# Integrated Resource Plan

# Appendix 6D-1

# Cluster Analysis Summary Memorandum

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# Memorandum

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**TO:** Nadja Holowaty, M.A.Sc., P.Eng. (BC Hydro)

**FROM:** Stefan Joyce, P.Eng.
Ron Monk, M.Eng., P.Eng.

**RE:** **BC HYDRO ROMAP UPDATE**
**Cluster Analysis Summary**
**478.098-300**

This memorandum outlines the potential resource options cluster analysis and clustered power line and road costing conducted for BC Hydro as a part of the *2010 Resource Options Update and 2011 Integrated Resource Plan* (IRP).

## INTRODUCTION

The cluster analysis, clustered power lines, and road costing discussed in this memorandum build upon the update to the resource options mapping (ROMAP) database in GIS, the density analysis of high energy and capacity regions, and the costing of individual roads and power lines.

The ROMAP update included at-gate (generation site) technical, cost (at-gate, road and power lines) and spatial information for each resource option. Please refer to the *Resource Options Mapping Update* report (KWL, May 2011) for more detail. The Resource Options in the update included potential:

- Biomass (Biogas);
- Biomass (MSW);
- Biomass (Wood Based);
- Geothermal;
- Hydro (Site C);
- Hydro (Pumped Storage);
- Hydro (Resource Smart);
- Hydro (Run of River Hydro);
- Solar;
- Thermal (Natural Gas);
- Thermal [Coal with carbon capture and sequestration (CCS)];
- Ocean (Tidal);
- Ocean (Wave); and
- Wind (On Shore & Off Shore).

The cluster analysis included:

- Identification and assessment of the regions of high energy and capacity density of the potential resource options;
- Selection of clusters and potential new node locations based on the energy and capacity densities;

- Costing of power lines and roads for projects to the new nodes and the selection of projects that would benefit from a new node as an interconnection point; and
- Costing of bulk transmission power lines from the potential new nodes to the exiting bulk transmission region, or, in the case of the NTL, the proposed new substation at Bob Quinn.

### CLUSTER AND NODE IDENTIFICATION

Regions of high energy and capacity density were considered when identifying potential clusters and ultimately potential new node locations.

The density of the energy and capacity of the resource options was mapped using the kernel density function of ARC GIS[1]. The density analysis was conducted excluding all projects in legally protected areas or in otherwise undevelopable areas (glaciers). In addition, the following resource options were excluded from the density analysis in an effort to avoid skewing the results:

- Pumped Storage (capacity projects were not considered applicable to the density analysis);
- Natural Gas (location of generation more a function of load, so not considered applicable);
- Site C (potential project close to transmission and would not trigger a new node, so not considered applicable);
- Coal with Carbon Capture and Sequestration (location of project site more a function of load, so not considered applicable); and
- Resource Smart (projects at existing generation sites, so not considered applicable).

A series of density analyses were conducted for a number of threshold at-gate unit energy costs (UECs). Density analyses (for both the capacity and energy) for the following at-gate UECs thresholds:

- All UECs;
- < $600/MWh;
- < $200/MWh;
- < $150/MWh; and
- < $100/MWh.

Figures 1 through 10 provide plots of the energy and capacity densities for the different price thresholds.

A cluster was generally defined as:

- A region with a density of 0.06 MW/km$^2$ and a minimum of 500 MW[2]; and
- At least 50 km away from the existing bulk transmission system.

There were seven regions that had in excess of 0.06 MW/km$^2$. See Figure 11 for a plot of the density boundaries. These regions were considered when selecting potential new nodes (substations):

- Most of the region around Vancouver Island was in relative close proximity to the existing transmission system, however this area was recognized as being transmission capacity challenged;

[1] The density analysis is described in more detail in Resource Options Mapping Update report (KWL, February 2011)
[2] As a comparison of capacity density with the WREZ method: WREZ uses 50 km x 50 km square grid while BC Hydro used a kernel density approach. WREZ Cluster definition: 1,500 kW within a 100-mile radius, which is equivalent to 0.018 MW/km2. Another difference in the approach for BC Hydro and WREZ, is that WREZ considered land use while BC Hydro considered legally protected status only.

- The south half of the region around Telegraph Creek and Bob Quinn was considered to be in relative close proximity of the proposed Bob Quinn substation;
- The region on the mainland across from Vancouver Island is particularly challenging for transmission due to terrain, coastal inlets, glaciers and legally protected areas. The south eastern portion of this region is essentially cut off from the rest of the region; and
- The region around Fort Nelson did not have greater than 500 MW of potential generation resources in close proximity; however, it is recognized as having load growth potential. It is presently connected to the transmission system via an Alberta interconnection, but is considered to be 'non-integrated', so was considered to be further than 50 km from the existing bulk transmission system.

Based on the considerations above, BC Hydro selected nine potential new nodes (See Figures 12 and 13):

- **North Peace River (NPR)** will connect to GM Shrum Substation (GMS);
- **Fort Nelson (FTN)** will be connected to NPR;
- **Liard (LRD)** will connect to FTN and then connect to NPR;
- **Telegraph Creek (TGC)** will connect to the future Bob Quinn Substation (BQN);
- **Dease Lake (DLK)** will connect to TGC;
- **Hecate (HCT)** will connect to Skeena Substation (SKA);
- **Knight Inlet (KTI)** will connect to Dunsmuir Substation (DMR) on Vancouver Island. It will collect resources in the northern part the high density region across from Vancouver Island;
- **Bute Inlet (BUI)** will connect to DMR. It will collect resources in the southern part the high density region across from Vancouver Island; and
- **North Vancouver Island (NVI)** will connect to DMR.

Note that KTI, BUI and NVI share a power line route between Campbell River and the interconnection point at Dunsmuir Substation (DMR).

### CLUSTER CONNECTED POWER LINE AND ROAD COSTING

The costing methodology was identical to the method for the individual power lines and roads as summarized in the ROMAP report.

The types of roads and power lines considered are defined below:

- T1: power line from a potential resource option generation site to the interconnection point at an existing power line or substation;
- R1: road (or barge) from a potential resource option generation site to an existing road (or large water body for barge access);
- T2: power line from a potential resource option generation site to the interconnection point at potential new node;
- R2: road from a potential resource option generation site to a potential road (R3) associated with a new node;
- T3: power line from a potential new node listed above (e.g., Hecate Strait, HCT) to the existing bulk transmission system (e.g., Skeena, SKA); and
- R3: a road from a new node to an existing road (if there is limited road density near the new node).

It was assumed that new nodes had all voltages required available at the new node (could include: 25, 69, 138, 230, and 500 kV), so no transformation costs were required. The cost of new nodes will be calculated by BC Hydro and are not included in the results provided in this work.

There were a number of exceptions made to the road and power line costing:

1. The following resource options had no roads, no power lines, and no interconnection costs calculated from GIS methods:

   - Site C; and
   - Resource Smart.

   This is because there should be more detailed and accurate data available from BC Hydro for these resources.

2. The following resource options will have no roads, no power lines, but were allowed to potentially have interconnection (T1) costs:

   - Biomass (Wood Based);
   - Biomass (Biogas);
   - Biomass (MSW); and
   - Pumped Storage at Mica.

   These resources were assumed to be in very close proximity to existing roads and power lines as they would be constructed at existing facilities, and hence should have minimal costs for roads and power lines.

   The interconnection cost was based on the interconnection location that the GIS selected. It would use the same interconnection cost methodology as the other resource options, just no power line cost.

3. There are two exceptions to the above for the following resource options in non-integrated areas:

   - Biomass (Wood Based) in Fort Neslon (WBBio_ST_LT_NE):
     - Will not have a road (assumed to be in very close proximity to existing roads); and
     - Will not have a T2 power line or interconnection costs (since there would be a node in Fort Nelson, and it was assumed that it would be in close proximity to existing infrastructure).

   - Biomass (Wood Based) in Dease Lake (WBBio_ST_LT_NW):
     - Will not have a road (assumed to be in very close proximity to existing roads); and
     - Will have a T2 power line (since there would not be a node in Dease Lake, and the community is not interconnected to the BC Hydro grid).

Costs and lengths of all selected T2 power lines were provided to BC Hydro in a dataset with the project information.

Costs of power lines from the new node to the existing bulk transmission system (T3) were provided for the least cost route for the following power line options: one circuit 230 kV, two circuit 230 kV, one circuit 500 kV, and two circuit 500 kV power lines.

## RESULTS

The new nodes allowed much shorter power lines for nearby resource options and hence much lower costs for power lines. Approximately one-third of the resource options (2457 out of 7758) benefited from connecting to a new node (i.e., T2 power line shorter, therefore cheaper than a T1 power line, so a T2 power line was selected).

On average there was a savings of 60% of the power line UEC and 45% of savings in the total UEC for projects that connected to new nodes (i.e., resource has connected through a T2 power line).

A summary of the new nodes and the resources interconnecting to them are presented in Table 1 below. Table 2 provides a summary of the T3 lengths and costs.

All the nodes with the exception of DLK had existing roads in the area, so there was only one R3 road between DLK and the existing roads near TGC. The potential R3 road length is 150 km and is estimated to cost approximately $40 million with annual costs of approximately $0.6 million of property tax and $0.7 million of operations and maintenance. Nearby potential generation resources were given an R2 road access from the generation site to the R3 if it was shorter (i.e., cheaper) than access to the existing road network.

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**Table 1: Summary of Resource Options Interconnecting to the New Nodes**

| New Node | Resource Type | Installed Capacity (MW) | Dependable Generating Capacity DGC (MW) | Effective Load-Carrying Capability ELCC (MW) | Average Annual Energy (GWh/yr) | Annual Firm Energy (GWh/yr) |
|---|---|---|---|---|---|---|
| **BUI** | Pumped Storage | | | 27,000 | | |
| | Run of River Hydro | 858 | 73 | 132 | 3,652 | 2,724 |
| **BUI Total** | | 858 | 73 | 27,132 | 3,652 | 2,724 |
| **DLK** | Biomass (Wood Based) | 3 | 3 | | 22 | 22 |
| | Run of River Hydro | 1,143 | 0.01 | 16 | 3,728 | 2,824 |
| | Wind (Onshore) | 920 | | | 2,038 | |
| **DLK Total** | | 2,065 | 3 | 16 | 5,788 | 2,846 |
| **FTN** | Biomass (Wood Based) | 61 | 61 | | 485 | 485 |
| | Run of River Hydro | 33 | | | 100 | 75 |
| **FTN Total** | | 94 | 61 | | 585 | 560 |
| **HCT** | Ocean (Wave) | 143 | | | 418 | |
| | Run of River Hydro | 38 | 0.2 | 7 | 123 | 96 |
| | Wind (Offshore) | 11,784 | | | 37,464 | |
| | Wind (Onshore) | 1,057 | | | 2,618 | |
| **HCT Total** | | 13,022 | 0.2 | 7 | 40,623 | 96 |
| **KTI** | Geothermal | 70 | | | 534 | |
| | Ocean (Tidal) | 27 | | | 81 | |
| | Pumped Storage | | | 13,000 | | |
| | Run of River Hydro | 2,066 | 141 | 325 | 8,838 | 6,694 |
| **KTI Total** | | 2,164 | 141 | 13,325 | 9,454 | 6,694 |
| **LRD** | Run of River Hydro | 337 | | 3 | 1,058 | 849 |
| | Wind (Onshore) | 1,559 | | | 3,470 | |
| **LRD Total** | | 1,897 | | 3 | 4,528 | 849 |
| **NPR** | Run of River Hydro | 350 | | 2 | 1,092 | 872 |
| | Wind (Onshore) | 1,530 | | | 4,391 | |
| **NPR Total** | | 1,880 | | 2 | 5,483 | 872 |
| **NVI** | Ocean (Wave) | 100 | | | 283 | |
| | Pumped Storage | | | 10,500 | | |
| | Run of River Hydro | 4 | | 1 | 9 | 6 |
| | Wind (Offshore) | 1,782 | | | 5,976 | |
| | Wind (Onshore) | 973 | | | 2,312 | |
| **NVI Total** | | 2,859 | | 10,501 | 8,581 | 6 |
| **TGC** | Geothermal | 200 | | | 1,577 | |
| | Run of River Hydro | 867 | | 24 | 3,090 | 2,557 |
| **TGC Total** | | 1,067 | | 24 | 4,666 | 2,557 |
| **Total** | | 25,905 | 277 | 51,010 | 83,360 | 17,204 |

**Table 2: Summary of Bulk Transmission (T3) Lengths and Costs**

| T3 Power Line Segment | Voltage (kV) | Number of Power Lines | Power Line Length (km) | Capital Cost (Not Including IDC, $ Millions) | Annual Costs: Property Tax ($ Millions) | Annual Costs: Operations & Maintenance ($ Millions) |
|---|---|---|---|---|---|---|
| LRD to FTN | 230 | 1 | 216 | $100 | $1.5 | $0.9 |
| FTN to NPR | 230 | 1 | 226 | $97 | $1.4 | $0.9 |
| NPR to GMS | 230 | 1 | 95 | $43 | $0.6 | $0.4 |
| HCT to SKN | 230 | 1 | 168 | $140 | $2.1 | $1.3 |
| DLK to TGC | 230 | 1 | 126 | $59 | $0.9 | $0.5 |
| TGC to BQN | 230 | 1 | 143 | $76 | $1.1 | $0.7 |
| NVI to CBL | 230 | 1 | 233 | $120 | $1.7 | $1.0 |
| KTI to CBL | 230 | 1 | 147 | $120 | $1.7 | $1.0 |
| BUI to CBL | 230 | 1 | 141 | $100 | $1.5 | $0.9 |
| CBL to DMR | 230 | 1 | 91 | $41 | $0.6 | $0.4 |
| LRD to FTN | 230 | 2 | 216 | $210 | $3.0 | $1.8 |
| FTN to NPR | 230 | 2 | 226 | $190 | $2.9 | $1.7 |
| NPR to GMS | 230 | 2 | 95 | $86 | $1.3 | $0.8 |
| HCT to SKN | 230 | 2 | 168 | $280 | $4.2 | $2.5 |
| DLK to TGC | 230 | 2 | 126 | $120 | $1.8 | $1.1 |
| TGC to BQN | 230 | 2 | 143 | $150 | $2.3 | $1.4 |
| NVI to CBL | 230 | 2 | 233 | $230 | $3.4 | $2.1 |
| KTI to CBL | 230 | 2 | 147 | $230 | $3.4 | $2.1 |
| BUI to CBL | 230 | 2 | 141 | $200 | $2.9 | $1.8 |
| CBL to DMR | 230 | 2 | 91 | $81 | $1.2 | $0.7 |
| LRD to FTN | 500 | 1 | 216 | $200 | $2.9 | $1.8 |
| FTN to NPR | 500 | 1 | 226 | $190 | $2.9 | $1.7 |
| NPR to GMS | 500 | 1 | 95 | $83 | $1.2 | $0.7 |
| HCT to SKN | 500 | 1 | 168 | $220 | $3.2 | $1.9 |
| DLK to TGC | 500 | 1 | 126 | $120 | $1.7 | $1.0 |
| TGC to BQN | 500 | 1 | 143 | $140 | $2.1 | $1.3 |
| NVI to CBL | 500 | 1 | 233 | $220 | $3.2 | $1.9 |
| KTI to CBL | 500 | 1 | 147 | $200 | $3.0 | $1.8 |
| BUI to CBL | 500 | 1 | 141 | $180 | $2.7 | $1.7 |
| CBL to DMR | 500 | 1 | 91 | $81 | $1.2 | $0.7 |
| LRD to FTN | 500 | 2 | 216 | $390 | $5.8 | $3.5 |
| FTN to NPR | 500 | 2 | 226 | $390 | $5.7 | $3.5 |
| NPR to GMS | 500 | 2 | 95 | $170 | $2.4 | $1.5 |
| HCT to SKN | 500 | 2 | 168 | $440 | $6.4 | $3.9 |
| DLK to TGC | 500 | 2 | 126 | $230 | $3.4 | $2.1 |
| TGC to BQN | 500 | 2 | 143 | $280 | $4.2 | $2.5 |
| NVI to CBL | 500 | 2 | 233 | $430 | $6.4 | $3.9 |
| KTI to CBL | 500 | 2 | 147 | $410 | $6.0 | $3.6 |
| BUI to CBL | 500 | 2 | 141 | $370 | $5.5 | $3.3 |
| CBL to DMR | 500 | 2 | 91 | $160 | $2.4 | $1.4 |

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