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Reconciling self-sufficiency and renewable energy targets in a hydro dominated system: The view from British Columbia

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HIGHLIGHTS

- Model of British Columbia's hydroelectric system with variable head heights.
- Variable water conditions simulate drought conditions.
- Estimates of import dependence with increased oil/gas demand.
- British Columbia cannot be both self-sufficient and meet its 93% RPS goal.

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ABSTRACT

British Columbia's energy policy is at a crossroads; the province has set a goal of electricity self-sufficiency, a 93% renewable portfolio standard and a natural gas development strategy that could increase electricity consumption by 21 TWh to 33 TWh. To ascertain the BC's supply position, a mathematical programming model of the physical workings of BC's hydroelectric generating system is developed, with head heights at the two dominant power stations treated as variable. Using historical water inflow and reservoir level data, the model is used to investigate whether BC is capable of meeting its self-sufficiency goals under various water supply and electricity demand scenarios.

1. Introduction

The Province of British Columbia (BC) is committed to becoming energy self-sufficient by 2016, and this includes the generation of an additional 3000 MWh of insurance energy. There is substantial controversy surrounding this goal, because it is remarkably difficult as a result of the distorting effects of BC's revenue-driven energy transactions to decipher whether the province has been a net importer or exporter of electricity in the past. At times, BC imports less expensive energy from adjacent regions to save water for future energy production, but it may also export energy to high priced regions for revenue and use the accrued financial gains to purchase lower-priced energy. Such decisions are meant to maximize net revenue, but there are occasions when BC imports electricity simply to meet internal load because of a shortfall in domestic supply. Because hydroelectricity accounts for more than 90% of generating capacity, shortfalls occur primarily when low reservoir levels reduce available generating capacity.

Whether the province can be self-sufficient given the current state of British Columbia's electrical system is the question addressed in this paper. We develop a mathematical programming model of the BC electrical system that allows the province to trade electricity with Alberta and the United States. Hydroelectric power production on the two largest rivers (Columbia and Peace) is modeled independently, while remaining hydroelectric production is assumed to be constant and treated as must run. There is also an option to produce thermal power from extant fossil fuel generators, although provincial policy aims to reduce electricity from fossil fuels. New investments in renewable sources of electricity generation (wind, biomass and run-of-river) are touted by government, while investments in nuclear power are untenable.

Our constrained optimization problem maximizes domestic revenue subject to meeting technical constraints, including serving daily domestic load over a one-year period. We find that, with no trade and no thermal generation, it is impossible to meet domestic load given the remaining resource configuration. When thermal generation is added, normal system demand can be met over a one year period even in the absence of trade, but reservoir live storage volumes will need to be drawn down to 70% of their original starting levels. Once imports from Alberta and/or the U.S. are permitted, imported energy displaces thermal generation of

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electricity, and, as the level of imports increases, higher end-of-year reservoir storage requirements can be met. Clearly, British Columbia is currently not self-sufficient in electricity production.

While load will likely continue to increase with population growth, the more pressing question relates to how the provincial government is going to rationalize the self-sufficiency goal with its commitment to produce and export liquefied natural gas (LNG). The *BC Jobs Plan* (British Columbia, 2012) states that BC will have at least one natural gas pipeline and LNG production facility and terminal in operation by 2015 and three by 2020. When shale gas exploitation is taken into account, the province will require between 2600 MW and 3750 MW of new generation capacity. The BC oil and gas industry, the largest revenue sector in BC's economy, will continue to drive both economic growth and electricity demand. In December 2010, BC Hydro forecast that the electrical load from the oil and gas industry would grow by 630% over the next five years.

To reduce the gap between actual and required generating capacity, the province could allow for self-generation via natural gas fired units in the province's northeast—the gas is available at low cost and, since generation is on-site, transmission issues are all but eliminated.[1] However, the 2010 *Clean Energy Act* requires the province to achieve an 18% reduction in provincial CO_2 emissions from 2007 levels, meet 66% of new energy demand through conservation initiatives, and use clean or renewable resources to generate electricity. Since natural gas-fired generation in BC is considered neither clean nor renewable, the development of gas-fired generation would count against the 93% renewable standard imposed by the legislation. Clearly, British Columbia is at a policy crossroads—it can try to achieve economic growth through resource development or it can aim for energy self-sufficiency, but it likely cannot achieve both.

2. Existing BC electricity infrastructure

BC Hydro is the single largest entity in BC's electricity sector and the third largest utility in Canada. The government-owned corporation serves 94% of the province's population. Its assets include large-scale hydro facilities with storage, run-of-river generating assets and two thermal generating units. BC Hydro divides its generating system into four regions: Peace, Columbia, Vancouver Island and the lower mainland (which includes Vancouver, the largest city in BC, and its suburbs).

The Peace region includes two major generating facilities on the Peace River—the GM Shrum and Peace Canyon dams. Shrum is comprised of ten generating units that are fed by water flowing from the province's largest storage system, the Williston Reservoir (39,462 million m^3). The Peace River flows through Shrum into Dinosaur reservoir and then through the Peace Canyon dam and generating station. The same amount of water flowing through Shrum also flows through the Peace Canyon turbines making the Peace Canyon station a run-of-river facility. Summary information regarding the various dams is provided in Table 1.

The Columbia basin includes the Columbia, Kootenay, Pend D'Oreille, Bull, Elk and Spillamacheen Rivers. The Columbia River originates in British Columbia and flows through Montana, Idaho, Washington and Oregon before spilling into the Pacific Ocean. The Columbia River Treaty is an international agreement negotiated between Canada and the U.S. that oversees the development and operation of dams in the upper Columbia River basin.

[1] Electricity generated in the northeast could not only service the oil and gas industry in this region but, given extant transmission lines from the northeast to the province's major load center in the southwest and to the U.S., gas-fired power could potentially be transferred farther afield.

Although the federal government negotiated the Treaty on behalf of Canada, the Canadian benefits and costs are solely attributable to British Columbia. Under the Columbia River Treaty, BC was obligated to construct and operate three dams (Mica, Arrow and Duncan) for the purpose of flood control that benefited the U.S. In essence, BC agreed to operate storage in Canada to prevent floods in the U.S. and optimize power production from U.S. dams on the Columbia River. Through BC Hydro, the province covered the cost of constructing and operating the Treaty dams, while receiving one-half of the resulting increase in power generated in the U.S., which was assigned to BC Hydro's marketing subsidiary, Powerex.

The Libby Coordination Agreement was negotiated in 2000 to resolve a dispute between BC Hydro and the Bonneville Power Authority (BPA)/U.S. Army Corps of Engineers. The Bonneville Power Administration is a U.S. federal energy agency in the Pacific Northwest. BPA markets wholesale electrical power from 31 federal hydro projects in the Columbia River Basin, one non-federal nuclear power plant and several other small non-federal power plants. The dams are operated by the U.S. Army Corps of Engineers and the Bureau of Reclamation. BPA also operates and maintains about three quarters of the high-voltage transmission in its service territory, which includes Idaho, Oregon, Washington, western Montana and small parts of eastern Montana, California, Nevada, Utah and Wyoming. The coordination agreement allows the BPA and the Corps to operate the Libby Dam in Montana for fisheries purposes without reducing the power benefits that British Columbia is entitled to under the Columbia River Treaty.

At the top of the Columbia River is the Kinbasket reservoir that stores 14,802 million m^3 of water behind the Mica dam and generating station. The Mica powerhouse has four turbines with a total 1792 MW of capacity. BC Hydro is in the process of upgrading Mica's generating capacity by installing another two 500 MW turbines that will provide an additional 1000 MW of capacity.

Downstream from Mica is the Revelstoke reservoir, generating station and dam. Revelstoke turbines are powered by water flowing from the Kinbasket reservoir as well as from local inflows. Essentially the Revelstoke power house operates as a massive run-of-river facility. Downstream of Revelstoke is the Hugh Keenleyside Dam that forms the Arrow Lakes Reservoir. BC Hydro and Columbia Power Corporation have recently completed the installation of 185 MW of generating capacity just downstream of the Keenleyside dam.

The Seven Mile generating station is located on the Pend D'Oreille River and has an installed capacity of 594 MW. The Skagit Valley Treaty provided the province with the ability to alter the reservoir level at the Seven Mile dam, but it obligates BC Hydro to deliver the equivalent of 35.4 MW of capacity to the Seattle load center. BC Hydro is compensated by Seattle for this energy through a series of negotiated payments.

The Columbia basin contains five other smaller generating stations (Aberfeldie, Elko, Spillimacheen, Walter Hardman and Whatshan) operated by BC Hydro. These provide the province with a total of 79 MW of generating capacity.

The largest generating facility in the lower mainland area, and the third largest of BC Hydro's units, is the Bridge River complex. It includes the La Joie Dam and its 25 MW powerhouse, the 480 MW Bridge River generating units and the 24 MW Seton power station. There are an additional nine hydro generating facilities in the lower mainland area with a total 542 MW of sustained generating capacity. In addition, the lower mainland area has the province's largest thermal power plant—the 912.5 MW capacity Burrard natural gas plant; a second thermal power plant with a 46 MW capacity is located in Prince Rupert.

Vancouver Island is tied to the lower mainland's transmission infrastructure. The lower mainland provides nearly 80% of the