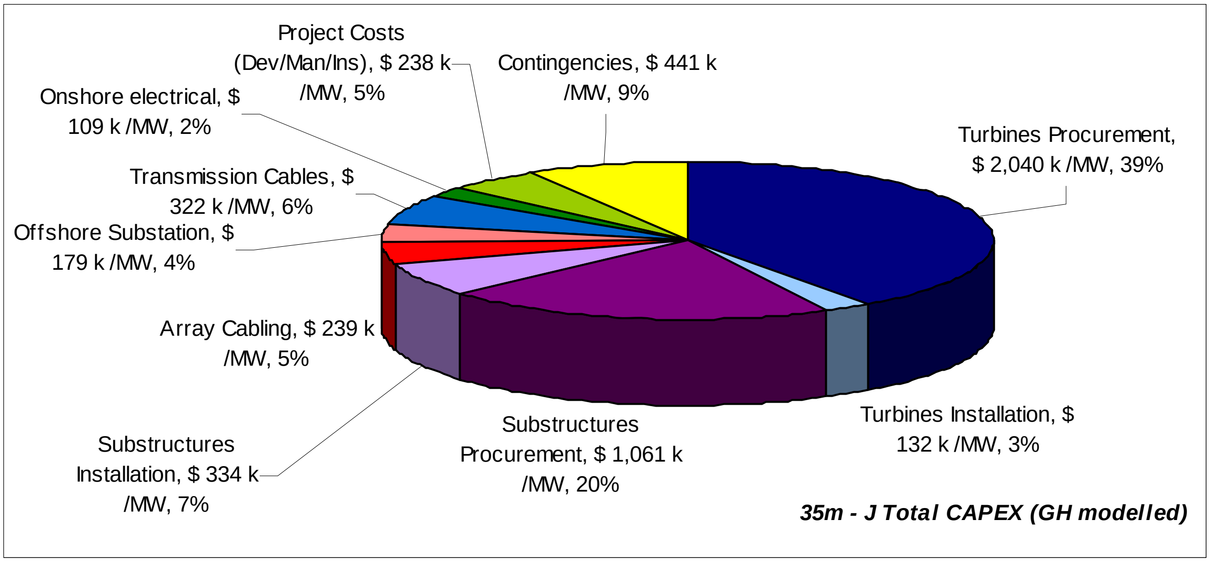
Figure 2-4: Offshore Wind Capital Costs Percentage – Monopiles and Jackets in Increasing Water Depth

Finally, Figure 2.5 and Figure 2.6 provide greater detail for two cases from the previous charts.



3 – 4 MW Class Turbine CAN $

Figure 2-5: Offshore Wind Capital Costs – Wind Farm using Monopiles Foundations in 15m



3 – 4 MW Class Turbine CAN $

Figure 2-6: Offshore Wind Capital Costs – Wind Farm using Jacket Foundations in 35 m

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