***Long Term Optimization of BC-Alberta Interconnected Energy System: Hydro-Wind Combined Case Study***

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## Overview

British Columbia has a high potential of hydroelectricity which makes it unique regarding green energy resources. However, Alberta has a wide combination of fossil and renewable based generation technologies, from coal to natural gas and other renewable sources such as wind energy. In this study, British Columbia and Alberta electricity grid expansion is taken into consideration and by taking into account wind energy potentials in these two provinces and electricity trade, substitution of wind by fossil fuel power plants, especially coal, will be analyzed. In this regard, evaluating the penetration of wind and hydro into the existing system is being evaluated considering the effects on GHG mitigation.

The methodology is based on large scale energy system optimization modeling. In this project, expansion of grid connection between BC and Alberta is seen in a long-term multi-objective optimization model. As renewable energies such as wind and hydro have different potentials in different times of year, load regions are defined in the model to be able to consider different wind and hydro potentials at different times in a year. As a result, cost effective policies are introduced by considering effects of wind-hydro integration on GHG mitigations in long term energy planning.

Three scenarios are considered. The first scenario allows no gas power plant expansion in BC, no new transmission expansion between BC and Alberta or BC and US. Second scenario will allow transmission expansion between BC and Alberta and the third scenario will allow new gas power plant installation in BC, grid expansion between BC and Alberta but no wind expansion.

The results show that by enabling transmission expansion between BC and Alberta, higher integration of wind energy potential in BC can be obtained which results in a total CO2 reduction of 43% in year 2050 relative to no wind scenario.

## Method

A mixed-integer mathematical programming approach is utilized in this approach and MESSAGE (Model for Energy Supply Strategy Alternatives and their General Environmental Impacts) was used as the platform [7, 8, 9]. A two region energy system is defiend in the model considering different technologies in the conversion and transmission levels. Renewable resources are defined according to regional potentials for different river systems and wind farms. Techno-economic specifications of different technologies, such as investment costs, fixed and variable O & M costs, fuel costs, efficiency, plant life and availability factor are considered to enable the economic competition of existing and new technologies. Dynamic constraints are defined to enable limitations of renewable potentials in different seasons and hours of the year, also limiting outflows of the reservoirs and reservoir levels according to environmental constraints.

Alternative energy supply strategies consistent with limits on new investment, fuel availability and trade, environmental regulations and market penetration rates for new technologies are evaluated. Environmental aspects are analyzed by accounting the amounts of pollutants emitted by various technologies at various steps in energy supplies.

## Results

When grid expansion is allowed, more wind-hydro penetration would be allowed in BC to substitute fossil fuel consumption in Alberta. Grid expansion up to 5300MW would be economical between BC and Alberta to allow renewable based electricity transmitted to Alberta's grid which will substitute coal and gas in Alberta. Generation mix for year 2050 for the integrated BC-Alberta energy system is shown in figure 2. It is seen that wind penetration increases to 23% of entire generation, hydro would supply another 24% and gas would provide the remaining 53% of electricity generation. The shadow price for electricity in the optimization model will be the marginal cost of electricity in the final level. The marginal price of electricity is calculated when there are no limitations on transmission expansion allowing wind penetration. It is seen that marginal costs of electricity is lower in BC than in Alberta most probably because of high hydro potentials in BC that is a cheaper energy source. Alberta electricity marginal cost decreases from 45 $/MWh in 2012 to 39 $/MWh in 2050 as it receives more electricity from BC. Marginal cost of Electricity in BC starts from 20 $/MWh up to 37 $/MWh in 2050 as it installs more wind farms.

Three Scenarios are defined for comparing the CO2 emissions from the entire BC-AB supply system. results and effects on transmission expansion when wind and hydro expansion are enabled. Scenario 1 is defined without allowing BC-AB transmission expansion and no gas generation expansion in BC. Scenario 2 is defined when transmission expansion between BC-AB is allowed and still no new fossil plant in BC. Scenario 3 is defined with no wind expansion plan and allows gas power plants installation in BC. Figure 4 shows the comparison of the three scenarios for CO2 emissions. It is seen that scenario 2 has the least carbon emissions for the entire period under study.

## Conclusions

It is concluded that in long term energy planning up to year 2050, by expanding the interprovincial transmission between provinces, wind and hydro energy would be much more economical compared to a limited grid connection between the provinces. The total cost of BC-AB energy system would be minimized when allowing grid expansion between provinces. This figure for wind capacity covers about 23% of BC-Alberta integrated load in year 2050.

It is seen that marginal costs of electricity is lower in BC than in Alberta most probably because of high hydro potentials in BC that is a cheaper energy source. In Scenario 2 which BC-AB grid expansion is allowed and no gas expansion allowed in BC, we have the least CO2 emission which reaches up to 24000 kton/yr in 2050. If BC-AB transmission is not allowed (scenario 3), CO2 emission would reach 28,000 kton/yr in 2050 and if no wind expansion is allowed and instead gas expansion allowed in BC, CO2 emission can reach as high as 42,000 kt/yr in 2050.

Alberta's fossil fuel consumption would reduce from today's 90% to as low as 80% which the decrease is a result of wind and hydro substitution. This conclusion is based on the economic aspects of grid expansion without considering externality effects of CO2 mitigation on the entire energy system.

4593MW of new grid capacity would be required totally up to year 2050. 1068MW of it would be required for year 2020 (requiring $854.4 million) and the rest 3525MW is required to be installed for the year starting 2025 (requiring $2820 million). Thus approximately a total of $3.7 billion investment on BC-Alberta grid expansion would result in a minimum cost energy system up to year 2050.

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