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Hydroelectric vulnerability and climate change

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The purpose of this briefing note is to bring together some findings from PICS-supported research related to the security of hydroelectricity supply in British Columbia under a changing climate. The research was published in three separate papers in the journals *Applied Energy*, *Climatic Change* and *Nature Geoscience,* and was carried out by scientists and engineers from several agencies including PICS' sister organization, the Pacific Climate Impacts Consortium, and the PICS supported 2060 Project.

Issue

Around the world, hydroelectricity is the work-horse of the clean-energy transition due to a pair of very desirable attributes: a low carbon footprint and the fact that large-scale hydro-electric plants are not intermittent, unlike wind and solar power.

Hydro currently represents 16 percent of global electricity generation[1]. In Canada, hydroelectric delivers approximately 60 percent of the country's electricity, a figure that climbs to around 90 percent in British Columbia (BC) and 96 percent in Quebec, depending on water flows each year. However the long-term security of this resource cannot be assumed given the impact of climate change on hydrological supplies both in a positive and negative way.

A group of European researchers' computer modeling work on the interplay between climate change and hydropower at a global level concluded[2] that many regions will suffer from reductions in usable capacity at the mid-century mark, but these effects will vary wildly. In some regions a warming world will give hydroelectricity a boost; in other areas, hydro resources are diminished. All areas, however, face increased uncertainty and a change in the seasonality of resources—and even in those regions and time periods where there will be a net benefit, providers will likely face increased costs associated with planning for such changes and uncertainty.

This briefing note considers the scenarios for British Columbia.

Background

The water used to generate hydroelectric power is derived either from glacier runoff or precipitation. BC's energy system depends on both types.

Projections of future deglaciation in BC have been modeled by a group of earth science and glaciology researchers from the University of Victoria, the University of British Columbia, the University of Northern British Columbia and the University of Iceland. Their findings, which were published the journal *Nature Geoscience*[3] in 2015, incorporated glacier movement into models – a first for such large scale modeling studies. They investigated the status of glaciers of the Coastal, Interior and Rocky Mountain ranges of BC and Alberta, and ran their simulations for each of the four main scenarios of likely global temperature increase within the UN's Intergovernmental Panel on Climate Change Fifth Assessment Report (AR5), ranging from 1.5°C of warming up to just shy of 5°C.

For all but the lowest temperature increase, by the end of the century, some 75 percent of the ice area and 70 percent of the ice volume of Coastal mountain glaciers will have been lost compared to 2005. The Interior and Rocky mountain glaciers will essentially have disappeared, losing 90 percent of their ice area and volume. Furthermore, the researchers determined that the maximum rate of ice volume loss, and therefore peak of deglacial meltwater delivery to streams and rivers, would occur around 2020-2040.

Moreover, other studies show that the increased precipitation as a result of climate change will be seen in the spring, winter and fall seasons and on an annual basis, although there will be sharply drier conditions in the summer. This increased rainfall combines with warming to trigger earlier spring snowmelt. As a result, a reduced snowpack together with warmer and drier summers means that run-off in the summer will be lower in many provincial basins.

This largely dovetails with BC Hydro's own findings from 2012[4] that annual precipitation in BC has increased by about 20 percent over the last century as temperatures increased, matched by a modest increase in inflows into BC Hydro reservoirs (although the trends are small). As a result, the company expects to see a modest increase in annual water supply for hydroelectric generation up to mid-century.

But how important are glaciers for BC hydroelectricity compared to the role of rainfall and snowfall? Will the increased overall precipitation be enough to make up for the glacier losses? And how will changes to the timing of the water's arrival to the reservoirs be managed to ensure continuity of energy supply? These are questions the researchers are now trying to answer.

Around the same time, a second paper—produced by University of Victoria mechanical engineering and energy systems researchers working on the PICS 2060 Project–was published in the journal *Climatic Change*[5,] that explored future projections of hydroelectricity supply and demand. The researchers combined three sets of data: results from models of hydrologic (water) cycles at the scale of a river basin, together with global climate model simulations downscaled for BC, and projections of electricity requirements, including how a warming climate may increase demand for electricity for more air-conditioning and reduce it for less heating.

On the supply side, the likely increase in streamflow from melting glaciers is significant, delivering an increase in the province's potential annual hydropower of 11 percent. Meanwhile on the demand side, the reductions in heating as a result of warmer temperatures drown out the modest increases in cooling in the summer, delivering a reduction in average and peak demand of two percent. Together, this translates to an *increase* of roughly 11 terrawatt hours of available energy by 2050. That is, for a period, climate change will expand BC's energy supply from hydropower.

The researchers do not conclude that this beneficial effect of climate change is any reason to sit back and relax. They stress the uncertainties in projected climate impacts, and so how BC Hydro configures its technological and infrastructural response over the next few decades will require significant operational flexibility over the long term, as well as significant shifts in the non-hydro components of the province's electricity generation mix in order to ensure reliability. This requirement for infrastructural flexibility will actually increase costs, by between 1 and 7 percent.

Neighbouring Washington state researchers[6] have identified similar substantial changes to the seasonality of energy supply in America's Pacific Northwest. In the 2020s, regional hydropower production will increase by 0.5-4 percent in winter, but then decrease by 9-11 percent in the summer, for total annual reductions of 1-4 percent. Slightly larger increases in the winter and slightly larger decreases in the summer, are projected at mid-century and by the 2080s.

Recommendations

Given BC's high dependence on hydroelectricity this research underscores the need to explore a mix of low-carbon, dispatchable (i.e. always available rather than intermittent) energy sources.

Hydroelectricity planners in BC (and beyond) need to take into account uncertainties[7] in projected climate impacts, projections of increases or decreases in generation, and increased seasonality of generation.

In particular, energy planners will be facing new operational realities in terms of reliable water supply after the 2040-2050 period identified by both papers, when the high point of run-off from glaciers has likely peaked and the electricity demand impacts from rising temperatures are ramping up.

Configuration of technological and infrastructural response over the next few decades will require significant operational flexibility in order to ensure reliability. Additional costs are a likely result of incorporating such flexibility.

Future research

PICS-supported hydrology researchers are currently exploring the balance between precipitation-fed and glacier-fed hydroelectricity production in BC, to further inform planning. In addition, the PICS 2060 Project: Integrated Energy Pathways for British Columbia and Canada is working to model energy futures for BC, Alberta and the country as a whole, investigating the challenges facing various decarbonisation options.

Endnotes

[1] Use and Capacity of Global Hydropower Increases. (n.d.). Retrieved May 26, 2016, from http://www.worldwatch.org/node/9527

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[5] Parkinson, S. C., and N. Djilali, 2015: Robust response to hydro-climatic change in electricity generation planning. *Climatic Change*, **130**, 475–489, doi:10.1007/s10584-015-1359-5.

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[7] Parkinson, S. C., and N. Djilali, 2015: Long-term energy planning with uncertain environmental performance metrics. *Applied Energy*, **147**, 402–412, doi:10.1016/j.apenergy.2015.02.006.