Climate change:
How BC Hydro is adapting

December 2020

BC Hydro
Power smart

Contents

Glossary[1]

ADAPTATION

Strategic action to respond to (actual or expected) climate change and its effects, intended to reduce harm or leverage opportunities. Adaptation strategies can range from short-term coping to longer-term, deeper transformations and can aim to meet more than climate change goals alone.

CLIMATE

Climate in a narrow sense is usually defined as the average weather, considering variables such as temperature, precipitation, and wind. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization. Climate in a wider sense is the state of the climate system.

CLIMATE CHANGE

A change in global or regional climate patterns, in particular a change apparent from the mid to late 20th century onwards and attributed largely to the increased levels of atmospheric carbon dioxide produced by the use of fossil fuels.[2]

MITIGATION

Action taken to reduce the net contribution of greenhouse gas emissions to the atmosphere.

RESILIENCE

Ability of a system to anticipate, absorb, accommodate, or recover from the effects of climate change in a timely and efficient manner, including the preservation, restoration, or improvement of its basic structures and functions.[3]

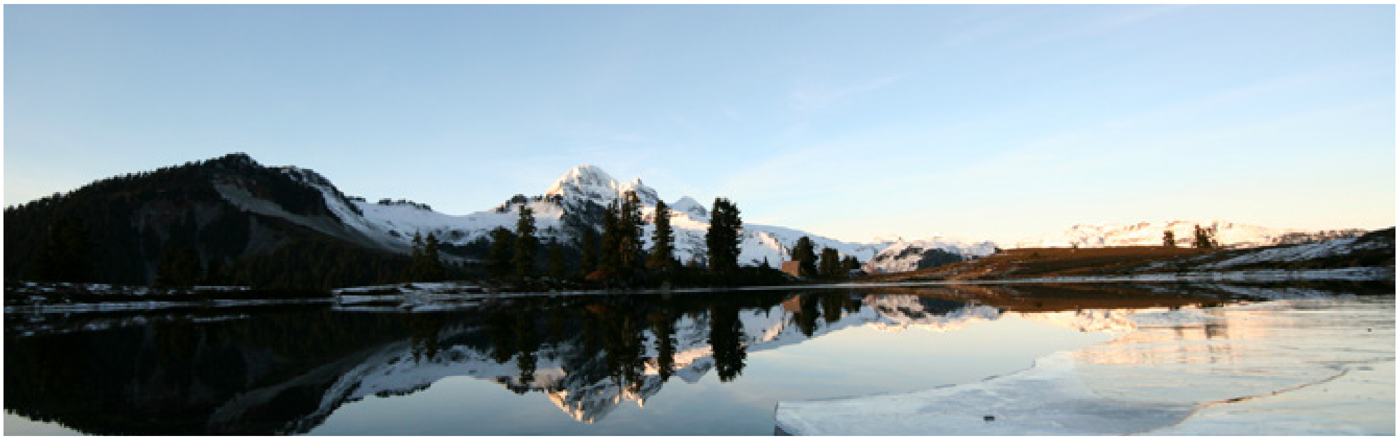
SYSTEM

In this document, refers to the electric power system, which is a network of electrical components that produce, transfer, distribute and use electric power.

1 Terms have been adapted from the United Nations Intergovernmental Panel on Climate Change (IPCC) definitions, unless otherwise specified.

2 **https://www.lexico.com/definition/climate_change**

3 IPCC, 2012: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, UK, and New York, USA, 582pp



Executive summary

The climate in British Columbia is changing. The Pacific Climate Impacts Consortium[4] (PCIC) reports that over the last century the average temperature in British Columbia has risen by 1.2°C and annual precipitation has increased by about 20 per cent. These trends are expected to continue and may accelerate over the current century.

We recognize that climate change is creating many weather related risks that could negatively impact our ability to deliver safe, reliable, and affordable power. We also recognize there may be some longer term opportunities associated with the impact of climate change on river basin inflows and water temperatures, on seasonal and daily load patterns, and electricity trade patterns.

BC Hydro has a significant responsibility as it relates to climate change adaptation. The power we generate and deliver supports the quality of life and the safety of our customers. Our actions can also have economic, environmental and societal impacts. Our approach to understanding, and managing the risks, impacts, and opportunities associated with a changing climate matters.

BC Hydro's climate actions include both adaptation and mitigation. Mitigation of climate change is achieved through reducing greenhouse gas emissions from our internal operations as well as those related to generating electricity, and our efforts to support a low carbon future through electrification. Adaptation to climate change, which is the focus of this document, involves understanding the magnitude of potential climatic changes to our business and addressing the associated risks.

BC Hydro has been investigating the science of climate change and impacts on the business since the early 1990s, when we participated in Environment Canada's impact study of the Mackenzie basin. Since that initial research, BC Hydro has undertaken internal studies and worked with some of the world's leading scientists to determine how climate change will impact our system. In addition to working with the scientific community, we have been collaborating with government, industry and local communities.

BC Hydro's approach of balancing system performance, risk and affordability includes adapting its business practices and modifying its electricity infrastructure to address climate and weather related risks. Where appropriate, we have been assessing the impacts and adapting our planning, design and operational practices to consider both the observed and potential impacts of climate change.

In the past ten years, BC Hydro has seen an increase in the frequency and intensity of extreme weather, wildfire and water–related events which have impacted our service to our customers and caused greater damage to our assets than was previously seen. Our asset management and emergency management processes have continuously evolved to prepare for and effectively respond to increasingly severe weather–related events. We have robust business practices in place to ensure an adaptive and resilient system, and plans to identify and address outstanding gaps.

[4] A regional climate service centre at the University of Victoria that provides practical information on the physical impacts of climate variability and change in the Pacific and Yukon Region of Canada.

1 Introduction

BC Hydro is a Crown corporation, owned by the government and people of British Columbia. It is our job to provide our customers with safe, reliable, affordable and clean electricity throughout the province. BC Hydro generates over 90 per cent of its energy by harnessing the power of water. Electricity is delivered to our customers through a network of approximately 78,000 kilometers of transmission and distribution lines, approximately 300 substations, 900,000 utility poles and 325,000 individual transformers. Given that BC Hydro relies on natural resources to generate electricity to serve our customers, we need to understand the various factors that can affect our ability to delivery on this mandate.

The climate in British Columbia is changing. The Pacific Climate Impacts Consortium (PCIC) reports that over the last century in British Columbia, the average temperature has risen by 1.2°C and annual precipitation has increased by about 20 per cent. These trends are expected to continue and may accelerate over the current century. PCIC also reports that extreme weather events are now more frequent and more severe than in the past.

Natural Resources Canada studies on the impacts of climate change concluded that “future changes in the frequency and magnitude of extreme weather events particularly ice storms; heavy snow storms and wind storms are likely to increase the risk of interrupted electricity supply”[5]. Potential risks to an electric utility include: outages and reduced system reliability; changes in generation and transmission capacities due to shifts in weather or climate patterns; changes in electricity demand due to rising temperatures and more frequent storms; and damage to assets due to extreme weather events.

BC Hydro recognizes that climate change is creating an increase in weather related challenges for our system that could negatively impact our operating flexibility, reliability of service, and asset maintenance and recovery costs. Adaptation to address the impacts of a changing climate is essential for us to continue to provide our customers with safe, reliable and affordable power. We also recognize there may be some longer term opportunities associated with the impact of climate change on river basin inflows and water temperatures, on seasonal and daily load patterns, and electricity trade patterns.

This is why BC Hydro has been actively engaged in understanding climate change risks and opportunities and the potential impacts on our system. We are working collaboratively across our company and with external partners to address these impacts and implement solutions. We have robust business practices in place to ensure an adaptive and resilient system, and plans to identify and address outstanding gaps.

The precise nature of the province’s future climate and weather remains uncertain. There is a broad range of potential future scenarios. We are working on reducing our vulnerability to climate change, while at the same time identifying how we may benefit from any potential new opportunities these changes may present.

[5] Lemmen, D.S., Warren, F.J., and Bush, E., editors (2008): From Impacts to Adaptation: Canada in a Changing Climate 2007; Government of Canada, Ottawa, ON, 448p.

1.1 How this report is organized

This report provides an update on BC Hydro's work to adapt to climate change in British Columbia to ensure we are continuously serving customers with affordable, clean, reliable power. We review the facts and uncertainty about climate change projections, some of the expected impacts on our business, and our work to adapt our business to accommodate the expected future weather patterns.

The information in this report is organized as follows:

Section 1.0, **Introduction**, describes BC Hydro's adaptation strategy and the history of adaptation work at BC Hydro.

Section 2.0, **Climate Trends and Projections**, outlines historical trends and future projections for temperature and precipitation in BC.

Section 3.0, **Working Together**, describes the internal and external collaboration BC Hydro has undertaken as part of its adaptation work.

Section 4.0, **Assessing Climate Change Impacts**, describes assessments we have undertaken and those we plan to pursue in an effort to understand the risks and impacts facing our system. A list of potential impacts is provided.

Section 5.0, **Adapting our Business Practices**, describes how we've been adapting to some of our current vulnerabilities: wildfire, extreme weather and water related events such as flood and drought.

Section 6.0, **Next Steps**, concludes the report with a list of planned and potential actions.

This report is intended to be a living document and will be updated as our understanding of our vulnerabilities and adaptive actions advances over time.

1.2 Our approach

CLIMATE ACTION

While the focus of this report is adaptation, BC Hydro's climate actions encompass both adaptation and mitigation.

The province's CleanBC plan calls for significant greenhouse gas (GHG) reductions from 2007 emission levels: 40% by 2030, 60% by 2040, and 80% by 2050. BC Hydro's clean electricity will play a key role in the shift away from fossil fuels. By 2030, the policies in the CleanBC plan will require an additional 4,000 gigawatt-hours of electricity above and beyond currently projected demand growth to electrify key segments of our economy[6].

BC Hydro currently contributes less than 1 per cent of the province's total GHG emissions from domestic sources. While our primary efforts toward climate change mitigation are through our electrification efforts to support achieving federal and provincial GHG reduction targets, we believe that there is opportunity to demonstrate low carbon leadership and to further reduce emissions from our corporate operations.

Our climate change adaptation and mitigation strategies will need to be complementary. As we increase our reliance on clean electricity through electrification, the more important a reliable system will become. At the same time, we face the increasing impacts of climate change. We will need to rise to the challenge while remaining affordable and safe.

[6] https://www2.gov.bc.ca/assets/gov/environment/climate-change/action/cleanbc/cleanbc_2018-bc-climate-strategy.pdf

ADAPTATION STRATEGY FRAMEWORK

Building internal capacity to identify and address climate vulnerability and risk is a key part of BC Hydro's approach to adaptation. We have embedded the risk assessment and responsibility for implementing required actions within existing roles at BC Hydro, drawing on external expertise where we have gaps. Recognizing adaptation as a continuous and evolving need, we are working to integrate it into existing business processes and asset and resource planning disciplines.

BC Hydro is using the adaptation strategy framework[7] in Figure 1 to identify climate change risks and adaptation actions:

1. Identify current and future climate changes relevant to the system
2. Assess risks
3. Evaluate options and plan response
4. Implement
5. Monitor and re–assess

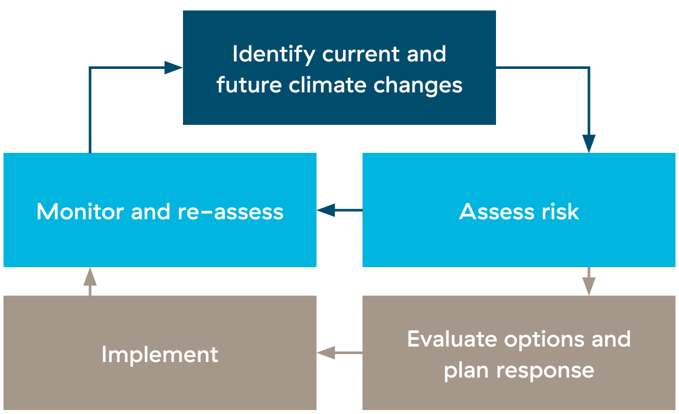


Figure 1: adaptation strategy framework

Identify current and future climate changes relevant to the system
BC Hydro has undertaken internal studies and consulted some of the world's leading scientists in climatology, hydrology and glaciology to determine how climate change may affect snowpack and water supply and the seasonal timing of reservoir inflows, including future modelled scenarios. Specifically, BC Hydro has worked with Pacific Climate Impacts Consortium (PCIC) to assess historical changes to B.C.'s climate over the last century and to produce future climate and hydrological scenarios out to the end of the current century. We've expanded our work with PCIC to include the study of climate impacts on the transmission and distribution system. Section 2 of this report provides a summary of climate projections for BC and Section 3.2 summarizes the current and completed research agreements with PCIC.

Assess risks
BC Hydro has and will continue to evaluate risks through climate impact assessments and studies, as described in Section 4. Assessments will use PCIC climate scenarios as an input to ensure consistency of results.

BC Hydro's investment planning process incorporates climate–related risk analysis through the use of the enterprise risk framework which supports analysis to quantify risk. Climate change risks are identified and prioritized along with other risks we are seeking to reduce as we work to balance system performance, safety, reliability, and affordability. With an increasing focus on identifying climate–related risks to ensure we have a resilient power system, we anticipate that a growing number of projects with a primary objective to reduce risks from a changing climate will be included in our capital plan.

Evaluate options and plan response
The third step in the framework is to evaluate options to address risks and develop a planned response.

There is a range of possible actions that could be taken in response to a climate–related risk. Actions may vary from monitor and re–assess, to adapting business practices and work methods, to investing in changes in infrastructure. Options will be evaluated using a structured decision making process which we use across our business to incorporate multi–attribute variables within complex scenarios such as this.

[7] Proceedings of the National Academy of Sciences, 2010: Research article "A framework to diagnose barriers to climate change adaptation" by Susanne C. Moser and Julia A. Ekstrom

Implement adaptation options
Any initiatives or projects to ensure an adaptive and resilient system will follow BC Hydro's standard processes. Any actions we take to reduce vulnerability will have clear outcomes or metrics of success identified in advance. Section 5 describes some of the actions that BC Hydro has completed or is currently taking to adapt to climate change.

To embed climate change considerations into our planning and decision making, we now require a demonstration of how climate change resiliency has been considered in the project scope. This applies to all of our capital infrastructure projects, including those that do not have a primary driver relating to climate change.

Monitor and re-assess
The outcome of adaptation initiatives and projects will be evaluated. This is to ensure that they are having the intended result and to make adjustments as required. Our findings will inform the design and implementation of future projects and initiatives. We expect that the climate, climate projections and our business will change over time. Risks will be monitored and re-assessed as required.

1.3 Where we are today

BC Hydro has been working to understand the impacts of climate change on our business for over 25 years. Figure 2 displays a high-level timeline of adaptation work at BC Hydro.

Figure 2: Adaptation at BC Hydro – Highlights

- **1994:** BC Hydro participates in Environment Canada's impact study of Mackenzie Basin
- **2003:** BC Hydro participates in BC arm of Canadian Climate Impacts and Adaptation Research Network
- **2006:** BC Hydro joins with provincial governnment and UVic to form PCIC
- **2007:** BC Hydro prepares Climate Action Strategy
- **2010:** BC Hydro holds stakeholder workshop on PCIC climate and hydrological projections
- **2011:** BC Hydro forms adaptation working group
- **2012:** BC Hydro publishes report on hydrological impacts of climate change
- **2015:** BC Hydro prepares study on future energy demand
- **2019:** BC Hydro forms adaptation and mitigation steering committee
- **2020:** BC Hydro prepares report documenting adaptation practices

BC Hydro has been investigating the science of climate change and impacts on the business since the early 1990s, when we participated in Environment Canada's impact study of the Mackenzie basin. Since 2006, BC Hydro has been collaborating with PCIC to understand global climate change impacts to regional climate and hydrology in our watersheds across the province and expected inflows to our hydroelectric projects. In addition to working with the scientific community, we have been collaborating with government, industry and local communities.

At the same time we have been assessing the impacts and adapting our planning, design and operations practices to consider both the observed and potential impacts of climate change. We continue to make improvements to our processes, so that we effectively and safely respond to increasingly severe weather-related events.

We have made progress on a number of fronts and are continuing to identify areas of opportunity as we work to ensure an adaptive and resilient power system. In the next sections of this report we will share specifics on how this work is being undertaken and is setting the stage for ongoing management on our adaptation journey.

2 Climate trends and projections

According to the Intergovernmental Panel on Climate Change (IPCC), there is underlying evidence and scientific agreement that[8]:

- Human influence on the climate has increased temperature since the 1950s to an extent that is unprecedented in the past. Atmospheric concentrations of carbon dioxide, methane and nitrous oxide are unprecedented in at least the last 800,000 years and GHG emissions are extremely likely to be the dominant cause of the observed warming.
- There are worldwide impacts on human and natural systems as a result of climate change. A decrease in cold temperature extremes, an increase in warm temperature extremes, an increase in extreme high sea levels and an increase in the number of heavy precipitation events have accompanied the change in climate since the 1950s.
- Continued emission of GHGs will cause further warming and long-lasting changes increasing the likelihood of severe, pervasive and irreversible impacts for people and ecosystems. Limiting climate change requires substantial and sustained reductions in greenhouse gas emissions together with adaptation to limit climate change risks.
- Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level will rise.

BC Hydro accepts the conclusions of the IPCC work and intends to use adaptation and mitigation strategies to reduce the amount and the impact of climate change.

2.1 Global trends

Measured global average surface temperature has risen 1.4°C since about 1910. The NASA graph below illustrates the change in global surface temperature relative to 1951 to 1980 average temperatures[9]. Nineteen of the 20 warmest years have all occurred since 2001, with the exception of 1998. The year 2016 ranks as the warmest on record[10].

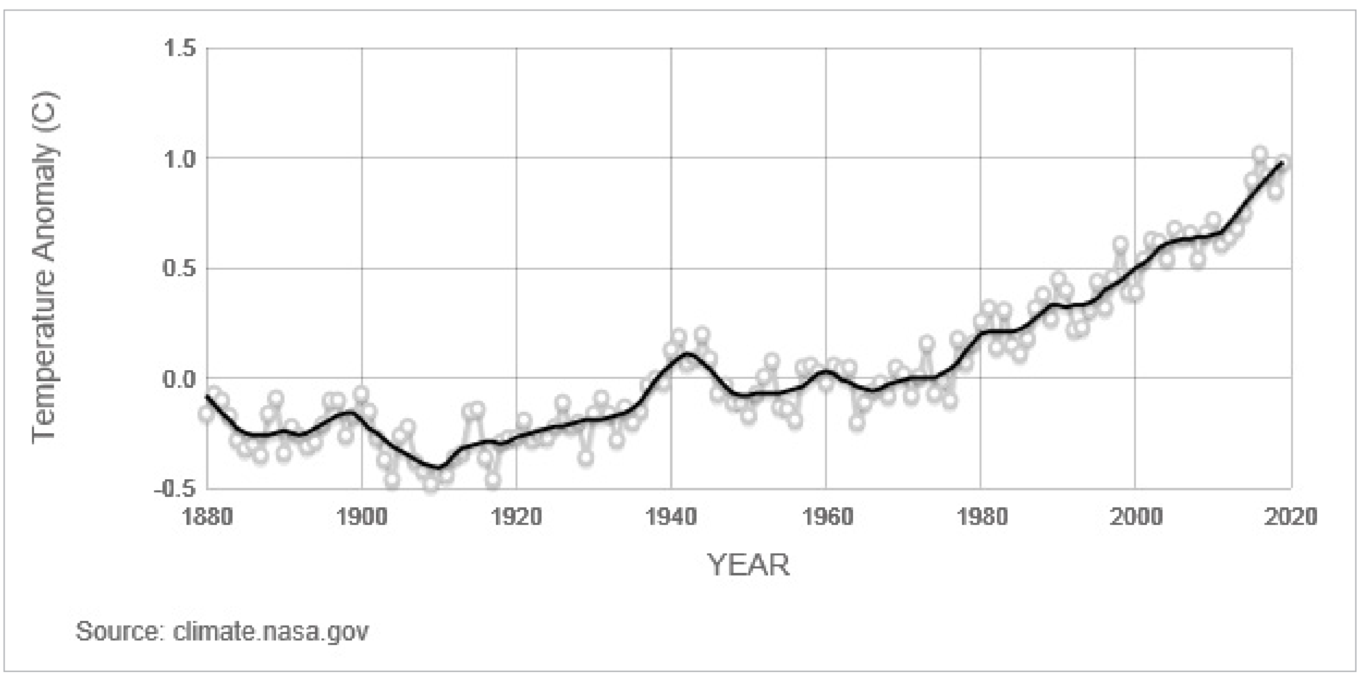


Figure 3: Change in global surface temperature relative to 1951–1980 average temperatures

[8] **https://www.ipcc.ch/site/assets/uploads/2018/02/AR5_SYR_FINAL_SPM.pdf** from IPCC, 2014: Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

[9] **https://climate.nasa.gov/vital-signs/global-temperature/**

[10] **https://data.giss.nasa.gov/gistemp/graphs/graph_data/Global_Mean_Estimates_based_on_Land_and_Ocean_Data/graph.txt**

2.2 Historical trends in BC

Analyses by BC Hydro and PCIC indicate that there have been significant changes in climate parameters such as temperature, precipitation, snow accumulation and resulting changes in streamflow in British Columbia.

The following are some key trends:

- over the last century, all regions of British Columbia became warmer by an average of about 1.2°C and annual precipitation increased by about 20 per cent
- there is some evidence of a modest historical increase in annual inflows into BC Hydro's reservoirs but trends are small and statistically not significant
- glacier melt outflows in glaciated basins where BC Hydro operates reservoirs have been increasing over the last 50 years. Glacier melt currently contributes about three per cent of system inflows into BC Hydro reservoirs
- there is evidence of historical changes in the seasonality of reservoir inflows. Fall and winter inflows have shown an increase in almost all regions, and there is weaker evidence of a modest decline in late-summer flows for those basins, driven primarily by melt of glacial ice and/or seasonal snowpack
- the severity of year-to-year variation in annual reservoir inflow has not changed

2.3 Future projections for BC

PCIC projects that the unprecedented climate and hydrology trends observed in British Columbia in recent decades will likely accelerate over the next century. This section presents precipitation and temperature projections for the period between 2041 and 2070 (referred to as the 2050s). Results of future changes in temperature and precipitation are presented on an annual basis and for each season. The seasons have been defined as follows:

Winter: December, January, February

Spring: March, April, May

Summer: June, July, August

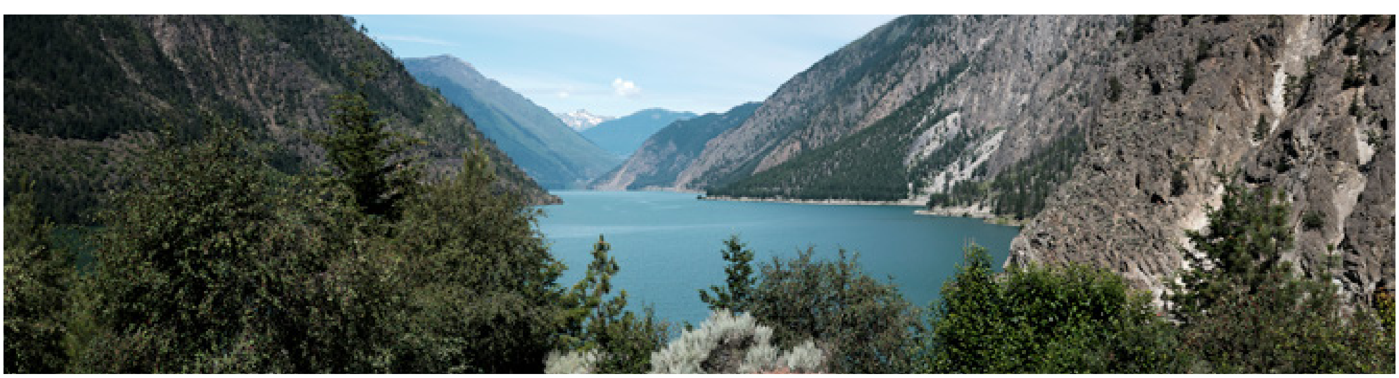
Fall: September, October, November

Results are presented for the region including British Columbia for an ensemble of six global climate models under CMIP5 RCP 8.5.

TEMPERATURE

Global climate models (GCMs) project increasing temperatures in all seasons in all regions of British Columbia during the 21st century.

Temperature increases will "very likely"[11] be larger than those observed during the 20th century. To show the regional pattern of change from the coarse scale GCMs they were adjusted with a statistical technique known as downscaling[12]. By the 2050s minimum temperature is projected to be 4.5°C warmer in Winter than average minimum temperature in the base period (1971–2000) according to the median of the six selected CMIP5 GCMs (Figure 4). Mean minimum temperature increases in the region are projected to be 3.4°C, 3.3°C and 3.2°C in Fall, Spring and Summer, respectively. Also under RCP 8.5, all GCMs agree that warming will be greatest in Winter.



[11] Corresponds with a probability of occurrence of greater than or equal to 90 per cent; assessed using expert judgement.

[12] This method is based on daily GCM data and was found to be particularly good for use with climate and streamflow extremes and made to match gridded observations made for this mountainous region. See **https://www.pacificclimate.org/data/gridded-hydrologic-model-output** for more information.

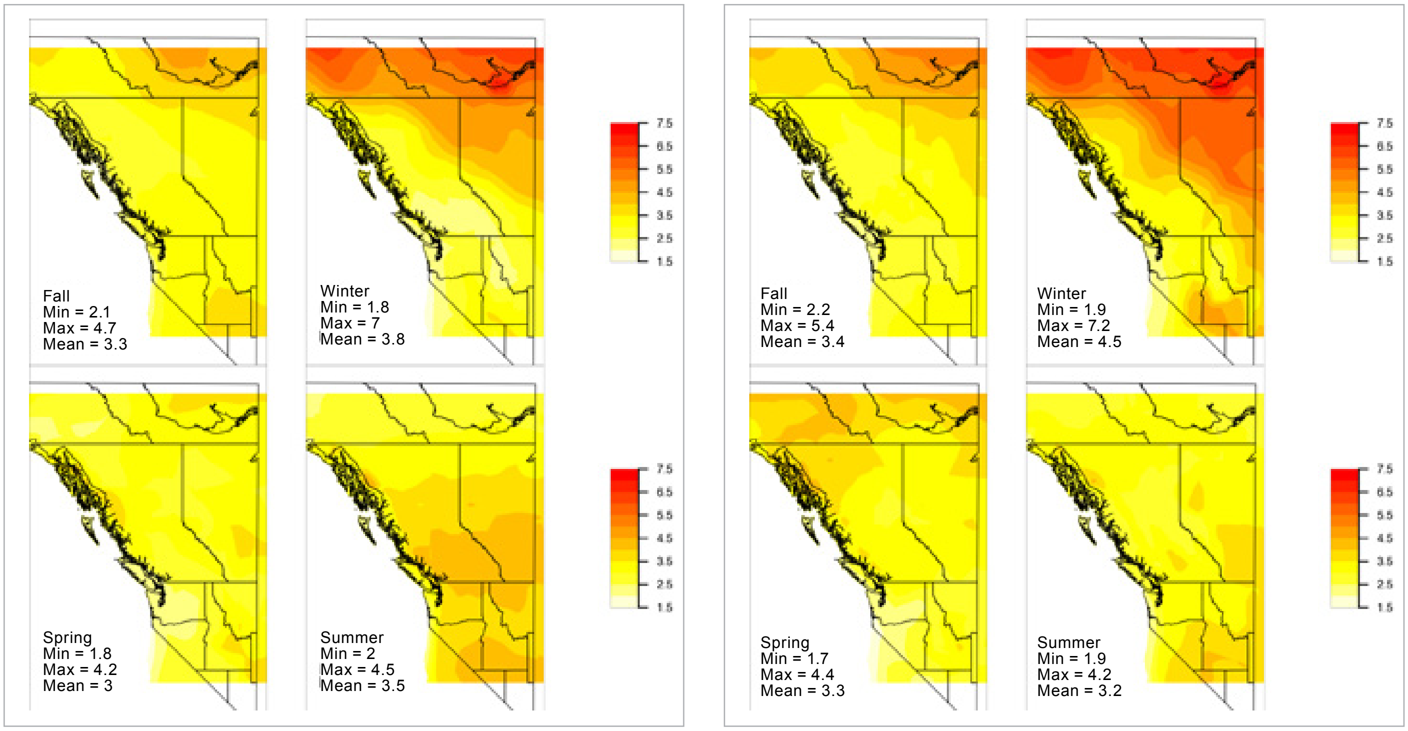


Figure 4: Ensemble median minimum (right) and maximum (left) temperature anomaly for the 2050s under RCP 8.5 (change from 1971–2000)*

The mean maximum daily temperatures by the 2050s are projected to increase by 3.8°C in Winter on average over the greater BC region under RCP 8.5. The northeast part of the province is expected to warm more than other parts of the province during the Winter. Warming in Winter for maximum temperatures is less than that projected for minimum temperatures.

PRECIPITATION

Future projections of precipitation indicate an overall increase in annual precipitation across all regions of the province, but with seasonal differences[13]. Increases are greatest in Fall and Spring, with increases of 13% projected in both seasons (Figure 5). Winter increases are projected to be 10% over the baseline period (1971–2000). Projected Summer decreases are 3% on average based on the median of the six selected CMIP5 GCMs[14]. Increases in Fall and Spring occur over most of the province, while in Winter they are more focused in the north. Summer precipitation decreases are prevalent in the southern part of BC and Alberta and in the US northwest.

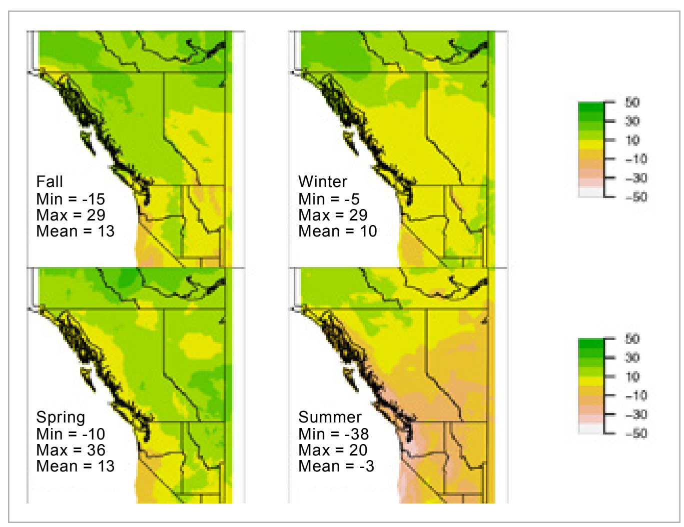


Figure 5: Ensemble median percent precipitation anomaly for the 2050s under RCP 8.5 (change from 1971–2000)*

* Future projections are provided by Pacific Climate Impacts Consortium using methodology described at **https://www.pacificclimate.org/data/gridded-hydrologic-model-output**

[13] The precipitation projections may differ in direction based on model. All models project an increase in Fall, Winter and Spring on average over the region. Roughly one third of the models show a decrease in Summer, while the remaining two-thirds project only moderate increases.

[14] Models were selected to span the widest spread in projected future climate for smaller subsets of the full ensemble.

3 Working together

Adapting to climate change in B.C. will require collaboration among various agencies in the province, as well as within BC Hydro. This is why BC Hydro is undertaking significant internal and external collaboration as part of its adaptation work.

3.1 Internal collaboration

Our approach of embedding adaptation practices into our business practices requires cross-company collaboration. One area where this is especially evident is in our emergency management practices. Further details and examples of our adaptation practices can be found in Chapter 5.

A steering committee from across the company provides oversight and coordination of our GHG emissions reduction and our climate change adaptation work and will ensure that our mitigation and adaptation measures are complementary. The committee is supported by working groups of subject-matter experts, which deliver specific adaptation strategies and actions. The committee presently has four active working groups:

- an adaptation practices working group is documenting our existing adaptation practices and developing an adaptation plan
- a mitigation practices working group is documenting our existing mitigation practices and develop an updated GHG management plan
- a wildfire risk reduction working group is updating and expanding the wildfire hazard assessment, and developing a wildfire vulnerability and risk assessment methodology
- the generation system planning group is assessing for the Integrated Resource Plan, the impact of climate change on the load serving capabilities and operations of the heritage hydroelectric system

3.2 External partnerships

ACADEMIA

BC Hydro relies on external expertise in the area of applied research. We partner with external agencies to conduct the research and then ensure that consistent data sets are used by all groups across BC Hydro.

In 2006, BC Hydro joined with the provincial government and the University of Victoria to form the PCIC and serves as both an advisor and client to their technical research.

PCIC's research is centered on three main themes:

- hydrologic impacts: focuses on analysis of the impacts of climate variability and change on regional climate and water resources
- regional climate impacts: aims to interpret regional climate information specific to user needs
- climate analysis and monitoring: consists of climate observations and future projections specific to the PCIC study region

PCIC's active areas of research include hydrologic models, Pacific storm mechanisms, flood frequency, water temperature, theoretical precipitation extremes, and wildfire attribution.

PCIC is building application tools to assess the results of climate change science in British Columbia, and specifically addressing the question of global climate change impacts to regional climate and hydrology in the watersheds across the province and expected inflows to our hydropower projects. This will contribute to our ability to develop a reasonable range of climate scenarios that might be expected in the future as climate and weather patterns continue to change. The chosen scenarios will provide the basis for continual reassessments of our risk exposure to climate change.

Since 2006, BC Hydro has engaged in multi-year research agreements with PCIC (Figure 6). Our current research agreement is for the 2019 to 2023 period.

2006–2010 Workplan

- Hydro-climate overview study: an overview of past trends and preliminary look into future
- Hydrologic modelling of future impacts to Peace, Columbia and Campbell River watersheds
- Regional climate modelling to account for unique and variable BC geography
- Bringing it all together: synthesis and applications

2011–2015 Workplan

- Extension and expansion of hydrologic impacts study

Study of past, present and future wind events in BC to build understanding of wind climatology

Study of synoptic-scale climatology to understand regional storm and severe weather patterns

Study of changes to water temperature regimes of key rivers and habitats

2015–2018 Workplan

- Future projections of severe and extreme events
- Inflow scenarios representing projected changes to the 60-year historic inflow sequences
- Update of Columbia basin hydrologic modelling using CMIP5 results
- Summary of Bridge River and Lower Mainland region hydrologic impacts using CMIP5 results

2019–2023 Workplan

- Improve hydrological model simulations for small coastal watersheds
- Investigate new climate models and analysis techniques related to severe and extreme events
- Improve storm forcasting, including studying wind speed and outage correlation
- Provide workshops, training, and support to BC Hydro staff in understanding and using climate scenarios

Figure 6: BC Hydro's research agreements with PCIC

BC Hydro is a member of the PCIC Program Advisory Council (PAC). The PAC provides direction and advice to the Director of PCIC on scientific content and priorities, stakeholder needs and participation in projects.

In addition to our work with PCIC, BC Hydro collaborated on studies with the Western Canadian Cryospheric Network, which consisted of six Western Canadian and two Washington state universities; the University of Victoria; and the Climate Impacts Group at the University of Washington.

We are also partnering with the University of Northern BC to assess the use of LIDAR remote sensing technology to better understand glacier change and snow distribution in the Columbia and Bridge River watersheds.

GOVERNMENT AND LOCAL COMMUNITIES

BC Hydro is collaborating with various levels of government, from the Ministry of Environment and Climate Change Strategy to local communities.

For example, BC Hydro has a Wildfire Services Agreement in place with the Province of BC. This agreement allows for planning and allocation of firefighting resources provided by the Province in the event of fires that put power system assets at risk.

BC Hydro is represented on the Union of BC Municipalities Special Committee on Climate Action. The committee is exploring opportunities and barriers to local government action, and identifying avenues for further partnership work in mitigating, and adapting to, the effects of climate change.

We're also working with impacted communities on resiliency planning. For example, BC Hydro is participating in the preparation of the Lower Mainland Flood Management Strategy (LMFMS). This is a collaborative regional initiative led by the Fraser Basin Council and aimed at better protecting the Lower Mainland from Fraser River and coastal flood risks. There are 43 funding partners in the LMFMS, including the federal government, provincial government, 27 local governments and 12 other organizations with interests in flood prevention and response. BC Hydro has been involved in the regional-scale planning to address sea level rise, coastal flood scenarios and associated vulnerabilities. Included in this work is the development of Lower Mainland regional flood vulnerability assessments.

We're also working with the Advisory Group for Surrey's Coastal Flood Adaptation Strategy. This strategy is being developed by The City of Surrey to prepare their coastal communities for a changing climate and reduce coastal flooding risks.

INDUSTRY

BC Hydro is working with the broader industry on adaptation through our participation in working groups and committees:

- **SFU Adapting to Climate Change (ACT) Program Advisory Committee (PAC)**
  The ACT is a university-based think tank dedicated to climate change adaptation. The ACT's research currently focused on adaptive actions in nine areas: biodiversity, extreme weather, energy, water security, crops & food supply, sea level rise, health risks, population displacement, and new technologies. BC Hydro has a representative that sits on the program advisory committee.
- **The Centre for Energy Advancement through Technological Innovation (CEATI) Climate Change Opportunities, Risks and Adaptation Working Group (CCORA)**
  BC Hydro has a representative actively involved on the CCORA Working Group. This working group is working to increase infrastructure and operational resiliency to climate change. The working group coordinates climate change research and adaptation efforts across HOPIG members, and will help prioritize specific projects for hydroelectric utilities/agencies.
- **CEATI Transmission Overhead Line Design and Extreme Event Mitigation (TODEM)**
  One of the objectives of this working group is to study the impact of extreme weather on overhead transmission lines and develop and share impact reduction strategies. BC Hydro has participated in this working group since 2007.
- **Canadian Standards Association (CSA) Codes and Standards Committees**
  The CSA is working to incorporate strategies for climate change in existing and new standards and codes. BC Hydro has representatives on some of the codes and standards committees working to identify and implement these changes.
- **Canadian Electric Association (CEA) Climate Change Adaptation Working Group**
  This working group aims to advance the understanding of climate modelling and potential climate change impacts amongst member utilities. A guidance document for climate change adaptation has been developed and workshops have been held regionally across the country, with BC Hydro being the host for the western region. The workshops allow member utilities to work hands-on with the guidance document and provide a platform for sharing experiences and best practices.

4 Assessing climate change impacts

Climate change impact assessments are largely based on scenarios – describing our possible future. They do not attempt to predict the future, but aim to better understand the uncertainties involved in making decisions that accommodate a range of possible outcomes. They also help researchers and decision-makers anticipate the consequences of those decisions.

BC Hydro uses scenarios that rely on:

- numerical computer models that generate GHG emission scenarios
- global climate models (GCMs) that resolve large-scale global weather patterns
- statistical techniques that add regional detail to the GCMs to create regional weather models
- specific models that convert climate scenarios into impact models that predict a range of changes that impact various elements of our system and its operation

One example is a hydrological model that predicts changes in inflows in our river basins in order to help us understand the impacts that climate change will have on our generation operations (Figure 7).

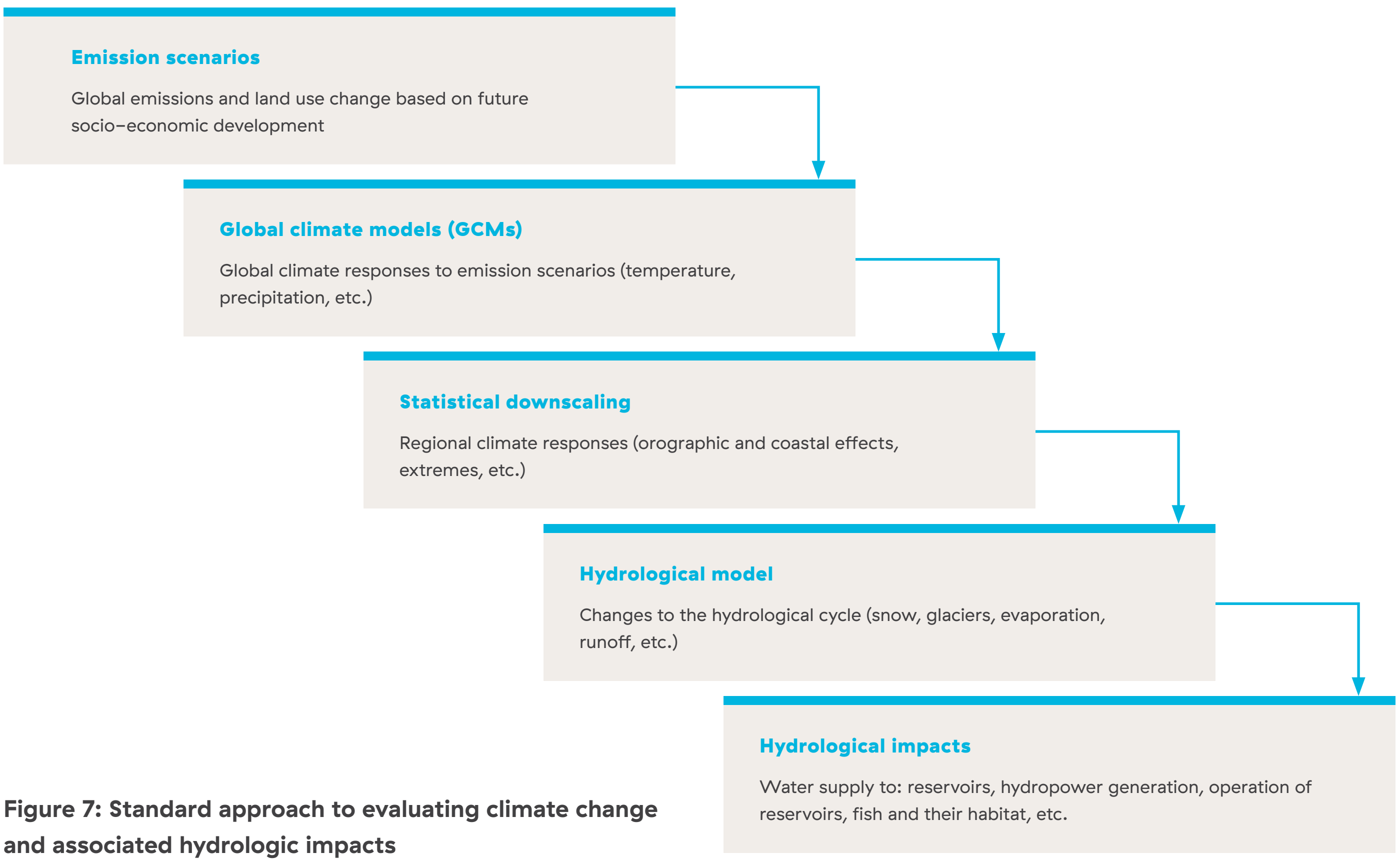


Figure 7: Standard approach to evaluating climate change and associated hydrologic impacts

4.1 Observed and potential impacts

Utilities can expect to experience specific challenges in the face of climate change (Figure 8). We are already experiencing some of these impacts, such as extreme weather, wildfire, low flows and flooding. In this section we expand on these impacts.

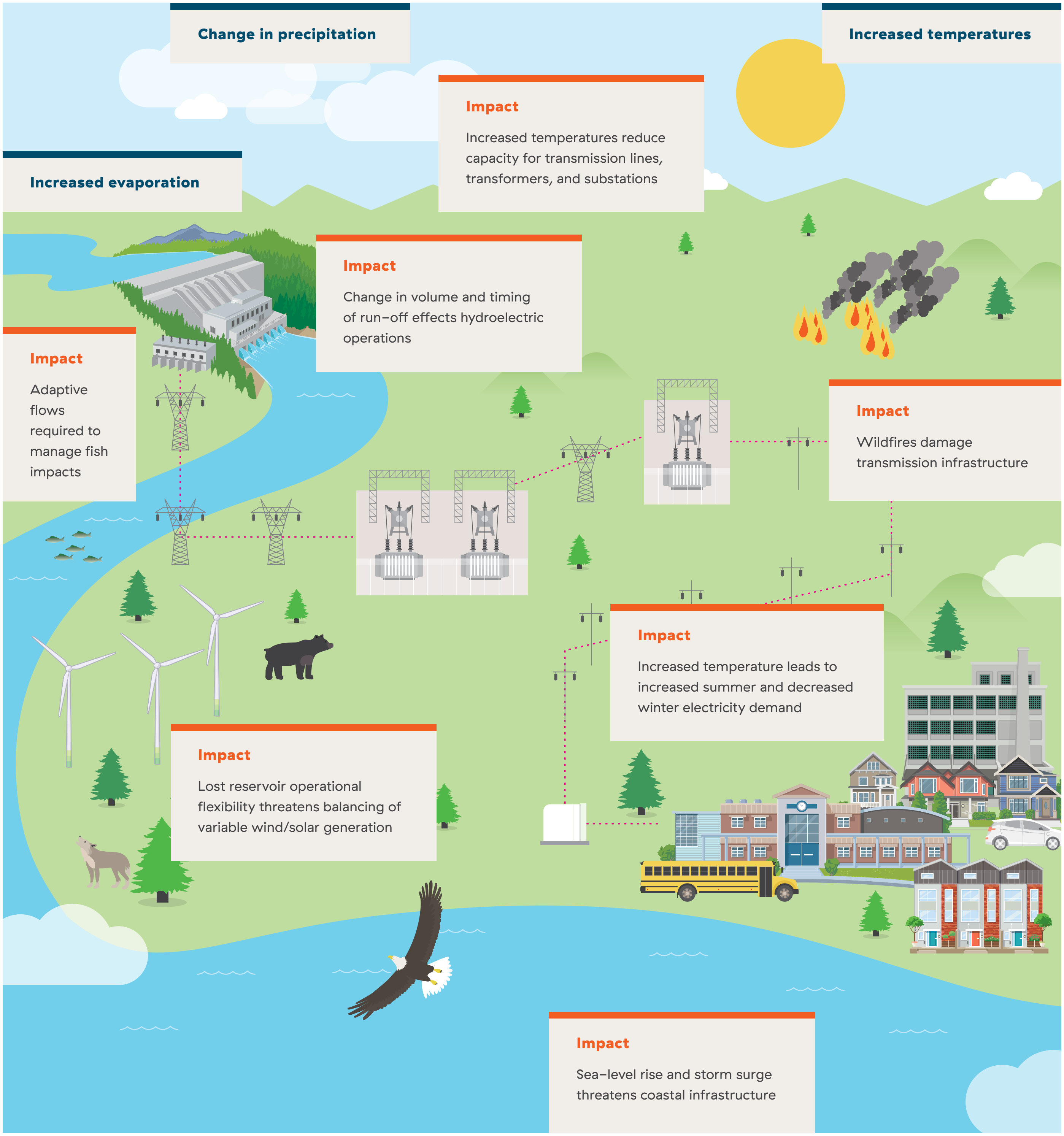


Figure 8: Impacts on utilities

CHANGE IN VOLUME AND TIMING OF RUNOFF

Evidence suggests there has been a modest increase in annual reservoir inflows over time, but the trends are too slight to be considered statistically significant. However, there is evidence that suggests the seasonality of reservoir inflows has changed. Fall and winter average inflows have increased in almost all regions, and there is some evidence of a modest decline in late summer flows in basins that are primarily driven by glacial ice or seasonal snowpack melt.

Climate change projections for BC Hydro's reservoirs suggest a modest increase in overall water supply on average annually to interior basins, and little change to average annual water supply on Vancouver Island.

BC Hydro does anticipate larger changes to the timing of runoff, with more runoff in winter and early spring, and less water available in summer, particularly across the southern half of the province. It has already seen changes in the timing of spring runoff and lower summer flows in recent years, including 2015 and 2018.

The seasonal timing of the inflows are also expected to change due to an increased frequency of drier summers and wetter winters, as well as an increase in more extreme weather events. As a result, climate change projections suggest there will be a decrease in summer streamflow, which will mean a decline in the amount of water available in BC Hydro reservoirs in the summer. Snowmelt is anticipated to start earlier and flows will also peak earlier.

INCREASED FREQUENCY AND SEVERITY OF STORM EVENTS

Storms and extreme weather events in B.C. are becoming more frequent and more severe. In the past five years, the average number of individual storm events BC Hydro has responded to in the province has tripled[15]. Extreme weather and weather-related events directly affect British Columbians more than any other climate risk. Windstorms, ice storms, snowstorms, hail and floods all have major impacts on communities, infrastructure and industry.

BC Hydro is vulnerable to the impacts of extreme weather events on our transmission and distribution system as these events result in customer outages and related repair costs. Falling trees and branches combined with adverse weather account for nearly 60 per cent of all outages.

CHANGES IN AVERAGE AND EXTREME TEMPERATURES

Substantial shifts in energy demand are anticipated as a result of increasing temperatures, with energy demand from heating decreasing and demand from cooling increasing. Although BC Hydro typically sees its highest peak demand in the winter months, an increase in the use of air conditioning in B.C. in recent years is increasing summer demand. The use of air conditioning in B.C. has more than tripled to 34 per cent of households since 2001[16]. In addition to domestic load requirements, wholesale energy prices are affected by temperature, especially as they relate to air conditioning loads in the Southwest U.S. in summer and heating loads in Alberta in winter. Electricity trade opportunities may be impacted by shifts in regional demand patterns and summer outage scheduling will be more difficult if domestic air conditioning demand increases the BC Hydro system load in summer. At the same time, hotter temperatures could reduce transmission and distribution capacity leading to compounded impacts in the summer.

Warmer temperatures can lead to imbalance in ecosystems and increase the proliferation of invasive species from plants, insects and animals. For example, the mountain pine beetle infestation in B.C. is a result of warmer winter temperatures together with forestry practices, and it severely affected forest ecosystems. The resulting dead or damaged pine trees are more vulnerable to forest fire or wind damage. This in turn increases the need for tree removal along transmission and distribution lines to reduce the risk of line outages and starting fires.

Invasive species may also more easily proliferate in warmer water temperatures. For example, preventing zebra and quagga mussels from entering B.C. waters and affecting BC Hydro infrastructure is a risk that is being actively managed. While zebra and quagga mussels have not taken hold in B.C., warmer water temperatures may aide their expansion north. These invasive species of mussels have the potential to impact our generation operations by attaching to our water intake assets. BC Hydro is providing ongoing funding to the Province's Mussel Perimeter Defence Program, which focuses on prevention, monitoring and early detection. We are sampling for larvae in the mid and lower Columbia basin. We have also updated our maintenance instructions for trash racks to include inspection for zebra and quagga mussels.

[15] https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/news-and-features/report-the-impact-wild-weather-is-having-on-british-columbians-and-their-power.pdf

[16] https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/news-and-features/air-conditioning-report-july-2018.pdf

The cooler water present in BC Hydro reservoirs may increasingly be a sought after resource to counteract the warmer water temperatures downstream of our facilities. Recently we have seen an increase in requests for supplementary flow releases from our facilities to manage downstream water temperatures.

SEA LEVEL RISE AND STORM SURGE

The average global sea level has been rising for at least the last century. Much of the rise is attributable to climate change, with increasing temperatures melting ice sheets and glaciers, as well as thermally expanding the ocean. We expect that existing BC Hydro coastal infrastructure will be more vulnerable to inundation in high tides, tsunamis and storm surges.

Based on a 2011 study, the Provincial government projects a sea level rise of half a metre by 2050, one metre by 2100 and two metres by 2200. In addition to adjustments for local rates of vertical land movement, these figures are also being recommended into the planning levels for new infrastructure. BC Hydro is working with municipalities and the Fraser Basin Council on regional-scale planning to understand coastal flood and sea level rise scenarios and associated vulnerabilities.

INCREASED RIVERINE FLOODING

Increased temperatures and precipitation can lead to higher flows on BC's rivers, putting BC Hydro assets at risk of riverine flooding. Critical transmission river crossings may be at risk, as higher flows, changing currents and debris can erode tower foundations and compromise structural integrity. Distribution assets and properties in the flood plain may be inundated by flood water. Of particular concern is the risk of severe flooding on the lower Fraser River and Skeena River during freshet, which has the potential to cause significant damage to our assets and properties. BC Hydro spent $25M on transmission restoration in one location after the 2011 freshet.

INCREASED WILDFIRE FREQUENCY AND INTENSITY

British Columbia experiences roughly 2,000 wildfires each year. Climate change has prolonged summer dry spells and the province has seen increases in wildfire activity in recent years. The summers of 2017 and 2018 were the worst fire years on record for British Columbia – exceeding the 1958 record. In these two years, wildfires burned over 1.2 and 1.3 million hectares, respectively (Table 1)[17]. BC Hydro spent $5.1M on service restoration due to the 2017 fire season alone.

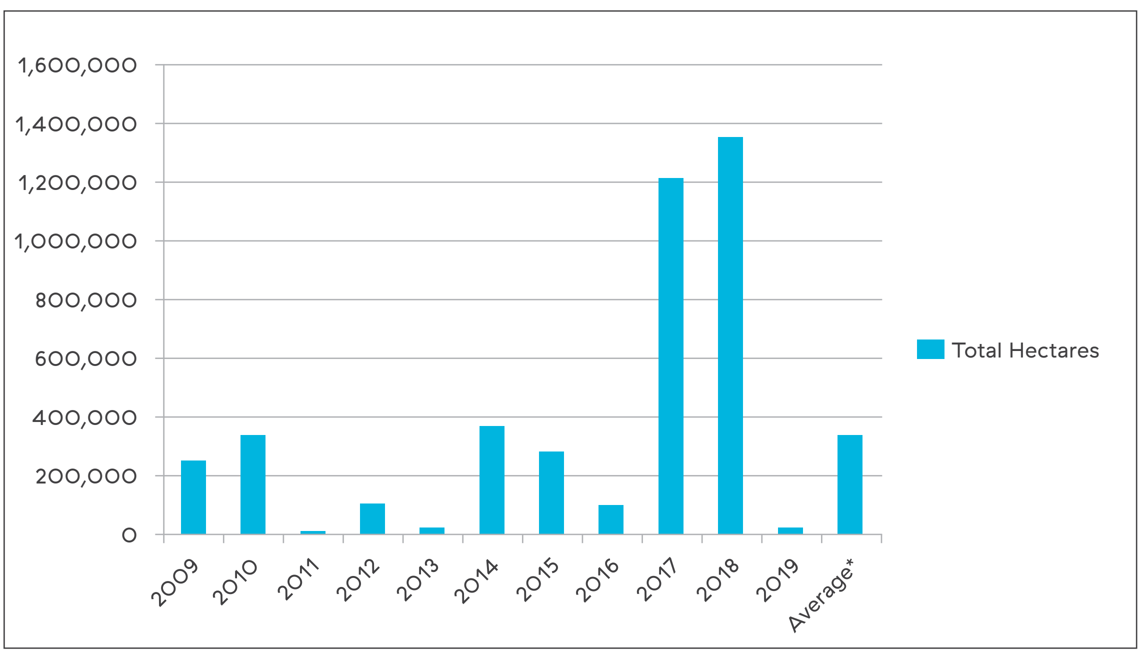


Table 1: Total hectares burned by wildfire in BC

[17] Table produced from data from BC Wildfire Service (2020)

Wildfires occur at any time of the year but most in B.C. occur between April and November. Wildfire risk is typically highest in the Central and Southern Interior and Southern Vancouver Island, which are more arid summer climates. The risk is lowest along the Coastal areas of the province, especially the Central and North West Coast.

Wildfires pose a significant risk to BC Hydro's system of transmission and distribution lines, substations and generation facilities and to the safety of the workers. BC Hydro's electrical system and field workers also pose risks of igniting wildfires through normal activities in high risk areas.

Figure 9: A power pole burned down by the 2017 wildfires

SUMMARY OF OBSERVED AND POTENTIAL IMPACTS

A high-level, qualitative assessment was first conducted by BC Hydro in 2010 to identify and document potential impacts to the company, and is revised as we identify new impacts. Table 2 lists the identified direct and indirect climate impacts to the business and potential risks or vulnerabilities to BC Hydro based on those impacts. Also listed are detailed assessments that have been completed and/or will be completed that will aid in further understanding and assessing each impact.

Change in climate	Potential impact to BC Hydro's operations	Type of impact	Detailed assessments
Change in volume and timing of runoff	Loss of operational flexibility	Financial	• Reservoir Inflow Assessment (2011, 2018) • Generation Capability Study (2021)
	Heritage hydro capability (water licence issues)	Financial	• Reservoir Inflow Assessment (2011, 2018) • Generation Capability Study (2021)
	Environmental flows vulnerable to extended dry summers	Environmental	• Reservoir Inflow Assessment (2011, 2018) • Generation Capability Study (2021)
	Higher flows and spilling in the winter	Environmental, Financial, Safety	• Reservoir Inflow Assessment (2011, 2018) • Generation Capability Study (2021)
Increased frequency and severity of storm events	Increased damage and outages to transmission and distribution infrastructure	Financial, Reliability, Safety	T&D Vulnerability Assessment (2021)
	Increased risk of landslides damaging or preventing access to infrastructure	Financial, Reliability	T&D Vulnerability Assessment (2021)
Changes in average and extreme temperatures	Reduced transmission line and substation equipment capacity in summer	Financial, Reliability	T&D Vulnerability Assessment (2021)
	Shift in domestic load shape and timing (increased demand in summer and decreased demand in winter)	Financial, Reliability	• Forecasted Impacts of Climate Change on BC Hydro Electricity Demand (2015) • 2021 Integrated Resource Plan
	Adaptive flows required to manage fish impacts from warmer stream temperature	Environmental	• Reservoir Inflow Assessment (2011, 2018) • Generation Capability Study (2021)
	Increased risk of avalanches damaging or preventing access to infrastructure	Financial, Reliability	T&D Vulnerability Assessment (2021)

Change in climate	Potential impact to BC Hydro's operations	Type of impact	Detailed assessments
Changes in average and extreme temperatures	Increased prevalence of invasive species impacting operations	Financial, Reliability	Aquatic Invasive Species Strategy (2017)
	Changes in demand from US electricity market	Financial	2021 Integrated Resource Plan (will assess climate change impact on market price)
Sea level rise and storm surge	Coastal infrastructure vulnerability to increased inundation	Financial, Reliability	• Municipality–led resiliency planning • T&D Vulnerability Assessment (2021)
Increased riverine flooding	Increased damage to infrastructure	Financial, Reliability, Environmental	• Municipality–led resiliency planning • BC Hydro flood management plans • T&D Vulnerability Assessment (2021)
Increased wildfire frequency and intensity	Increased damage to infrastructure	Financial, Reliability	• Wildfire Risk Model • T&D Vulnerability Assessment (2021)
	Reduced availability of transmission and generation capacity due to proactive outages	Financial, Reliability	• Wildfire Risk Model • T&D Vulnerability Assessment (2021)

4.2 Hydrological impact assessments

RESERVOIR INFLOW ASSESSMENT

A 2011 PCIC study assessed historical and future trends in climate across British Columbia and projected future reservoir inflows in three distinct regions critical to BC Hydro's hydroelectric capacity: the Upper Columbia region, the Peace region, and the Campbell River region (Figure 10).

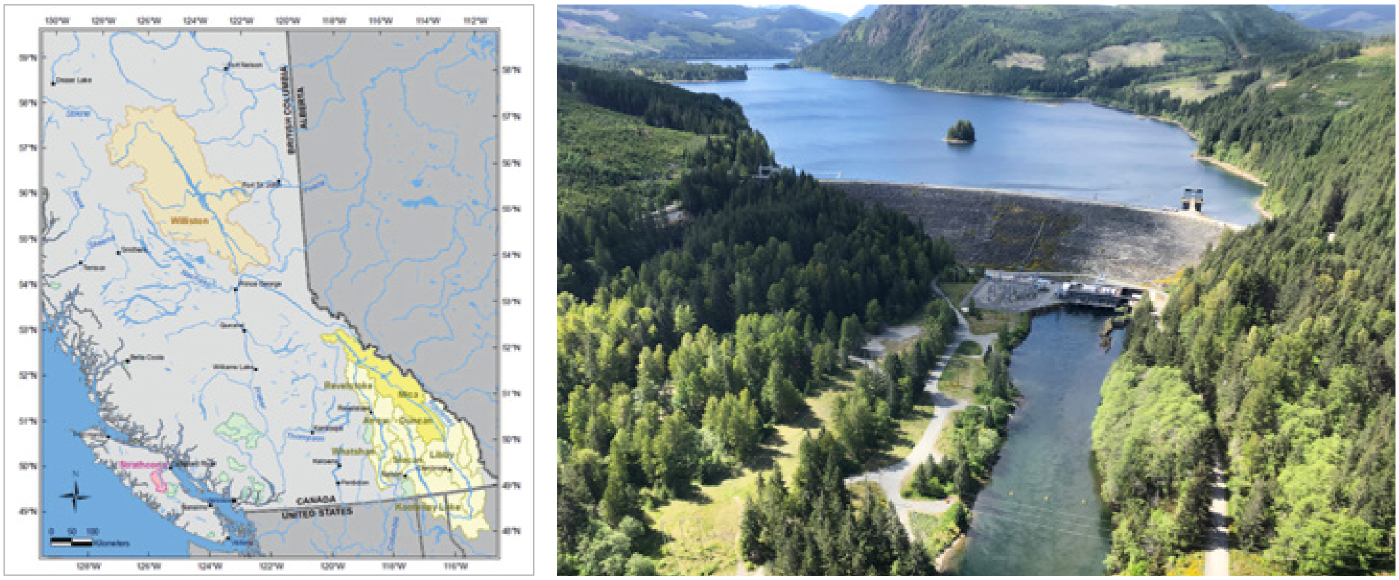


Figure 10: Study areas for hydrological impact assessments

Projections from the 2011 assessment indicate that BC Hydro could see a slight increase in overall water supply on average caused by the modest increase in future precipitation.

- the Upper Columbia watershed could see an increase in water supply of between 10 and 21 per cent. The greatest increases are projected for the winter and spring periods with much less change in the summer and fall runoff. The increases in the lower Columbia and Kootenay are projected to be less than in the Upper Columbia, with average annual increases ranging from zero to 10 per cent over the baseline
- the Peace region could see a 10 per cent increase in average water supply by 2050. Inflows in late-fall and winter would increase; the snowmelt would begin earlier in spring; and summer flows could be 15 per cent lower than in the past
- the Campbell River area and most Coastal watersheds will likely see negligible changes to average annual water supply, but could see significant changes in timing of runoff, with much more winter precipitation falling as rain. Projections indicate winter precipitation could increase by as much as 50 per cent on average by 2050, and with the loss of snow, summer flows could decrease by 40 to 60 per cent

The specific potential impacts of climate change on water resources managed by BC Hydro were outlined in BC Hydro's 2013 publication "Potential Impacts of Climate Change on BC Hydro-Managed Water Resources".

PCIC is currently finalizing the results of their second assessment (2018 assessment) which builds on the lessons learned from the 2011 assessment methodology and incorporates improved models, and updated global climate projections and GHG emission models. Preliminary findings maintain the projected trajectories from the 2011 assessment, but indicate that the changes in precipitation could happen faster than projected in 2011. The 2018 assessment will provide more information about the uncertainty in the projections, data on a finer timescale (daily resolution rather than monthly), and greater regional coverage in BC.

GENERATION CAPABILITY STUDY

We know that current B.C. climate projections indicate overall warmer and wetter conditions in the future. In summary, runoff into BC Hydro–managed reservoirs is projected to increase on average in the interior, and stay about the same on average on the coast. We currently anticipate that we'll have ample inflows in the future but seasonal changes in the timing of runoff are already occurring[18]. More runoff is occurring in the winter and early spring and we are seeing less in the late summer. Reservoir water management is an important adaptation to both higher flows in winter and late summer low–flow conditions. Because we have some very large storage reservoirs we are able to plan their operation to adapt to low–water or high–water years if they occur.

Based on climate projections, we expect that the timing (monthly pattern over the year) of both the river basin inflows and system load will change in the future. This could result in different annual plans for storage and generation at our large storage reservoirs in order to optimize them to meet the load and avoid spilling water. This may result in more or less energy being available on an annual basis depending on the inflow forecasts for a given year. By using several scenario studies we will determine the annual energy we expect to produce in a typical year, in low water years, and the year–over–year variability of our production.

The expected energy production in future years will inform the development of our next Integrated Resource Plan, as described in Section 4.4.

WATER LICENSE RENEWAL APPLICATIONS

BC Hydro's recent water license renewal applications for the Shuswap (2017), Alouette (2018) and Bridge River (2018) systems included an assessment of the potential impacts of climate change. BC Hydro used an in–house operations planning model to simulate reservoir operations for a number of future climate scenarios to investigate the system response to potential climate change effects. Physical and operating constraints were modeled to assess whether the ordered requirements would continue to be met in the 2050s and 2080s.

[18] While seasonal runoff patterns are changing, current 2050 and 2080 models suggest a modest increase to overall inflows across the province as a result of increased precipitation.

4.3 Future energy demand

Our load forecast accounts for current climate trends through the energy requirements for heating and cooling buildings, which is a direct input to our residential and commercial energy use models. This requirement is measured in Heating Degree Days (HDD) and Cooling Degree Days (CDD), the difference between the average outdoor temperature and an indoor temperature of 18°C[19].

The model load forecasts are made for specific regions of BC Hydro's service area. They are based on a normal temperature which is defined as the rolling average taken over the most recent ten-year period of monthly heating and cooling degree days. The ten year rolling average reflects recent climate trends with some smoothing and is believed to be a better predictor under conditions of global change compared to traditional long-term averaging periods. Our modelling also shows the uncertainty of the impact of temperature on load through a random simulation of the heating degrees over the past ten years.

In 2015, BC Hydro participated in a Natural Resource Canada led study, involving various utilities within Canada, which examined the impact of climate change on electricity demand. As part of this project, BC Hydro examined the impact of future temperature profiles from a range of climate change and greenhouse gas emissions scenarios, and estimated the impacts of these scenarios on its electricity demand. The study included an analysis of temperature outcomes from the climate models and greenhouse gas emissions scenarios. The analysis at the time suggested that over the studied 20-year load forecast horizon, the range in projected temperature changes would be more influenced by natural variability than by climate change.

The BC Hydro draft study examined the load impacts of various temperature scenarios resulting from climate change and greenhouse gas emissions scenarios, covering a 70 year period. The results suggest that for the period fiscal 2014 to fiscal 2070, the sales for the mid scenario will on average decrease by about two per cent due to the changing temperatures. It is important to note that these are the isolated impacts on load due to changing temperatures. This does not account for economic or other impacts to load.

The studies are summarized in the following reports:

1. Forecasted Impacts of Climate Change on BC Hydro Electricity Demand (draft).
2. Projected future, minimum, maximum and mean temperature for Canadian provinces and territories under climate change scenarios by Ouranos, prepared for Natural Resources Canada.

As part of the development of the next Integrated Resource Plan, the potential impacts of climate change on the load forecast will be reassessed.

4.4 Integrated resource plan

BC Hydro's Integrated Resource Plan describes our 20-year plan to meet B.C.'s future electricity demand through conservation, generation, transmission and through upgrades to existing infrastructure. Because new resources require significant time to develop, we plan ahead in order to have them when needed.

Our last Integrated Resource Plan was issued in 2013. At the time, BC Hydro had been involved in a number of studies identifying both historical and future impacts of climate change on the water cycle and water availability in watersheds managed by BC Hydro. None of the studies completed at that point had identified a need to change the way our hydroelectric facilities are planned or relied upon.

BC Hydro, in developing our next Integrated Resource Plan, will be informed by the results of system modelling on future hydrologic changes due to climate change. The modeling will reflect the impact of possible inflow changes on the load serving capabilities and the operation of the heritage hydroelectric system. As part of this modeling study, the potential impact of climate change on load shape and the potential impact on electricity market price due to inflow and load shape changes in the Western Interconnection are being assessed. We anticipate, however, that policies to manage greenhouse gas emissions will have a far greater impact on electricity markets than the effects of climate change itself.

[19] For example: A day with an average outdoor temperature of 10°C contributes 8 HDD while a 20°C day contributes 2 CDD. See **http://www.env.gov.bc.ca/soe/indicators/climate-change/heating-cooling-days.html**.

4.5 Transmission and distribution assessments

Due to the linear nature of BC Hydro's transmission and distribution system, the assets traverse 14 bio-geo climatic zones across the province. As a result of the volume of assets, extent and range of potential impacts, the effects of climate change on this system are currently not as well understood as with our hydrological system. We expect that some impacts on the system will come directly from a single source, such as ice loading, while others may result from combined effects, such as landslides and wildfires.

Over the years, we've completed several studies on our transmission and distribution assets which considered climate and environmental impacts:

- Civil Protective studies
- Transmission line ice study
- Ongoing wildfire mapping, projection and assessment
- High-level transmission system geographic information system (GIS) risk assessment
- Ongoing hazard review inspections

However, in many cases these assessments use historical weather data and rolling averages, which do not account for more extreme conditions projected into the future. Future assessments, such as the vulnerability assessment and wildfire risk model update described in the following sections, will incorporate future climate projections.

TRANSMISSION AND DISTRIBUTION VULNERABILITY ASSESSMENT

The vulnerability assessment will leverage existing PCIC climate models and apply them to our transmission and distribution infrastructure by interfacing with existing GIS data. Engineering assessments will identify mechanical and structural capacities and vulnerabilities of structures based on current design standards and specifications.

The deliverables from the study will include:

- a vulnerability assessment which identifies key areas of concern for specific hazards
- quantifiable (probabilistic) risk scores describing where we are today
- recommendations for adaptation investment

The actions identified from the assessment will be incorporated into our adaptation plan.

WILDFIRE RISK MODELLING

We are in the process of refreshing BC Hydro's wild fire risk models, which will now include full coverage of all power system assets. Several aspects of our existing risk model will be enhanced, including new forest cover data from the BC government Vegetation Resource Inventory, new computing tools and techniques, and improved prediction modelling for wildfire rate of spread and intensity. Refreshed wildfire risk data for the power system is expected to be available for the 2020 fire season. The result of this work will be a key input into the overall transmission and distribution vulnerability assessment.

5 Adapting our business practices

While many climate change risks have yet to materialize, in some areas such as extreme weather, wildfire, and water-related events, we have already been experiencing an increase in the intensity and frequency of events (see Figure 11).

Wildfire

- 2017 and 2018 = worst fire seasons on record
- BC Hydro 2017 forest fire restoration spend:$5.1M
- Average hectare burnt/fire: 639 in 2018 vs. 6 in 2008

Extreme weather

- 2018: most damaging storm in BC Hydro's history
- In past 5 years, storm events have trippled
- Fraser Valley ice storm damage 2017/2018
- Customer interruptions due to major events has doubled in 5 years

Water

- BC Hydro spend on transmission restoration after 2011 freshet: $25M
- Flooding in Salmon Arm and Enderby 2017
- Record rainfall in Columbia and Kootenay region 2012
- 2019 water lowest since the 1940s

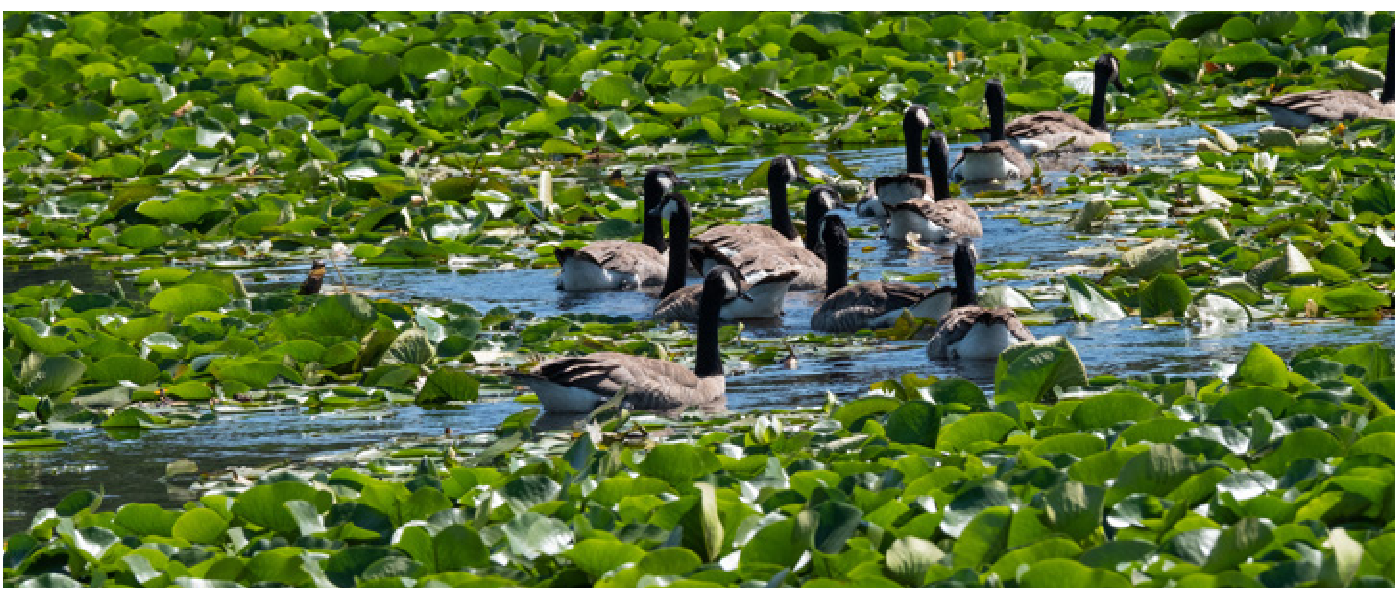
Figure 11: We're experiencing an increase in the frequency and severity of events

BC Hydro has taken action to address these immediate threats and maintain system resiliency. Our adaptation actions fall into four broad categories: prevent, detect, abate and respond.

These categories are defined as:

- **Prevent:** refers to the capability to prevent the event (applicable to wildfires only)
- **Detect:** refers to the capability to detect threats to the system
- **Abate:** refers to the capability to reduce the impacts of an event
- **Respond:** the capability to respond to the impacts of the event and restore service

Our adaptation actions, as they relate to each of these categories, are described in the sections that follow.



5.1 Prevent

At BC Hydro we reduce wildfire risk through practices which have and will continue to change over time as the risks evolve. BC Hydro's action to manage wildfire risk accelerated after the 2003 Okanagan and Barriere fires in which huge areas of forest and grassland burnt, many people lost their homes, and extensive damage occurred to transmission and distribution lines in the area. The BC Wildfire Act and Regulation was created after this event to specify responsibilities and obligations with regard to wildfire prevention and related activities.

A total of 136 wildfires started along our transmission and distribution corridors in 2015, 2016 and 2017. Fortunately, most of these were small and easily controlled. As much as possible, BC Hydro also prevents the ignition of vegetation through contact with energized conductors on transmission and distribution lines. This risk is primarily managed by appropriate vegetation maintenance programs that remove or trim and trees that could either grow into the line or fall onto it. Annual maintenance plans inspect, identify and trim or remove vegetation at risk of contact with our lines.

We have procedures in place across the company to ensure that wildfire risk is considered and documented in crew tailboards or in a documented risk evaluation prior to undertaking maintenance or construction activities that could create a high risk during the fire season. Risk reduction actions are documented or the work is deferred until the risk of ignition from the work falls to an acceptable level.

We conduct a system wide fire risk evaluation annually, enabling our prevention and protection strategies to be revised as necessary and to focus resources where the expected harm of an approaching fire is greatest. Current Fire Services Agreements with the Province of BC provide access to planning and firefighting resources with a 3-year renewable option. The current agreement was renewed in March 2019.

To continue reducing the risk, our 10-year plan includes:

- incorporating Fire Smart principles into facility site management plans
- maintaining fuel debris levels on transmission and distribution lines to an acceptable level and create fuel breaks where feasible to reduce spread of wildlife along or off right of ways
- training staff on fire risk and how to manage that risk
- routine risk assessments documented in project development and crew tailboards
- use of fire retardant to protect wood structures; brushing around poles, and guys to reduce fuels in fire prone areas

Wildfire App

It was recognized that BC Hydro could prevent and manage fire risk through situational awareness of current fire risk across the province. This awareness could allow crews to adjust either the timing or manner of carrying out maintenance work.

How we adapted

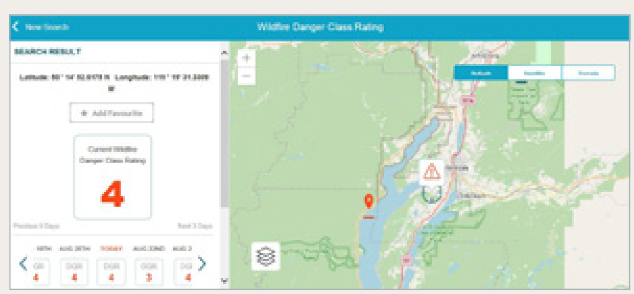


Figure 12: Wildfire app

The newly developed Wildfire Danger Class rating mobile application provides fire danger class ratings for the entire province and is searchable by a mapped location, BC Hydro asset or government weather station. The app is used to determine the Danger Class Rating for work sites when conducting High Risk Activities (as per the Wildfire Act & Regulations) between March 1st and October 31st.

Field crews use this app daily to check whether it is safe to proceed with maintenance work during fire season. It can be used to assess the risk and determine whether fire tools, additional water delivery, wetting down the work site, or early shutdown and monitoring are necessary to enable maintenance work to be carried out.

5.2 Detect

BC Hydro has the tools, expertise and ability to continue managing unpredictable weather events associated with climate change. This includes routine work on in-house weather forecasting, runoff forecasting, and optimization of generation operations plans. BC Hydro has its own climate, water and snow monitoring network and is also a contributing partner in complementary networks in B.C. for water, climate, snow and glacier monitoring.

We are continuously improving our weather and inflow forecasting as new tools and techniques become available. For example, all coastal watersheds can now be forecasted at an hourly time interval, which improves the forecast accuracy and generation scheduling in extreme rainfall events. Probabilistic forecasts are now available for a two week forecast horizon. Seasonal forecasts with a range of possible weather patterns are being extended to better predict extreme weather events.

BC Hydro continues to invest in its hydroclimate monitoring technology to provide even more accurate and timely information about the current state and to discover any new trends in temperature, precipitation, snow and surface water availability. Off the shelf technology has proven insufficient to meet our precipitation and snow-water monitoring requirements. As a result, all our precipitation and snow water monitors are custom-made and designed in-house. Our research and development is ongoing to improve their accuracy and robustness. BC Hydro is also upgrading our snow survey stations into automated, real-time snow and climate stations. Improved meteorology models give BC Hydro greater insight into where and when a storm might hit so that BC Hydro can ensure crews are ready to mobilize and respond quickly.

BC Hydro maintains a wildfire risk mapping system to reflect the probability of wildfire based on vegetation type, climate and local site conditions together with the criticality of assets that would be impacted. This information is available in BC Hydro's geographic information system using PowerGrid, and allows us assess the potential impact of a fire in an area. Together with information from the Wildfire Service on active fires, this allows us to quickly make an assessment of real time risk to the system and start planning an appropriate response to protect the assets at greatest risk.

5.3 Abate

BC Hydro abates climate change risk through a variety of means including asset siting and routing, material selection and maintenance practices.

ASSET SITING AND ROUTING

We consider risks such as climate related terrain instability, wildfire, sea-level rise and riverine flooding when we site our stations and route transmission and distribution infrastructure. Provincial and municipal flood mapping is used to assess flood risk. Any new stations we build are designed to withstand a 1 in 200 year flood. BC Hydro has developed a wildfire risk modelling tool to assist in the determination of wildfire risk in locations of interest (Figure 13). When alternative sites and routes are being considered, the risk of fire and flood is an input into our decision making process.

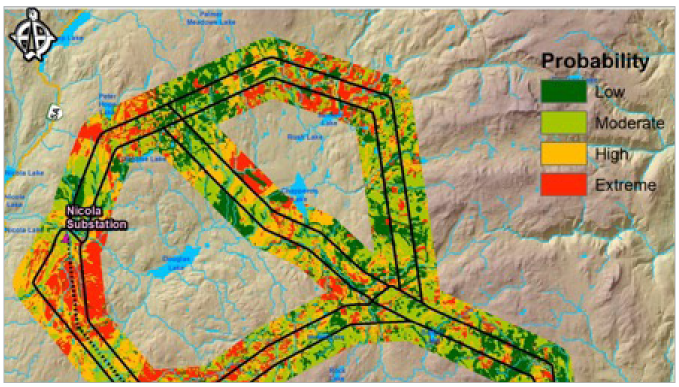


Figure 13: Wildfire risk modelling tool

In 2016, BC Hydro completed a wildfire risk assessment for the West Kelowna Transmission Project. The wildfire risk assessment looked at the project alternatives at the time and the existing transmission line. The assessment reviewed the likelihood, impact and response for each alternative and the existing line in terms of probability of ignition (lighting caused fires, human caused fires, ignition potential), fire behavior (fire intensity, rate of spread, crown fraction burned) and suppression response capability (constraints to detection, proximity to water sources, helicopter arrival time, air tanker arrival time, terrain steepness, proximity to roads). The assessment also looked at the potential for a wildfire to simultaneously impact the existing line and each of the alternatives. The results of this assessment were included as one of the decision-making criteria to identify a leading alternative.

DESIGN STANDARDS

Many design codes, standards and guidelines include embedded assumptions about the climate, while others require the designer to add safety margins based on expected changes to the local climate.

BC Hydro is working with the broader Canadian electric utility industry to update design practices to account for projected changes in the climate. For example, we are working with the Canadian Standards Association to incorporate strategies for climate change in both existing and new standards and codes. Specific areas being addressed are adaptations to ice, hail and snow loads; floods and droughts; wildfires; wind; and permafrost thaws. This initial work has resulted in 50 proposals for changes to electrical standards, including 30 proposals for Part III of Canadian Electrical Code and other utility-related standards. It is expected that these proposals will be incorporated into updated standards and codes. The release of these updates will result in changes to our internal design and construction standards. For example, based on the Canadian Standards Association's recommendation, we've recently changed our design standards to adapt to changes in wind and ice loads on transmission lines.

In terms of the design of our dams and discharge facilities, there are many uncertainties in modeling extreme floods. Recent studies performed by dam owners in Western North America have found that these uncertainties envelop the potential impacts of climate change. As a consequence, the modeling of design level floods is not currently impacted by climate change projections. There is an expectation of more frequent, lower magnitude flooding events in the future. As a result, our focus is on increasing the operational reliability of our flood discharge systems, such as spillways, gates and valves. Current modeling results notwithstanding, we recognize that through our present uncertainties, we may in the future identify extreme flood levels that do exceed current calculations. We currently address this in two ways: (1) in applying results of stochastic flood models we consider not just the mean results but also the less probable upper bounds in our decision making, and (2) when the needs for structural modifications for dams are required for various reasons, we consider incorporating greater flood routing capacity as the opportunity arises. For example, BC Hydro is currently working on a project to upgrade our discharge facilities at Strathcona Generating Station. As part of the design, stochastic modelling confirmed that the design of the new spillway is expected to accommodate the future variability in inflows due to climate change. However as an added precaution, we're designing the project to allow for a possible future dam height raise.

In cases where BC Hydro has needed to reinforce our towers against erosion from high water levels and changing currents, we've placed riprap around the tower foundation and along banks to protect them from water scour.

MATERIAL SELECTION

With material selection, we've made adjustments on a case-by-case basis to adapt to climate change related risks. For example, as part of BC Hydro's drive to increase reliability, we have been exploring alternative materials for use as transmission structures. Due to its non-combustible nature, steel poles have been used in areas with high wildfire risk. Steel poles have also been installed in applications where BC Hydro needs to reinforce against avalanche risk. Fibre-reinforced polymer (FRP) is proving to be a promising material, especially in areas where aesthetics, minimal maintenance, resistance to pests and biological agents, and lightweight construction are desired. We're evaluating the use of FRP poles for two upcoming projects where wildfire risk is a significant concern.

MAINTENANCE

BC Hydro and its contractor crews perform regular maintenance to prevent outages from occurring. For example BC Hydro inspects poles annually and replaces around 10,000 each year to keep them resilient to high mechanical stresses. BC Hydro also applies a systematic schedule to clear vegetation from being too close to its network of 78,000 kilometres of transmission and distribution lines. Certified arborists inspect vegetation located near BC Hydro's infrastructure and remove any dead or diseased vegetation, and prune back anything that is growing too close to equipment.

BC Hydro primarily reduces the risk to our assets from spreading wildfires by reducing the amount of fuel debris and vegetation around our lines, stations and along our rights of way in accordance with the Wildfire Act and Regulation. At specific remote sites, where critical assets are at risk, fire breaks have been constructed and sprinklers installed with assistance from the BC Wildfire Branch when critical assets were at risk. Transmission and distribution lines are the most vulnerable assets and have experienced damage in the past with burned wood pole structures and cross arms. In some cases in high-risk areas, contractors are hired to remove brush away from wood pole bases and to treat the poles with fire retardant so they are less likely to be severely damaged if a fire passes through.

Steel vs. avalanche[20]

After one of our transmission line structures was damaged by an avalanche for the third time in recent history, teams across BC Hydro worked together to design and install two new, avalanche-resistant steel poles.

In March 2018, about 40 kilometres southwest of Terrace, a large avalanche occurred uphill from one of our transmission structures and caused the tower to collapse. The structure had been damaged by avalanches on three previous occasions: in 1977, 1989 and 2007. A temporary tower was put up to restore power, but a long-term solution was needed to protect the transmission line from future avalanche damage.

Figure 14: The damaged tower, March 2018

Figure 15: One of the new poles in place

How we adapted

BC Hydro worked with an avalanche consultant to design a permanent structure that could withstand the frequent avalanches in the area. The consultant used sophisticated software to model potential avalanche forces and provided the team with new design parameters for a pole that would minimize the risk of damage to the overhead transmission line from avalanches in the area. They also reviewed historical data for avalanches in the area to find optimal new locations for the poles.

For this type of transmission line, there are generally two options: a steel pole or a lattice steel tower. Based on the engineering design and life cycle requirements for the site, our project team decided to use steel poles. The pole foundations were also designed to withstand the high loads from an avalanche. With teamwork from across the company, the towers were installed and re-energized in time for the next snow season.

[20] http://hw/news/keeping_current/Pages/avanlance_proof_tower.aspx

5.4 Respond

Our emergency management processes have continuously evolved in the past decades to prepare for and effectively respond to increasingly severe weather-related events. In the past ten years, BC Hydro has seen an increase in the frequency and intensity of extreme weather, wildfire and water-related events which have resulted in larger customer outages and more damage to assets than was seen in the previous history of BC Hydro.

BC Hydro has the ability to activate corporate and regional emergency operations centers that can communicate with the Provincial Emergency Program and other provincial agencies, and with BC Hydro teams such as Real Time Operations. In the case of wildfire risk, the emergency operations centers coordinate activities that address fire threats to our assets. They allocate resources to have the most impact in protecting the system and our customers from forced outages. Real Time Operations has the ability to impose no reclose restrictions on lines that are at risk from an approaching fire to reduce the potential for harm to firefighters until the line is inspected, workers are clear and the line is declared safe to energize.

Across our system, the application of enhanced prediction logic using an algorithm and the smart meter network, enables BC Hydro to quickly confirm an outage and mark its location on a map so that a dispatcher can send a crew to investigate and make necessary repairs. New mobile dispatch tools are used to communicate updated information via satellite from the field to the operations staff faster and more frequently, in turn providing more timely updates for customers. If damage is minor it can often be repaired quickly by the first crew on site. However, if it is significant, crews need to perform damage assessments in order to put together a construction plan for the required repairs. These repair plans can involve engineering expertise and the use of specialized equipment. In some cases, helicopters or unmanned aerial vehicles are needed to survey damage from the air and determine the required repairs.

Successful storm response depends on preparation — ensuring the right people and the right resources are in the right place at the right time. With over 55 offices located throughout the province and access to a network of contractors, crews are well-positioned to respond quickly when problems occur. BC Hydro also relies on a team of in-house meteorologists to track storms so they know where and when a storm might hit, and initiates an emergency response center in large storms to communicate and coordinate with both internal and external groups during the storm response. This enables rapid allocation of resources to strengthen the response activity.

In 2018, we developed a Lower Fraser Flood Management Plan to manage the risk of flooding during the freshet season. The plan identifies risks and associated tactical elements for BC Hydro assets. The plan is reviewed annually and includes criteria to determine level of risks. For example, the plan identifies river gauge level criteria where BC Hydro would proactively deploy temporary flood barriers at identified stations, and switching plans to reduce risk of customer outages if a station is impacted.

We've adjusted our material stockpiling practices for improved response to emergencies. We plan for inventory seasonality and increase our volumes of inventory of overhead transformers and poles ahead of storm season. Our new warehouse in Salmon Arm is fully stocked and allows for quicker regional response.

Through the improvement in our processes, we have been able to reduce response times, speed up the coordination and allocation of company resources, communicate better to the crews and to our customers, and arrange for external resources in cases where they are needed.

Our biggest storm yet[21]

The storm that began December 20, 2018 was the most damaging in BC Hydro's history. It was particularly destructive because the wind exceeded 100 kilometers per hour in some areas and came from multiple directions—the southeast, south and southwest. The windstorm was preceded by several heavy rain events—more than 400 millimetres of rain fell in some areas leading up to the storm, which destabilized trees.

This storm left more than 750,000 customers without power, more than the August 2015 windstorm that affected the Lower Mainland and Fraser Valley, and more than the 2006 windstorm that hit Vancouver Island and devastated Stanley Park in Vancouver. More than 400,000 customers in the Lower Mainland and Fraser Valley were impacted. Nearly 350,000 customers on Vancouver Island and over 80 per cent of Gulf Island customers were out of power. With over 1,900 spans of wire, 390 power poles, 700 cross-arms and 230 transformers damaged, responding to the storm required BC Hydro's single biggest mobilization of resources ever.

Figure 16: Crews responding to downed lines, December 2018

How we adapted

An Emergency Center was set up to coordinate access to personnel, materials, and equipment so that the restoration could proceed as quickly and safely as possible. Over 900 field workers were deployed to restore power, including crews brought from the Interior and contracted crews from Alberta and the East Coast. Within the first 24 hours, BC Hydro had restored power to over 550,000 customers and all customers in the Lower Mainland and Fraser Valley were restored by December 24. The damage and access issues on Vancouver Island and the Gulf Islands due to trees on the roads made it particularly challenging and full restoration there took much longer. All customer outages from the storm were restored by December 31.

BC Hydro reviewed the response experience and identified improvements to help us prepare for and respond to similar future events. These include:

- safety-related reports of downed lines were sometimes delayed because 9-1-1 operators were overwhelmed with calls. BC Hydro is working with community partners to make it easier for line-down reports to get through quicker
- BC Hydro is working with cities and municipalities to map out major intersections and primary traffic routes and will prioritize circuits feeding those areas to avoid traffic congestion and safety issues
- BC Hydro will provide more support to communities that experience outages over 72 hours. This includes providing a customer service representative for face-to-face communication
- BC Hydro will provide more timely updates to customers who need information regarding the status of their outages

[21] https://www.bchydro.com/content/dam/BCHydro/customer-portal/documents/news-and-features/report-most-damaging-storm-bc-hydro-history-january-2019.pdf

6 Next steps

We will continue to integrate current climate change science with coordinated and evidence-based assessments of BC Hydro's strengths and vulnerabilities in a changing climate. This will be achieved by using a balanced approach to managing climate and non-climate risks, and by integrating adaptation into our business practices.

The next major step in our adaptation work is the completion of a detailed climate change vulnerability assessment of our transmission and distribution infrastructure which will be incorporated into the broader body of work in our climate adaptation plan.

We will continue to work with PCIC and the scientific community to understand the effects of climate change and what it means for our operations, including the potential impacts on the health and safety of our employees and the public. An area we would like to better understand relates to the compounding effects of multiple climate change impacts. We would also like to further explore the opportunities that climate change may present.

We are also working to increase employee awareness and education around climate change and adaptation. In addition to presentations and workshops, this may include developing guidelines for the incorporation of climate projections in our work.

In summary, BC Hydro has actions underway to evolve and refine our adaptation practices. Over the next months and years, we plan to continue to:

- enable a coordinated and cost-effective approach to understanding the impacts of climate change on our planning, design and operations
- use consistent, quantitative, evidence-based assessments to inform our decision-making related to climate change adaptation
- integrate current climate change science into our planning, design and operations
- ensure our adaptation and mitigation strategies are complimentary
- engage, consult and transparently communicate our efforts with key stakeholders, peers, First Nations communities, and our customers

While the exact nature of our province's future climate remains uncertain, we are working to ensure that we are ready regardless of which scenario unfolds. Our goal is to ensure that BC Hydro has the adaptive capacity to continue to safely provide our customers with reliable, affordable, clean electricity.

BC Hydro
Power smart