



**ASSESSMENT OF THE ENERGY  
POTENTIAL AND ESTIMATED COSTS OF  
WIND ENERGY IN BRITISH COLUMBIA**

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## 1 INTRODUCTION AND BACKGROUND

Large scale wind farm projects are in the process of being developed in the province of British Columbia (BC). In order to establish the wind resource potential and estimated costs, British Columbia Hydro and Power Authority (BC Hydro) has instructed Garrad Hassan Canada Inc. (GH) to carry out an independent assessment of the energy potential and estimated costs of wind energy power generation within the province of British Columbia. This analysis is an update of a previous report by GH issued in May 2005 [1.1] and will contribute to an update of the BC Hydro Resource Options Report (ROR).

Given the broad scope of work required and time constraints imposed by BC Hydro, this study has been necessarily limited to:

- Four main regions in British Columbia identified as having the best wind potential as shown in Figure 2.1. Namely, Vancouver Island, the North Coast, the Peace region, and the Southern and Eastern Interior.
- All sites with Investigative Use Permits (IUP) either offered to, or applied for by, Independent Power Producers (IPP) in any of the four regions;
- A high level wind energy resource study based on wind data sets collected by BC Hydro and IPPs, the Canadian Wind Atlas [1.2], as well as available mesoscale wind resource maps of British Columbia from previous studies; and
- A general per project cost analysis for each region assuming some expected development and operational conditions.

It is important to note that this work has in no way tried to characterize the potential wind energy and cost of any particular IUP site but rather to give indicative estimates for BC's potential wind energy and cost in each of the four wind regions.

This report provides the methodology and conclusion of the above work.

Sections 2.1 and 2.2 describe the applied methodology used to estimate the wind regime and energy potential for each region. Sections 2.3 to 2.6 report the estimated wind regime and energy potential results on a regional basis.

Section 3 summarises the energy cost assessment, including the assumptions used as inputs in the cost modelling.

Section 4 provides a summary of the main conclusions.

## **2 ENERGY POTENTIAL ASSESSMENT**

### **2.1 GENERAL CHARACTERIZATION OF SITES**

For each region, a general categorization of sites with IUPs has been undertaken. For the purposes of this study, three categories based on the level of wind data available and access to a transmission line have been identified:

- A** – Sites with 1-year or more of on-site wind data and within 50 km of a transmission line;
- B** – Sites with less than 1-year of wind data or not within 50 km of a transmission line; and
- C** – Sites with less than 1-year of wind data and not within 100 km of a transmission line.

A comprehensive list of IUP sites for each region with associated category is provided in Appendix A. Note that the information presented in Appendix A has been based on an output of all IUP sites from the Integrated Land and Resource Registry (ILRR) database as of September 2007 [2.1]. Active sites not reported in the ILRR database have been added to Appendix A.

### **2.2 WIND REGIME AND ENERGY POTENTIAL METHODOLOGY**

The high-level analysis of the wind regime and energy potential for each region involved several steps, which are summarised below:

- A mean annual wind speed and a joint wind speed and direction frequency distribution were derived for all regions from all available on-site wind data, the Canadian Wind Atlas, as well as any useful nearby Environment Canada meteorological data.
- The resulting mean wind speeds and frequency distributions were factored to a hub height of 80 m and 70 m for onshore and offshore locations respectively, using an appropriate wind shear exponent.
- These estimated hub height wind regimes were assigned a general uncertainty of plus or minus 10% to account for measurement uncertainties, hub height extrapolation, wind speed variations across the site, and inter-annual variability.
- For each region, annual mean wind speeds for the remaining IUP site areas were estimated using available wind resource maps of BC by comparing relative changes between measured wind speeds and the remaining site areas.
- A range of net capacity factors for each region has been calculated using the estimated wind regimes as well as generic assumptions for turbine type, air density and production losses including wake, topographic, high wind hysteresis, electrical, availability, icing and blade degradation. A generic 2.3 MW turbine is used in all onshore sites, and a generic 3.0 MW turbine is used in all offshore sites. Although a common turbine type is used for all onshore sites, it should be noted that this is for capacity factor comparison purposes only. It is expected that different turbine sizes and models would be used in different regions, based on characteristic wind regimes and site-specific conditions.
- When not provided or available, total rated capacity for each IUP site has been approximated using 3-D mapping tools to estimate the potential available capacity at each site. For sites in complex terrain, the length of available ridges was estimated, and an inter-turbine spacing of 5 rotor diameters was assumed to derive each estimated site capacity. For all other sites, a percentage of total exploitable area was estimated, and a turbine density of 6 MW/km<sup>2</sup> and 7 MW/km<sup>2</sup> was assumed for onshore and offshore sites, respectively.

It should be noted that these assumptions are for indicative purposes only and should be expected to vary on a regional and site-specific basis. For example, in the Peace region, known for a unidirectional wind regime, it would be expected that most sites would consider an inter-turbine spacing of less than 5 rotor diameters in the non-prevailing wind direction.

It should also be noted that this analysis takes into consideration all sites with IUPs as well as those with applications for IUPs pending. It is therefore assumed that all applications for IUPs will be approved.

Due to the broad scope of work and timescale required by BC Hydro, GH has not inspected the sites and associated measurement equipment or directly considered any sources of long-term reference wind data.

It is assumed that the available site data and information provided are accurate within the uncertainty range considered and that the wind regime and potential energy of all sites are well represented by the methodology described above.

## **2.3 VANCOUVER ISLAND REGION**

### **2.3.1 Potential IUP sites**

As listed in Appendix A, 48 sites for the Vancouver Island region have been considered in this study. The site boundaries are shown in Figure 2.2. Note that while the large majority of sites in this region are focussed in the northern portion of Vancouver Island, there are also sites located in central and southern Vancouver Island, as well as the Sunshine Coast and Coastal Mountain regions. For simplicity, these have all been incorporated into the Vancouver Island region.

A large majority of the proposed wind farm areas are onshore, taking advantage of terrain features and coastal exposure.

### **2.3.2 Wind regime**

The wind regime is driven predominately from the south-southeast and north-northwest directions with mean annual wind speeds expected to range between 6.5 m/s and 8.0 m/s at a hub height of 80 m for reasonably well exposed sites with favourable wind conditions. A typical wind rose for the northern part of the region is shown in Figure 2.3.

### **2.3.3 Estimated energy potential**

When combining the potential of all onshore and offshore IUP sites, a total rated capacity of approximately 6.0 GW can be projected. It is expected, however, that this energy potential will be severely limited due to available electrical transmission, environmental planning constraints, and the expected power demand in this region.

Based upon GH's review of the wind data supplied for this region, GH has calculated that a typical project located in this region, using a 2.3 MW generic turbine, would demonstrate capacity factors in the range of 25% to 38% on a net basis after production losses. These capacity factors were used as inputs in the energy cost assessment in Section 3.

## **2.4 NORTH COAST REGION**

### **2.4.1 Potential IUP sites**

As listed in Appendix A, 37 IUP sites for the North Coast region have been considered in this study. The site boundaries are shown in Figure 2.4.

Large offshore areas in the Hecate Strait off the coasts of the Queen Charlotte and Porcher Islands have been identified as IUP sites in this region. The remaining IUP sites are located onshore, both on coastal islands along the east side of Hecate Strait, as well as inland located near Prince Rupert, Kitimat, Terrace and Smithers.

### **2.4.2 Wind regime**

The wind regime is driven predominately parallel to the coast from the southeast direction. There is also some limited evidence of significant westerly wind in this region. This is shown by the wind rose in Figure 2.5, which was derived from Environment Canada wind data collected at the northeast tip of the Queen Charlotte Islands. One source of coastal data indicates that the wind originates from the west.

GH estimates that the mean annual wind speeds are expected to range between 6.5 m/s and 8.5 m/s at a hub height of 80 m for the more sheltered onshore coastal island and inland sites, while the offshore sites are expected to receive mean annual wind speeds between 9.0 m/s and 10.0 m/s at a typical offshore hub height of 70 m.

### **2.4.3 Estimated energy potential**

When considering both onshore and offshore IUP sites, a maximum total rated capacity of approximately 5.0 GW onshore and 13.5 GW offshore can be projected. It is, however, expected that this energy potential will be severely limited due to the financial feasibility of projects, available electrical transmission, environmental planning constraints, and the expected power demand in this region.

#### **2.4.3.1 Onshore**

Based upon GH's review of the wind data supplied for this region, GH has calculated that a typical project located in this region, using a 2.3 MW generic turbine, would demonstrate capacity factors in the range of 27% to 40%, on a net basis after production losses. These capacity factors were used as inputs in the energy cost assessment in Section 3.

#### **2.4.3.2 Offshore**

For offshore sites, GH has not been given on-site data for this region. For analysis purposes, GH has considered Environment Canada data and available mesoscale mapping to estimate a range of capacity factors that could be expected for an offshore site in the North Coast region. Consequently, GH has calculated that a typical offshore project located in this region, using a 3.0 MW generic turbine, would demonstrate capacity factors in the range of 34% to 40% on a net basis after production losses. These capacity factors were used as inputs in the energy cost assessment in Section 3.

It is important to note that since the power curve for the 3.0 MW turbine considered differs significantly from that of the 2.3 MW turbine, a direct capacity factor comparison between the onshore and offshore regions is not indicative. If the same 2.3 MW turbine was used in the offshore case, it would demonstrate a range of significantly higher capacity factors based on the more energetic offshore wind regime.

## **2.5 PEACE REGION**

### **2.5.1 Potential IUP sites**

A total of 96 IUP sites have been considered in this study and the site boundaries are shown in Figures 2.6 to 2.8.

The large majority of the IUP sites are located in elevated areas to maximize terrain speedup effects and exposure.

### **2.5.2 Wind regime**

The wind regime for the Peace region appears to be strongly unidirectional with strong wind coming from the west and southwest depending on the location of the site. A typical wind rose from the Peace region is shown in Figure 2.9.

From the on-site wind data provided, and experience in the region, GH estimates that the mean annual wind speeds at IUP sites can be expected to range between 7.5 m/s and 10.5 m/s at a hub height of 80 m.

It is noted that it is difficult to estimate local site wind conditions in the Peace region without the analysis of on-site wind data due to the highly complex nature of the mountainous terrain. It can therefore be expected that the wind regime will be highly localized for each IUP site.

### **2.5.3 Estimated energy potential**

When combining the potential of all IUP sites for this region, a maximum total rated capacity of approximately 18.5 GW can be projected. It is expected, however, that this energy potential will be severely limited due to terrain features such as ridges, suitability of turbines to site conditions, available electrical transmission, environmental planning constraints, and the expected power demand in this region.

Based upon GH's review of the wind data supplied for this region, GH has calculated that a typical project located in this region, using a 2.3 MW generic turbine, would demonstrate net capacity factors in the range of 32% to 48% after production losses. These capacity factors were used as inputs in the energy cost assessment in Section 3.

## **2.6 SOUTHERN AND EASTERN INTERIOR REGION**

### **2.6.1 Potential IUP sites**

A total of 74 IUP sites have been considered in this study and the site boundaries are shown in Figure 2.10.

The large majority of the IUP sites are located in elevated areas to maximize terrain speedup effects and exposure. Many sites are also located atop expansive plateaus, maximizing site area in elevated regions.

### **2.6.2 Wind regime**

The wind regime for the Interior region appears to vary between unidirectional wind flowing from the southwest in some areas, to relatively omnidirectional flow with predominant winds from northeast and southwest directions. This is shown by the two typical wind roses in Figures 2.11 and 2.12, respectively.

From the limited wind data and mesoscale mapping available, GH estimates that the mean annual wind speeds at IUP sites can be expected to range between 6.0 m/s and 8.0 m/s at a hub height of 80 m for reasonably well exposed sites with favourable wind conditions.

It is noted that it is difficult to estimate local site wind conditions in the Interior region without the analysis of substantial on-site wind data due to the highly complex nature of the mountainous terrain where many of the sites are located. It can therefore be expected that the wind regime will be highly localized for each IUP site.

### **2.6.3 Estimated energy potential**

When combining potential of all IUP sites for this region, a maximum total rated capacity of approximately 9.5 GW can be projected. It is expected, however, that this energy potential will be severely limited due to terrain features such as ridges, suitability of turbines to site conditions, available electrical transmission, environmental planning constraints, and the expected power demand in this region.

Based upon GH's review of the limited wind data available for this region, GH has calculated that a typical project located in this region, using a 2.3 MW generic turbine, would demonstrate net capacity factors in the range of 21% to 33% after production losses. These capacity factors were used as inputs in the energy cost assessment in Section 3.

### 3 ENERGY COST ASSESSMENT

GH has considered the likely cost of development in the BC market, based upon experience of project costs in the North American market. This includes experience from 500 MW of projects built in Canada in 2006 and 2007. GH has then considered the influence of current market conditions on these costs. GH also considered likely adjustments to these costs for the BC market by issuing a questionnaire to IPPs with active sites in the Province [3.1].

It is important to note that costs and financing structure can be expected to vary significantly for individual wind farm projects. GH has attempted to address this within the analysis through consideration of a range of capacity factors and costs. It is possible that this range will not be suitable for all projects in BC. It should also be noted that GH has created an updated cost estimate model since the last report was released in 2005.

GH has not projected future changes in the turbine supply or construction market, but notes that the prices used do already reflect recent increases in turbine supply costs. All costs are reported in 2008 Canadian Dollars.

#### 3.1 PROJECT ASSUMPTIONS

Five project types are considered within this analysis. Broad project assumptions are as follows:

	<b>Vancouver Island</b>	<b>North Coast</b>		<b>Peace Region</b>	<b>Interior</b>
Location	Onshore	Onshore	Offshore	Onshore	Onshore
Number of turbines	65	22	100	87	65
Turbine Size – MW	2.3	2.3	3.0	2.3	2.3
Project Capacity	150	50	300	200	150

**Table 3.1: Project assumptions**

Road and collection system requirements are based on an assumption of 0.5 km per turbine.

For the purpose of this assessment, it has been assumed that all projects will have an internal collection voltage of 34.5 kV and connect into the transmission system at 230 kV, although it is likely that some projects will be able to connect at 138 kV. Transmission line lengths are assumed to be:

	<b>Vancouver Island</b>	<b>North Coast</b>	<b>Peace Region</b>	<b>Interior</b>
Transmission line length	50	100	25	25

**Table 3.2: Transmission length (km)**

In practise there may be sharing of transmission costs between projects, however, this assumption is not used within this analysis.

A range of capacity factors have been assumed, and GH has used three cases within the cost analysis (high, central, low), as outlined in Table 3.3:

	<b>Vancouver Island</b>	<b>North Coast</b>		<b>Peace Region</b>	<b>Interior</b>
Location	Onshore	Onshore	Offshore	Onshore	Onshore
High	38	40	40	48	33
Central	32	34	37	40	27
Low	25	27	34	32	21

**Table 3.3: Capacity factors (%)**

### 3.1.1 Onshore cost assumptions

Onshore cost assumptions (\$000's) used are listed in the tables below. Base case figures are provided as well as those used for sensitivity testing (high case).

	<b>Base</b>	<b>High</b>
Development	500	750
Site studies	100	150
Project SCADA	300	400
Connection charge	1000	2000

**Table 3.4: Costs per project (\$000's)**

	<b>Base</b>	<b>High</b>
Project management	50	75
Turbine transport	150	200
Turbine installation	300	400
Turbine transformer	80	120
Foundation	250	350
Crane pad and laydown	25	75
Public Roads, Culverts, Reinstatement etc	50	100
Communication	15	25
Substation	150	200

**Table 3.5: Costs per WTG (\$000's)**

	<b>Base</b>	<b>High</b>
Insurance	10	12
Advisers	5	7.5
Turbine	1400	1600

**Table 3.6: Costs per MW (\$000's)**

	<b>Base</b>	<b>High</b>
Site roads	100	200
On-site collection system	100	150
Transmission line	300	600

**Table 3.7: Costs per km (\$000's)****3.1.2 Offshore cost assumptions**

Offshore cost assumptions (\$000's) used are listed in the tables below. Base case figures are provided as well as those used for sensitivity testing (high case).

	<b>Base</b>	<b>High</b>
Development	1000	1500
Site studies	400	600
Project SCADA	300	400
Connection charge	1000	2000
Substation	100000	150000

**Table 3.8: Costs per project (\$000's)**

	<b>Base</b>	<b>High</b>
Project management	100	200
Turbine transport	150	200
Turbine installation	1250	1500
Turbine transformer	-	-
Foundation	1500	2500
Crane pad and laydown	-	-
Public Roads, Culverts, Reinstatement etc	20	40
Communication	25	50

**Table 3.9: Costs per WTG (\$000's)**

	<b>Base</b>	<b>High</b>
Insurance	20	25
Advisers	10	15
Turbine	1800	2200

**Table 3.10: Costs per MW (\$000's)**

	<b>Base</b>	<b>High</b>
Site roads	-	-
On-site collection system	200	400
Transmission line	300	600

**Table 3.11: Costs per km (\$000's)**

### 3.1.3 Summary of cost assumptions

The cost assumptions are summarised for the various projects as follows:

	<b>Vancouver Island</b>	<b>North Coast</b>		<b>Peace Region</b>	<b>Interior</b>
Location	<b>Onshore</b>	<b>Onshore</b>	<b>Offshore</b>	<b>Onshore</b>	<b>Onshore</b>
Base Cost – Indirect	2,843	1,359	10,400	3,602	2,873
Base Cost – Direct Construction	301,650	127,880	985,800	391,730	294,150
<b>Total Cost – Base (\$k)</b>	<b>304,493</b>	<b>129,239</b>	<b>996,200</b>	<b>394,332</b>	<b>296,993</b>
High Cost – Indirect	3,815	1,887	14,100	4,802	3815
High Cost – Direct Construction	383,400	181,200	1,341,400	487,200	368,400
<b>Total Cost – High (\$k)</b>	<b>387,215</b>	<b>183,087</b>	<b>1,355,500</b>	<b>492,002</b>	<b>372,215</b>
<b>Cost per MW – Base (\$k/MW)</b>	<b>2,037</b>	<b>2,554</b>	<b>3,321</b>	<b>1,971</b>	<b>1,987</b>
<b>Cost per MW – High (\$k/MW)</b>	<b>2,590</b>	<b>3,618</b>	<b>4,518</b>	<b>2,459</b>	<b>2,490</b>

**Table 3.12: Project Costs**

The above costs are for development and construction related items alone, before financing costs and transaction costs.

It is important to note that GH has not assumed that there is a large up-front development fee per project. Instead, the developer benefit is assumed to be contained within the projected equity return. In order to obtain an up front fee, the owner may be able to sell the project at a lower required equity return rate. Additionally, a set rate has been assumed for transaction costs (see Table 3.13) and developers may be able to take a profit from this line item where there will be a relative reduction in fees per MW for larger projects. GH considers the approach taken to be appropriate.

The base and high costs shown for onshore projects are in line with GH experience of Canadian project costs.

There is currently no experience of offshore costs in Canada against which to benchmark.

### 3.1.4 Financing assumptions

Financing assumptions used are as follows:

	<b>Assumption</b>	<b>Unit</b>
Construction Period	12	months
Weighted Average Cost of Capital	See Section 3.2	%
Loan term	20	years
Capital Contingency	10	%
Transaction Costs	2	% capital cost
Corporate Tax	31 <sup>1</sup>	%

**Table 3.13: Finance assumptions**

As tax treatments may vary from region to region and may change over time, this analysis uses simple straight line depreciation on equipment costs, rather than any accelerated mechanism.

While it is assumed that it would be available to qualifying projects for at least part of their project life, BC Hydro has asked that all ecoENERGY support from the Canadian Federal Government be omitted from the analyses of the unit energy costs of the various renewable resource options.

### 3.1.5 O&M Cost assumptions

Operating cost assumptions used are as follows:

<b>Item</b>	<b>Cost</b>	<b>Per</b>
Maintenance	20	MW
Non-Routine Maintenance	10	MW
Electricity Usage	1	MW
Management fees	5	MW
Insurance	1	MW
BoP Expenses	1	MW
Business Rates	1	MW
General Administration	1	MW
Use of System Charges	1	MW
Bank fees	1	MW
Land Payments	2	% revenue

**Table 3.14: Operational cost assumptions (\$000 or %)**

It is assumed that non-routine maintenance costs start in year 2.

<sup>1</sup> [http://www.kpmg.ca/en/services/tax/documents/FPT\\_2008\\_09\\_CCPC.pdf](http://www.kpmg.ca/en/services/tax/documents/FPT_2008_09_CCPC.pdf)

### 3.2 COST SCENARIOS

Assuming each energy case for each of the projects in turn, the cost of energy for each project (base and high cost scenarios) has been estimated. GH has rounded the cost of energy to the nearest \$.

#### 3.2.1 Weighted Average Cost of Capital of 8%

GH has carried out a cost analysis based upon a Weighted Average Cost of Capital (WACC) of 8%. The resulting energy rates are summarised in Table 3.15.

Energy Case <sup>1</sup>	Cost Case <sup>2</sup>	Vancouver Island	North Coast		Peace Region	Interior
		Onshore	Onshore	Offshore	Onshore	Onshore
High	Base	91	105	133	70	102
	High	112	144	177	85	125
Central	Base	110	126	144	84	125
	High	135	172	191	102	152
Low	Base	139	156	157	105	161
	High	170	213	208	127	196

Note 1: See table 3.3

Note 2: See table 3.12

**Table 3.15: Required energy rates for 8% WACC (\$/MWh)**

The resulting range of cost estimates are summarised graphically in Figure 3.1.

#### 3.2.2 Weighted Average Cost of Capital of 10%

GH has carried out a cost analysis based upon a Weighted Average Cost of Capital (WACC) of 10%. The resulting energy rates are summarised in Table 3.16.

Energy Case <sup>1</sup>	Cost Case <sup>2</sup>	Vancouver Island	North Coast		Peace River	Interior
		Onshore	Onshore	Offshore	Onshore	Onshore
High	Base	108	125	159	83	121
	High	133	172	212	101	148
Central	Base	130	149	172	99	148
	High	161	205	229	121	181
Low	Base	163	185	187	124	190
	High	202	255	249	151	232

Note 1: See table 3.3

Note 2: See table 3.12

**Table 3.16: Required energy rates for 10% WACC (\$/MWh)**

The resulting range of cost estimates are summarised graphically in Figure 3.2.

### 3.3 SUPPLY CURVES

Using the estimated capacity factor ranges for each region, the following assumptions have been used to estimate the regional supply curves presented in Figures 3.3 to 3.12:

- Only one tenth of the maximum identified potential wind capacity will be built in the region;
- The available capacity factor of built projects will follow a standard distribution with a mean equal to the mean capacity factor and standard deviation of 5%;
- The highest capacity factor, lowest cost sites will be built first;
- The project and cost assumptions used in the cost estimates are representative of built projects; and
- The construction cost assumptions made are accurate to a range of plus or minus 10%.

Supply curves are provided for base and high cost scenarios for each region. It is important to note that these assumptions are based on very limited information and are used solely as a way to estimate an indicative supply curve for the region. It is recommended that extreme caution be used when applying the supply curve.

## 4 CONCLUSIONS

GH has carried out an independent assessment of the energy potential and estimated costs of wind energy power generation within the province of British Columbia. The four British Columbia regions have been characterised as follows:

### **Vancouver Island**

- The wind regime is driven predominately from the southeast and northwest directions with mean annual wind speeds estimated to range between 6.5 m/s and 8.0 m/s.
- When considering all IUP areas in this region and assuming that 10% of the theoretical wind energy potential is achievable due to available electrical transmission, environmental planning constraints, and the expected power demand, a total rated capacity of approximately 0.6 GW is estimated for the Vancouver Island region.
- Site capacity factors are estimated to be 25% to 38% on a net basis after production losses.
- GH expects that for a 150 MW onshore project BC Hydro would receive offers in the range of \$90 to \$170 per MWh at an 8% WACC, and between \$110 to \$200 per MWh at a 10% WACC.

### **North Coast**

- The wind regime is driven predominately from the southwest parallel to the coast with hub height mean annual wind speeds expected to range between 6.5 m/s and 8.5 m/s for the more sheltered onshore coastal island sites, and between 9.0 m/s and 10.0 m/s for offshore sites.
- When considering all IUP areas in this region and assuming that 10% of the theoretical wind energy potential is achievable due to available financial feasibility of projects, electrical transmission, environmental planning constraints, and the expected power demand, a total rated capacity of approximately 0.5 GW for onshore projects and 1.4 GW for offshore projects is estimated for the North Coast region.
- Site capacity factors are estimated to be 27% to 40% on a net basis after production losses for an onshore site using a 2.3 MW turbine.
- Site capacity factors are estimated to be 34% to 40% on a net basis after production losses for an offshore site using a generic 3.0 MW turbine.
- GH expects that for a 50 MW onshore project BC Hydro would receive offers in the range of \$105 to \$215 per MWh at an 8% WACC, and between \$125 to \$255 per MWh at a 10% WACC.
- GH expects that for a 300 MW offshore project BC Hydro would receive offers in the range of \$135 to \$210 per MWh at an 8% WACC, and between \$160 to \$250 per MWh at a 10% WACC.
- It can be seen from the above analysis that the higher offshore capital costs are offset to some extent by the relatively higher capacity factor compared to the onshore projects.
- The cost of energy of the North Coast onshore project is higher than the other onshore projects as a result of higher connection costs, but again this is offset to some extent by high capacity factors.

**Peace Region**

- The wind regime is unidirectional from the west with mean annual wind speeds expected to range between 7.5 m/s and 10.5 m/s. Due to the complexity of the mountainous terrain in this region, the wind regime will be highly localized for each IUP site.
- When considering all IUP areas and ridgelines in this region and assuming that 10% of the theoretical wind energy potential is achievable due to the suitability of turbines to site conditions, available electrical transmission, environmental planning constraints, and the expected power demand, a total rated capacity of approximately 1.9 GW is estimated for the Peace region.
- As a starting point for estimated project costs, site capacity factors are assumed to be 32% to 48% on a net basis after production losses.
- GH expects that for a 200 MW project BC Hydro would receive offers in the range of \$70 to \$130 per MWh at an 8% WACC, and between \$85 to \$150 per MWh at a 10% WACC.
- The cost of energy of the Peace region project is lower than the other onshore projects, mainly as a result of very high forecast capacity factors in this location, as a result of high wind speeds. There is also a high forecast installed capacity at the sample site due to the expected unidirectional wind regime, with resulting cost efficiencies.

**Southern and Eastern Interior**

- The wind regime varies between unidirectional wind flowing from the southwest in some areas, to relatively omnidirectional flow with predominant winds from northeast and southwest directions. Mean annual wind speeds are expected to range between 6.0 m/s and 8.0 m/s. Due to the complexity of the mountainous terrain in this region, the wind regime will be highly localized for each IUP site.
- When considering all IUP areas and ridgelines in this region and assuming that 10% of the theoretical wind energy potential is achievable due to the suitability of turbines to site conditions, available electrical transmission, environmental planning constraints, and the expected power demand, a total rated capacity of approximately 1.0 GW is estimated for the Interior region.
- As a starting point for estimated project costs, site capacity factors are assumed to be 21% to 33% on a net basis after production losses.
- GH expects that for a 150 MW project BC Hydro would receive offers in the range of \$100 to \$195 per MWh at an 8% WACC, and between \$120 to \$230 per MWh at a 10% WACC.
- While the costs of the Interior project are similar to the other onshore sites, the relatively lower forecast capacity factor in this region results in a comparatively high cost of energy.

## REFERENCES

- 1.1 “Assessment of energy potential and estimated costs of wind energy in British Columbia”, GH report 4579/OR/01 Issue E, 25 May 2005.
- 1.2 Canadian Wind Energy Atlas, [www.windatlas.ca](http://www.windatlas.ca)
- 2.1 Integrated Land Resource Registry, <http://ilmbwww.gov.bc.ca/ilrr/ILRR.htm>
- 3.1 “Wind Power Future in British Columbia - IPP Input Form”, GH technical note 38094/OT/01 Issue A, 26 September 2007

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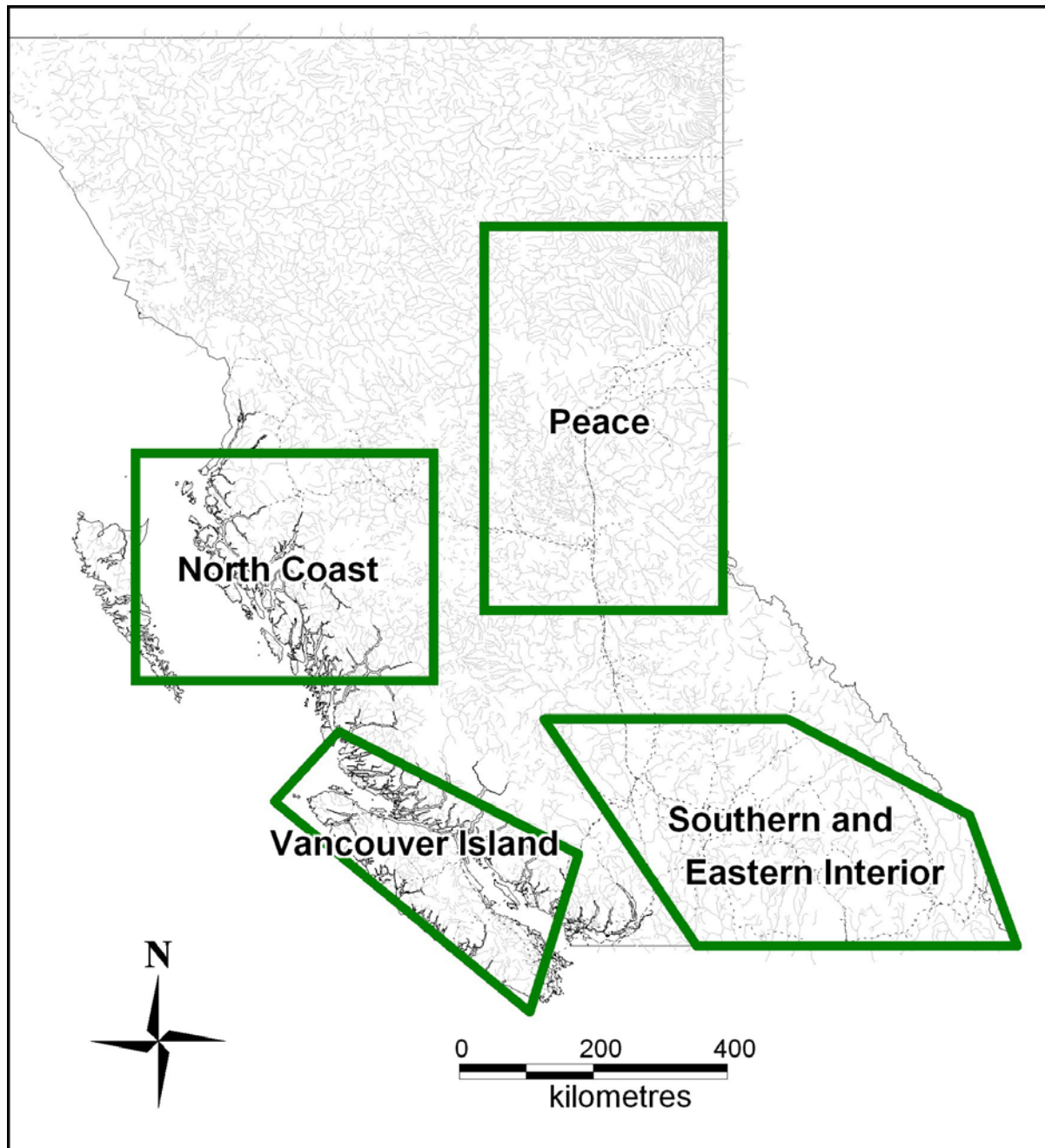


Figure 2.1 – The four wind regions of British Columbia

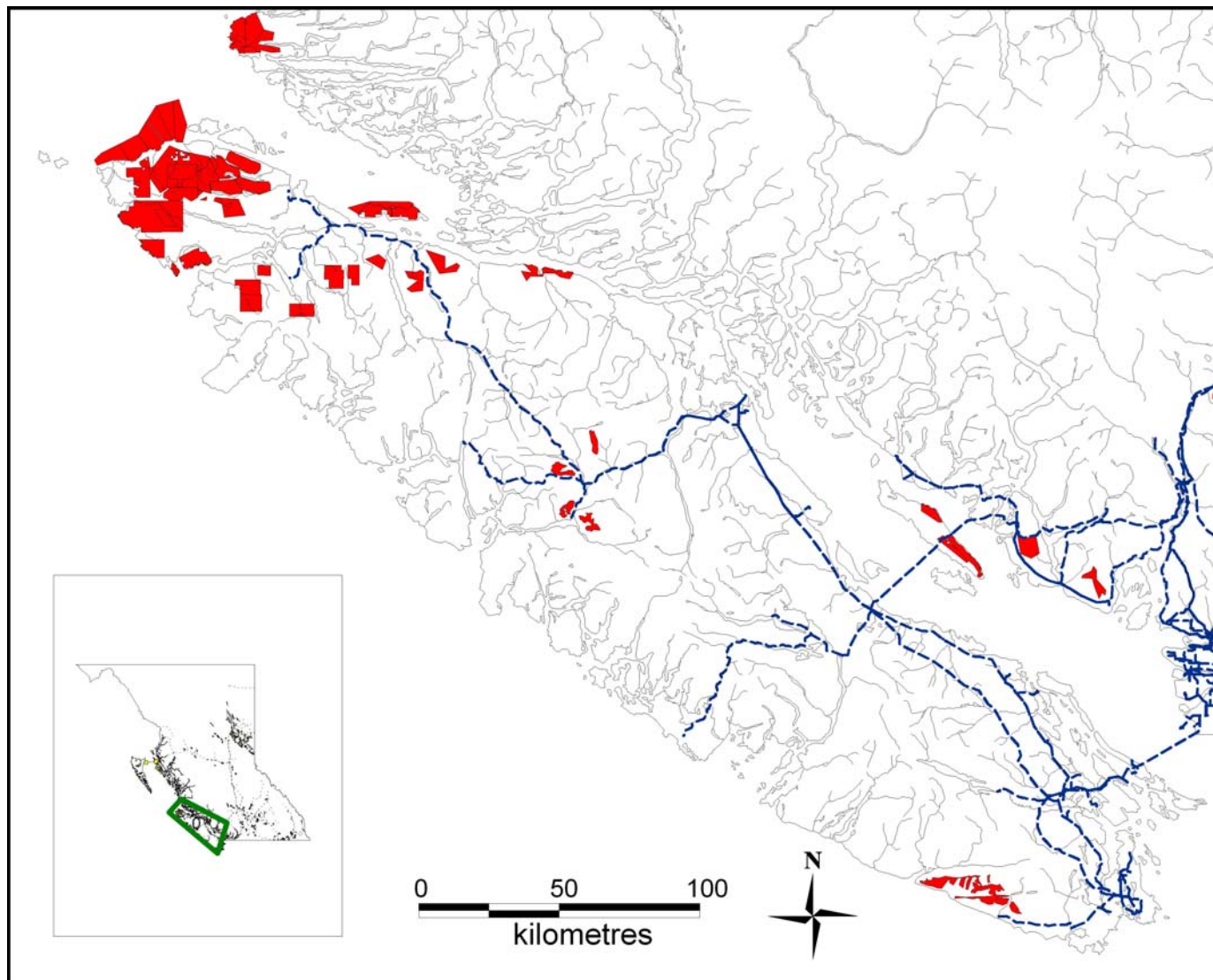


Figure 2.2 – IUP sites for the Vancouver Island region

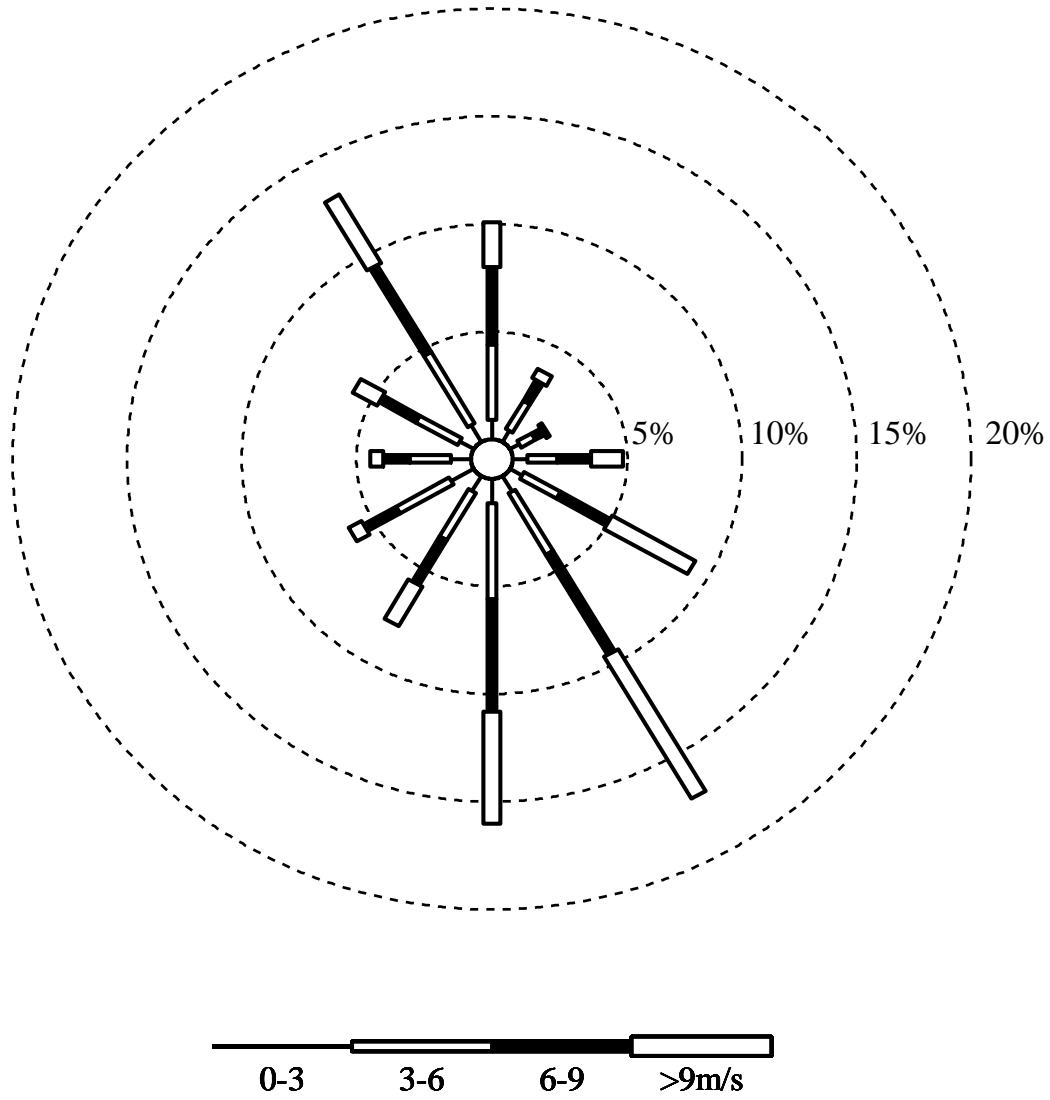
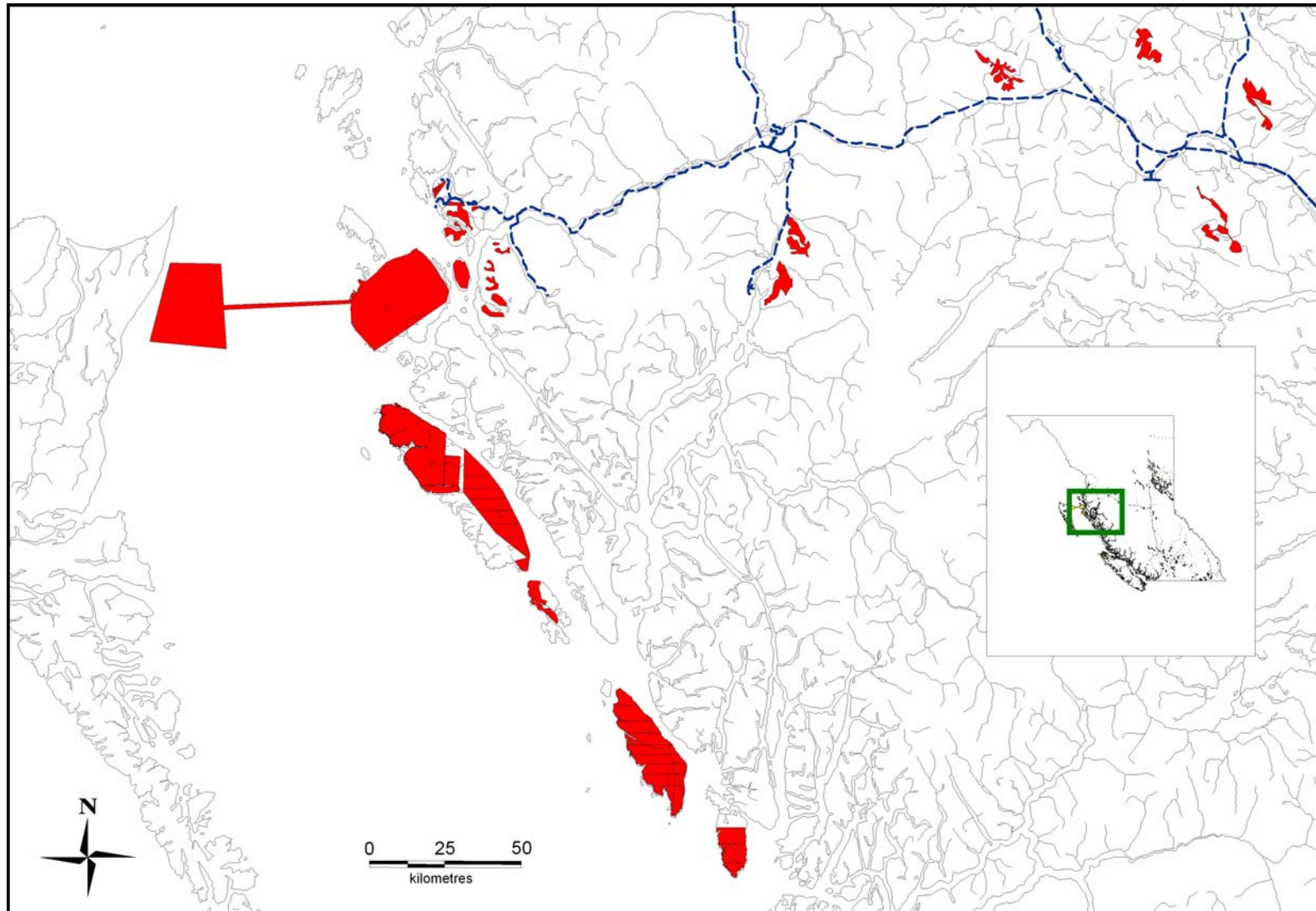


Figure 2.3 – Wind rose for the Vancouver Island region



**Figure 2.4 – IUP sites for the North Coast region**

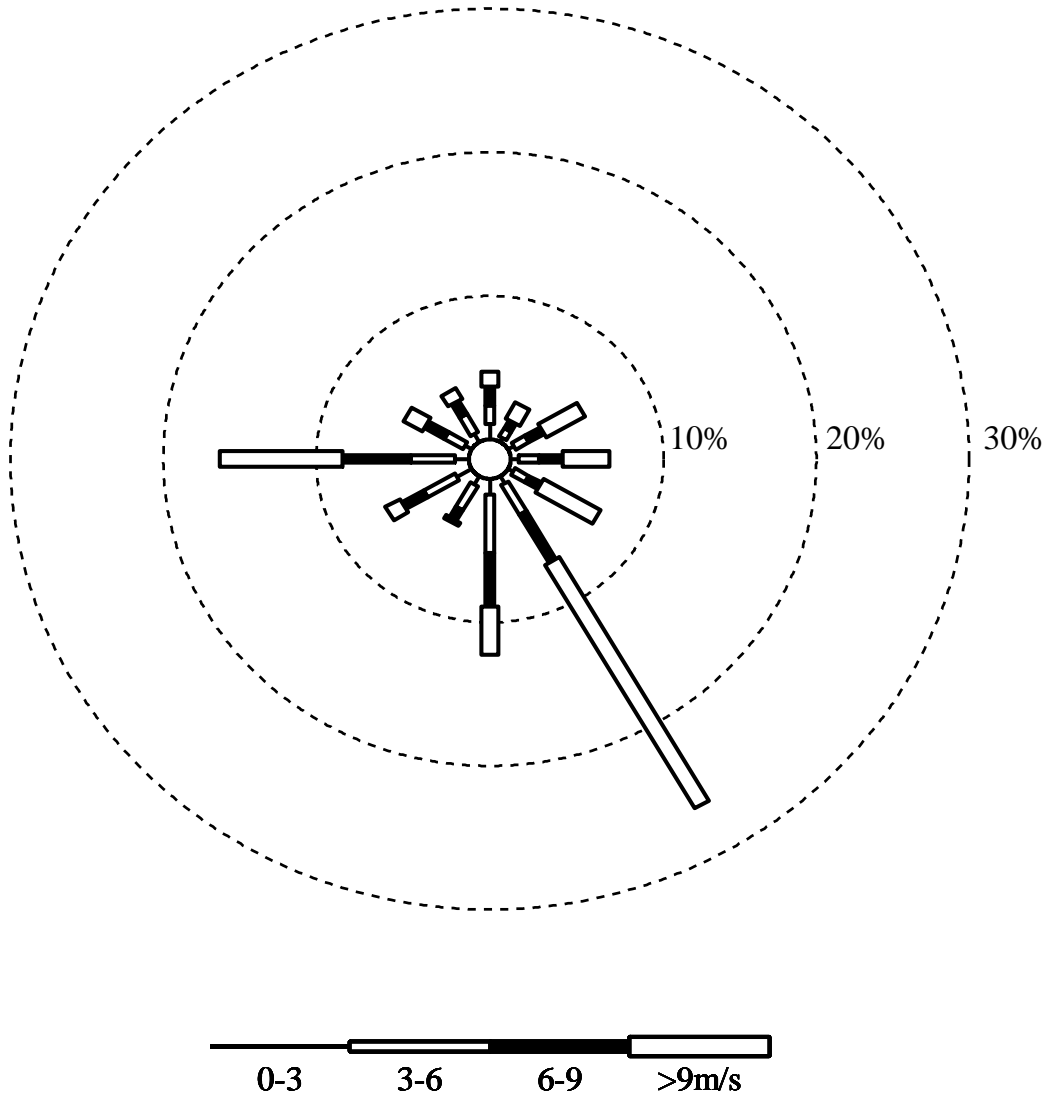


Figure 2.5 – Wind rose for the northeast tip of the Queen Charlotte Islands

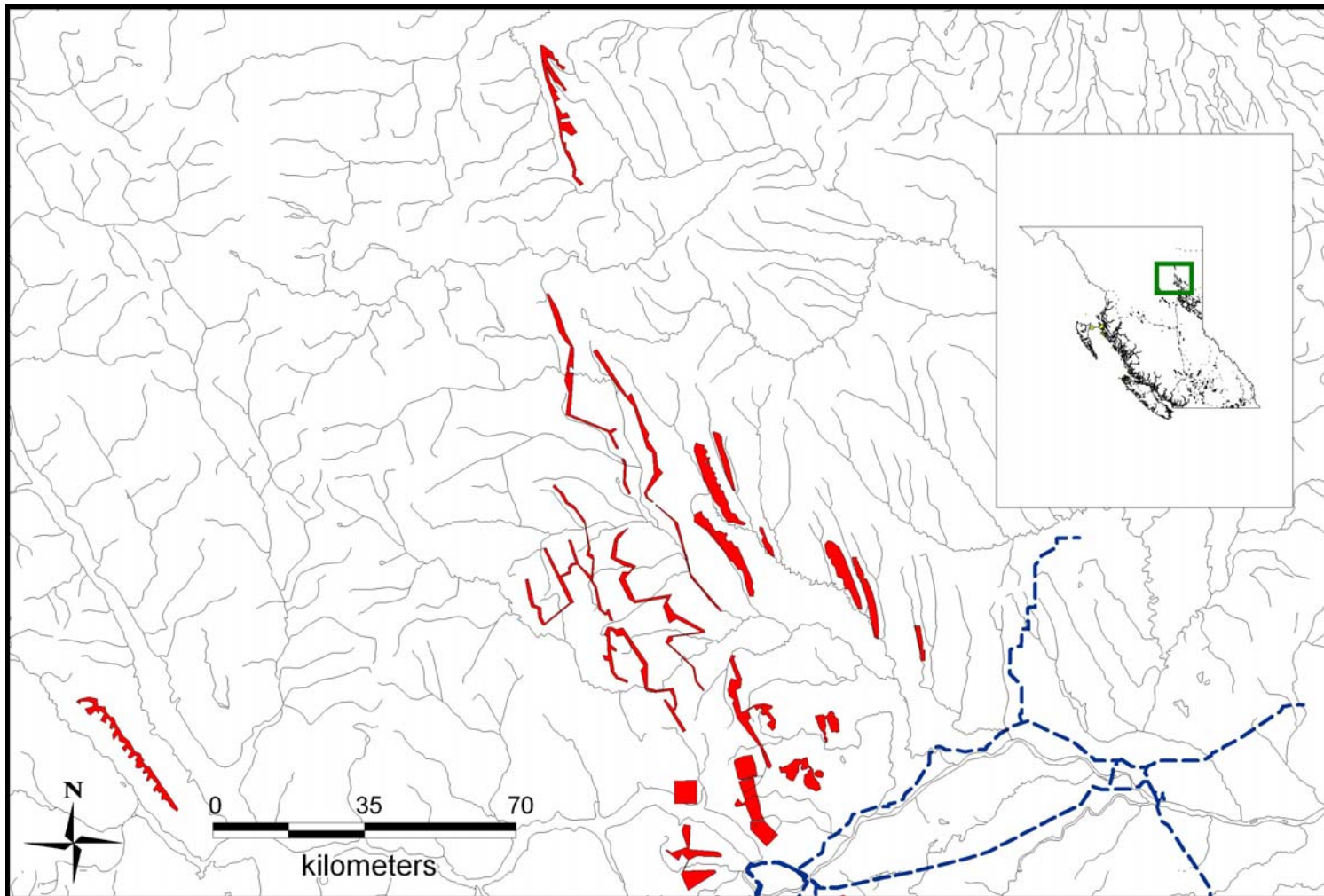


Figure 2.6 – IUP sites for the northern Peace region

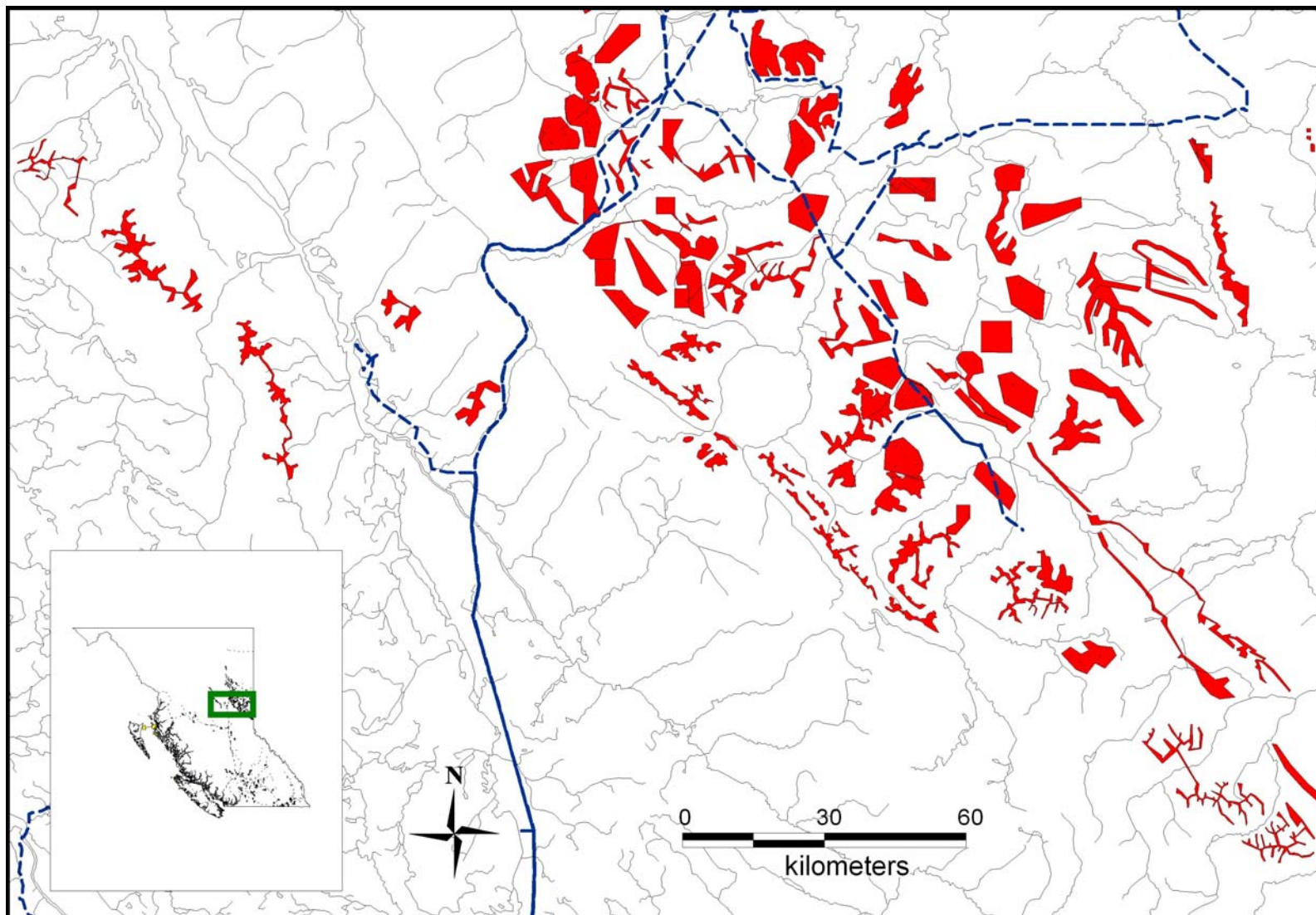


Figure 2.7 – IUP sites for the central Peace region

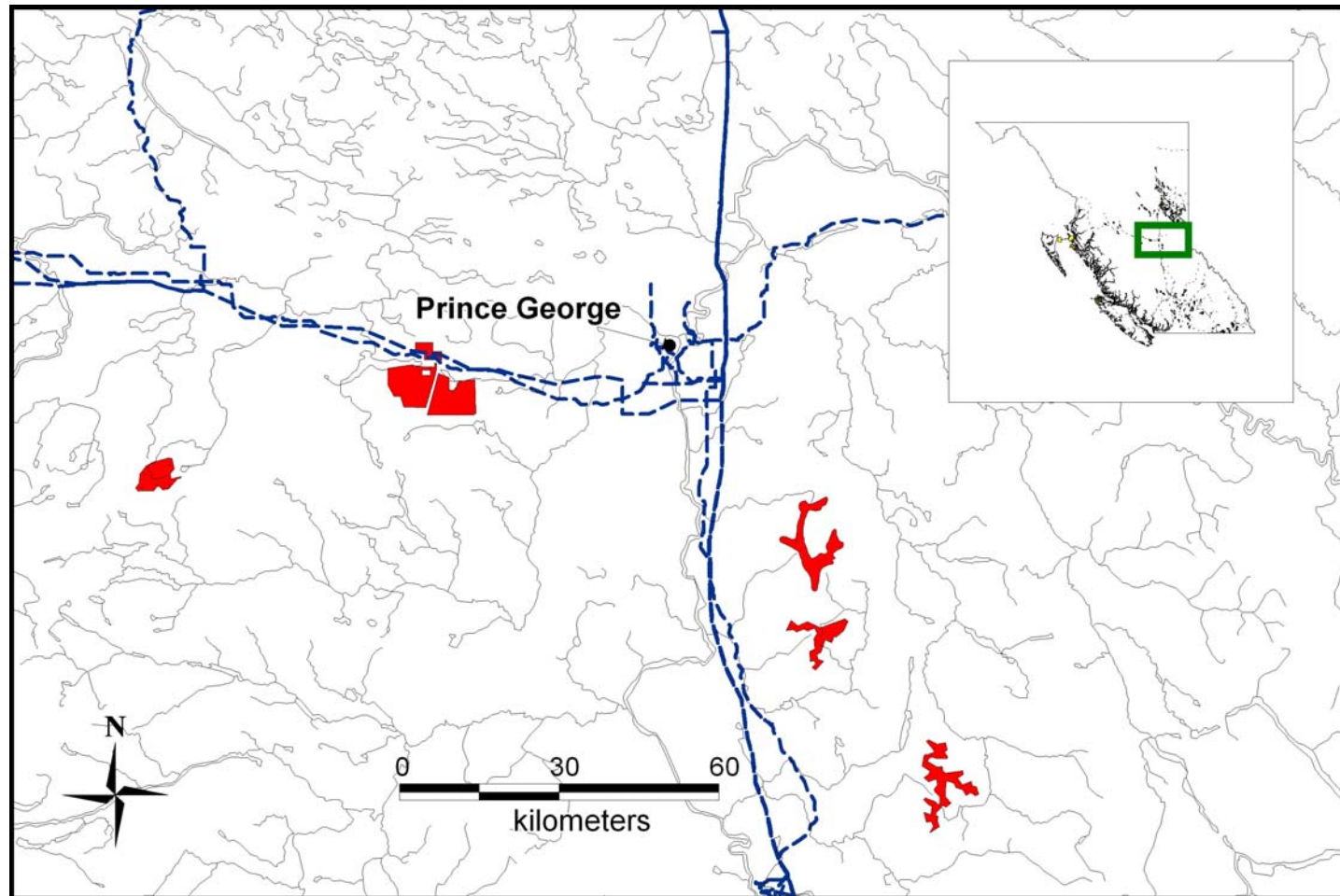


Figure 2.8 – IUP sites for the southern Peace region

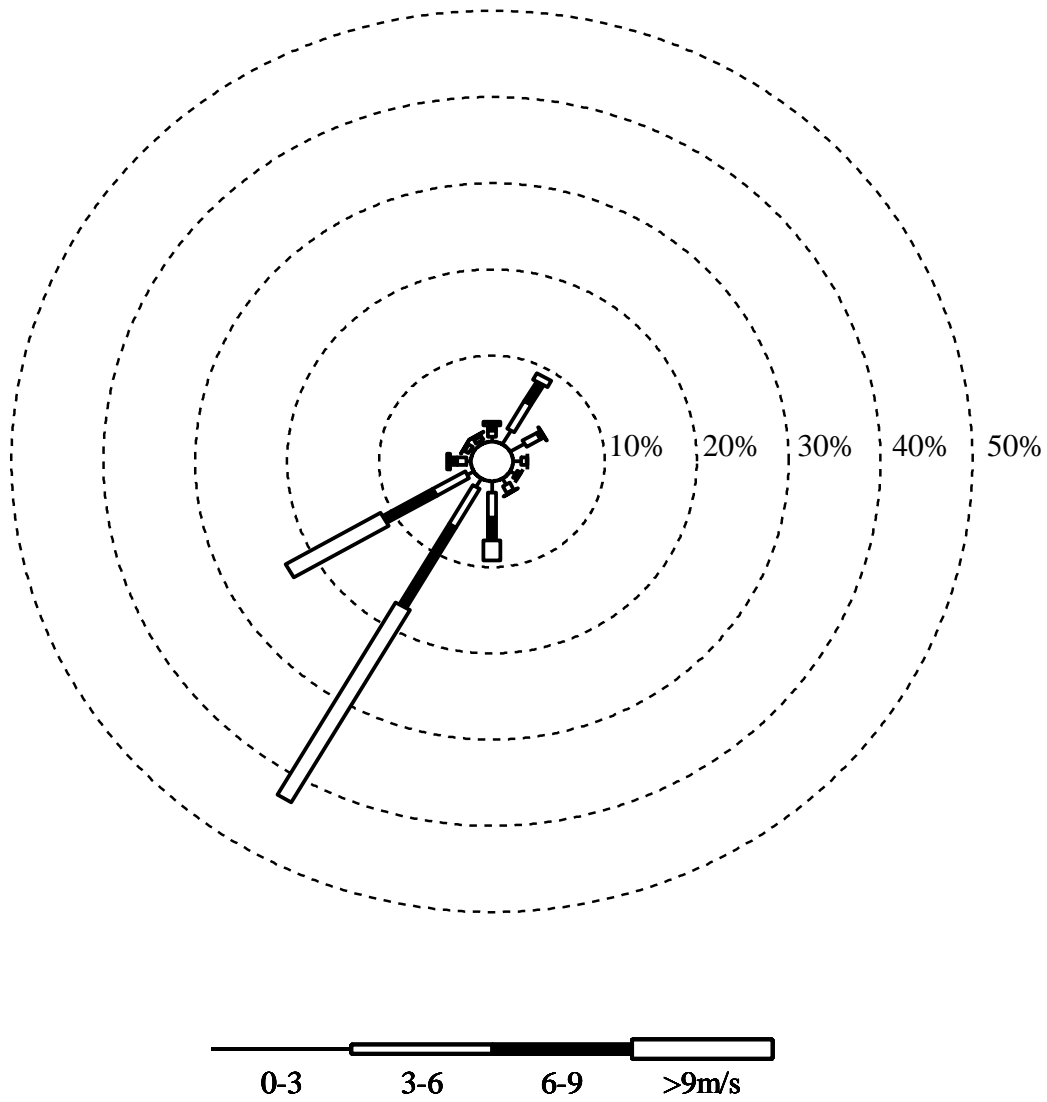


Figure 2.9 – Wind rose for the Peace region

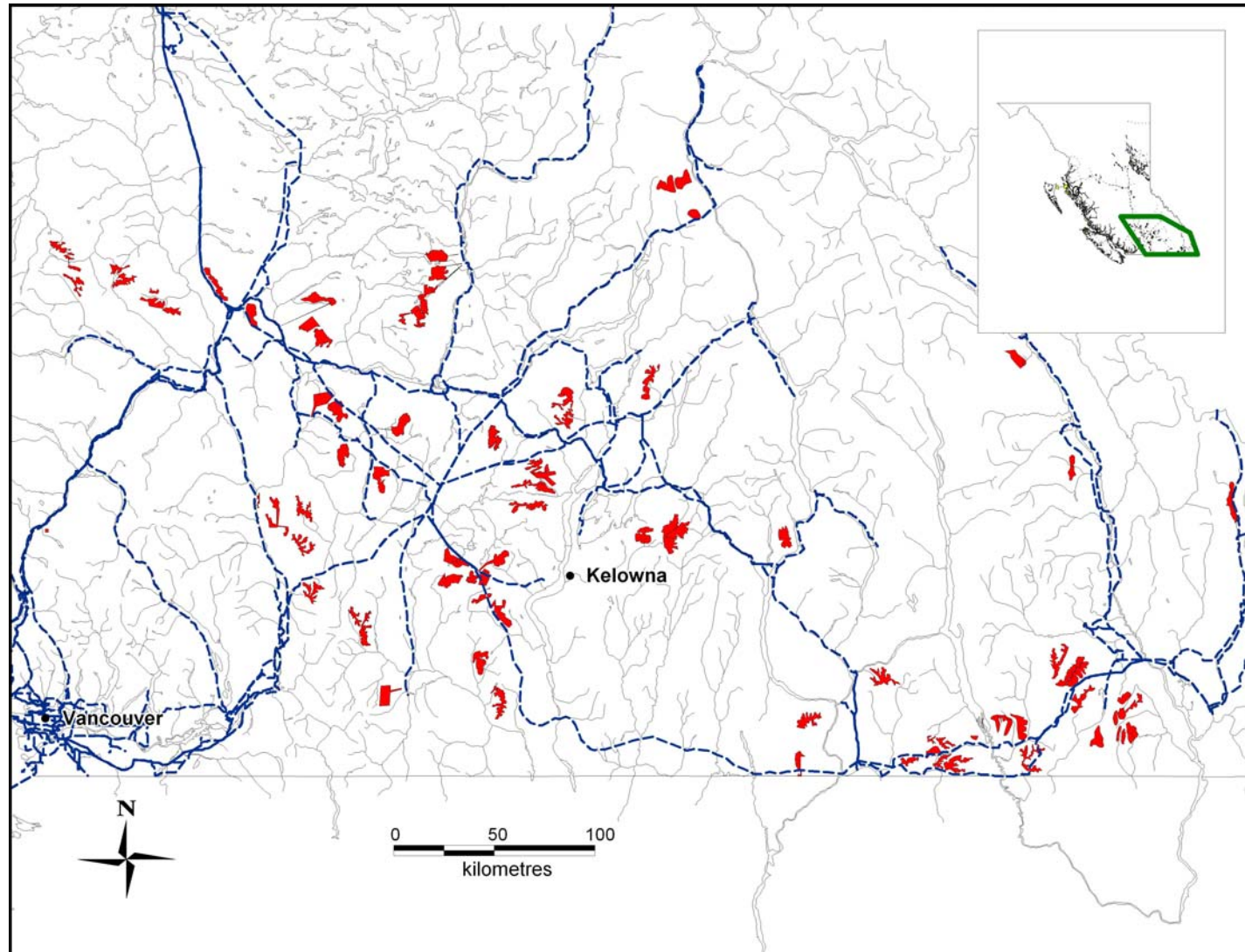


Figure 2.10 – IUP sites for the Southern and Eastern Interior

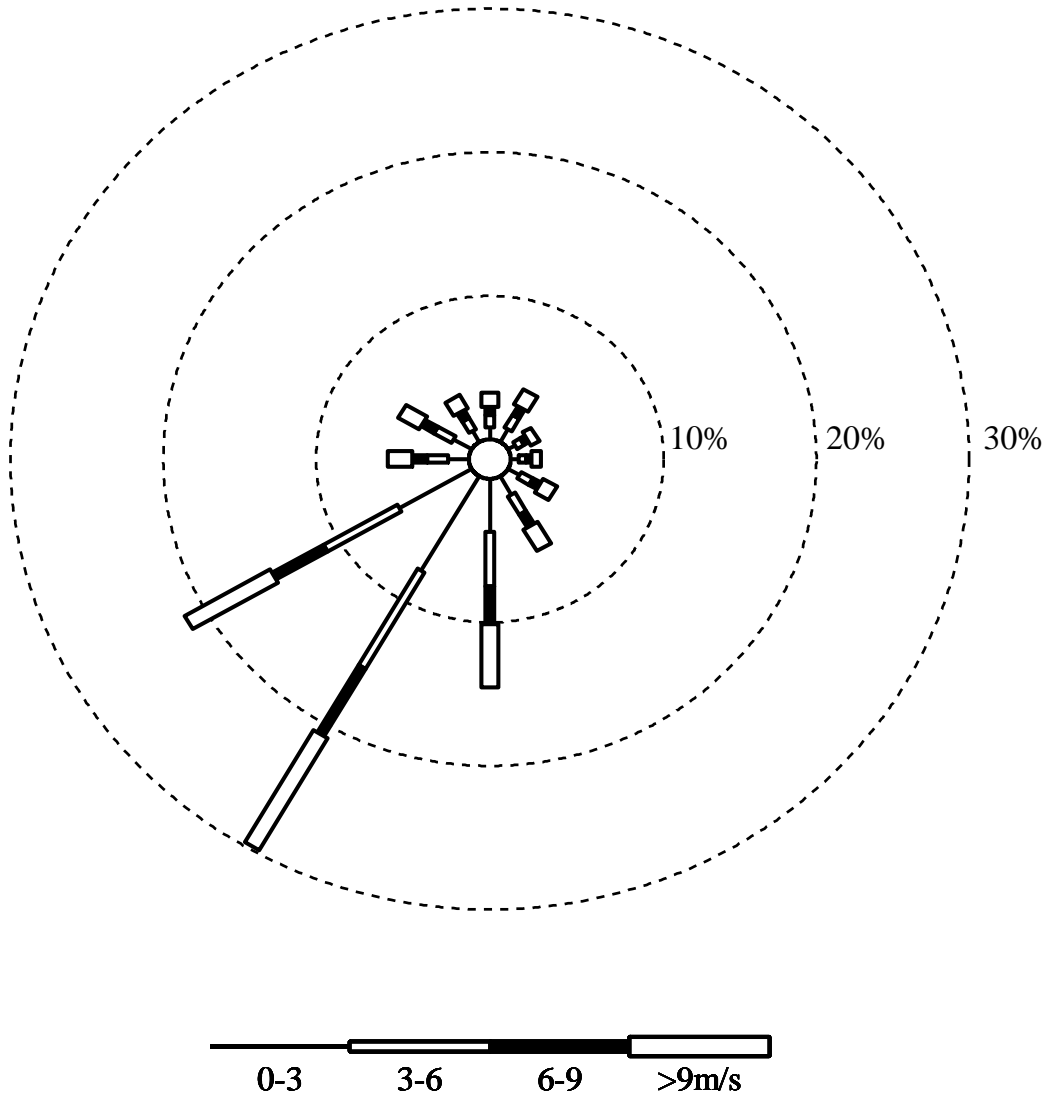


Figure 2.11 – Typical unidirectional wind rose for the Southern and Eastern Interior region



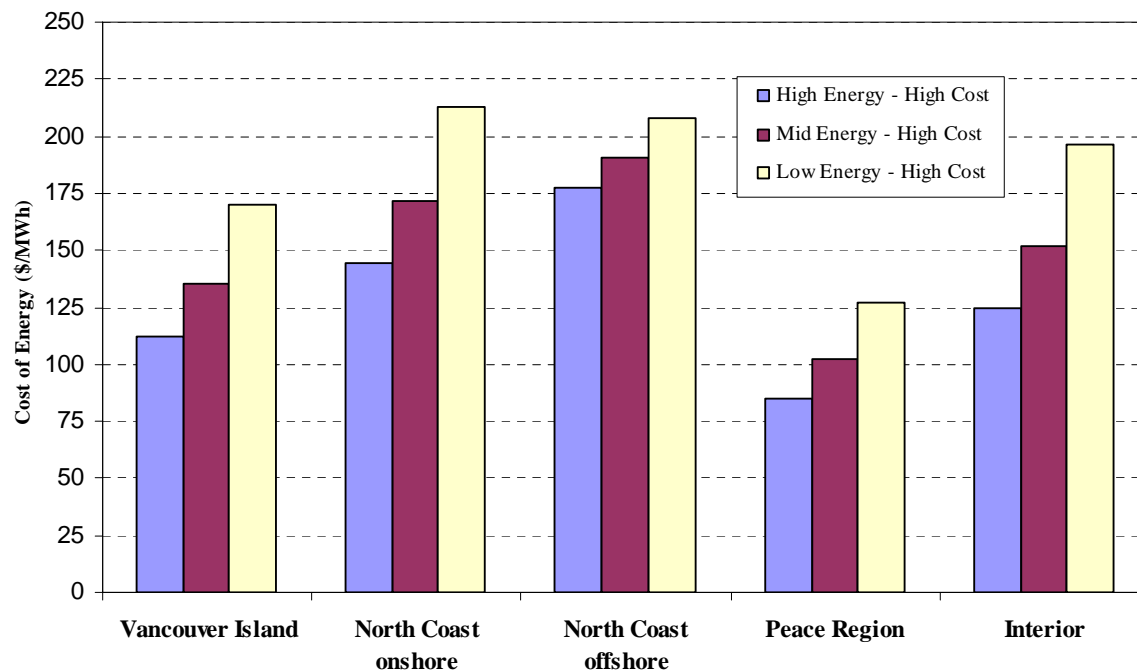
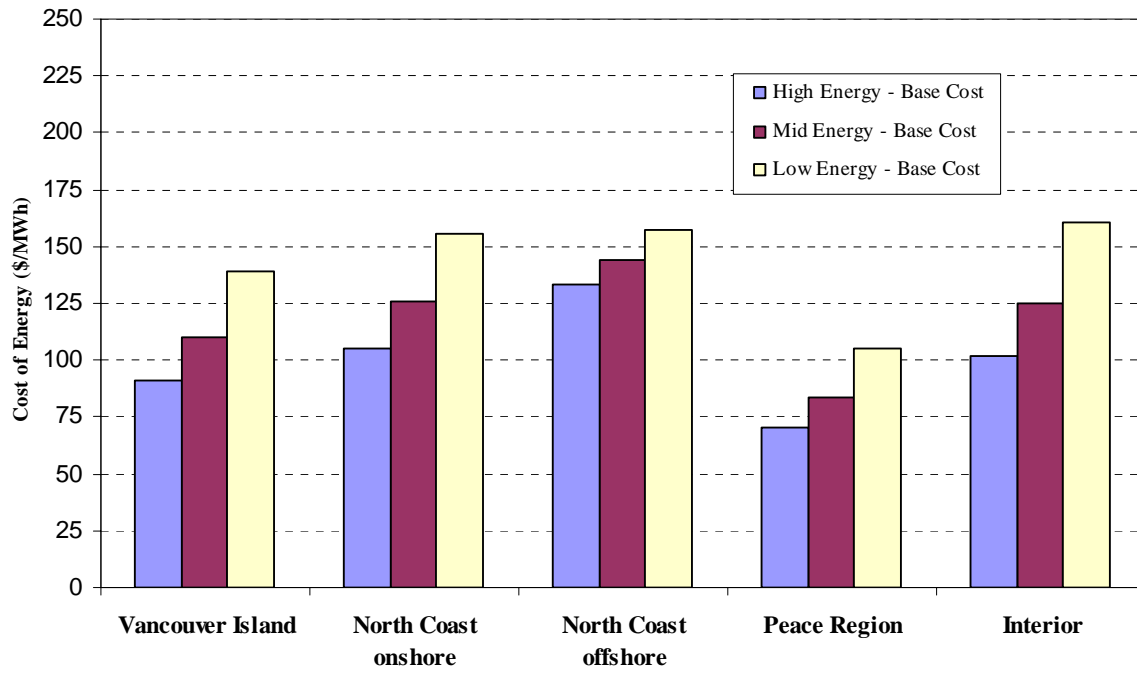


Figure 3.1 – Summary of cost estimate range (8% WACC)

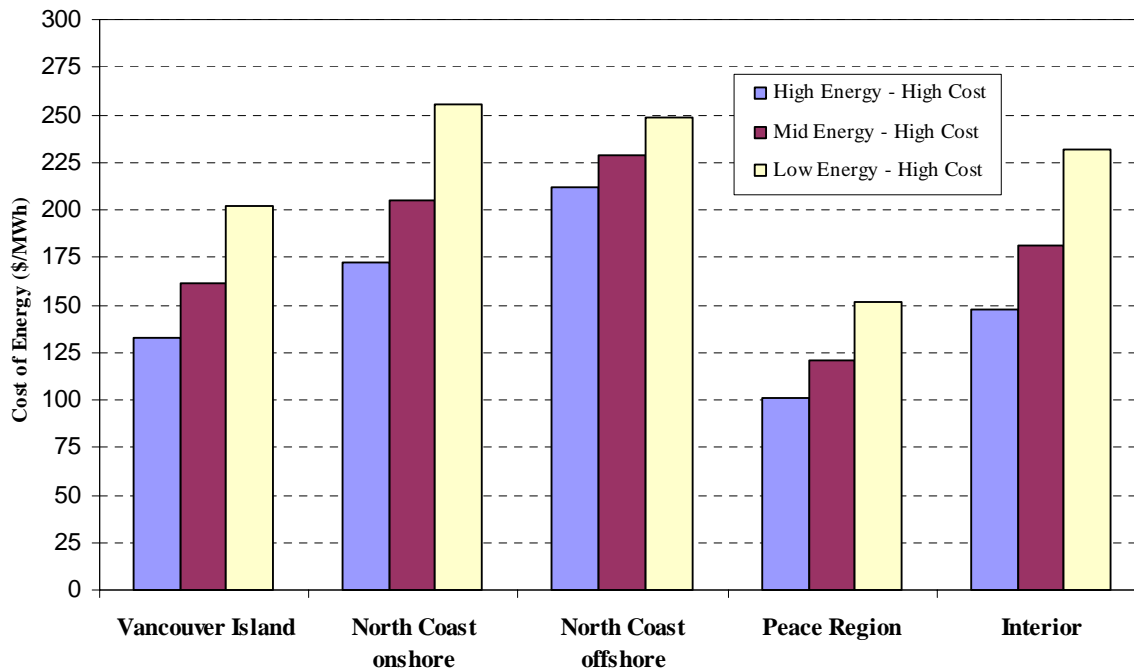
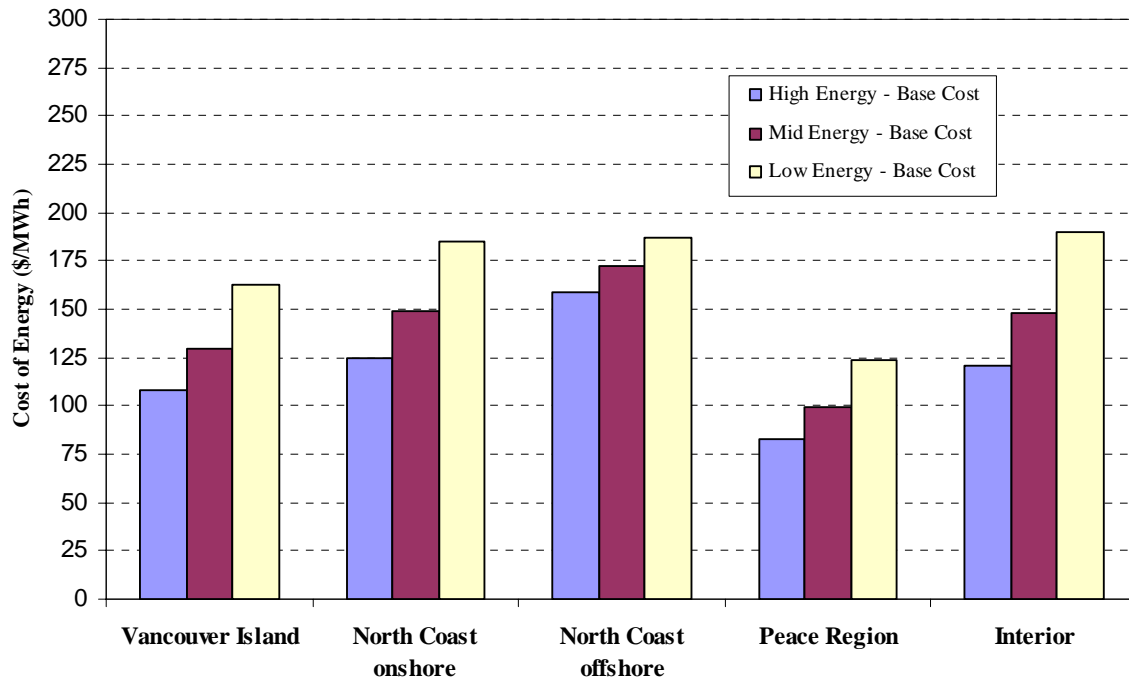


Figure 3.2 – Summary of cost estimate range (10% WACC)

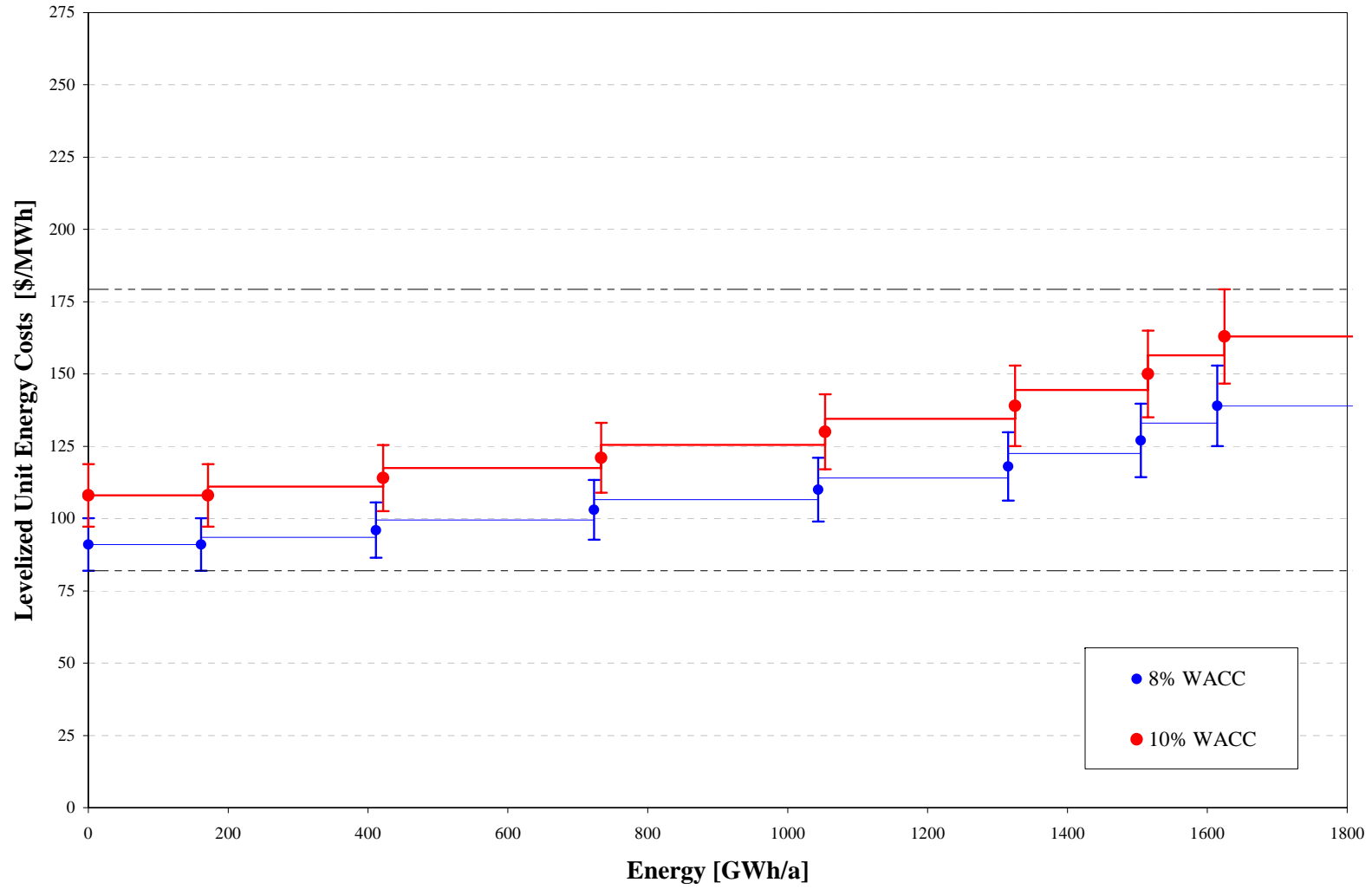


Figure 3.3 – Estimated supply curve for the Vancouver Island region – base cost

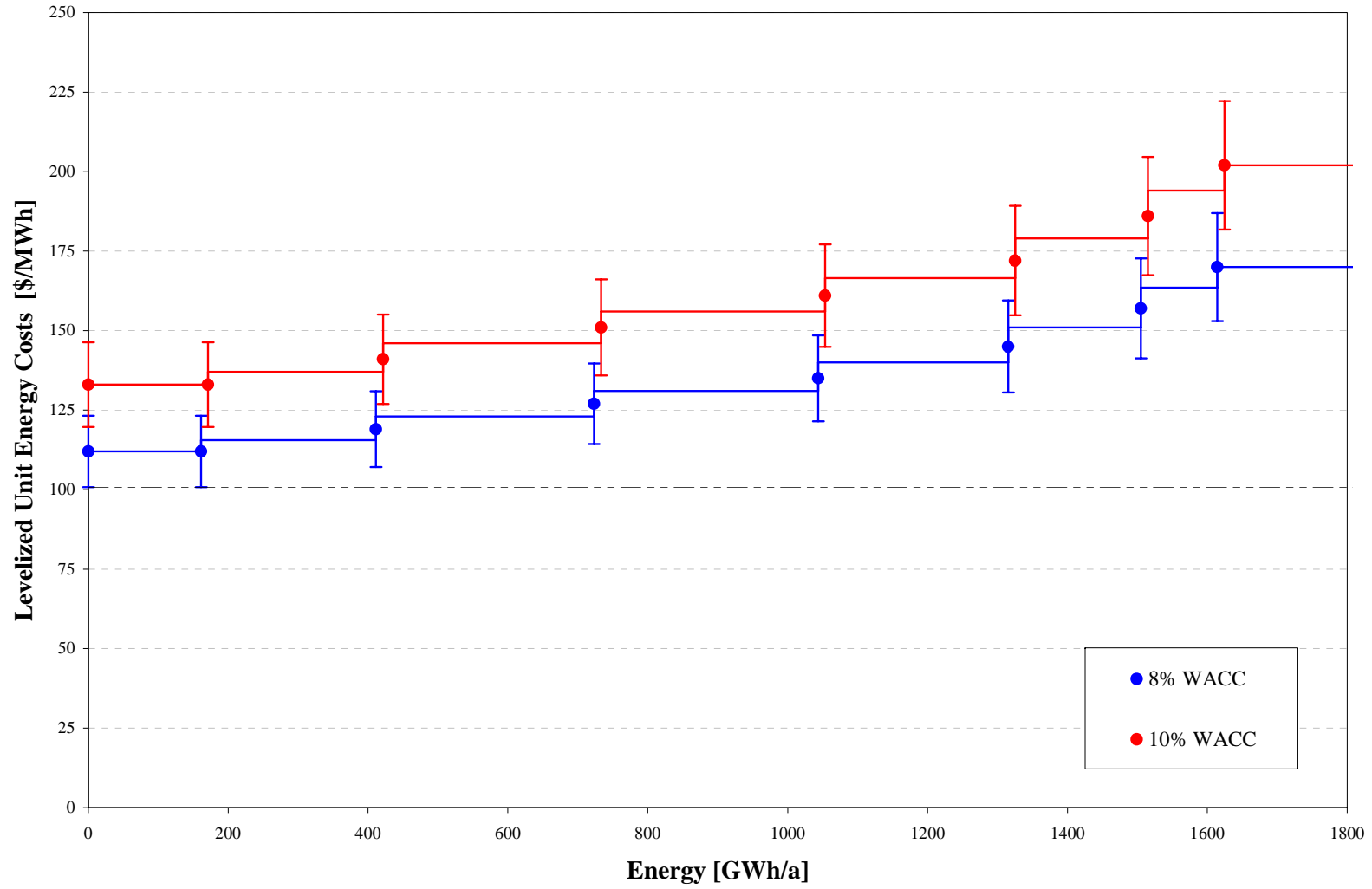


Figure 3.4 – Estimated supply curve for the Vancouver Island region – high cost

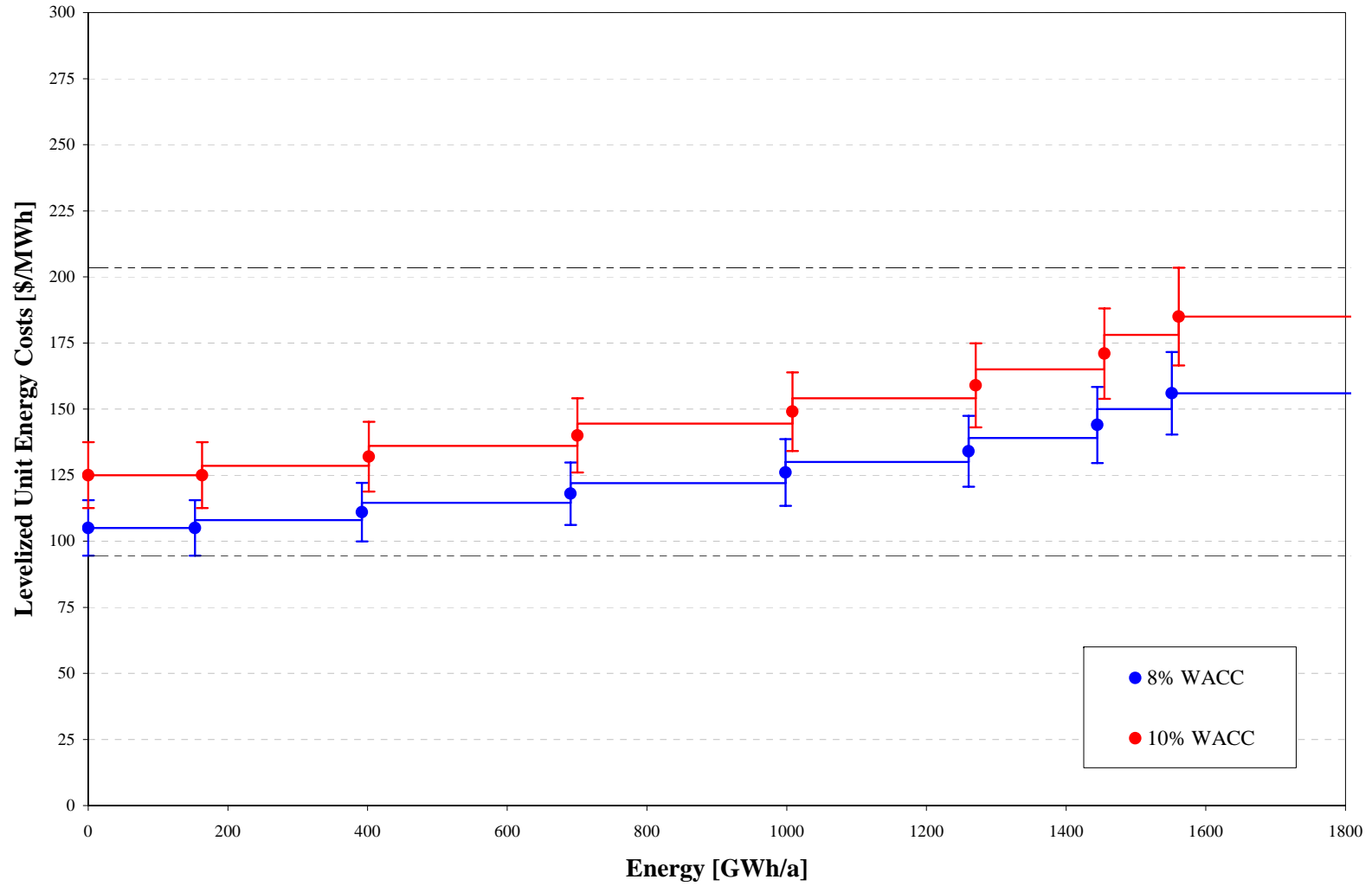


Figure 3.5 – Estimated supply curve for the North Coast region (onshore) – base cost

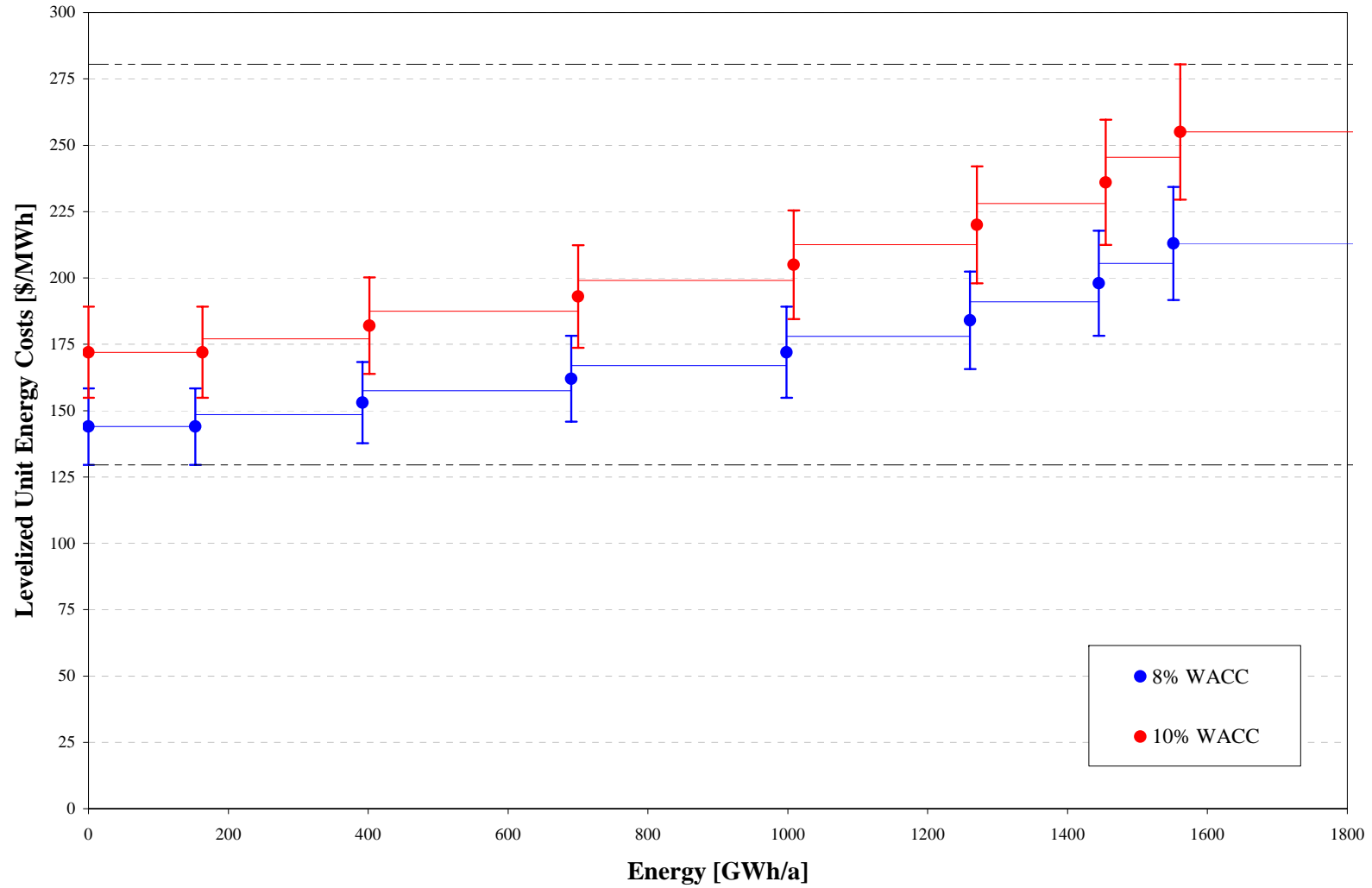


Figure 3.6 – Estimated supply curve for the North Coast region (onshore) – high cost

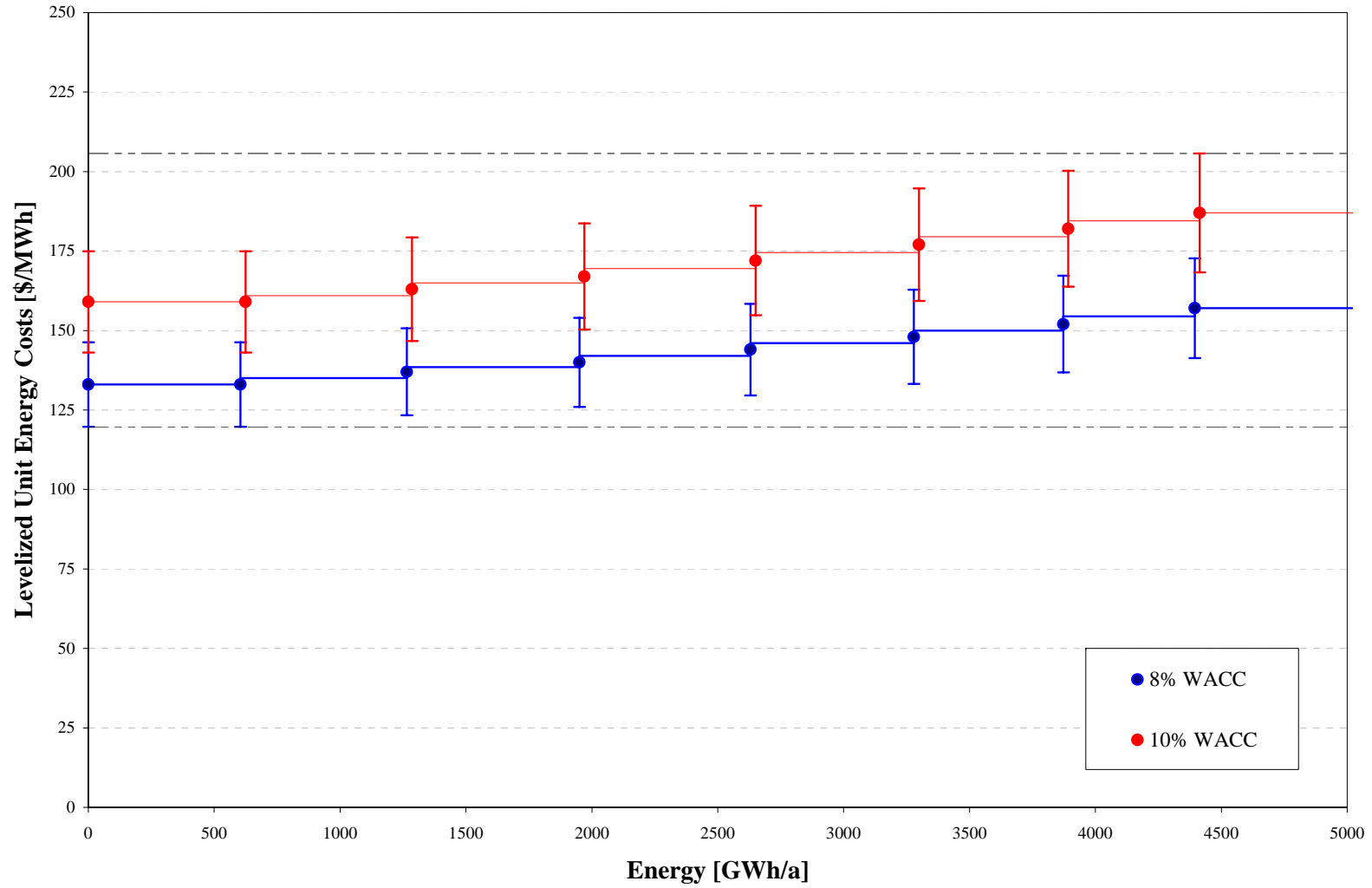


Figure 3.7 – Estimated supply curve for the North Coast region (offshore) – base cost

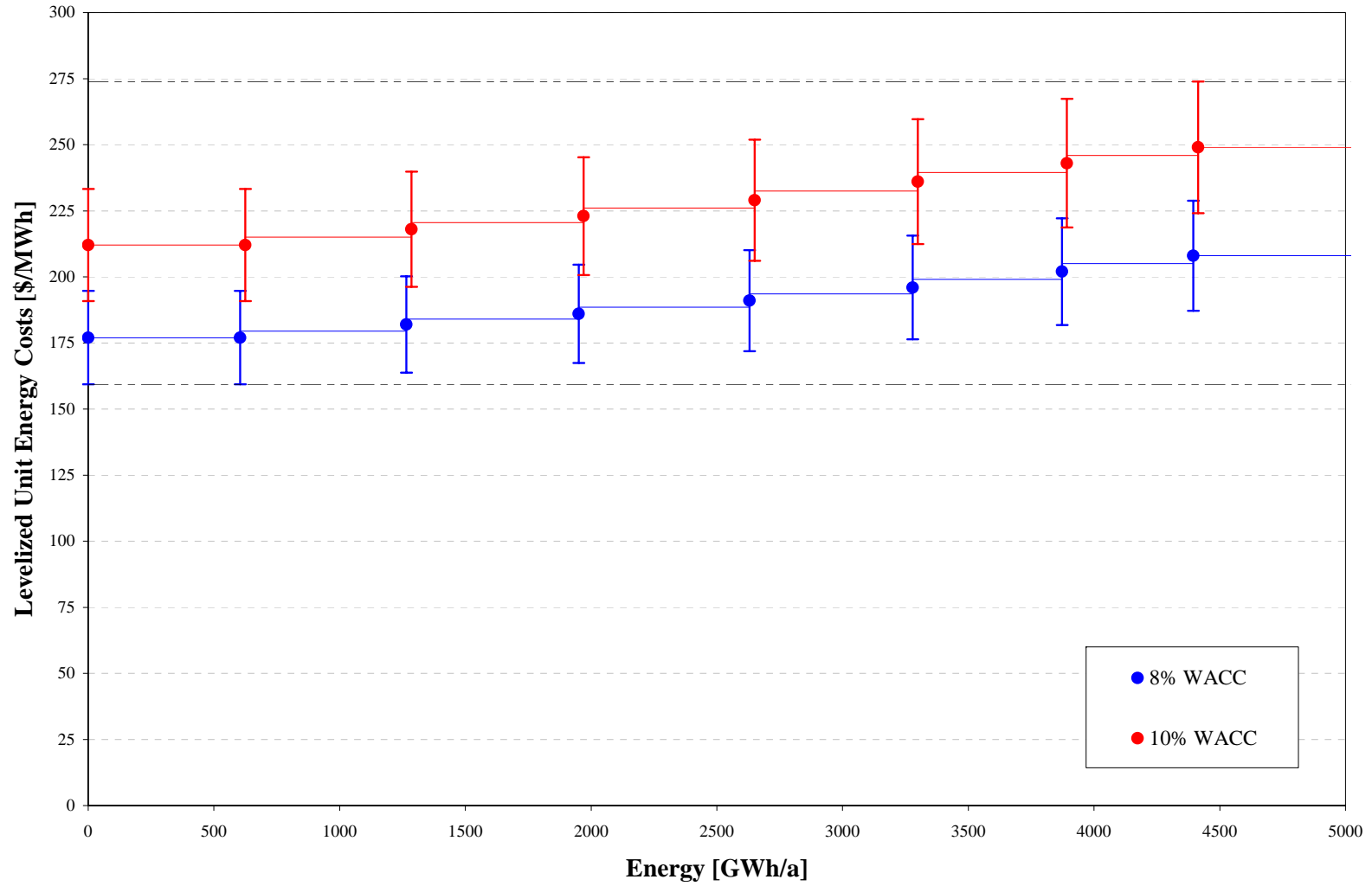


Figure 3.8 – Estimated supply curve for the North Coast region (offshore) – high cost

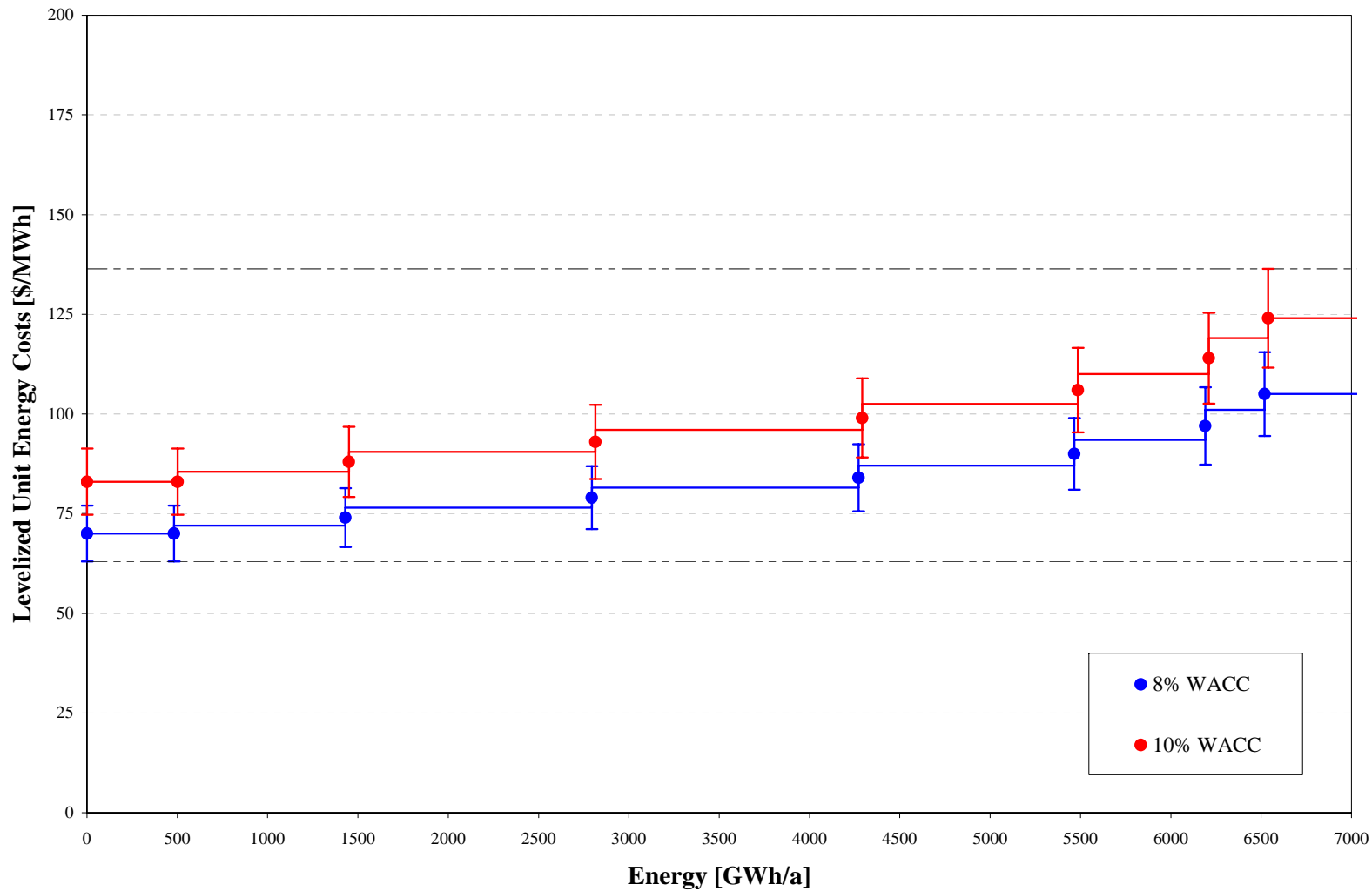


Figure 3.9 – Estimated supply curve for the Peace region – base cost

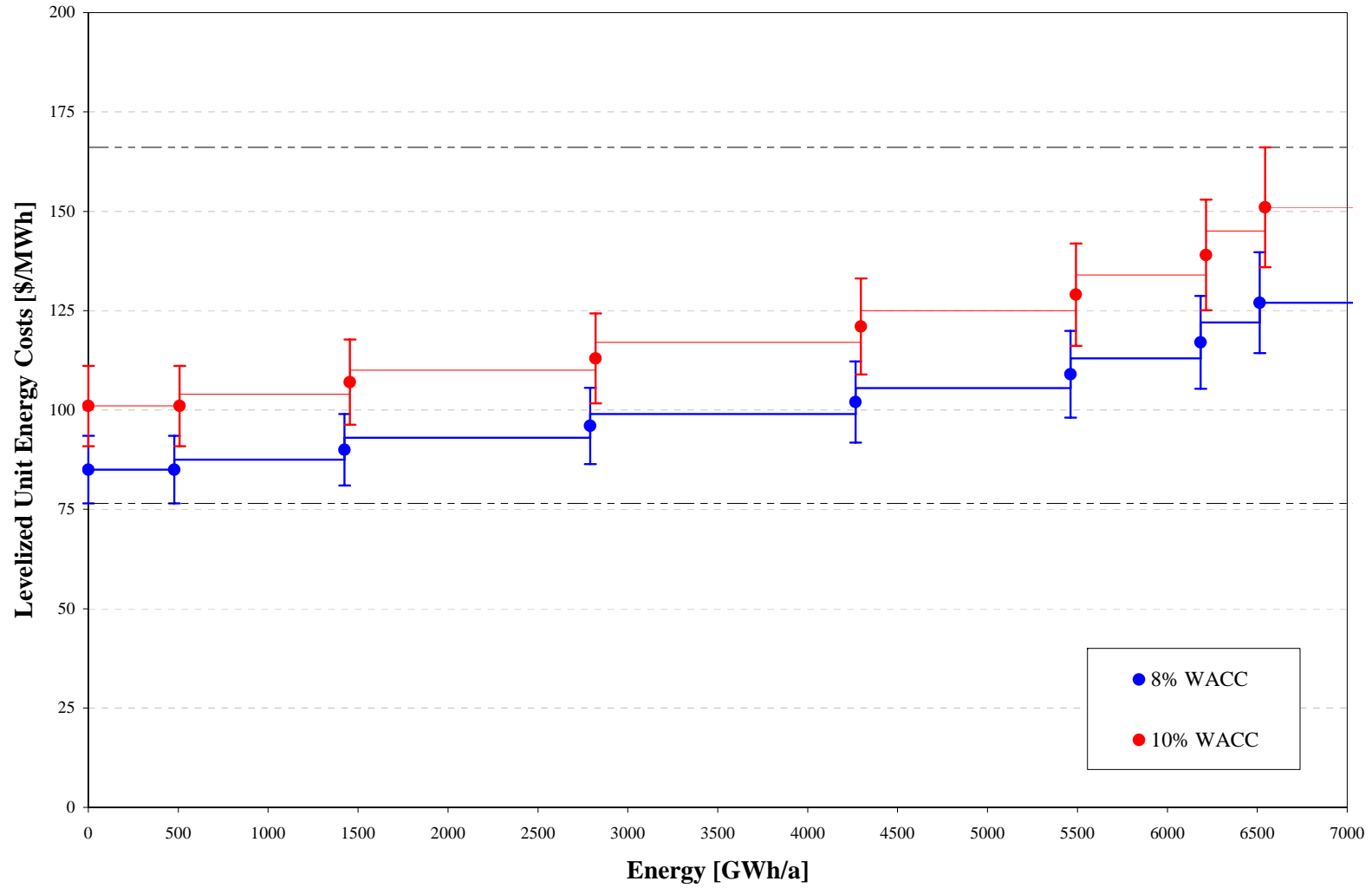


Figure 3.10 – Estimated supply curve for the Peace region – high cost

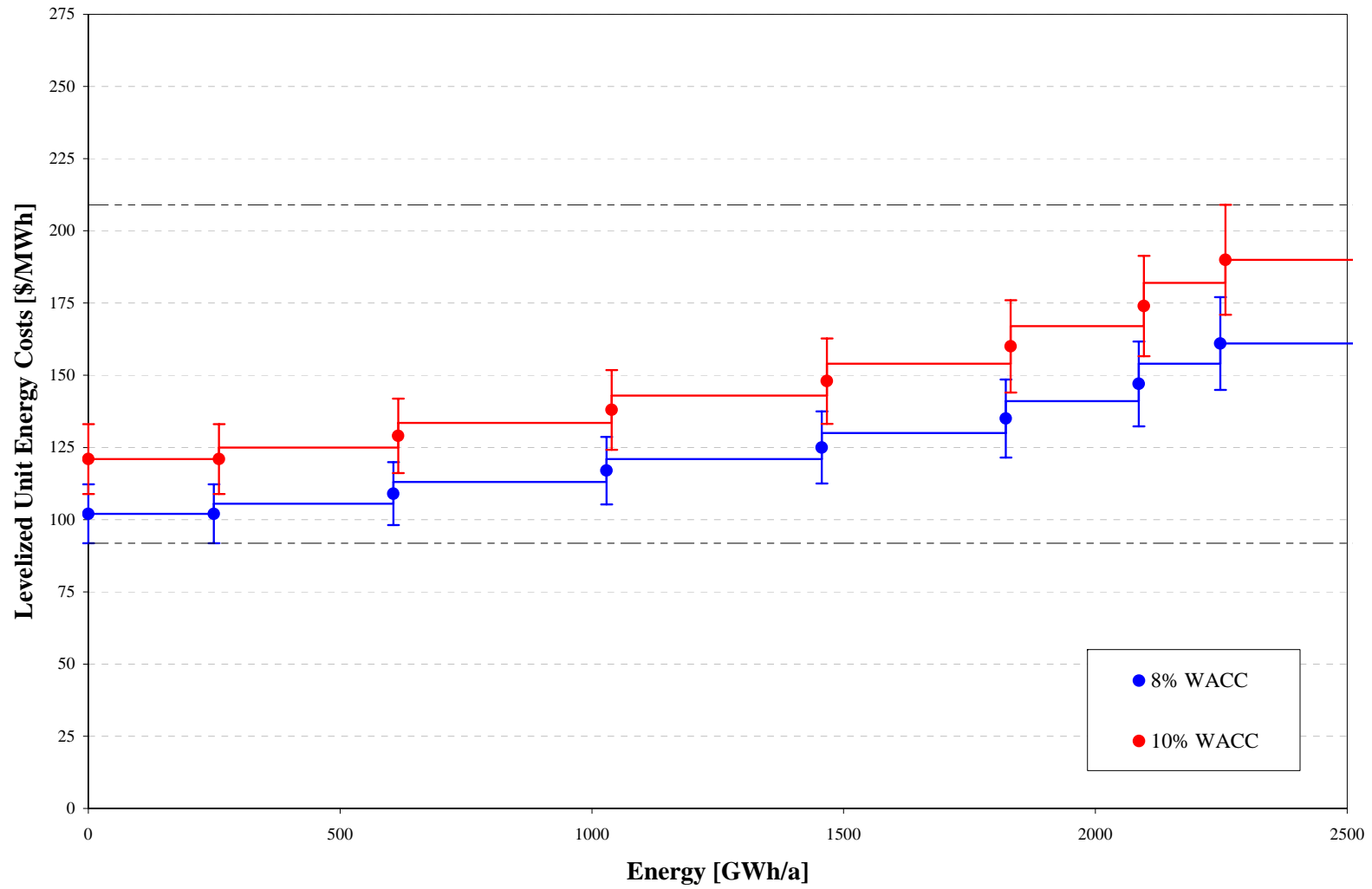


Figure 3.11 – Estimated supply curve for the Southern and Eastern Interior region – base cost

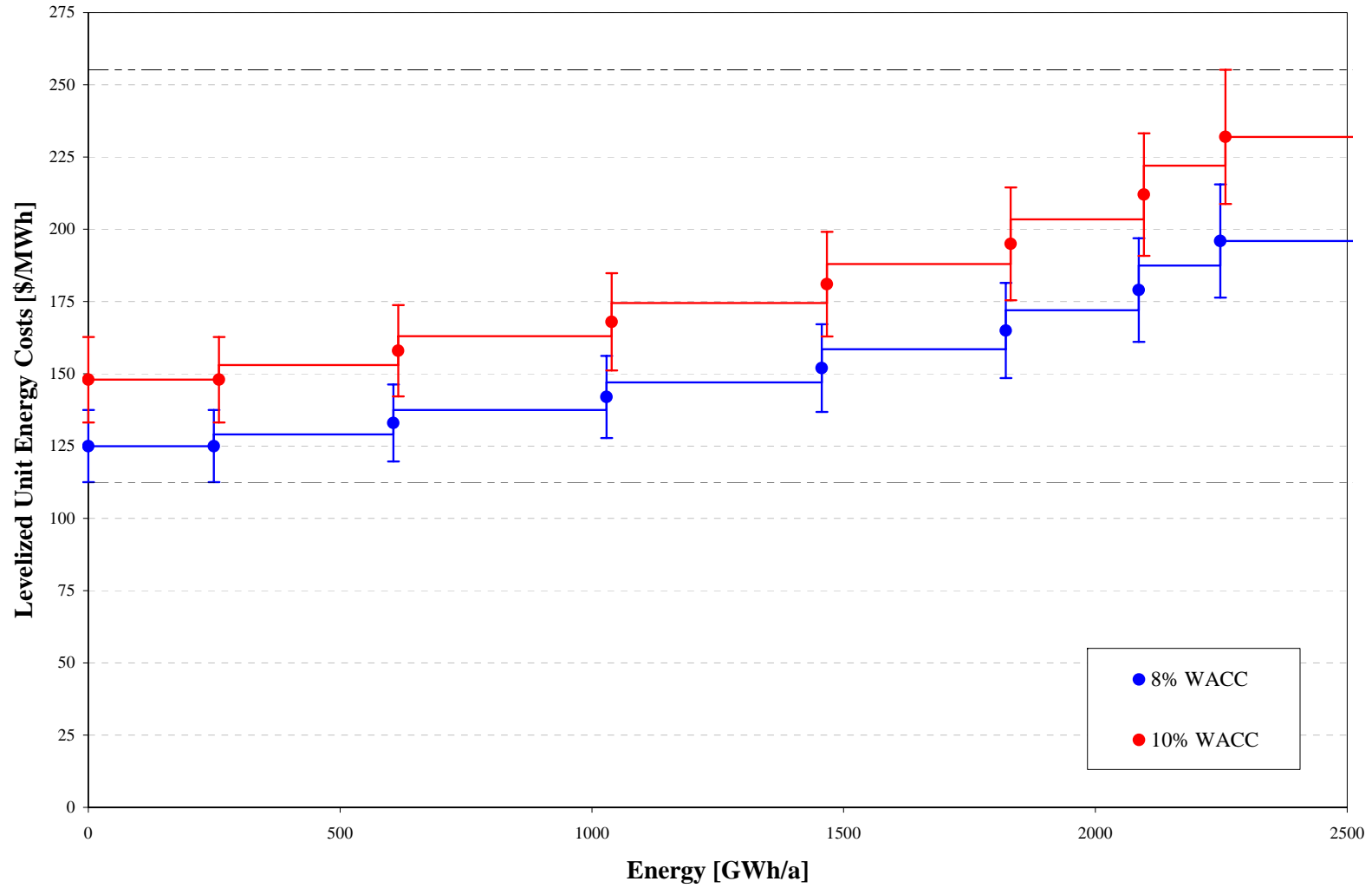


Figure 3.12 – Estimated supply curve for the Southern and Eastern Interior region – high cost

## **APPENDIX A**

### **List of Investigative Use Permit Sites**

Site Name	IUP ID	Project	Approximate Size [sq km]	Approximate Distance to Transmission [km]	Estimated Site Capacity [MW]	Site Categorization
Adam River	1412439	Onshore	38	30	50	B
Ahamingas and Gold River	1412732	Onshore	16	0	70	B
Bloedel	1413925	Onshore	16	5	70	B
Cape Caution	5406982	Onshore	50	50	100	B
Cape Caution	5406983	Onshore	50	50	100	B
Cape Caution	5406986	Onshore	50	50	100	B
Cape Palmerston	1412099	Onshore	185	35	250	B
Cape Sutil - 1	1412348	Offshore	45	45	310	B
Cape Sutil - 2	1412349	Offshore	45	45	310	B
Cape Sutil - 3	1412350	Offshore	46	45	320	B
Cape Sutil - 4	1412351	Offshore	48	45	340	B
Cape Sutil - 5	1412352	Offshore	49	45	340	B
Cape Sutil - 6	1412353	Offshore	47	45	330	B
Comstock Mountain	1412075	Onshore	16	10	50	B
Franklin Range	1412313	Onshore	39	5	40	B
Gold River/Crumble Mountain	1412730	Onshore	20	5	100	B
Gold River/Upana River	1412731	Onshore	21	0	100	B
Goodspeed	1412467	Onshore	48	30	40	B
Great Bear	1412469	Onshore	42	15	40	B
Hushamu Creek	1412026	Onshore	10	20	20	A
Jordan Ridge - 1	1413912	Onshore	46	10	150	B
Jordan Ridge - 2	1413913	Onshore	27	5	70	B

**Table A.1 – Investigative Use Permit sites for the Vancouver Island region – continued**

Site Name	IUP ID	Project	Approximate Size [sq km]	Approximate Distance to Transmission [km]	Estimated Site Capacity [MW]	Site Categorization
Jordan Ridge - 3	1413914	Onshore	41	5	150	B
Knob Hill	1412028	Onshore	45	25	150	A
Malcolm Island - East	1412499	Onshore	32	10	100	B
Malcolm Island - North	1412442	Ofshore	40	5	280	B
Malcolm Island - West	1412441	Onshore	30	5	90	A
Mount Brandes	1412104	Onshore	18	40	60	B
Nimpkish Lake	1412027	Onshore	34	0	36	A
Nimpkish Lake Block 2	1412494	Onshore	20	5	30	B
NW of Nahwitti Lake	1412361	Onshore	37	35	150	B
O'Connell Lake North	1412315	Onshore	45	10	200	B
Pemberton Hills	1412459	Onshore	39	20	30	B
Pinch Creek	1412461	Onshore	34	15	200	B
Roberts Creek	2409501	Onshore	29	0	50	B
Sechelt	2408993	Onshore	43	0	130	B
Shushartie North	1412024	Onshore	47	25	50	A
Shushartie South	1412466	Onshore	50	25	100	A
Texada Island	2409453	Onshore	54	0	150	B
Texada Island, South End	2409297	Onshore	20	0	70	B
Three Isle Lake	1412130	Onshore	25	15	50	B
Topknot Point	1412068	Onshore	35	45	20	B
Victoria Lake	1412070	Onshore	38	10	50	B
Whistler/Blackcomb Mountain	2409166	Onshore	3	5	20	B

**Table A.1 – Investigative Use Permit sites for the Vancouver Island region – continued**

<b>Site Name</b>	<b>IUP ID</b>	<b>Project</b>	<b>Approximate Size [sq km]</b>	<b>Approximate Distance to Transmission [km]</b>	<b>Estimated Site Capacity [MW]</b>	<b>Site Categorization</b>
William Lake	1412069	Onshore	64	45	150	B
Windy Ridge	1412133	Onshore	47	30	30	B
Wolverine	1412468	Onshore	46	5	40	B
Wolverine	1412129	Onshore	40	10	120	B

**Table A.1 – Investigative Use Permit sites for the Vancouver Island region – concluded**

Site Name	IUP ID	Project	Approximate Size [sq km]	Approximate Distance to Transmission [km]	Estimated Site Capacity [MW]	Site Categorization
Aristazabal Island - 3	6407568	Offshore	26	130	110	C
Aristazabal Island - 4	6407569	Offshore	50	140	110	C
Aristazabal Island - 5	6407570	Offshore	50	145	110	C
Aristazabal Island - 6	6407571	Offshore	50	150	110	C
Aristazabal Island - 7	6407572	Offshore	50	150	110	C
Aristazabal Island - 8	6407573	Offshore	50	150	110	C
Aristazabal Island - 9	6407574	Offshore	49	160	110	C
Aristazabal Island - 10	6407575	Offshore	50	170	110	C
Aristazabal Island - 11	6407576	Offshore	50	180	110	C
Banks Island	6407676	Onshore	50	60	350	B
Banks Island	6407677	Onshore	25	70	350	B
Banks Island - 1	6407779	Onshore	44	60	90	B
Banks Island - 2	6407891	Onshore	44	60	90	B
Banks Island - 3	6407892	Onshore	45	65	90	B
Banks Island - 4	6407893	Onshore	48	70	100	B
Banks Island - 5	6407894	Onshore	48	75	90	B
Banks Island - 6	6407895	Onshore	46	80	90	B
Banks Island - 7	6407896	Onshore	43	85	90	B
Dome Mountain	6407754	Onshore	50	20	100	B
Hirsch Creek	6407808	Onshore	50	5	100	B
Humphrys Creek	6407809	Onshore	48	0	120	B
Kennedy Island	6407816	Onshore	36	20	100	B

**Table A.2 – Investigative Use Permit sites for the North Coast region – continued**

Site Name	IUP ID	Project	Approximate Size [sq km]	Approximate Distance to Transmission [km]	Estimated Site Capacity [MW]	Site Categorization
Klo Creek	6407752	Onshore	50	10	200	B
Matzehtzel Mountain	6407753	Onshore	50	5	100	B
McCauley Island	6407411	Onshore	217	45	250	B
Mount Hays	6407359	Onshore	8	0	30	A
Nai Kun	6407371	Offshore	648	95	4540	B
Porcher Island	6407372	Onshore	651	15	980	B
Porcher Island	6407489	Offshore	1292	30	9040	B
Price Island - 1	6407562	Onshore	50	170	100	C
Price Island - 2	6407563	Onshore	48	170	100	C
Price Island - 3	6407564	Onshore	50	175	100	C
Price Island - 4	6407565	Onshore	19	180	100	C
S Of Port Edward	6407688	Onshore	50	5	150	B
Sinclair Creek	6407751	Onshore	50	0	200	B
Telegraph Passage/Ecstall River	6407846	Onshore	49	10	150	B
Trutch And Barnard Islands	6407416	Onshore	44	95	90	B

**Table A.2 – Investigative Use Permit sites for the North Coast region – concluded**

Site Name	IUP ID	Approximate Size [sq km]	Approximate Distance to Transmission [km]	Estimated Site Capacity [MW]	Site Categorization
Aikman Creek	8014639	48	55	120	B
Albright Ridge	8014771	16	25	200	B
Alexander Creek	8014630	40	35	50	B
Bear Mountain	8013937	19	5	120	A
Bergeron Ridge	8013969	18	5	70	B
Blair Creek	8014627	25	70	20	B
Briar Ridge	8014632	5	15	20	B
Bullmoose Creek	8014497	50	0	110	A
Burnt River	8014803	26	30	250	B
Butler Ridge	8014752	32	15	100	B
Butler Ridge	8014764	23	15	70	B
Cameron Lakes	8014636	47	0	100	B
Cameron River	8014633	49	65	30	B
Cluculz Lake South	7408690	50	0	100	B
Coldstream Creek	8014103	38	10	250	B
Coldstream Creek	8014631	29	10	10	B
Copeland Creek	8014637	9	20	30	B
Deadhorse Creek	8014638	28	30	40	B
Dokie Ridge	8014640	39	0	180	A
East Butler Ridge	8014322	48	15	400	A
East of Mackenzie	7408414	50	5	220	B
Falling Creek	8014024	14	25	50	B

**Table A.3 – Investigative Use Permit sites for the Peace region – continued**

Site Name	IUP ID	Approximate Size [sq km]	Approximate Distance to Transmission [km]	Estimated Site Capacity [MW]	Site Categorization
Farrell Creek	8014629	17	20	45	B
Fellers Heights	8014102	28	25	80	B
Finlay Ranges	7408428	50	115	220	C
Gwillam River	8014020	40	20	80	B
Hackney Ridge	8014186	44	35	1000	A
Halfmoon Lake	8014634	50	5	100	B
Halfway River Ridge	8014367	48	55	750	B
Hamelin Ridges	8014127	45	60	1400	B
Hasler Creek	8014446	37	5	100	B
Hidden Hill	8014664	40	35	120	B
Hidden Hill - Area B	8014663	40	35	120	B
High Hat Mountain	8014430	38	0	200	B
High Hat River	8014429	39	0	120	B
Hixon	7408426	30	10	70	B
Horseshoe Ridges	8014187	44	55	1000	B
Hourglass Creek	8014575	50	25	150	B
Huguenot Ridge	8014316	23	70	150	B
Johnson Creek	8014235	43	5	100	B
Kinuseo Creek	8014354	35	0	150	B
Kiskatinaw Ridge	8014346	46	15	400	A
Lemoray Creek	8014021	24	10	70	B
Little Boulder Creek	8014518	50	0	70	A

**Table A.3 – Investigative Use Permit sites for the Peace region – continued**

Site Name	IUP ID	Approximate Size [sq km]	Approximate Distance to Transmission [km]	Estimated Site Capacity [MW]	Site Categorization
Lynx Creek	8014628	32	10	30	B
Meikle Creek 1	8014511	38	0	60	A
Meikle Creek 2	8014498	38	0	40	A
Meikle Ridge	8014470	5	0	20	B
Minaker River	8014424	48	135	250	C
Moberly Lake	8014635	44	0	120	B
Moberly Lake	8014765	41	0	150	B
Mount Bennett	8014523	50	10	60	A
Mount Bickford	8014512	50	0	170	A
Mount Bisson	7408430	50	40	200	B
Mount Bullmoose	8014762	44	5	150	B
Mount Chamberlain	8014801	31	15	70	B
Mount Clifford	8014513	43	25	80	A
Mount Frank Roy	8014524	50	10	50	A
Mount George	7408379	53	15	150	B
Mount Gething	8014438	46	5	120	B
Mount Gillis	7408439	22	70	300	B
Mount Lehudette	8013951	32	10	100	B
Mount Lehudette	8014715	49	10	200	B
Mount Mcallister	8014761	45	10	70	B
Mount Montieth	8014525	46	10	50	A
Mount Puggins	8014576	50	25	70	B

**Table A.3 – Investigative Use Permit sites for the Peace region – continued**

Site Name	IUP ID	Approximate Size [sq km]	Approximate Distance to Transmission [km]	Estimated Site Capacity [MW]	Site Categorization
Mount Reesor	8014763	46	5	150	B
Mount Roberts	8013968	16	5	30	B
Mount Skovil	7408429	50	20	270	B
Mount Stephenson	8014526	30	15	40	A
Mount Wartenbe	8014105	35	0	50	A
N of Norman Lake	7408688	50	5	100	B
NE of Quesnel	7408427	50	25	200	B
North Peace Foothills	8014366	47	40	500	B
NW of Bednesti Lake	7408687	10	0	20	B
Oetata Ridge	8014468	50	20	220	B
Pink Mountain Ridges	8014368	48	100	550	C
Portage Creek	8014149	15	0	50	B
Ptarmigan Ridges	8014128	30	80	1000	B
Pyramis Peak	8014445	47	5	150	B
Quality Creek	8014425	50	15	150	A
Quintette	8013925	15	5	70	B
Redwillow River	8014347	48	20	750	A
South of Chetwynd	8014439	47	10	200	B
South of Vanderhoof	7408396	31	30	90	B
Swannell	7408440	10	35	100	B
Tumbler Ridge	8014485	37	0	100	A
Tumbler Ridge	8014753	35	10	70	B

**Table A.3 – Investigative Use Permit sites for the Peace region – continued**

<b>Site Name</b>	<b>IUP ID</b>	<b>Approximate Size [sq km]</b>	<b>Approximate Distance to Transmission [km]</b>	<b>Estimated Site Capacity [MW]</b>	<b>Site Categorization</b>
Wapiti - Thunder Mountain	8014348	48	20	750	A
West of Chetwynd	8014519	50	0	150	B
Wildmare	8014529	40	0	75	A
Williston Lake	8014150	27	20	70	B
Willow Creek	8014023	18	10	70	B
Wolverine Creek	8014796	6	25	250	B
Wolverine Ridge	7408441	19	70	500	B
Wolverine River	8014754	45	15	200	B

**Table A.3 – Investigative Use Permit sites for the Peace region – concluded**

Site Name	IUP ID	Approximate Size [sq km]	Approximate Distance to Transmission [km]	Estimated Site Capacity [MW]	Site Categorization
Apex Mountain	3411182	48	5	100	B
Arrow Creek	4404642	50	0	120	B
Arrowstone	3411615	36	10	110	B
Arrowstone Hills	3411565	46	10	120	B
Big Dog Mountain	3411352	6	20	200	B
Bingay Creek	4404619	44	0	130	B
Bonaparte Ridge	3411566	47	10	140	B
Bouleau Mountain	3410545	32	0	60	B
Bouleau Mountain	3410550	40	10	80	B
Boundary Creek	4404458	50	0	170	B
Brewer Creek	4404620	26	5	120	B
Buck Mountain	3411097	46	15	140	B
Chuwahls Mountain	3411567	51	5	150	B
Copper Mountain	4404536	49	5	170	B
Dash Hill	5407255	38	30	150	B
Duck Lake	4404641	44	5	150	B
East Anderson River	3411239	39	0	170	B
East of Whatshan Lake	4404422	42	5	120	B
Eneas Lakes	3411223	49	0	150	B
Fly Hill	3411096	50	10	150	B
Fly Hill 2	3411473	41	0	120	B
Forge Mountain	3411568	50	0	120	B

**Table A.4 – Investigative Use Permit sites for the Southern and Eastern Interior region – continued**

Site Name	IUP ID	Approximate Size [sq km]	Approximate Distance to Transmission [km]	Estimated Site Capacity [MW]	Site Categorization
French Mountain	3411375	50	25	220	B
Glossy Mountain	3411623	52	0	160	B
Gnawed Mountain	3411569	43	5	130	B
Hihuim Lake	3411570	47	20	280	B
Hogback Mountain	3411353	19	20	100	B
Home/Ferry/Fish Lakes	3411631	42	10	120	B
Jackass/Kanaka Mountain	3411317	45	5	170	B
John Bull Mountain/Mount Irene	4404465	38	0	220	B
Junction Creek	3411351	30	25	120	B
Kay Creek	3411629	43	0	150	B
Kelly Lake	3411354	38	0	150	B
Kirbyville Creek	4404626	41	5	120	B
Kirbyville Lake	4404624	42	10	100	B
Kootenay Mountain/Next Creek	4404464	5	0	20	B
Lamb Creek	4404589	40	0	200	B
Lamont Creek	3411628	50	10	100	B
Lost Mountain	4404463	20	0	100	B
Lytton	3411618	4	5	10	B
McNulty Creek	3411098	50	10	120	B
Metoots Hill	3411571	46	10	140	B
Monte Creek	3410548	47	5	140	B
Mount Chapperon	3410542	46	15	140	B

**Table A.4 – Investigative Use Permit sites for the Southern and Eastern Interior region – continued**

Site Name	IUP ID	Approximate Size [sq km]	Approximate Distance to Transmission [km]	Estimated Site Capacity [MW]	Site Categorization
Mount Kathleen	3411084	17	0	100	B
Mount Mara	3411152	49	5	120	B
Mount Neptune	4404461	47	10	150	B
Mount Thompson	4404459	48	0	150	B
Mount Thynne	3411237	19	25	70	B
Moyie Lake	4404426	49	5	170	B
Moyie Mountain	4404638	22	10	170	B
Mt. Olson	4404632	39	10	100	B
Otter Lake	3411464	41	20	120	B
Pattison Lake	3411469	49	0	150	B
Pennask Lake	3411479	44	5	130	B
Pennask Mountain	3410549	20	0	40	B
Porcupine Ridge North	3411572	49	15	150	B
Porcupine Ridge South	3411573	50	15	150	B
Prospect Creek	3411235	37	15	120	B
Record Ridge	4404460	24	0	70	B
Relay Creek	3411376	23	20	100	B
SE of St. Mary's Lake	4404424	48	5	200	B
Semour Creek	4404618	22	0	100	B
Spillimacheen	4404648	37	10	110	B
St. Mary's Lake	4404472	48	10	200	B
Stoyoma Mountain	3411236	38	10	150	B

**Table A.4 – Investigative Use Permit sites for the Southern and Eastern Interior region – continued**

<b>Site Name</b>	<b>IUP ID</b>	<b>Approximate Size [sq km]</b>	<b>Approximate Distance to Transmission [km]</b>	<b>Estimated Site Capacity [MW]</b>	<b>Site Categorization</b>
Swakum Mountain	3411624	53	0	160	B
Tahaetkun Mountain	3410541	40	10	80	B
Tee Pee Creek	4404637	17	5	100	B
Trepanage Plateau	3411472	47	5	140	B
Weaver Creek	4404625	49	0	120	B
West Bruer/Gunnar Creeks	3411641	34	20	100	B
Windy Ridge/Three Sisters Peak	4404462	27	0	120	B
Yahk Mountain	4404633	36	15	100	B

**Table A.4 – Investigative Use Permit sites for the Southern and Eastern Interior region – concluded**