Adaptation Case Studies in the Energy Sector

Overcoming Barriers to Adaptation

OURANOS

Ressources naturelles Canada
Natural Resources Canada

Canada

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FOREWORD

Climate change poses clear challenges for the energy sector. Beyond its central role in the low-carbon transition, the energy sector also faces increasing risks from a wide range of climate change impacts. The International Energy Agency (IEA) works to ensure reliable, affordable and clean energy for its 29 member countries and beyond, providing authoritative statistics and analysis to inform energy and climate policies around the world. The threat that climate change poses to energy systems goes to the IEA's core mission of enhancing energy security.

Over the past four years, the IEA has convened a series of workshops on the climate-energy security nexus to facilitate dialogue among businesses, researchers, and policy-makers to explore ideas and share best practices on enhancing resilience of the energy sector to climate change impacts. Given that climate change affects all aspects of the energy system – from infrastructure to supply and demand – action to improve resilience is needed across a wide range of energy sectors and activities. The workshops have therefore explored the impacts on energy users and suppliers (e.g., businesses, cities, and electricity sector), as well as the role of financing, insurance, and government policy. These discussions have also highlighted the importance of enhancing resilience of the energy sector of the future: one in which the increased uptake of low-carbon technologies and changing demand patterns present new resilience risks and opportunities.

The case studies documented by Ouranos show how energy companies – collaborating with climate scientists and other partners – can find a range of creative solutions to build resilience into their infrastructure and operations. These 11 examples are but a small sample of the efforts made to ensure a safe and reliable supply of energy in the face of a changing environment. We hope that these examples may inspire others to take action and to share their own experiences with the broader energy community.

David Turk
Head, Energy Environment Division
International Energy Agency

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EXECUTIVE SUMMARY

Weather and climate pose a constant threat to infrastructures and the delivery of sufficient and reliable energy to consumers and businesses. Over time, energy companies have built a considerable amount of expertise dealing with the natural variability of climate and its most extreme manifestations. Now climate change is modifying both normal conditions as well as the severity and frequency of extreme events. Because changes are not uniform over the globe, some companies have had to react earlier than others to adjust to new and evolving conditions.

This document presents eleven examples of actions taken by forward-looking energy companies around the world to adapt their operations or infrastructures to the changing climate. These adaptations take many forms, including structural upgrades, update of forecasting and operating rules, changes in asset management practices, and cover different sectors such as thermal generators, electric transmission, energy demand and hydropower. Each case study is based on interviews with project leaders, scientists or managers who championed the initiative.

Our discussions and a survey among the Canadian energy sector revealed a number of barriers to adaptation actions, including access to data and expertise, resistance within the corporate culture or the lack of funding mechanisms. The case studies present examples of companies that have overcome these barriers and that can inspire others to define and implement their own response to climate change.

TABLE OF CONTENTS

INTRODUCTION

The generation of energy is of paramount importance to the prosperity of societies and economies around the world. Many links within the energy value chain, however, are sensitive to weather and climate. As such, long-term changes in climate and increased climate variability introduce new unknowns to the energy sector. Utilities, regulators and governments must consider both current challenges and the cost of future climate risks to plan and implement robust and cost-effective measures.

While there are good individual examples of how to foster climate resilience, energy-sector adaptation is rarely integral to the strategies of most Canadian energy companies. Furthermore, most current efforts concentrate on understanding potential impacts on hydroelectric generation; little work has been done to leverage existing data and to use it to inform business strategy, planning, asset management, project design, opportunity management, compliance and reporting.

The Ouranos Consortium, in collaboration with its energy-sector members and Deloitte Sustainability, studied projects underway around the globe to gather state-of-the-art examples of adaptation to a changing climate. Interviews with project leaders, specialists and early adopters helped document illustrative examples and explore the difficulties encountered during the adaptation process. These examples cover a range of initiatives related to the risks of, and vulnerability to climate change, as well as the assessment and implementation of various adaptation measures.

The next section of this report describes the process followed to identify appropriate case studies. The following presentation of results includes three sections: an overview of Adaptation in the Energy Sector; 11 Case Studies of Energy Sector Adaptation to Climate change; and Barriers and Drivers of Adaptation. The 11 case studies forming the centrepiece of this report are designed to be showcased and shared on their own.

METHODOLOGY

To identify relevant and interesting examples of adaptation in the energy sector, the research team followed five steps.

1 A review of scientific articles, reports, trade journals, corporate annual reports and online publications identified more than 200 studies of energy businesses responding to impacts of climate change or unprecedented extreme weather. The chapter "Overview of Adaptation in the Energy Sector" presents an overview of the database.

2 From these 200 mentions, the researchers chose 11 perceived to be most relevant to the interests and needs of the Canadian energy sector. To guide the choice, first the 200 cases were aggregated into 38 generic adaptation measures. In a survey, representatives of Canadian energy businesses then ranked the measures in terms of importance. The ranking enabled us to identify 11 projects that covered a wide range of energy subsectors and generated the most interest among survey participants.

3 The researchers then identified, contacted and interviewed at least one project leader for each case study. The interviews were semi-structured and explored topics such as the genesis of the adaptation project within the company, along with the larger context, details and results of the project such as dealing with uncertainties, the decision-making process, funding, human resources, benefits and evaluation processes. The interviews also addressed the barriers to, and the drivers of, adaptation.

4 The 11 case studies are based on these interviews, along with materials provided by the companies or other sources. Company representatives provided feedback on early versions of the case studies; this feedback informed the final versions presented here. The chapter *11 Case Studies of Energy Sector Adaptation to Climate Change* presents an overview of the case studies.

5 The chapter Barriers to Adaptation is based on an analysis of the interviews, survey and review of company-provided materials.

RESULTS

OVERVIEW OF ADAPTATION IN THE ENERGY SECTOR

A collection of more than 200 projects suggests that climate change adaptation activities are rapidly becoming mainstream. These activities vary considerably, however, by sub-sector. Indeed, the hydropower sector accounts for a large portion (22%) of the adaptation projects, presumably due to its direct connection to climate and water availability. A similar percentage of projects relate to the electricity sector, irrespective of the primary energy source. About 30% of the projects involve organizations active in multiple fields of the energy sector: about 15% can be allotted to the coal, oil and gas sectors. Nuclear and thermal generation account for 5% each.

After electricity generation, the subsector represented most often in adaptation projects is transportation—i.e. the distribution and transmission of electricity. The example projects address, in roughly equal proportions, the general adaptation topics of (1) gathering information about climate change, (2) adjusting the management and (3) adaptation of physical assets. In the collection of projects, almost 60% resulted in final implementation actions, 10% identified adaptation measures that have yet to be implemented and 25% aimed to only gather knowledge about climate vulnerabilities and adaptation opportunities.

Appendix A presents details about the classification scheme based on which the above percentages were calculated. The percentages reflect the studies that we identified and may deviate from the real proportions for several reasons. There is, for instance, no single definition of the term adaptation; some organizations instead describe projects with terms such as upgrade, building resilience or maintenance. In addition, the information contained in the database is limited to publicly available documents and information obtained exclusively by Ouranos or Deloitte. An undetermined portion of information about adaptation to climate change is non-public, often due to competitiveness issues, and could therefore not be taken into account.

11 CASE STUDIES OF ENERGY-SECTOR ADAPTATION TO CLIMATE CHANGE

Our sample of adaptation case studies in the energy sector showed that many organizations around the world have acknowledged the reality of climate change and have begun to respond by integrating climate information and adaptation into their operations.

The first example of adaptation relates to changes in river flow in Australia. AECOM worked with a consultant and researchers to establish the best ways of **"Protecting Assets Against an Increasing Risk of Flood"** by studying climate change projections.

A second example is the story of Landsvirkjun, Iceland's national power company, which seeks optimal exploitation of the additional flows generated by melting glaciers by **"Fine-tuning Observations to Better Manage and Design Hydroelectricity Assets."**

Eskom in South Africa takes a holistic perspective and involves asset managers and climate change specialists throughout the company to optimize its operations, and to develop and implement a company-wide **"Strategic Approach to Climate Change Resilience."**

Manitoba Hydro established an in-house climate expert team to advance the company's understanding of climate dependencies and to carry out the **"Climate Change Assessment for Hydropower Project Licencing."**

A fifth case study documents New York City's energy utility's response to the devastations caused by superstorm Sandy, which resulted in an overall **"Storm Hardening in a Climate Change Context."**

Another case study takes us to France, where Réseau de Transport d'Électricité de France (RTE) developed an interesting way of **"Engaging the Public in Climate Resilience"** to decrease peak demand and improve supply management.

Case study #7 addresses the benefits of **"New Climate Normals for Energy Demand Forecasting"** that Hydro-Québec (Canada) began to use nearly a decade ago. The approach has evolved over time and addresses the impacts that changes in mean temperatures have on demand as well as on peak demand resulting from the use of electric heating during winter.

Increasing temperatures also impact on the **"Cooling for Thermal Generation in a Changing Climate".** Companies in South Africa, France and Canada have addressed such impacts on their cooling systems such as the amount of ice particles in the cooling water, cooling efficiency, environmental performance and the use of dry cooling technology.

The ninth case study describes how companies in Canada, Australia and the U.K. have developed ways of **"Adapting to Reduced Equipment Thermal Ratings",** including aspects of power-line sagging and the temperature-dependent resistance of conductors.

BC-Hydro (Canada) strives to better prevent the potentially negative consequences

Figure R1: Locations associated with the case studies: 1 - Protecting Assets against an Increasing Risk of Flood; 2 - Fine-Tuning Observations to Better Manage and Design Hydroelectricity Assets; 3 - Strategic Approach to Climate Change; 4 - Climate Change Assessment for Hydropower Project Licensing; 5 - Storm Hardening in a Climate Change Context; 6 - Engaging the Public into Climate Resilience; 7 - New Climate Normals for Electricity Demand Forecasting; 8 - Cooling for Thermal Generation in a Changing Climate; 9 - Adapting to Reduced Equipment Thermal Ratings; 10 - Increasing Network Resilience with Specialized Weather Forecasts; 11 - Using Climate Change Risk Assessment Wisely.

of extreme weather events. The concept of **"Increasing Network Resilience with Specialized Weather Forecasts"** was implemented in a new system that uses combined weather and hydrological data to inform decision-making processes. The final case study documents the activities of Ireland's EirGrid, which developed ways of **"Using Climate Change Risk Assessment Wisely"** to identify the risks posed by storm surges, sea-level rise and extreme precipitation events.

Note that the order of appearance of the studies reflects no ranking or preference.

BARRIERS TO ADAPTATION

The successful climate change adaptation efforts documented here are examples that overcame a variety of barriers that could impede the completion of the projects. We identified these barriers and gathered additional information about hindrances during interviews with project leaders. The list below summarizes the principal barriers to adaptation and features anonymous excerpts from interviews. Appendix B presents a detailed discussion of the barriers.

Understanding and perception of Climate change

"For most there are no doubts about climate change, there are rather questions concerning whether or not there is a need for assessment and adaptation and when."

Lack of a rationale for investment

"How do you value the climate resiliency to each individual customer and society? What are the real costs for society when a multiple-day outage occurs? There is a lot of debate over what are the true costs, what are the true risks of climate change."

Communication between players

"The concept of a 'model' is fundamentally different for a climate scientist, a hydrologist and an economist."

Lack of technical guidance

"There was really no textbook recipe of how to incorporate climate change; we had to come up with our own plan."

Insufficient institutional guidance

"The economic motivation for private companies to adapt to climate change fades out rapidly if there is not a political will underneath."

"There is all the time a need for a champion who drives things forward."

Inadequate leadership

Inaccessibility of information and customized data

"To the novice, it is not easy to find appropriate data and references about climate change."

"Collaboration between companies will be valuable wherever you are."

Absence of opportunity for collaboration

Climate projection uncertainty

"The difficulty with multiple climate scenarios is that you end up with too many answers. Now what do we do? Which one of those do we choose?"

"We modified our model for temperature to become a direct input."

Need to adapt existing tools

LESSONS LEARNED

The study of international adaptation projects in the energy sector suggests that climate change adaptation activities are becoming mainstream in many parts of the world. Utilities strive for resilience and flexibility in the face of changing conditions, whether they are climatic, regulatory, technological or financial. Measures that increase the robustness or adaptive capacity help utilities improve and secure customer service, keep costs down and remain competitive. In this effort, the changing climate is acknowledged as a relevant factor.

"Even if you don't adapt now, then you need to know why."

Our interviews with participants and leaders of adaptation efforts reveal several features common to successful projects. An example is the formation of consortia that engage industry, government, academia and regulators to promote a common understanding and to lift the technical, financial and regulatory constraints that could delay or impede progress. These consortia also facilitate access to, and collaborations with, climate and data specialists that can help garner the support of senior management—a critical ingredient—and provide a neutral platform for engagement with the media and public.

On the other hand, selecting an adaptation measure is ultimately a decision-making exercise, which can benefit from a diverse set of alternative strategies, including: low-regret options; various levels of trade-offs between resilience, and environmental and technical performance; and incremental or stepwise approaches. Indeed, a simple storm-hardening exercise can progressively evolve into a long-term climate-vulnerability assessment. Decision-making is often facilitated when climate-adaptation measures also produce other benefits beyond reducing climate risk, such as operational improvements; the short-term benefits of such measures often accrue and help achieve larger, longer-term adaptation goals.

By actively promoting what proactive utilities are doing to adapt to climate change, we hope to achieve two objectives. One is to improve public understanding of the energy-climate-security nexus; many people fail to recognize that generating enough electricity to keep the lights is an everyday battle. The second objective is to spur other utilities to share and compare their own adaptation experiences. The thoughtful and professional stance adopted by many in the energy sector can have a powerful influence both inside and outside of the sector.

As some of the case studies show, successful implementation of climate change adaptation can be a long process that often creates beneficial synergies for the organization. There is clearly a need to acknowledge the challenge and explore what climate change means for energy sector businesses. This study demonstrates that many in the sector have begun to do so. As one interviewee stated: "Even if you don't adapt now, then you need to know why."

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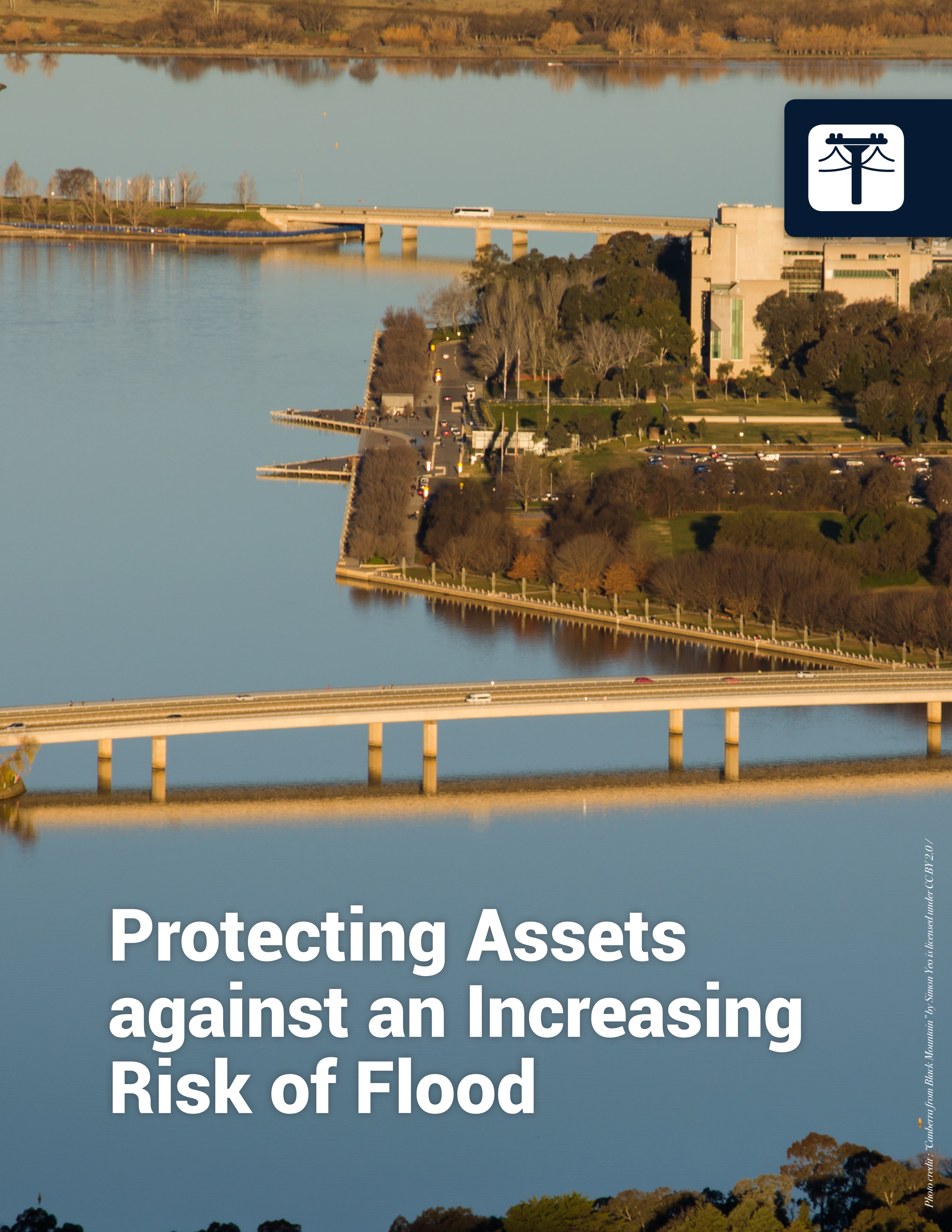

Protecting Assets against an Increasing Risk of Flood

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SUMMARY

In some parts of the world, climate change will likely increase the frequency and severity of floods. Components of an electrical network, such as substations, can be highly vulnerable to flooding. And when electrical equipment comes into contact with water, the damages are often irreversible; in some cases, entire substations must be replaced. Floods can cause entire sections of electrical networks to be de-energized resulting in a loss of power for customers. This case study describes the approaches and solutions adopted by several utilities to reduce vulnerability to extreme floods. A cost-effective approach is to create a safety buffer when building new substations by ensuring that vulnerable equipment sits above the higher floodwater levels expected due to climate change. As some utilities do not have the capacity to evaluate potential future floodwater levels, they turn to external consultants for assistance in determining the risk of flooding and the appropriate levels to use for planning.

"When the client learned that keeping a one-metre safety buffer between the equipment and floodwater level was feasible and inexpensive, they gave us the go-ahead quickly".

Guillaume Prudent-Richard,
Associate Director of the Environment Department, AECOM[1]

CONTEXT

An essential part of electricity networks, substations convert high-voltage electricity from generating stations into lower-voltage levels for distribution to homes, institutions and businesses. Substations also isolate faults, regulate voltage and monitor the quality and security of electricity.

Floodwater can cause severe structural and material damages to substations and lead to power outages and fire.[2] Other problems caused by water include the loss of temperature control (heating and air conditioning) and communications failure. In the last 15 years, storm surges and river floods have caused major damages to substations. During Hurricanes Katrina and Rita, for instance, controllers, switches and other components of substations in Mississippi and Louisiana suffered damage due to storm surges and waves.[3] In Rhode Island, floods in 2010 inundated 67 substations.[4] In 2013, a major flood in southern Alberta completely destroyed AltaLink Barrier 32S substation (see figure CS1.1).[5]

Figure CS1.1 The flood-damaged Barrier 32S substation, June 2013[5]

To prevent exposure of infrastructure such as substations to flood hazards, the electricity industry typically considers a "one in 100 years flood"—a flood with a one-percent chance of occurring each year, and that poses a severe hazard. When deciding where and how to build substations, engineers typically either avoid locations in one in 100 years flood zones or install vulnerable equipment higher than the expected floodwater level. Many substations were built before flood hazards had been properly documented, however.[6] Furthermore, climate change and factors such as increased urbanization can increase the one in 100 years flood level and the related risks for substations. The electricity industry has adopted several methods to mitigate the increased risks. Experience has shown that relocating substations outside flood zones and increasing the height of control buildings and vulnerable equipment tends to generate more cost-benefit advantages than building flood-protection infrastructure.[7]

EXAMPLE OF ADAPTATION

Many companies around the world adapt their substations to the increased risks posed by river floods and storm surges. National Grid, an electricity distributor in the United Kingdom, Massachusetts, New York and Rhode Island, continues to decrease its vulnerability to floods on both sides of the ocean. The company assessed the risks associated with the one in 100 years flood at 130 of its substations using river- and tidal-flood risk data from the UK Environmental Agency. Some 47 substations were found to be in the one in 100 years flood zone; 13 of these were prioritized based on detailed site surveys and cost-benefit analyses. The company will rebuild and elevate parts of these substations by 2022. Each substation will then be ready for a flood of between one in 200 years and one in 1,000 years, depending on the cost-benefit analysis and societal risk.[4]

American companies with coastal facilities can access a useful tool to determine appropriate elevations for substations vulnerable to floods: the Seas and Lakes Overland Surges (SLOSH) model. Developed by National Hurricane Center of the National Oceanic and Atmospheric Administration (NOAA/NHC), SLOSH is a numerical model that estimates storm-surge heights and wind speeds caused by hurricanes. Following the results of SLOSH, some substations were elevated by 7.60m to withstand a hurricane of category 3. Hurricanes of category 4 and 5 occur so infrequently that the risks associated with them are usually managed by investing in spare equipment; the cost-benefit ratio does not usually justify investments in raising substations to withstand hurricanes above category 3. In some areas, elevating substations was not feasible and utilities opted to install flood infrastructure such as concrete walls and levees.[3]

AECOM CONSULTING APPROACH FOR ADAPTATION TO CLIMATE CHANGE

Given the growing demand for expertise in managing climate change risk, companies around the world are building their capacity in the discipline. AECOM, for example, is an international engineering consulting firm with a team devoted to climate change and resilience. The company often collaborates with transmission and distribution companies in the Asia-Pacific region. AECOM recently assisted ActewAGL, a provider of electricity to 195,000 customers in the Australian Capital Territory, to conduct an environmental-impact assessment (EIA) of a project to relocate a substation near a wetland. The project, known as East Lake Electrical Infrastructure, was needed to accommodate a new residential development, and local laws required an EIA that takes into account the impacts of climate change.

Guillaume Prudent-Richard, Associate Director of the Environment Department at AECOM who contributed to the East Lake Project EIA, explains: "As with every EIA, we started by considering local climate and climate projections. We worked with engineers to understand the impacts of floods [on the substation] and to find solutions to respond to these impacts".[1] To identify the potential risks associated with Australia's current climate, Prudent-Richard and his team used a risk-rating matrix—a tool that takes into account both risk probability and risk consequence (see figure CS1.2). The team then studied climate projections to understand how climate hazards will change over time. Based on this information, the team updated the risk-rating matrix.

To evaluate future climate hazards and risks for the East Lake project, the team used public data from the Australian Government Bureau of

Likelihood	Consequences: Insignificant 1	Minor 2	Moderate 3	Major 4	Catastrophic 5
Almost certain (5)	M (5)	M (10)	H (15)	E (20)	E (25)
Likely (4)	L (4)	M (8)	H (12)	H (16)	E (20)
Possible (3)	L (3)	M (6)	M (9)	H (12)	H (15)
Unlikely (2)	L (2)	L (4)	M (6)	M (8)	M (10)
Rare (1)	L (1)	L (2)	L (3)	L (4)	M (5)

Notes:
E = > 20: Extreme risks demand urgent attention at the most senior level and cannot be simply accepted as a part of routine operations without executive sanction.
H = > 12: High risks are the most severe that can be accepted as a part of routine operations without executive sanction but they will be the responsability of the most senior operational menagement and reported upon at the executive level.
M = > 5: Medium risks can be expected to form part of routine operations but they will be explicitly assigned to relevant managers for action, maintained under review and reported upon at senior management level.
L = < 5: Low risks will be maintained under review but it is expected that existing controls will be sufficient and no further action will be required to treat them unless they become more severe.

Figure CS1.2 AECOM's Risk Rating Matrix

Meteorology and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). "We also have the internal capacity to generate custom-made climate change information," says Prudent-Richard. "We have software that enables us to generate projections at the project scale. The choice to go for the custom-made data that have a high production cost often depends on the budget allocated to the project. On this project, an increasing hazard of higher flood levels due to increases in extreme daily rainfall and in the frequency and intensity of storm was identified."

"The next step after identifying the risk is the decision of whether to consider adaptation options. It is not a decision that should be made by the consulting firm, but rather by the organization that will be investing and owning the risks." The current one in a 100 years flood level of Jerrabomberra Creek is 556.8m; the substation site lies between 558.1m and 559.1m, leaving a buffer of 1.3m (see figure CS1.3). It was decided that a minimum buffer of 1m should be kept to protect the substation against the increasing risk of flood.[8] "For East Lake, there was no cost-benefit analysis carried out. The decision to keep a one-metre buffer between the vulnerable equipment and the current one in a 100 years flood level was made quickly, during a meeting involving engineers and the client. The decision was obvious".

Figure CS1.3 The one in a 100 years flood zone of Jerrabomberra Creek[8]

LESSONS LEARNED

Guillaume Prudent-Richard has been working on projects similar to East Lake for several years. He acquired good insight into the challenges of implementing climate change adaptation.

The first challenge involves communication: many of the studies he completed are not publicly available. "Obviously, private companies are not interested in publishing a risk profile, because there are few benefits or incentives for them to do so," Prudent-Richard explains. "It can take up to 15 years to publish this kind of information if it is published at all." It is therefore quite difficult to rely on published literature to understand climate change adaptation from the private sector. On the East Lake Project, information about climate change was made available only because it was part of the EIA process, which requires public consultation.
Shifting politics represent another significant challenge for Prudent-Richard's team. When the government changes after an election, priorities also change, which can lead to a significant decrease in the number of climate change adaptation projects. Also tricky for the company is coping with legislative changes and the various methodologies for climate change impact studies. "Sometimes two areas with identical geographic characteristics are subject to different legislation and methodologies," says Prudent-Richard. "That leads to duplication of effort or confusion."

Prudent-Richard appreciates that the motivation for climate change adaptation comes not only from legislation: "Most of the studies we carried out were financed by companies on a voluntarily basis, and the main motivation was to save on long-term costs. Many companies are also motivated by the fiduciary duty to understand their risk profile and to take appropriate action."

Prudent-Richard emphasizes that more and better data on climate, physical and socio-economic conditions are needed for some parts of the world, such as Asia. He also stresses the advantages of working with custom-made data. “It enables us to work with the same format of data that engineers use, such as the actual return period and duration of events used for the design and construction of infrastructure,” he says.

Prudent-Richard notes that it is easier for clients knowledgeable about climate change to adapt effectively. “They better understand the issues, the methodology and the results,” he says, “so we have richer discussions and the process goes faster.” He also notes that problems within a working group can arise when not everyone accepts climate change science to the same degree. Finally, he explains that some companies will turn to his team to start the discussion about climate change and begin capacity building. “We help some companies with the scoping part of the assessment, provide training and then they take over the rest of the assessment,” he says. “Sometimes we revise their final work.” In this case, the engineering consultant acts like a facilitator in the adaptation process.

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AT A GLANCE

KEY TAKEAWAYS

1. **The assistance of a consultant at the beginning of the climate change adaptation process is a good way to start building capacity.**

2. **Learning from peers is difficult in some parts of the world, because companies are reluctant to disclose their adaptation initiatives and risk profiles.**

ORGANIZATION(S)
ActewAGL and AECOM (Australia),
National Grid (United Kingdom and United-States)

POWER SUB-SECTOR(S)
- Transmission and distribution

ADAPTATION TYPE(S)
- Informational – Climate Services
- Physical – Equipment protection, upgrades and alternative materials

CLIMATE CHANGE IMPACT(S)
- Higher river floods and storm surges

ADAPTATION COSTS
- The cost of elevating equipment and control rooms above floodwater level for new substations is low to medium.
- The cost of elevating equipment and control rooms above floodwater level for existing substations is high.

ADAPTATION BENEFIT(S)
- Minimization of damages during floods
- Increased network resilience

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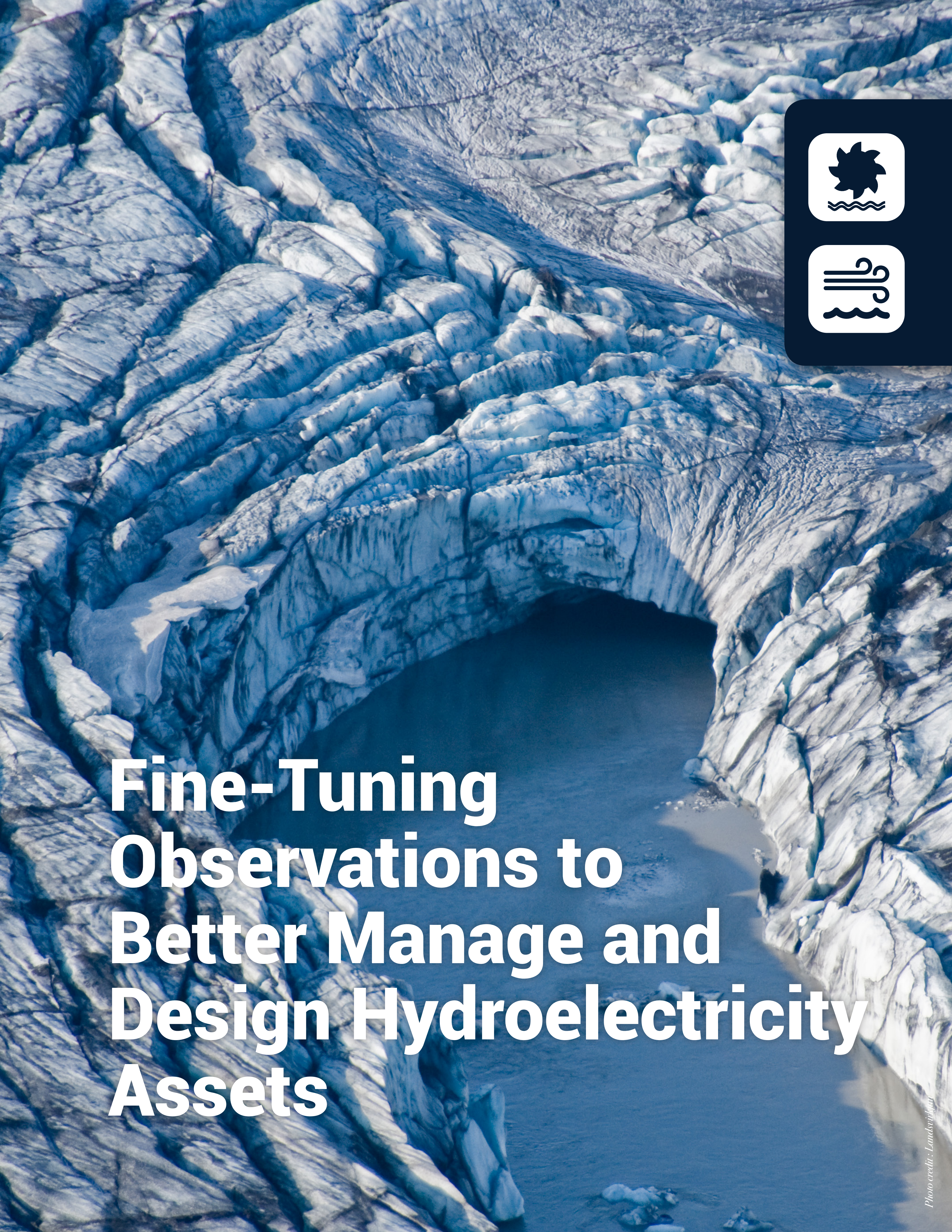

Fine-Tuning Observations to Better Manage and Design Hydroelectricity Assets

Photo credit: Landsvirkjun

SUMMARY

The hydroelectric sector stands to benefit from some aspects of climate change, such as increased flows due to melting glaciers. To take advantage of these potential opportunities, however, requires considerable knowledge of climate change projections and hydroelectric generation. Landsvirkjun, the National Power Company of Iceland, has become a leader in this field during the last 15 years. In collaboration with other power companies, universities and meteorological services across Scandinavia, Landsvirkjun has produced data on river flows that incorporate climate trends. Every five years, the company uses the data to adjust its reservoir-management plans. Landsvirkjun also uses the long-term perspective provided by climate projections to design and adjust existing and proposed new assets to take advantage of anticipated increases in flow rates.

"When we first considered expanding the Búrfell power plant, it was not economically feasible. Once we factored in expected increases in flow, however, it became more than feasible."

Óli Grétar Blöndal Sveinsson, Executive Vice-President of Research and Development, Landsvirkjun[1]

CONTEXT

While climate change remains one of the world's biggest issues, it also creates opportunities for the hydroelectric sector. Rising global temperatures cause glaciers around the world to melt. In some of the watersheds fed largely by glacial melt, climate change is expected to accelerate glacial melting and increase flow rates. In watersheds fed by glaciers that have already lost significant mass, flow rates may decrease. Projected changes in precipitation—and whether they will create opportunities for hydroelectric generation—vary by region; water availability will increase in some regions and decrease in others. Along with water availability, regional demand for electricity is also likely to vary due to climate change. A warmer climate could reduce demand for electric heat in winter, for instance, and increase usage of air conditioning in summer.

To take advantage of potential opportunities, hydro projects must adapt to new and changing conditions. In some cases, existing hydro resources, such as dams, turbines and reservoirs, are able to cope with changes in flow rates, water availability and demand through careful management strategies. In other cases, though, changes in management practices will not be enough. A common reason is that the capacity of the reservoir and/or turbines is too small to handle significantly larger volumes of water. In these cases, asset modifications are needed. Few companies around the world have justified asset modifications of this type to take advantage of the opportunities—or to mitigate the risks—associated with climate change.

Iceland is blessed with an abundance of renewable-energy resources; hydro and geothermal generate virtually all of the country's electricity. Power-intensive industries, such as aluminum manufacturing, account for 80% of the total demand for electricity. Hydro and geothermal generation meets this fixed base load, while direct use of geothermal energy meets 90% of the demand related to heating. Increases in the melting rate of Iceland's glaciers represent an opportunity to produce clean energy and attract new power-intensive industries.

Landsvirkjun, The National Power Company of Iceland, produces and distributes electricity to both industries and utilities. The company has long recognized that it must take advantage of increased flows on the island. During the last 15 years, Landsvirkjun has become a pioneer in adapting to climate change by modifying not only the management of its hydroelectric power plants, but also the design of its assets.

FINE-TUNING OBSERVATIONS

"Sometime around 2005, we saw that the flows into the system were different from what the history was suggesting they should be"[1] says Óli Grétar Blöndal Sveinsson, Landsvirkjun's Executive Vice-President of Research and Development. At that time, the company was already engaged with

Norden—a coalition of Scandinavian governments and research agencies—to identify and analyze the impacts of climate change on renewable energy.

In this collaborative research, observed temperature and precipitation data, as well as glacier area-volume-elevation curves, were adjusted according to climate model trends. For example, temperature trends call for increases of 0.75°C per century for the period 1950–1975, 1.55°C per century for 1975–2000 and 2.35°C per century after 2000. These trends were applied to historical data on observed temperatures to project future climate. This information was then fed into a hydrological model to produce corrected flow series.[2] Watersheds with large shares of glacial inflow showed the strongest responses to increased temperature. For the Karahnjukar watershed—75% covered by glacier—the corrected flow series shows an increase of about 10% compared to the last 50 years of records (See figure CS2.1).

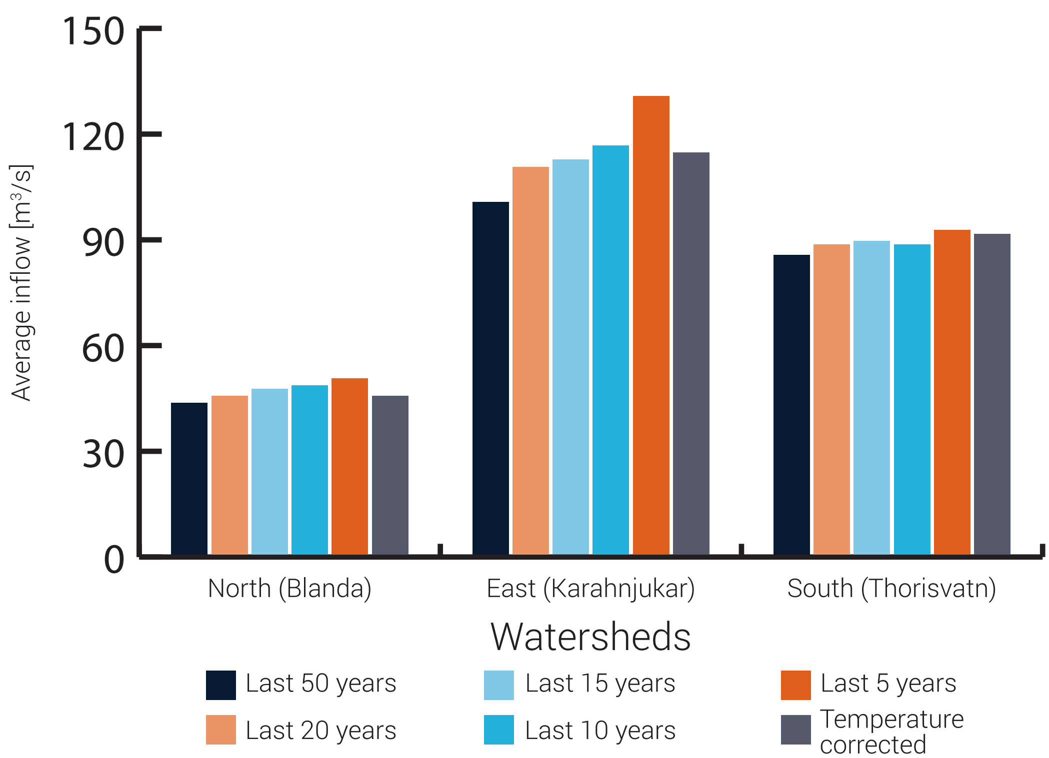

Figure CS2.1 In 2005, when historical flows were being analyzed, an upward trend became clear. The average flow reduced for all watersheds when the averaging window was extended further back. The average flow for temperature-corrected series (grey) was in all cases higher than the historical mean (black), especially for watersheds with considerable glacial-flow contribution.

LANDSVIRKJUN TAKING THE LEAD

Following the collaboration with Norden, Landsvirkjun went beyond analyzing the impacts of climate change based on corrected flows and incorporated the data into its reservoir-management strategies. Managing reservoirs to maximize hydro capacity while balancing environmental and social considerations is a complex undertaking. As a first step, Landsvirkjun decided to use only the 20 most recent years of river flows to manage reservoirs. By doing this, their production capacity jumped from 12.4 to 13.1 TWh/yr, as shown in figure CS2.2. (blue line Meas to blue line Meas20). The second step was to use the 20 most recent years of river flows and join them end to end with selected corrected flow series. The last step—and the approach they use today—is to consider only corrected flow series and to update the series every five years to reflect current climate conditions.

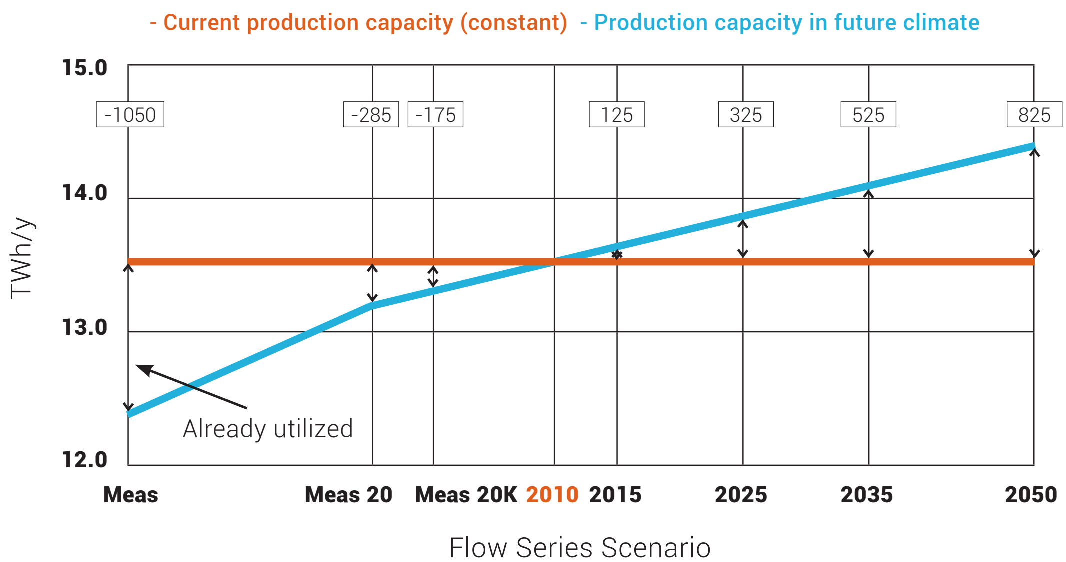

Figure CS2.2 Production capacity of Landsvirkjun for the 2010 series (orange line) and potential production capacity in a warming climate (blue line). Meas considers 50 years worth of data of river flows; Meas20 includes the 20 most recent years of data; Meas20K combines Meas20 with corrected river flows; and 2010, 2015, 2025, etc., represent corrected river flows for specific years. Numbers in boxes show the differences between production capacity of the flow scenario and the 2010 flow scenario (GWh) .

As the inflow increases with warming climate, modification of reservoir-management plans will not be enough to take full advantage of increased river flows and higher proportions of the flows will go over the spillway, because the capacity of assets will be exceeded. The runoff increase between the historical records and the 2050 flow scenario is 3.9 TWh/yr, but at the same time, the system can only cope with a 1.9 TWh/yr increase in production capacity, as shown on figure CS2.2 (1050 GWh+825 GWh). Therefore, Landsvirkjun has also adjusted the designs of planned new assets to take advantage of increased flows. "We use the flows that we expect in the future, 15 years or 20 years from now, to design the capacity of new power plants" [1] explains M. Sveinsson.

"The proposed expansion of Bùrfell power plant is a good example. At first, it didn't seem economically feasible to add 70 MW of capacity. But taking into account the corrected flows for 2025, the project is economically feasible and we increased the capacity of the turbine from 70MW to 100MW" [1] (see figure CS2.3 and CS2.4). At another proposed project, Hvammur, the original plan called for a capacity of 83MW. To accommodate the expected increased flows, the new plan is to increase the capacity to 95MW. Landsvirkjun evaluates that once those projects are complete, the company will be able to increase its sales of electricity by 8%.

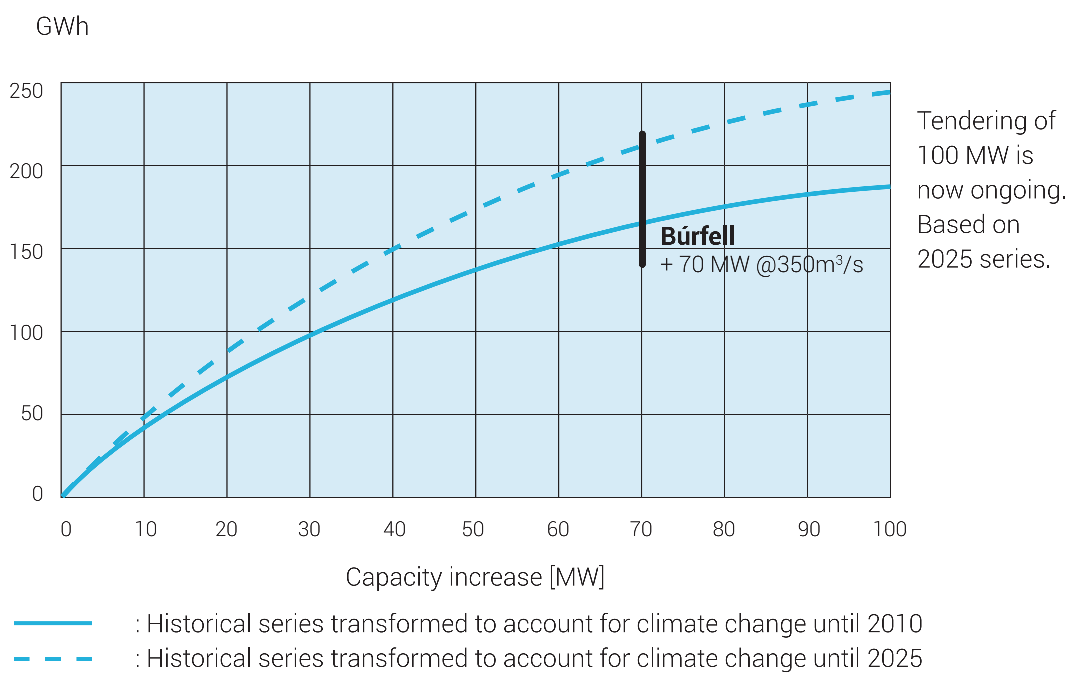

Figure CS2.3 Potential annual generation increase at Búrfell power plant when using corrected flows of 2025 instead of 2010 flows

And what will happen when there are no more glaciers? "We expect the total amount of rain will remain about the same" [1] explains Úlfar Linnet, Landsvirkjun's Director of Resources. "The system is not going to dry out, but the flows into the reservoirs will be more steady throughout the year, instead of coming mostly during from glacial melt during the summer months," [1] adds Óli Sveinsson. "By 2030, we expect the flows to reach a plateau, then not change much between 2030 and 2080. By 2080, the volume of the glaciers will have decreased so much that the flows will start reducing. [1] At that time, the system and the market will both be completely different." [1] This long-term phenomenon has little impact on current project, because investment decisions are based on projections of only 50 years.

Figure CS2.4 Graphic modelling of the projected underground expansion of 100 MW at Búrfell generating station. The left side of the picture shows the old Búrfell generating station and the right side shows a computer drawing of the projected discharge channel of the underground generating station.

LESSONS LEARNED

When they began to work on incorporating data about climate change, glacial melting and hydro generation, Sveinsson and Linnet say they faced a lot of scepticism. As early adopters, they now have much to share to help others in their climate change adaptation journeys.

Úlfar Linnet explains that convincing sceptics can be difficult if they cannot see clear trends in the observed data. "For us it was maybe easier, because we have these measurements that really show different characteristics in flow, as well as glacier measurements that show long-term shrinkage during the past two decades." [1]

Ultimately, though, the scepticism had a positive effect: "it forced us to answer many tricky questions and improved the quality of our work." [1]

According to Óli Grétar Blöndal Sveinsson, following a careful step-by-step approach was key to the project's success. "Back in 2006, a decision was made to omit the oldest years of the historical records and use only the 20 most recent years. As a result, some of the natural variability inherent in the record was lost, but it enabled us to move on to the next step: joining 20 years of historical records end to end with corrected flows series. Finally, we began to use only corrected flow series in the year 2010." [1]

Another key to success was collaborating with other groups. "Working as part of a big Scandinavian group with many power companies, universities and other institutions, gave the project credibility and significance," [1] says Linnet, and Sveinsson adds: "it would have been impossible at the time to sell the idea without participating in the international collaboration. The climate scenarios were selected jointly by all of those institutions, for the region as a whole." [1] Sharing the workload also facilitated the project.

Landsvirkjun bases its estimate of future changes on both IPCC scenarios and specific results for Iceland, revising them every five years.

Analysis has shown that the distribution of inflow for the last 10 years is significantly different from historical flows and follows the corrected flow series. Given the uncertainty in climate forecasts, Landsvirkjun maintains alternate plans that can be implemented should the selected scenario prove to be inaccurate. There has been much less uncertainty about the economic benefits for Landsvirkjun. "This is how you sell the idea," says Óli Sveinsson, "let the people feel it in their pockets." [1]

Today, there is a good consensus within the company that it is on the right track, largely thanks to the commitment of Óli Sveinsson and Úlfar Linnet.

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AT A GLANCE

KEY TAKEAWAYS

1. **People are more receptive to a step-by-step approach to climate change adaptation.**

2. **Collaboration with other power companies, universities and other institutions facilitates and boosts the credibility of adaptation efforts.**

3. **Having an alternative plan is a good way to cope with the inherent uncertainty of greenhouse gas emission scenarios.**

ORGANIZATION(S)
Landsvirkjun (Iceland)

POWER SUB-SECTOR(S)
Water endowment and hydroelectricity

ADAPTATION TYPE(S)
- Physical – New generation, carrying and transformation capacity
- Management – Design and operation standards, guidelines, tools and maintenance schedules

CLIMATE CHANGE IMPACT(S)
- Increased rate of glacier melt
- Changing availability of water resources

ADAPTATION COSTS
- The cost of investing in research projects as part of a Scandinavian collaborative is moderate.
- The cost of modifying the reservoir management plans is moderate.
- The cost of modifying the design of planned assets is high.

ADAPTATION BENEFIT(S)
- Increased generating capacity

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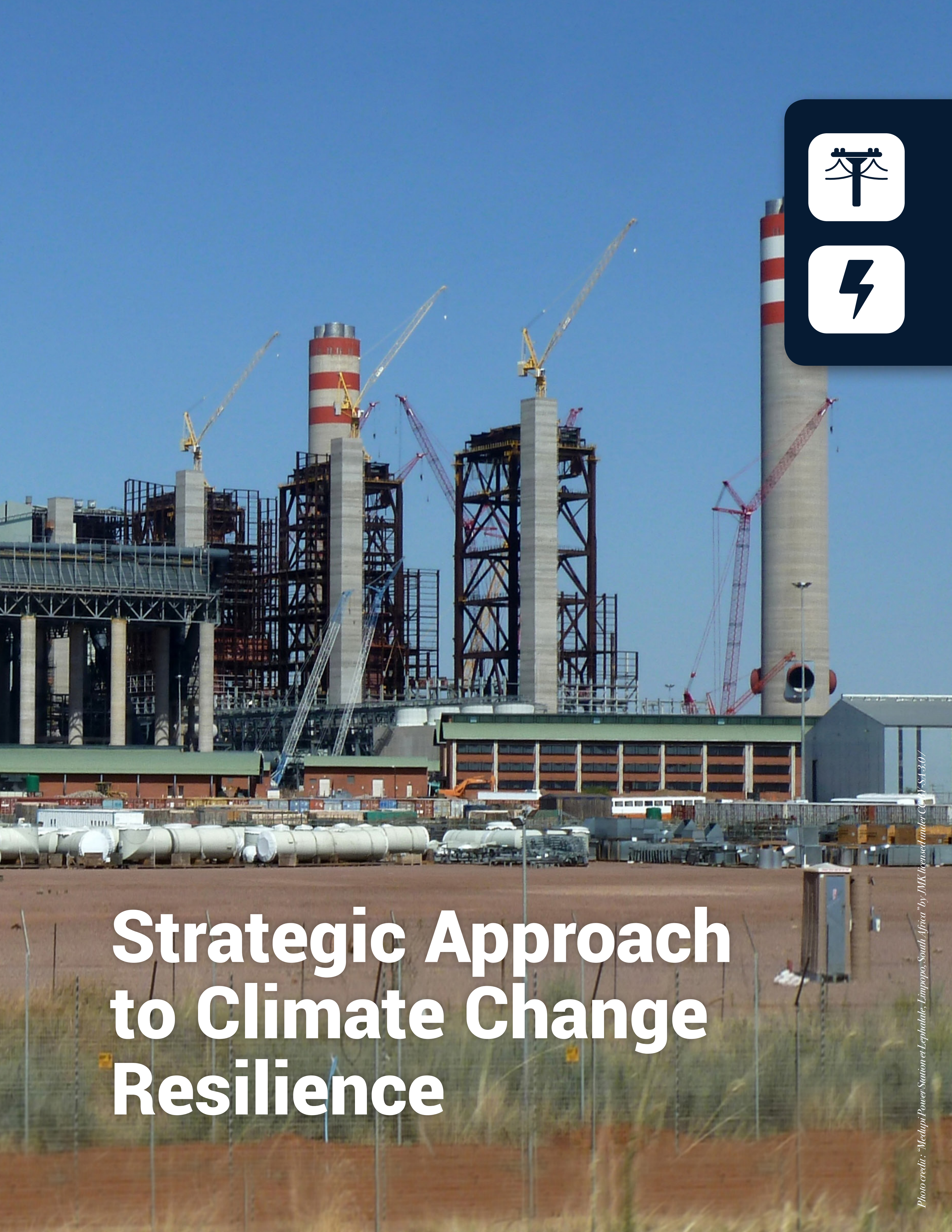

Strategic Approach to Climate Change Resilience

SUMMARY

South Africa's power company, Eskom Holdings SOC Ltd., has adopted a holistic, integrated risk-based approach to understanding and responding to the challenges associated with climate change. Its approach involves not only research with national climate change centres to understand, produce and use climate data but also to better understand operational thresholds that are sensitive to climate factors.

Engaging asset managers—who are required to report on the impacts of climate—is an important component of Eskom's approach. They are encouraged to document and share climate-related impacts and the resilience measures they put in place in the integrated risk management system via adaptation case studies. Corporate climate change specialists support and shape this process with guidance and tools.

Finally, with large investments in dry-cooling technology, Eskom acknowledges that additional capital expenditures and resulting reductions in operating efficiency are required to ensure energy security in an environment of increased water scarcity.

"Climate change is a of major importance, which means that its management gets directly reported back to our Management Committee Operations."

Lwandle Mqadi, Climate Change and Sustainable Development Senior Specialist, Eskom SOC Ltd[1]

CONTEXT

South Africa, like Canada, is on the frontlines of climate change. And while climate change impacts and responses differ between the two countries, the power sector in each nation faces similar planning and operational challenges.

In 2015, South Africa recorded above-normal temperatures across the country—a trend expected to further intensify. In the Highveld region, the first nine months of the year were the warmest ever recorded. The 2015 winter is also expected to receive below-average rainfall.

Average temperatures in South Africa have risen by 0.6°C during the last century, and hot days and nights have become more frequent.[2] Accelerated climate change will lead to even higher temperatures and will further deplete South Africa's limited freshwater resources. Other impacts, such as rising sea levels and increased variability in rainfall, could cause more intense floods and infrastructure damage if adaptation efforts are not adequate. Eskom, Africa's largest power company and one of its biggest consumers of freshwater, has long acknowledged its role in reducing greenhouse gas emissions and in improving the resilience of the power network.

CORPORATE-LEVEL CLIMATE CHANGE ADAPTATION STRATEGY

Established in 1923 as the Electricity Supply Commission, Eskom became a public, limited-liability company in 2002, wholly owned by the Government of South Africa. Its generation portfolio boasts more than 44,000MW worth of installed capacity, 85% of which comes from coal-fired plants. Eskom also operates gas-fired thermal stations, hydropower assets, pumped storage plants, a wind farm, a small photovoltaic plant and a nuclear plant.[3] The company also administers large transmission and distribution networks spanning close to 30,000 and 325,000 kilometres, respectively.

Eskom adopted a Climate Change Policy in 2004 focused on carbon reduction and later amended it to include all aspects of climate change. In 2007, the company launched a Six-point Plan to deal with climate change in the following areas:

- Diversification of power generation sources and technologies
- Energy efficiency
- Adaptation
- Innovation through research demonstration and development
- Investment in carbon markets
- Progress through advocacy, partnerships and collaboration[3]

Eskom's Integrated Risk Management Process identified climate change risks faced by each business area; each area then began to implement its own climate change risk management plan. The company's Climate Change and Sustainable Development Department (part of the Sustainability Group) provided technical support and relevant business intelligence.[3] Eskom reviews its strategy every three-to-four years, as new relevant information becomes available.

In 2011, the year Durban hosted the negotiations of the United Nations Framework Convention on Climate Change (UNFCCC), Eskom reviewed its plan in line with South Africa's national climate change commitments. The review led Eskom's leaders to prioritize and formalize an adaptation strategy because of concerns that climate-related hazards would increasingly threaten energy security. The strategy features short- and long-term actions to build Eskom's adaptive capacity and long-term resilience.[4]

"Climate change is a level 1 risk, which means that its management gets directly reported back to the Management Committee Operations," says Lwandle Mqadi, a Climate Change and Sustainable Development Senior Specialist with Eskom's Climate Change and Sustainability Department. "The fact that Eskom is a state-owned utility, and that the Department of Public Enterprise has a Climate Change Framework for State-Owned Companies in place covering adaptation, further influences Eskom to follow an integrated approach to climate change."

PROMOTING RESILIENCE AT THE ASSET LEVEL

Eskom recognizes that an effective adaptation strategy must be based on science and has invested in applied research. Some of this research focuses on defining the maximum climate-related loads that Eskom's assets can cope with before incurring costly operational failures or interruptions. To help identify these operational thresholds, Eskom continuously undertakes a comprehensive survey of its generation and transmission/distribution assets.

So far, the surveys have yielded a wealth of asset-level information, along with ideas about which data to collect and analyze in the future. The surveys also assist the organisation's efforts to build a strong business case to support further adaptation work.

Eskom launched a Climate Change Adaptation Research Case Studies Program: each year, the Climate Change and Sustainability Department helps a few asset managers complete studies on the impacts of weather, climate variability, seasonal changes, and long terme climate changes along with assessments of adaptation measures.[5] The case studies, along with any best practices that emerge, are shared widely within the company. The program ties in with the company's integrated risk management process by encouraging asset managers to include climate change resilience in their integrated risk management (IRM) plans.

The climate adaptation case studies align with a five-step procedure that standardizes how practitioners and asset managers will manage adverse impacts due to climate-related risks:

1. Assess key weather and climate variables, and their associated impacts within the identified **vulnerable areas** (information gathering through research or observations).
2. Outline project boundaries.
3. Explain operational vulnerability through the IRM process and outputs.

4. Identify and describe current plans, strategies, policies, standards and procedures that manage climate change risks.
5. Define a climate change adaptation plan, including required studies and information, within IRM plans.

To improve access to relevant climate-related data, Eskom partnered with research groups from the University of Cape Town, the University of KwaZulu-Natal and the Council for Scientific and Industrial Research (CSIR). The partners develop high-resolution climate projections, along with forecasts of extreme-weather events. Asset managers use these custom data, together with internal business intelligence, to inform medium- to long-term strategies to assess Climate change impact(S) and adaptation options.

Eskom recognizes that an effective adaptation strategy must be based on science and has invested in applied research.

INNOVATION AND CLIMATE CHANGE ADAPTATION

South Africa's limited freshwater resources help Eskom justify large investments in alternative cooling technologies that rely on air rather than on water.[6] In the 1980s, the company began to invest in dry cooling as a tactical response to water scarcity—a decision later justified by the reductions in freshwater resources due to climate change. Eskom's Six-point Plan on climate change identifies dry cooling as a short-term adaptation solution for all of its new thermal-generation assets. This approach is discussed in more detail in CaseStudy 8 — Cooling for Thermal Power Generation in a Changing Climate.

LESSONS LEARNED

The success of Eskom's Climate Change Adaptation Research Case Studies Program was not instantaneous. "It required a lot of man-effort and technical capabilities from experienced engineers," says Lwandle Mqadi[1]. However, with more than 10 case studies completed and shared across the company, momentum is building. Lwandle Mqadi reports that most challenges associated with the integration of climate resilience into risk management relate to how climate change risks are interpreted and captured within the IRM process, rather than to climate change science itself. "Not every climate risk gets addressed or captured appropriately. Sometimes because of financial constraints, the management of some risks gets delayed while other risks are being managed." [1]

Eskom's example illustrates that climate change adaptation sometimes requires making trade-offs between economic and environmental performance, and resilience. Dry cooling, for instance, incurs higher construction and operating costs than conventional wet cooling and reduces efficiency. However, Eskom accepts these trade-offs and costs as necessary to reduce the company's dependence on South Africa's diminishing freshwater resources and to enhance the security of its power supply.

Today, the equivalent of four full-time employees support the implementation of Eskom's climate change adaptation strategy, and individual business areas provide additional resources. "Thus far, budgets for climate change adaptation have come from within the business, but we are looking at other funding opportunities," says Eskom's Lwandle Mqadi. [1]

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Suggested citation : Ouranos 2016. Strategic Approach to Climate Change Resilience. Case Study presented to Climate Change Impacts and Adaptation Division, Natural Resources Canada, 7 p.

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AT A GLANCE

KEY TAKEAWAYS

1. Covering the costs of adaptation to climate change is a challenge
2. Incorporating climate change resilience into Eskom's Integrated Risk Management requires custom data and specialist support
3. Adaptation decisions sometimes require choosing between resilience and technical/financial performance

ORGANIZATION(S)
Eskom Holdings SOC Ltd. (South Africa)

POWER SUB-SECTOR(S)
Electricity generation, transmission and distribution

ADAPTATION TYPE(S)
- Informational – Climate Services
- Management – Insurance and financial risk management
- Management – Re-organization and governance
- Physical – New generation, carrying and transformation capacity

CLIMATE CHANGE IMPACT(S)
- Rising ambient temperature, droughts, and number of hot days

ADAPTATION COSTS
- The estimated overall cost of Eskom's climate change adaptation is moderate to high.
- The cost of applied research varies from low to moderate.
- Capital and operating costs of dry-cooling technologies are high compared with wet cooling.

ADAPTATION BENEFIT(S)
- Increased reliability
- Better environmental performance
- Improved resilience of Eskom's systems
- Reduced vulnerability to extreme weather events

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FULL REPORT
https://ouranos.ca/en/programs/energy-adaptation-case-studies/

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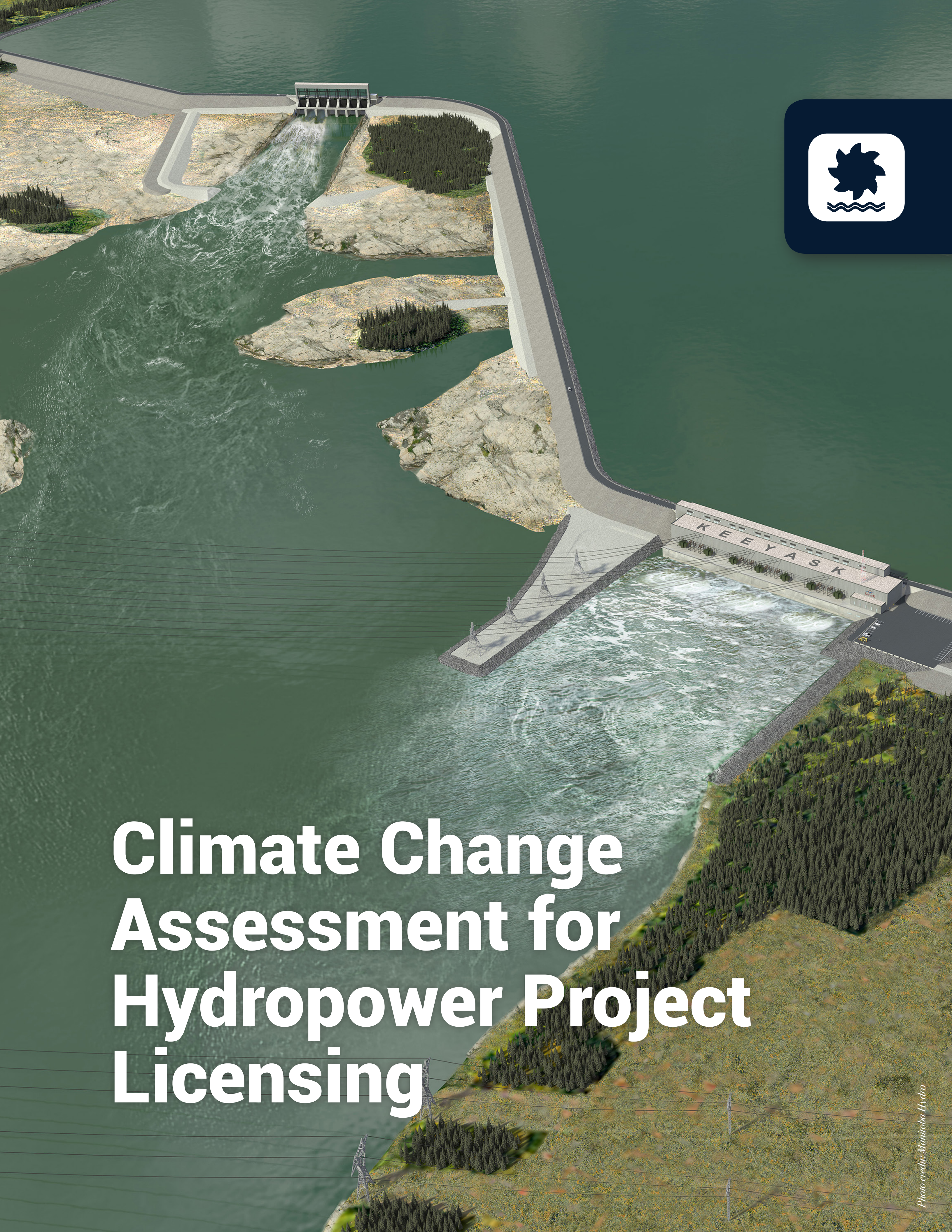

Climate Change Assessment for Hydropower Project Licensing

Photo credit: Manitoba Hydro

SUMMARY

Manitoba Hydro is currently building the Keeyask Generating Station in northern Manitoba on the lower Nelson River. During the licensing process, regulators recognized the necessity to ensure that the new facility would operate effectively and efficiently, including in an era when changing climate may affect water resources. The licencing procedures and public hearings addressed this issue in unprecedented detail. Having initiated the study of climate change impacts on its operations more than a decade ago, Manitoba Hydro was well positioned to incorporate climate change impacts into the environmental assessment and into an economic assessment as a sensitivity analysis to evaluate climate change against other risks for the project.

"We learned that climate change is very important to our stakeholders and they want to know that Manitoba Hydro is prepared for it."

Kristina Koenig, Head of Hydrologic and Hydroclimatic Studies, Manitoba Hydro [1]

CONTEXT

Traditionally, large investments in hydropower are based on observations and measurements of the natural environment. Climate and hydrological characteristics are of particular interest in the conceptualization and sizing of equipment built to harness the forces of nature.

To date, most facilities have endured very long periods of relatively consistent climate and hydrological conditions. Research shows that these conditions have started to change in recent years. These changes can increasingly affect the future operation, performance and safety of existing hydropower assets. In addition, the changes indicate that the planning of new installations can no longer rely solely on historical records, as they may no longer be good predictors of future patterns.

In Manitoba, Canada, an average of 98% of all electricity is generated from hydropower. Manitoba Hydro, a Crown corporation based in Winnipeg, manages and maintains hydropower facilities that serve approximately 500,000 electric customers. A large portion of the corporation's generating capacity is located near the outlet of the Nelson-Churchill river system, one of North America's largest watersheds. From the eastern slopes of the Rocky Mountains in southern Alberta, water flows eastward more than 2,000 kilometres to the mouth of the Nelson River on Hudson Bay (see Figure CS4.1).

The watershed dips slightly into the United States and extends into the northern limits of the boreal forest, spanning several climatic zones that influence water availability in the system. Manitoba Hydro has extensive knowledge of the hydrological characteristics of the sub-watersheds that contribute to its network of hydropower generating stations and has a long-term streamflow database (LTFD) that extends back to 1912.

Well aware of its dependency on climate and streamflows, Manitoba Hydro incorporates the assessment of future climate into its business strategy and resource planning. During the last decade, the study of climate change has become an integral part of several environmental and economic assessments.

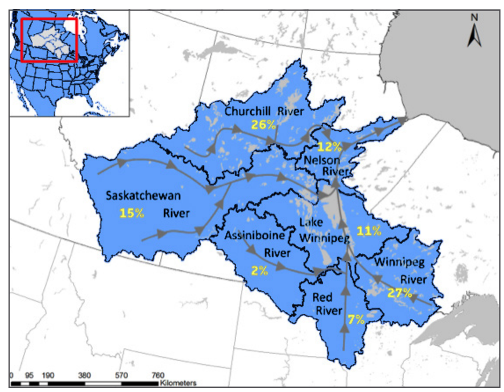

Figure CS4.1 Map of the basins of the Nelson-Churchill watershed (Approximate % flow contributions to total average water supply)

KEEYASK GENERATING STATION PROJECT LICENSING

Like every major public-infrastructure project, the 695 megawatt (MW) Keeyask Generating Station (the Project) on the lower Nelson River[2], went through regulatory approvals and environmental licensing processes. Unlike similarly large projects from the past, this time the procedure considered a new factor that could affect the environment and economic viability - climate change.

Manitoba Hydro's climate change team—part of its Water Resources Engineering Department—was up to the challenge. The team on behalf of the The Keeyask Hydropower Limited Partnership (KHLP) took an anticipatory approach by addressing climate change in the project's Environmental Impact Statement (EIS) and Needs for and Alternatives to (NFAT) business case[3].

The EIS considered three aspects of climate change: (1) the effect of the environment, including climate, on the Project, (2) the effect of the Project on the environment, including greenhouse gas (GHG) emissions and (3) the sensitivity of the assessment to climate change.

While the first two were requirements of the federal EIS Guidelines, the latter was done by the Partnership as a precautionary approach to assess whether the environmental assessment conclusions would hold for future climate conditions.

This information was presented to the Clean Environment Commission (CEC), which is an arms-length agency of the Government of Manitoba and provides the Minister of Conservation and Water Stewardship with licensing recommendations (see Figure CS4.2).

For the NFAT business case, Manitoba Hydro assessed the needs for its Preferred Development Plan, which included the Keeyask Generating Station, to determine whether or not the Plan is in the best long-term interest of the Province. As part of the business case review, the Province of Manitoba assigned a panel of the Public Utilities Board (PUB) of Manitoba to conduct the review and issue a recommendation to the Minister. Climate change and its possible impacts were discussed as one of the uncertainties in several alternative development plans presented.

To assess the potential impacts of climate change, the company's team of climate-savvy engineers selected five out of 109 Global Climate Model (GCM) simulations to represent future changes in average system inflows through the 2050s—the equivalent of a 35-year planning horizon. The selected projections cover 90% of all the climate simulations' uncertainty and range from a 9.6% reduction in overall inflows to a 28% increase. To integrate this hydrological assessment into an economic-feasibility analysis, the change signals from the five simulations

Figure CS4.2 Keeyask Clean Environment Commission Hearing at the Fort Gary Hotel in Winnipeg, Manitoba (October 21, 2013).

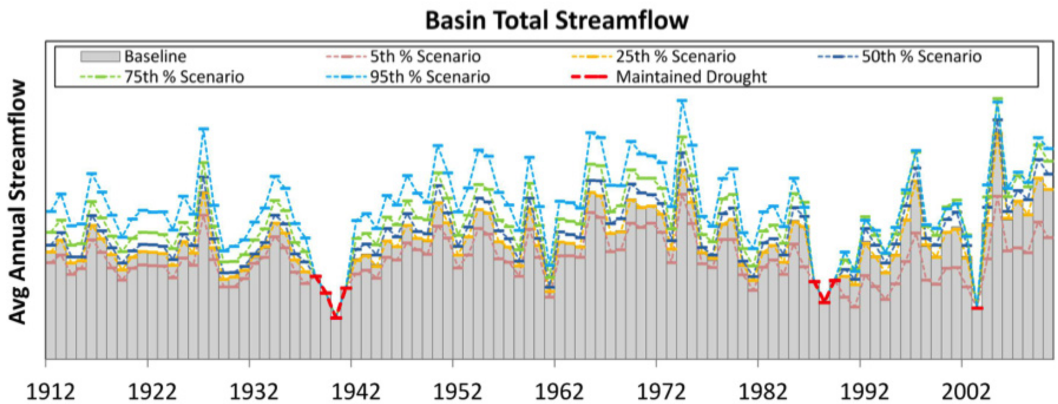

Figure CS4.3 Observed long-term flow data and their perturbations using five climate change scenarios. These scenarios were used to drive the Simulation Program for Long-Term Analysis of System Hydraulics to assess revenues as a function of climate change impacts.

were added to the observed long-term streamflow database record (see Figure CS4.3).

The resulting five future stream flow scenarios were then fed into the Simulation Program for Long-term Analysis of System Hydraulics (SPLASH) to estimate average annual revenues. As Manitoba Hydro's existing system consists of predominantly hydro-based generation, the assessed development plans showed sensitivity to changes in inflows. The preferred plan - which included Keeyask - showed the highest potential for increases in both incremental average revenues and incremental net present value. With 70% of the initial 109 climate model projections showing increased inflows, the analysis attributed a higher likelihood of increased revenues to the plan which included Keeyask.

To address the complex question of the future risk of drought, the worst drought periods were held constant in the historic record, while mean annual inflows were modified using the climate model simulations. This addressed the fact that current research remains undecided concerning confident statements about the future evolution of drought risk. During the review process, Manitoba Hydro indicated that it was able to deal with the largest drought of record and would further increase its resilience for any future potential droughts by developing generation and transmission capacity for energy imports so that a drought more severe than the ones on record could be withstood.

During PUB hearings, external expert reviewers scrutinized the company's analysis. Concerns included that the resolution of the climate models used was inadequate and that the company's analysis focused exclusively on mean annual runoff and did not address changes to the seasonal cycle and in the severity of drought. However, the rebuttal of the criticism presented little difficulty as it addressed issues that Manitoba Hydro's climate change team had considered extensively in their studies, for example, the fact that the runoff variable they used integrates changes in precipitation, evapotranspiration, radiation and wind.

Manitoba Hydro also took advantage of its membership in the Ouranos consortium which supported the utility's case with written and oral evidence from scientists dedicated to regional climate change and adaptation to climate change.

"Our affiliated membership with Ouranos enhanced our ability to address regulator concerns and added credibility,"[1] said Michael Vieira, professional engineer, Manitoba Hydro's Water Resources Engineering Department.

BECOMING AWARE OF CLIMATE CHANGE EARLY

According to Kristina Koenig, head of Manitoba Hydro's Hydrologic and Hydroclimatic Studies, Manitoba Hydro's interest in climate change started more than two decades ago in the planning process for the proposed future Conawapa Generating Station on the lower Nelson River, when engineers first started to notice small changes in the watershed and questioned what the future climate and streamflows would look like in Northern Manitoba.

Work on the Conawapa project of the 1990s later ceased, but interest in quantifying climate change impacts and vulnerabilities resurfaced in the mid-2000s, when Manitoba Hydro began to plan and construct the Wuskwatim Generating Station on the Burntwood River in Northern Manitoba.

Future drought risk was one of the drivers behind that interest but public and stakeholder expectations were also growing. "Manitoba Hydro realized that if we wanted to carry out future developments, we would need to become more involved in climate change studies and be able to demonstrate that the infrastructure would be resilient into the future under a changing climate," said Koenig. "Shortly after the regulatory hearings for the licensing of the Wuskwatim Generating Station, the company established the Hydrologic and Hydroclimatic Studies Section that we have today."[1]

Embedded in the Water Resource Department, the section is responsible for providing specialized engineering and expertise across the corporation in the areas of climate change impact studies, hydrology, watershed modelling and inflow forecasting with a focus on environmental studies, resource planning, regulatory review, operations, licensing and technical support during planning, design and construction.

BUILDING A TEAM TO STUDY CLIMATE

Manitoba Hydro chose to develop and strengthen climate-related capacity in-house, eventually assembling a team with the appropriate knowledge and aptitude (see Figure CS4.4). The team started to study the latest science on climate change and what it indicates for its facilities in the Nelson-Churchill watershed. Manitoba Hydro became an affiliated member of Ouranos in 2007 to benefit from a large climate database, participate in joint projects and to tap into the experience of other climate experts.

The company conducted several studies that established important knowledge about historic climate normals and trends, and developed future climate scenarios for numerous project sites, as well as for the individual sub-basins of the Nelson-Churchill watershed. The studies informed long-term planning and operations, and enabled the company to start to plan for future adaption for infrastructure and business practices as required[4].

Many of Manitoba Hydro's major capital projects involve regulatory review processes. Although these processes may not explicitly require assessments of climate change impacts, a precautionary approach suggests that they should be completed. As a result, the team prepared reports on the past and projected climate conditions at the sites of new or modified infrastructure. These reports supported the company's case for climate resilience during environmental review and licensing process for projects such as the Pointe du Bois spillway replacement, the Bipole III transmission line, Lake Winnipeg Regulation and the planned Manitoba-Minnesota Transmission Project (MMTP).

Figure CS4.4 The Hydrologic and Hydroclimatic Studies Section at Manitoba Hydro (left to right): Phil Slota, Mark Gervais, Kristina Koenig, Michael Vieira, Shane Wruth

Preparations for hearings into Keeyask represented the team's biggest challenge to date and required an increasingly sophisticated understanding of climate change compared to past studies.

LESSONS LEARNED

The company's understanding of its climate dependency has increased substantially over time and eventually this knowledge was required to be incorporated into regulatory processes. There was really no textbook recipe for how to exhaustively incorporate climate change into the environmental assessment, so they had to develop a method that would follow the original approach as close as possible but allow them to add the climate change layer to it.

Close contact with scientists at Ouranos helped the team evolve in a consistent and professional manner, yielding positive effects on the company's business practices. For example, tools that had been developed for climate change studies like physically based watershed models were adapted to also be used in short-term forecasting.

Whenever climate-related questions arise in the company, the in-house team responds, and it

Figure CS4.5 Keeyask Construction Site Photo (June 21, 2015)

drives the company to look further into adaptation to climate change. Consequently, Manitoba Hydro's latest integrated resource plan, a high-level strategic document that outlines the various resource combinations being considered to meet Manitoba's future electricity needs, will explore additional steps to better factor climate change impacts into long-term planning. These include exploring future changes to seasonal water-supply variations, droughts, energy demand and peak demand forecasting.

After considering recommendations from both the CEC and PUB, in 2014 the Province of Manitoba issued a licence to the Keeyask Hydropower Limited Partnership and the project is currently under construction (see figure CS4.5). During the economic assessment, uncertainties due to climate change impacts on streamflow were found to have less impact on the assessment when compared to other uncertainties such as future electricity prices.

The Manitoba Hydro team sees increasing stakeholder interest in climate change topics. "We believe hydroelectric companies looking into new generation may be faced with a lot of the same climate issues and the scrutiny of regulators, stakeholders and interveners in regulatory processes," states Mr. Vieira. Ms. Koenig concludes "We learned very quickly that we have to stay on top of the continually advancing climate sciences and be current in our studies."[1]

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[1] Koenig, K. & Vieira, M. Personal Communication (2015)
[2] Keeyask Hydropower Limited Partnership, http://keeyask.com/
[3] NFAT Business Case; http://www.pub.gov.mb.ca/nfat_mbhydro_application.html
[4] Manitoba Hydro Climate Change Report Fiscal Year 2014-2015; https://www.hydro.mb.ca/environment/pdf/climate_change_report_2014_15.pdf

AT A GLANCE

KEY TAKEAWAYS

1. **Public and stakeholder interest in climate resilience is strong and increasing.**

2. **Developing in-house expertise while partnering with climate experts and other businesses is a good practice for highly climate-dependent energy businesses.**

3. **Developing and fully understanding climate change impact studies is a long process.**

ORGANIZATION(S)
Manitoba Hydro (Canada)

POWER SUB-SECTOR(S)
Hydropower generation

ADAPTATION TYPE(S)
- Informational – Climate services
- Management – Regulatory exemptions and contracts
- Management – Re-organization and governance

CLIMATE CHANGE IMPACT(S)
- Long-term changes in basin hydrology

ADAPTATION COSTS
- The cost of developing in-house climate expertise is medium.

ADAPTATION BENEFIT(S)
- Climate-related risks were evaluated to obtain the regulatory approval for a new hydropower generating station.
- Studying climate change improved overall system understanding and fostered the implementation of new tools to analyze climate change and hydrological assessment.
- Climate resilience of the production system increased.

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FULL REPORT
https://ouranos.ca/en/programs/energy-adaptation-case-studies/

OURANOS

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Canada

Storm Hardening in a Climate Change Context

Photo credit : ConEdison

SUMMARY

"Some of the strategies we have adopted post-Hurricane Sandy are examples of permanent adaptation to a fundamentally different future... For other parts of our system, such as overhead cables and electrical equipment, we have adopted a resilience approach to reduce service-restoration times when unavoidable impacts are felt."

Griffin Reilly, Senior Engineer, ConEdison[1]

In 2012, New York City (NYC) suffered serious flood damage due to Superstorm Sandy. The storm spurred NYC to adopt a strategic approach to climate change resilience. In 2013, NYC convened an expert panel to update its city-level climate change projections. The Mayor's office also published a municipal-resilience plan calling for 250 initiatives worth a total of US$15 billion.

NYC's actions have helped to promote and shape the climate resilience decisions of ConEdison, a gas, electricity and steam provider. It is a perfect example of how cities can promote and support power utilities (see figure CS5.1). A week following Superstorm Sandy, ConEdison established a goal of hardening its critical facilities before the next hurricane season. It identified US$1 billion worth of capital investments for 2013-2016. Part of these investments had already been identified as necessary, but Superstorm Sandy and NYC's climate change projections created a need to act urgently. Furthermore, a collaboration with NYC and other stakeholders led ConEdison to approve new resilience actions.

CONTEXT

Superstorm Sandy struck NYC during high tide and a full moon on October 29, 2012. Its 14-foot storm surge was the highest recorded to date in the area. Approximately 90,000 buildings across 51 square miles were inundated.[2] With sustained wind speeds exceeding 60 miles per hour, and gusts of up to 90 miles per hour, the storm took down a large portion of the NYC's overhead power lines. A significant portion of NYC's power-distribution system was either flooded, pre-emptively shut down or overloaded (see figure CS5.2). Close to one million customers in Con Edison's service territory (including Westchester) lost power, and Con Edison's total repair and restoration costs exceeded $300 million.[3] Superstorm Sandy did not stop at the electricity system. It also had far-reaching impacts on petroleum-supply networks in the northeastern states. For instance, it caused reductions of approximately 30% in the output of several refineries over a week's time. The storm also shut down several petroleum terminals and pipelines.[4] In comparison, the natural-gas system coped relatively well, with only 84,000 customers cut off from service because of flooded pipes.[2]

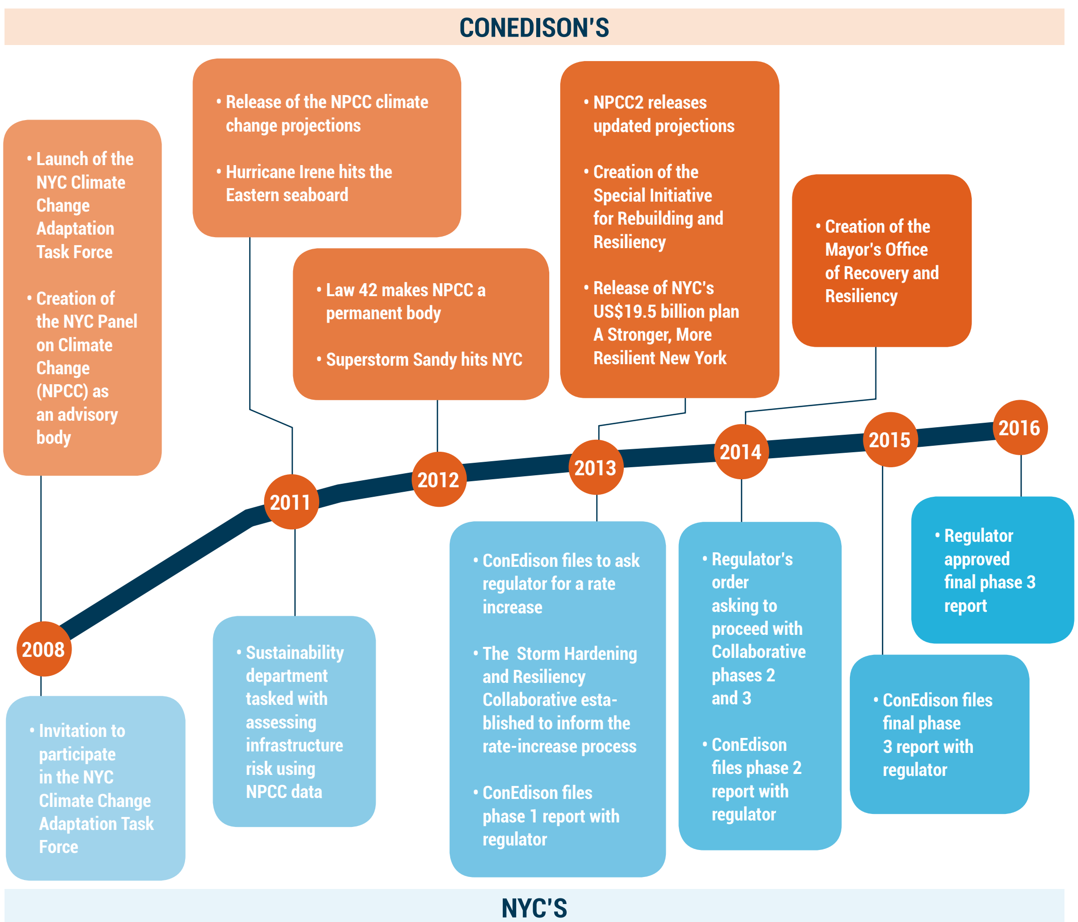
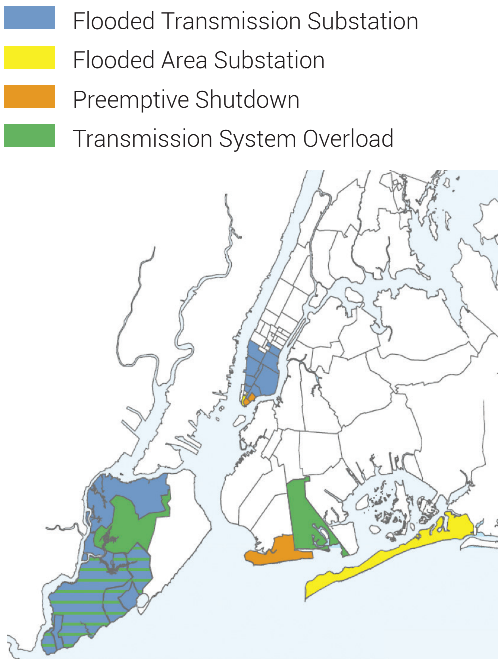


Figure CS5.1 Timeline of NYC's and ConEdison's climate resilience journey



Source: Con Edison, LIPA

Figure CS5.2 Impacts of Superstorm Sandy on NYC's power network[2]

MUNICIPAL CLIMATE CHANGE ADAPTATION RESPONSE

With more than 520 miles of vulnerable coastline, NYC is considered highly vulnerable to extreme storms and long-term climate change. In 2008, NYC Mayor Michael Bloomberg launched the Climate Change Adaptation Task Force with a mandate of developing strategies for improving the resilience of critical infrastructure to climate change impacts. The same year, and thanks to funding from the Rockefeller Foundation, the NYC launched the New York City Panel on Climate Change (NPCC) to advise and provide the Task Force with technical data and information. Comprised of experts in climate and ocean sciences, urban planning, civil engineering, law and risk management, the NPCC's outputs laid the foundation for the City's climate resilience process to date. The NPCC produced two important sets of information for climate change adaptation in NYC, namely: high-resolution projections[i], and adaptation-assessment guidelines and protocols.[5]

In September 2012, two weeks before a destructive tropical cyclone hit, NY City Council passed Local Law 42, establishing the NPCC as a permanent body required to meet twice a year to review recent scientific data on climate change and its potential implications for the City. It also stipulates that new climate change projections are to be prepared within one year of the publication of new data by the Intergovernmental Panel on Climate Change.

Superstorm Sandy prompted the City to convene a second NYC Panel on Climate Change (NPCC2) to present updated climate change projections for the 2020s and 2050s, and to establish new coastal flood-risk maps. Without explicitly linking Sandy with climate change, the NPCC2 demonstrated that unusually warm sea-surface temperatures further intensified the strength of the tropical storm. Further, the Panel noted that rises in local sea levels averaging 1.2 inches per decade, most of it due to climate change, increased the extent of flooding during the storm.[6] This new information came out a few months prior to the release of the *Preliminary Flood Insurance Rate Maps* by the Federal Emergency Management Agency (FEMA), which established new building standards for dwellings in floodplains.

A few months following Superstorm Sandy, NYC also initiated the Special Initiative for Rebuilding and Resiliency (SIRR) to prepare actionable recommendations for rebuilding communities and assets affected by the storm, while increasing the City's overall resilience. In *A Stronger, More Resilient New York,* released in June 2013, the SIRR identified increased storm-surge height due to sea-level rises and stronger hurricanes as a major risk to NYC's electricity and steam systems both today and throughout the century (see figure CS5.3). It also flags more heatwaves as a major risk to peak-demand management from the 2020s onwards.

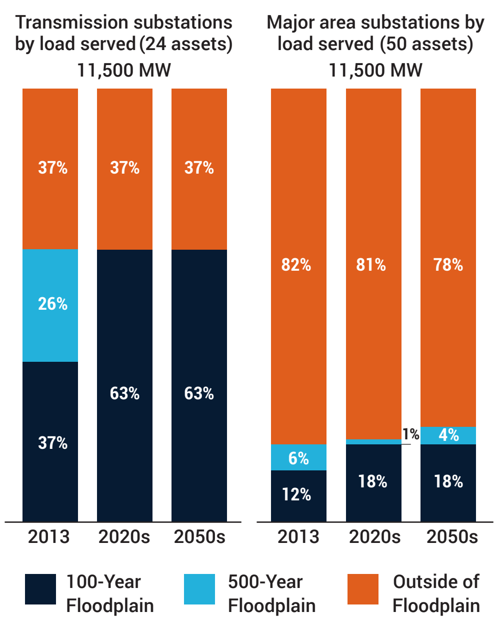


Figure CS5.3 Increased coastal flood risk for New York City transmission (left) and distribution (right) substations due to climate change[2]

SIRR's plan proposes more than 250 initiatives at a total cost of US$19.5 billion. Seth Pinsky, Director of SIRR, explained that the plan "will not only help New York City's most-affected neighborhoods to rebuild stronger and safer, but will help make New York City less vulnerable to the effects of climate change."[7] A new office, the Mayor's Office of Recovery and Resiliency, created in 2014, is responsible for implementing the plan.

CONEDISON'S STORM HARDENING AND RESILIENCY PLAN

As the City's primary distributor of electricity, gas and steam, ConEdison is an important part of NYC's climate resilience approach. In 2008, NYC's Mayor invited ConEdison to participate in the Climate Change Adaptation Task Force alongside city and state agencies, as well as other critical-infrastructure operators. Soon after the publication of the NPCC's 2011 climate change projections, ConEdison's executive leadership asked its Sustainability Department to consider what the data meant for infrastructure risk levels. As part of this high-level risk assessment, the company estimated the costs of climate-induced hazards and concluded that it could pose significant challenges to its operations.

Two weeks prior to Superstorm Sandy, several ConEdison executives met with NYC officials to discuss commissioning pilot studies to model service interruptions and the resulting economic impacts due to severe climate hazards. When Sandy struck, these early-stage discussions moved from hypothetical to urgent reality.

"We had two hurricanes with significant impacts two years in a row; Hurricane Irene turned out to be a very good drill for Sandy", reports Griffin Reilly, Senior Engineer at ConEdison. In 2011, Hurricane Irene resulted in close to 200,000 power outages, the largest service-interruption in company history. Superstorm Sandy broke this record: more than 300 000 of ConEdison's electricity customers experienced service interruptions. Five transmission substations and 18 distribution networks across Manhattan, Brooklyn and Staten Island shut down. Operations were also reduced at an additional nine substations due to the storm. ConEdison's steam system was unable to supply one-third of its customers when the storm inundated four of six plants and many tunnels. It took two weeks to fully restore service.[2]

"We had two hurricanes with significant impacts two years in a row; Hurricane Irene turned out to be a very good drill for Sandy"
- Griffin Reilly

"As storms and coastal flooding was a well-recognized risk to our system before Sandy hit, it became clear that our immediate response after Sandy had to target improving our resilience to more severe storms" says Griffin. Rather than delaying detailed vulnerability assessments, the company leapt into action. "The week after Sandy, we had engineers in those affected substations looking into how to prevent that kind of damage." Before flood waters had receded, ConEdison's leadership team had established an internal goal to harden its critical facilities by June 1st 2013, ahead of the next hurricane season.

ConEdison's engineers identified a large portfolio of necessary resilience investments with preliminary design and cost specifications. On January 25, 2013, the company filed with the New York State Public Service Commission (NYSPSC) to propose changes to its rates in support of US$1 billion worth of investments in storm-hardening capital initiatives for the 2013-2016 period.

The goals of the company's *Storm Hardening and Resiliency* Plan are two-fold: make ConEdison's assets more resilient to climate-driven failures; and reduce the time needed to restore customer service after a disaster. The plan includes a wide range of measures, such as equipment relocation, flood walls and barriers, water pumps, submersible equipment, isolation switches on network feeders, reducing the number of customers served by single overhead-circuit segments, and burying some overhead-distribution equipment.

By June 2013, ConEdison had built more than a mile of flood defences around vulnerable critical infrastructure, and replaced or installed more than 3,000 isolation switches on its overhead network.

ConEdison's rate case with the NYSPSC triggered reactions from influential organizations such as the City of New York, the Natural Resources Defence Council and the Environmental Defense Fund, urging the company to expedite investment and incorporate climate change into system planning. Rather than engage in a traditional litigation, the NYSPSC assigned an administrative judge to the case, and urged ConEdison to engage with all interested parties by convening the Storm Hardening and Resiliency Collaborative. The Collaborative was mandated to discuss and reach agreement on ConEdison's plan, including design standards that take climate change into account.

The Collaborative met regularly between July and December 2013, and made the following critical recommendations to improve ConEdison's resilience plan:

1. Adoption of the 'three feet plus' standard, equal to three feet of additional freeboard above the updated 100-year flood depth released by the U.S. FEMA in June 2013, as the minimum standard for new Con Edison capital projects in NYC[ii]
2. Alignment with the storm-surge inundation model developed by the NYC Mayor's Office of Long Term Planning and Sustainability
3. Commissioning of a *Climate Change Vulnerability Study* to synthesize current knowledge on climate change impacts
4. Prioritization of ConEdison's plans based on cost-benefit analysis[8]

ConEdison's Griffin Reilly clarifies: "Storm and flooding preparedness is nothing new to ConEdison; we have in-house models that predict flooding boundaries across our service territory and asset portfolio based on storm-surge forecasts from government agencies. We use these models to inform our storm-readiness response, and determine where protection measures need to be put in place in advance of an incoming storm."[1] What's changed is the company's commitment to designing projects in NYC based on FEMA's 'three feet plus' flood-resilience standard. The additional three feet above FEMA's 100-year floodplain height builds leeway to cope with storm-surge uncertainty and projected rises in sea level.[iii,6] The updated design standard added significantly to project costs, though some of it is also due to design-standard refinements.[9]

LESSONS LEARNED

A large part of the US$1 billion worth of investments in ConEdison's Storm Hardening and Resiliency Plan had already been identified by the organization as necessary. "What Hurricane Sandy did was to create a need to take action on these measures right away" explains Richard Miller, Director of the Energy Markets Policy Group at ConEdison.[1] This demonstrates that climate change adaptation does not always justify 'net new' actions. It can grow out of efforts to strengthen operational excellence.

What began as a storm-hardening plan is slowly morphing into a full-fledged post-2016 climate change resilience plan that will also provide benefits during smaller storms and 'blue sky' days when outages may occur for other reasons. With increased knowledge of climate change vulnerability and capacity for resilience planning, ConEdison identified that other climate-driven hazards deserve corporate attention. This prompted the company to include an assessment of the impacts of higher temperatures and changing humidity levels on power-load management in the scope of its Climate Change Vulnerability Study. "Even a one-degree Fahrenheit change in temperature variable used for projecting power loads would have huge impacts on future system planning," explains David Westman, former Regulatory Manager at ConEdison.[10]

Clearly, NYC's actions on climate change adaptation, specifically its role in convening the NPCC to produce updated climate change projections and its participation in the Collaborative, have provided additional drivers for ConEdison's resilience journey. It is a perfect example of how cities can encourage and support their electrical utilities in climate change adaptation.

"We identified the necessary resilience investments based on reliability and risk management standards", clarifies ConEdison's Senior Engineer, Griffin Reilly. It is the Storm Hardening and Resiliency Collaborative put in place by the NYSPSC that was interested in using cost-benefit analysis, not as a tool to select projects, but as a way to prioritize projects. "Cost-benefit analysis has highlighted a serious issue: how to monetize the benefits of improved resilience for individual customers; for instance, the value of reduced outages." Customers differ in their evaluation of climate change risks: for instance, the cost of power outages for hospitals or manufacturing is likely much higher than for residential customers or business offices.

ConEdison has faced another interesting challenge related to managing the cost of storm-hardening projects. On some projects, engineering companies submitted initial bids that were much more costly than anticipated, citing the added expense of resilience measures.[10] This has forced ConEdison to re-tender a few projects.

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[i] These projections rely on outputs from 35 Global Climate Models (24 for sea-level rise) used in the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).
[ii] This is also known as 'FEMA's plus three' standard.
[iii] The 'high-end' sea level rise projections by NPCC2 (31 inches between 2000-2004 and 2050-2059) are based on the 90th percentile of a range of simulations from 24 climate models and 2 greenhouse gas Representative Concentration Pathways.

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AT A GLANCE

KEY TAKEAWAYS

1. **A storm-hardening process can lead to a full-fledged climate resilience plan**

2. **Climate change adaptation does not always require 'net new' investments; often it raises the profile of operational-excellence measures that have already been identified**

3. **Cost-benefit analysis can be a useful tool to prioritize adaptation, but it raises issues about the value of impacts and benefits for different populations**

ORGANIZATION(S)
New York City (United-States), ConEdison (United-States)

POWER SUB-SECTOR(S)
- Natural gas supply
- Electricity transmission and distribution

ADAPTATION TYPE(S)
- Informational – Monitoring equipment and technology
- Management – Design and operation standards, guidelines, tools and maintenance schedules
- Physical – Equipment protection, upgrades and alternative materials

CLIMATE CHANGE IMPACT(S)
- Increased storm and tropical-cyclone intensity
- Sea-level rise and coastal flooding
- Rising temperatures and numbers of hot days

ADAPTATION COSTS
- The cost of strengthening the resilience of New York City to more severe storms is very high.
- The total value of ConEdison's climate resilience investment plans for 2013-2016 is very high.
- The cost of enhanced flood-risk standards for substations is medium.

ADAPTATION BENEFIT(S)
- Increased resilience to climate-driven failures
- Reduced service-restoration times during climate-related disasters

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FULL REPORT
https://ouranos.ca/en/programs/energy-adaptation-case-studies/

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Canada

Engaging the Public into Climate Resilience

Photo credit: RTE

SUMMARY

Managing electricity consumption is a sometimes-neglected way of coping with the demand peaks caused by extreme temperatures. There are several reasons that few companies follow this approach: it runs counter to their core business of selling electricity, for instance. And since the effectiveness of the approach depends entirely on the ability of a company to convince consumers to take action, communications expertise is essential. Réseau de Transport d'Électricité de France (RTE) followed this approach to successfully manage demand for electricity with an initiative known as *ÉcoWatt.* As a transmission-system operator, RTE balances electricity supply and demand by managing fluctuations in output and forecasting demand peaks. In the Provence-Alpes-Côte d'Azur (PACA) and Brittany regions, the utility uses *ÉcoWatt* to decrease peak demand and increase the network's climate resilience. Over the long term, this benefits everyone: RTE is better able to manage the supply of electricity and the public learns about—and contributes to—managing important energy issues.

"Through the ÉcoWatt initiative, citizens started to understand electricity issues that they did not understand before."

Solange Audibert, Communication Manager in the PACA region, RTE[1]

CONTEXT

For most people, electricity is intangible. Few ever think about the complexity of the electricity system, because they can access it by simply flicking a switch. Yet the cumulative impact of small conservation measures, such as reducing thermostat settings during extremely cold weather, can produce significant benefits. In the French region of Provence-Alpes-Côte d'Azur (population of nearly 5,000,000) heating accounts for a significant portion of the demand for electricity; during winter, a decrease of just 1°C in outside temperatures can trigger a massive spike in demand. Reducing the temperature settings on home thermostats by even a degree or two would significantly reduce not only demand but also the pressure on electricity networks and generation plants. Convincing the public to take these types of actions, however, has proven to be a difficult task.

Toward the end of the 2000s, periods of extreme cold in the PACA region became a significant issue for the electricity network. The region's limited generating and transmission capacity could not always satisfy demand. During one period of cold weather, power outages had to be imposed on 50% of the region This outage, along with smaller ones, have negative economic and social impacts, as some businesses—and even hospitals—must temporarily reduce their operations.

To address the issue, Réseau de transport d'électricité (RTE) embarked on a plan that combined the costly and time-consuming actions of increasing generation and transmission capacity with a less expensive and quicker option: a campaign to raise public awareness. Engaging the public to take action in this way has rarely been successful in France or other countries. RTE's program, however, proved to be a huge success.

This case study demonstrates a way to increase climate resilience that is not directly linked to climate change. It is a story about how to successfully engage the public in managing electricity demand—an adaptation method that all energy companies should consider.

THE *ÉCOWATT* INITIATIVE

RTE transports high-voltage electricity from generating stations to low-voltage distribution networks all over France. Part of its mission is to treat all stakeholders—providers, distributors, clients, etc.—fairly. RTE had originally planned a new transmission line for the PACA region to ensure a consistent supply of electricity, even during periods of extreme cold. The initial plan failed due to environmental concerns, however. "We understood quickly that we would need a different plan, because it would take at least six years to plan, gain approval of and build a new transmission line," says Solange Audibert, RTE's Communication Manager for the PACA region.[1] "So we asked ourselves: what can we do to make the population aware that the risk of major power outages still exists and to help them take action to prevent outages?"[1] At this point, RTE decided to collaborate with local communities and the Government of France by creating *Sécurité électrique* PACA, the initiative that later became *ÉcoWatt*.[2] *ÉcoWatt* aims to control electricity

Figure CS6.1 Snapshot of the ÉcoWatt system webpage during a red alert[2]

consumption by educating consumers and by alerting them to potentially major power outages. At the core of *ÉcoWatt* is a website that uses colour codes to indicate the current state of the electricity system: green indicates no risk of outage, orange shows moderate risk and red indicates high risk (see figure CS6.1). When an orange or red situation arises, all *Écow'acteurs*—people and organizations who have subscribed to *ÉcoWatt*—receive alerts by email, sms, Facebook or Twitter. In addition, the company suggests *Éco'Gestes*—actions to reduce consumption—based on the type of alert.

Currently, there are approximately 25,000 *Écow'acteurs* in the PACA region. Solange Audibert is quick to point out that this number is a little misleading, since several large organizations subscribe to the system as single *Éco'Wacteurs* and relay alerts to many individuals (see figure CS6.2). In addition, many communities, local governments and the media share *ÉcoWatt* messages, further amplifying the initiative's impact.

Figure CS6.2 Sample of the *Écow'acteurs* community[2]

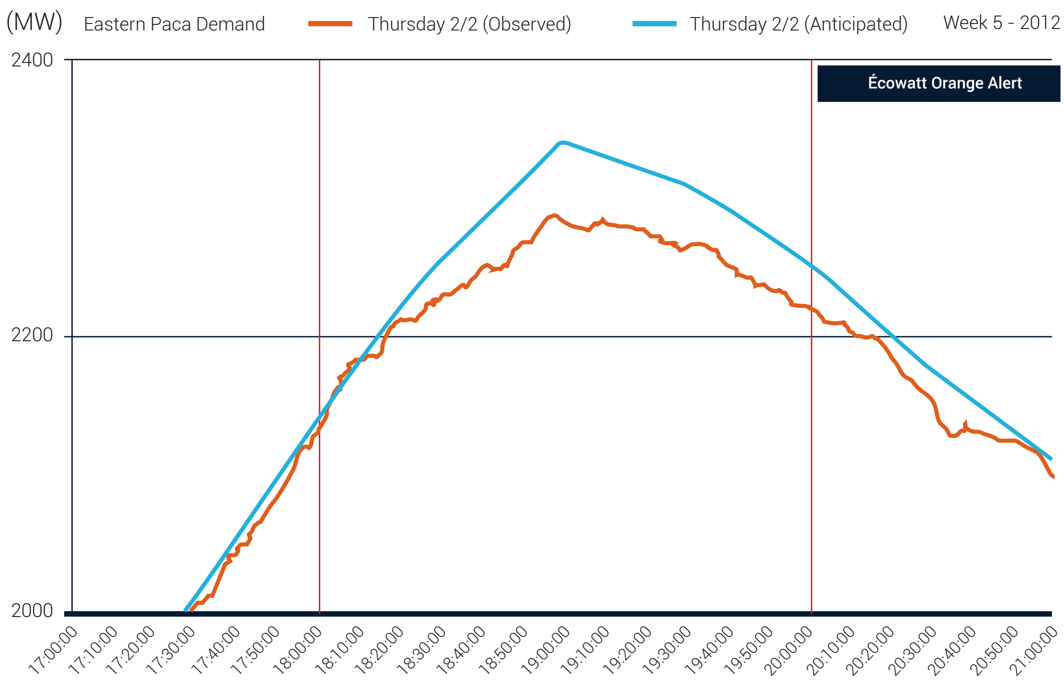


Figure CS6.3 Anticipated (blue line) and observed (orange line) electricity consumption in the PACA region on the night February 2nd 2012 during an orange alert[1]

At the beginning of February, 2012, *ÉcoWatt* communicated multiple orange alerts and its first red alert. "The response was phenomenal," says Audibert. "The media broadcast the message actively, elected officials made public announcements, and there were even messages posted on electronic billboards along highways." The impact on peak demand is significant during orange and red alerts: a decline of approximately 2-3%, as illustrated in figure CS6.3. "There was a multiplier effect during those events; we figure that we reached 20 times the number of *Écow'acteurs* subscribers." [1]

The success of *ÉcoWatt* also drew the attention of others across Europe. Belgium recently implemented a similar initiative called OffOn, largely inspired by *ÉcoWatt*. "It is a good initiative that also gets a lot of media attention," says Audibert.[1] OffOn enjoys the support of Elia, Belgium's transmission-network manager, and of the Government of Belgium.[3]

ÉcoWatt requires only a relatively small human-resource effort from RTE, as the regional communications team (three people) and a specialized communication firm performs most of the work. Solange Audibert manages and coordinates the firm's work, a task that takes up between a quarter to a half of her working hours during the winter, and all of her working hours during orange and red alerts. The annual budget for the initiative is 80,000 to 100,000 Euros, a relatively small amount given the significant benefits it delivers to the region. "When an outage hits 40 to 50% of the region, it drains millions of

Euros from the economy and exposes people to all kinds of risks" [1] says Solange Audibert. She also emphasizes that the initiative was created to educate and sensitize, rather than to improve RTE's bottom line.

LESSONS LEARNED

"One of the key success factors was to work hand-in-hand with local communities and the government. Everyone took the problem seriously; they understood that the impacts of a potential power outage were large," says Audibert.[1] Some entities, such as the *Agence de l'environnement et de la maîtrise de l'énergie,* had tried for some time to sensitize the public about energy consumption on a daily basis. The *Agence* and other similar organizations recognized *ÉcoWatt* as an ideal tool to deal with the risk of shortage and respond to the specifics of the PACA region and are founding partners of ÉcoWatt, along with RTE, to reduce peak consumption.

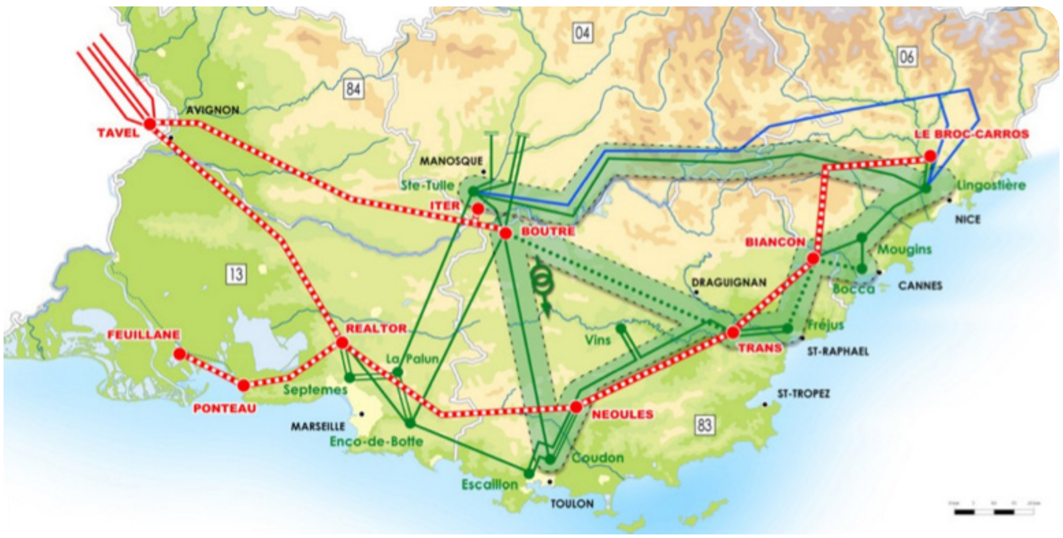
Another important factor was transforming a directive to reduce consumption into an eco-friendly message. "I think the public's main interest in the initiative was to avoid a power outage," says Audibert. "People also wanted to associate themselves with a positive initiative that has strong links to the environment, sustainable development and social responsibility." [1]

The catchiness of message also played an important role in the media engagement. "Media were great fans of the initiative, they liked it and gave it ample coverage."[1] During the month of February 2012, "there were over 1,000 press appearances, in all the media—radio, television, etc.—there was quite a buzz." [1]

According to Solange Audibert, "Interest in the initiative created something of a virtuous cycle: because we had institutional partners and the media liked it, we succeeded in engaging the population. That attracted private companies and more communities, so the initiative continued to grow." [1] Audibert also adds that RTE was lucky in a sense: at the beginning, unusually cold winters helped attract many subscribers.

In 2015, RTE completed the installation of a network of three underground transmission-lines known as *Le filet de sécurité* PACA (security net) (see figure CS6.4). The new network can supply the region with electricity in case of an outage along the main transmission line. As a result, *ÉcoWatt* lost its original raison d'être, but residents do not want the initiative to end just yet, according to a survey commissioned by RTE. "The survey showed that many are still interested in the information *ÉcoWatt* provides, even if the risk of an outage is almost nil," says Audibert. "People just want to know."[1] RTE also held internal discussions about whether to continue the initiative. "Many within the company wondered whether we were overstepping our role and compromising our neutrality by sending messages about reducing regular consumption patterns." Ultimately, RTE decided to continue *ÉcoWatt* without alerts, and with less emphasis on risk and more emphasis on the helpful actions—*Éco'Gestes*—to take during periods of peak demand."[1] Given the long-term benefits of increasing public awareness about reducing consumption, discussions are also underway about expanding *ÉcoWatt* to other regions of France.

Before *ÉcoWatt*, RTE questioned the legitimacy and impact of its public-relations efforts. Today, RTE recognizes that the initiative improved the company's reputation and helped raise public awareness of important electricity issues.



Circuit: 400 000 volts | 225 000 volts | 150 000 volts
Transmission-lines to be built: 225 000 volts

Figure CS6.4 The Filet de sécurité PACA was brought into service in 2015. These three new, 225,000-volt transmission lines are shown as green dotted lines.[4]

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AT A GLANCE

KEY TAKEAWAYS

1. **A well-designed communications campaign can help educate the public about climate resilience and engage people to take action.**

2. **A positive message that has strong links to the environment, sustainable development and social responsibility helps to engage the media and the public in climate resilience efforts.**

ORGANIZATION(S)
Réseau de transport d'électricité (France)

POWER SUB-SECTOR(S)
Electricity transmission and generation

ADAPTATION TYPE(S)
- Management - Demand management and tariffs

CLIMATE CHANGE IMPACT(S)
- Periods of extreme cold

ADAPTATION COSTS
- The cost of implementing and maintaining ÉcoWatt is moderate.

ADAPTATION BENEFIT(S)
- Prevent power outages
- Increased network resilience
- Increased public awareness about the long-term benefits of reducing electricity consumption

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FULL REPORT
https://ouranos.ca/en/programs/energy-adaptation-case-studies/

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Canada

New Climate Normals for Electricity Demand Forecasting

Photocredit : Photo Hydro-Québec

SUMMARY

"In the context of Hydro Québec, updating our climate normals based on temperature trends is not only simple and effective, but also absolutely necessary."

Alexandre Deslauriers, Demand forecast Team Leader at Hydro Québec Distribution[1]

Outside temperatures are an important factor in electricity demand in Quebec, because many households and businesses rely on electricity for heating and cooling. Hydro-Québec's distribution division, in collaboration with the Ouranos Consortium, studied these impacts in depth and implemented ways to incorporate recent changes in average temperature into energy and peak demand forecast.

CONTEXT

Temperatures are the principal criterion that determines when people start to heat or cool their homes and workplaces. In Quebec, this criterion has a direct impact on electricity consumption, as most people use electricity for heating and cooling. To meet demand, electricity providers like Hydro-Québec plan ahead using complex numerical models. Observed records of average temperatures are key components of these calculations. In the forecasting horizon, demand forecast models should use normal weather assumptions consistent with economic and demographic assumptions. In a warming climate with higher average temperatures than those of a few decades ago, observed records no longer provide the best statistical basis for demand forecasts. Hydro-Québec developed methods to improve demand forecasts that incorporate climate change trends. These methods are further refined for forecasting peak demand during the winter, as temperatures below -30°C are common in Québec.

ADAPTING CLIMATE RECORDS FOR IMPROVED DEMAND FORECASTS

Hydro-Québec's distribution division noted back in 2001 that average temperatures during 1991-2000 were clearly warmer than they had been between 1961 and 2000. Alexandre Deslauriers, Demand forecast team leader recalls: "The years around 2000 were certainly very hot in Quebec, which might have triggered our attention, but at the same time the Kyoto Protocol had just been adopted. These factors, along with an avant-garde spirit at Hydro-Québec, inspired us to explore further."[1] A study of the effects of higher temperatures on electricity demand revealed corresponding shifts in consumption and sales patterns during both winter and summer. Says Nadhem Idoudi, former Chief of the forecasting and characterization department and now Director of market risk management and analysis at Hydro-Québec: "We found that our sales often deviated from what we had predicted if they were based on a simple observed temperature mean."[1]

The distribution division wanted to better understand these findings and explore the potential relationship with climate change. As a founding member of the Ouranos Consortium on Regional Climatology and Adaptation to Climate Change, Hydro-Québec could readily provide its demand-forecast team with access to climate scenarios and services. In response to the team's request in 2004, Ouranos scientists developed a regionalized scenario of the evolution of monthly average temperatures using a single climate model simulation. At the distribution division, experts began to explore how to incorporate these long-term monthly temperature trends into demand forecasts, and whether the results would be useful. The results of this early exploration were unequivocal: "There was clearly a reduction in heating degree-days due to long-term warming,"[1] explains Alexandre, who uses the heating degree-day indicator to measure the heating consumption intensity.

To develop a way to use climate-model temperature data in Hydro-Québec demand forecasts, a more sophisticated assessment was completed in 2007. "Using the CMIP3 climate simulations—which were brand new at the time—we first identified where temperature trends begin to rise sharply in the time series," recalls Diane Chaumont, Coordinator of the Climate Scenarios and Services Group at Ouranos. Based on this analysis, 1970 was defined as a starting point for warming and used in the simplification of warming trends through the 2030s. The evolution of mean temperatures was established by fitting linear trends to the data from 1971-2040, using the deviation of this period's values from the average of 1901-1970. The analysis used the median value from 39 climate model simulations, yielding trend estimates for each month of the year (see Figure CS7.1).

Since 2007, the distribution division has used these trends to update the normal weather used in operational forecasting[2,3]. "We needed a way to represent the fact that the normals will continue to evolve and that the climate is no longer stationary, and to link this with demand and sales forecasts,"[1] says Nadhem. Figure CS7.2 illustrates the adopted procedure. A multiple of the annual-temperature increase due to the long-term trend is added to each year's value in the historical temperature record. The age of a record in years is equal to the number of times the annual increase

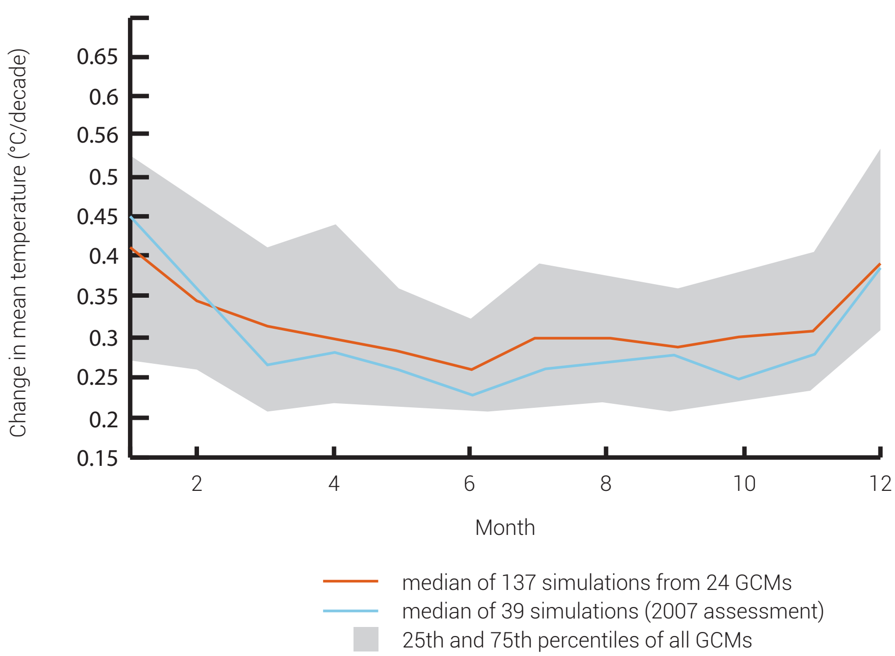
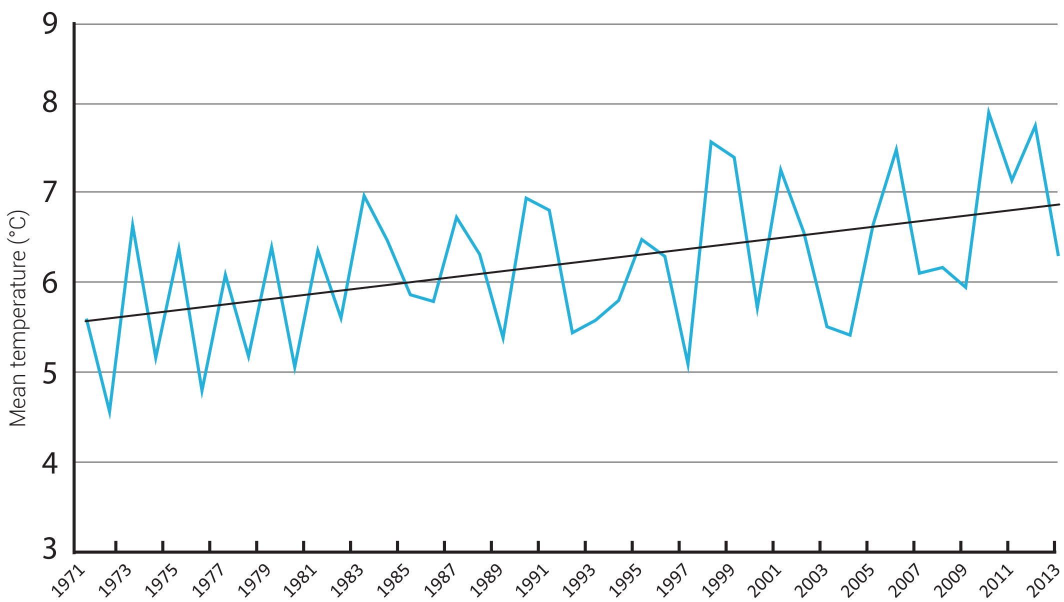


Figure CS7.1 Mean rate of temperature change per month through the 2030s for southern Quebec. Data from two assessments from 2007 (blue line) and 2012 (red line) show the stability of results. The grey area represents the uncertainty interval from all climate simulations between the 25th and 75th percentile.

Annual temperature - Observed and homogenized data



Temperature at Dorval (°C)

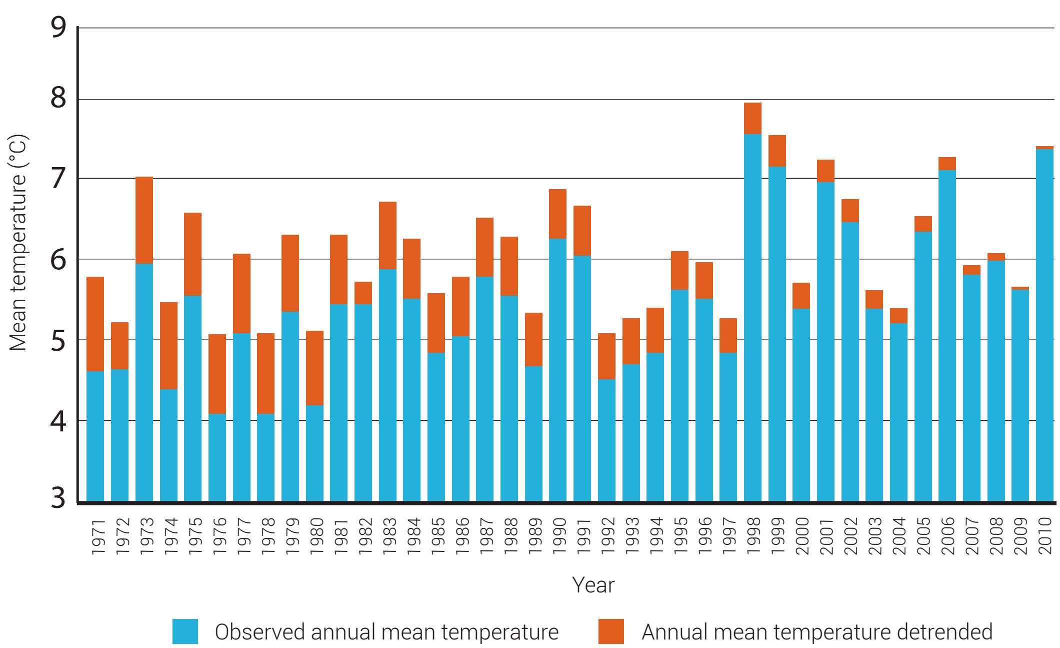


Figure CS7.2 Correction of a temperature/time series for the year 2010. The further a year is back in time, the larger the de-trending factor that must be applied.

needs to be added. As a result, the records for the cooler years of the past are raised to reflect today's warmer climate. A normal based on these corrected historical records provided a better-centered energy demand forecast than a normal based on uncorrected data. To keep its database current, Hydro-Québec requested an update of the climate assessment in 2012, this time based on a larger ensemble of 137 climate simulations. As can be seen in Figure CS7.1, the update confirms the robustness of the earlier assessment, with only minor differences in monthly trends.

Managing peak demand during Canada's cold winters represents another important challenge for Hydro-Québec. About three-quarters of households in Quebec rely on electricity for heating. Thus, the coldest days of the year usually coincide with the annual peaks in electricity consumption. "As we have started to correct our climate normals to reflect warmer temperatures, we should study the temperature effect specifically on high energy requirements for extremely cold winter days," explains Nadhem. "And buying electricity on the energy market at the last minute can be very expensive."[1] The 4th IPCC report[4]

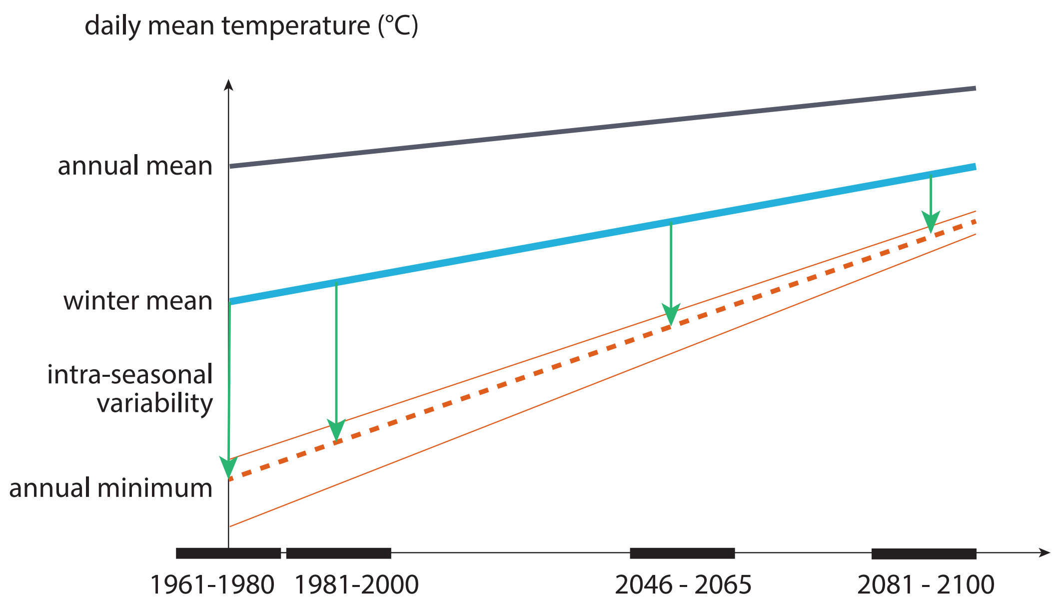


Figure CS7.3 Schematic of the different rates of change for annual mean temperatures, winter mean temperatures and extreme cold temperatures.

suggests that extreme temperatures may change at different rates than mean temperatures (see Figure CS7.3) "So we wanted to study temperature extremes and improve our ability to forecast winter peak demand,"[1] says Nadhem. Hydro-Québec again relied on the climate experts at Ouranos to explore this topic.Extreme events—rare by definition—are challenging to study and require the application of sophisticated statistical and mathematical skills. Barbara Casati of Ouranos dedicated several months to studying extreme weather events and shared the results with the scientific community[5].

Her research confirmed the hypothesis of faster warming of extreme cold temperatures in Quebec compared to mean winter temperatures. Hydro-Québec now incorporates these findings on the winter's coldest temperature's trends into its peak forecasting. The experts at Hydro-Québec expect that the model will improve the accuracy of their forecasts during winter, just as the model based on projected warming trends improved their forecasting during the rest of the year.

Figure CS7.4 Montreal in the morning of January 23rd, 2013. Minimum Temperature was -26.9 °C with a wind chill factor of -39°C (Environment Canada)

LESSONS LEARNED

When the forecasters within Hydro-Québec's distribution division started considering whether long-term temperature trends would have an impact on electricity demand and sales, many of their colleagues were sceptical. "Whenever we mentioned climate change," says Nadhem, "we always heard the same questions: 'Are you sure about this? Do you really think that next year will be warmer?' For many people, global warming remains abstract because it occurs gradually; temperatures don't always increase from one year to the next. We've found that graphics help people understand not only global warming, but also show why our forecast is well centered."[1] Nadhem supports these explanations with statistics that show the financial benefits that the new forecasting model has produced for Hydro-Québec over the years.

The in-depth study of the meteorological database in collaboration with climate experts yielded an unexpected benefit: they were able to explain anomalies in the record of historical temperatures. "The observed temperature data trend contradicted the climate models temperature trend," says Nadhem. "Looking more closely, we found anomalies in the observed data that coincided with the introduction of new measuring equipment in the 1990s."[1] This ultimately resulted in an improvement of their database by homogenizing the observed data. "We had always been confident that the observed data from a thermometer were good and consistent until we did a thorough analysis and found the homogeneity problem."[1]

The distribution division has since upgraded its forecasting approach[6]. "After 2012, we revised our entire forecasting system and began to follow an econometric approach," says Nadhem. "This approach integrates normal temperatures and accounts for their evolution over time." However, the team must still explain the climate's natural variability, such as the recent pattern of two very warm winters followed by two very cold winters (see figure CS7.4). They are convinced that the experience they've acquired has made them better forecasters. "All of our team has gained a lot of insight, and we pass this on and educate others at Hydro-Québec about climate change."[1]

The provincial electricity regulator made note of this information sharing and recommended that the forecasters at another Quebec energy company consult with Nadhem, Alexandre and their team to learn more about their approach to forecasting. Meanwhile, Hydro-Québec's distribution division continuously update their climatic normal to reflect impacts of climate change in demand forecast.

Author : Marco Braun, Ouranos | **Collaborators :** Élyse Fournier, Alexandre Deslaurier, Nadhem Idoudi | **Copy Editing :** Peter McKinnon
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AT A GLANCE

KEY TAKEAWAYS

1. Demand forecast can be improved by incorporating temperature trends
2. Adaptation of demand forecast is simple and effective
3. Long-term collaboration with climate experts ensures continual updates of information and builds confidence in climate model data

ORGANIZATION(S)
Hydro-Québec (Canada)

POWER SUB-SECTOR(S)
Distribution

ADAPTATION TYPE(S)
- Informational – Supply and demand forecasts

CLIMATE CHANGE IMPACT(S)
- Increasing temperature and changing extreme events

ADAPTATION COSTS
- Low

ADAPTATION BENEFIT(S)
- Improved demand forecast
- Modeled climate trends helped identify errors in observed station data

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FULL REPORT
https://ouranos.ca/en/programs/energy-adaptation-case-studies/

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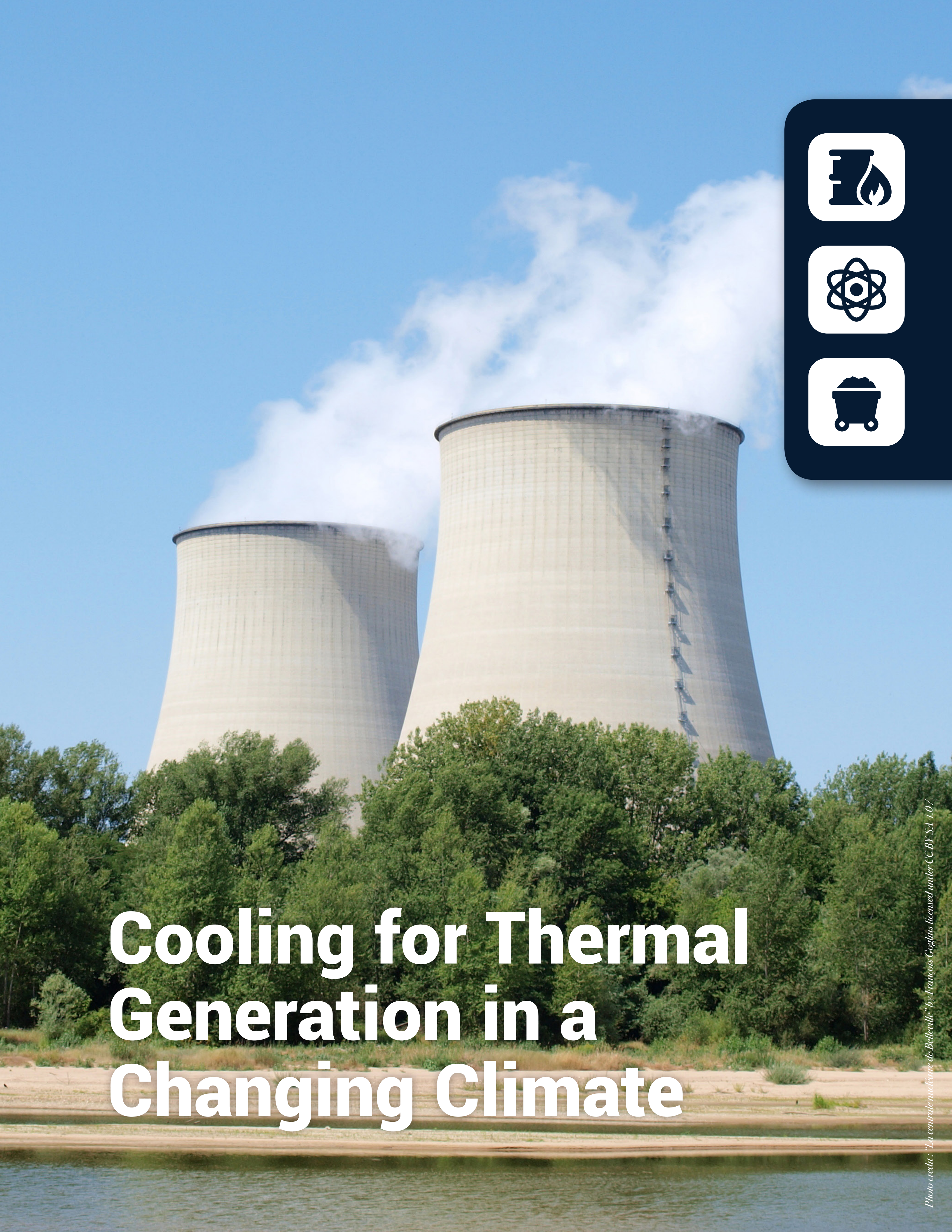

Cooling for Thermal Generation in a Changing Climate

SUMMARY

> ***"To comply with regulatory limits on the temperature of water discharges, power output reductions, and in some cases production interruptions have been necessary… Production losses have reached 5.5TWh in 2003 and 2.5 TWh in 2006."***
>
> Alain Vicaud, Director Environment and Prospection, and Éric Jouen, Director Projects, Électricité de France (EDF)[1]

Thermal power plants have large cooling needs, usually met by using nearby water or outside air. Climate change represents a significant challenge for these cooling processes, as it changes the baseline conditions, such as air and water temperature. To meet the challenge, the power sector must pay greater attention to technologies and design options that reduce the vulnerabilities arising from changes in regional climate.

This case study highlights various challenges and respective solutions implemented by three companies around the world. Ontario Power Generation (OPG) invested in equipment to prevent clogging of water-intake structures due to ice particles suspended in the lake during freeze/thaw transitions. Électricité de France (EDF) is conducting research to quantify the trade-offs between cooling efficiency and environmental performance for available technologies. Eskom invested in dry-cooling technology for all of its new thermal-generation plants.

CONTEXT

Nuclear, fossil-fuel, and biomass power plants are built to transform their respective fuels into heat. To generate electricity, these thermal power plants use heat to convert water into steam and spin a turbine that drives an electrical generator. These plants typically rely on cold water (from a river, lake or ocean) and sometimes on air to convert steam back into water.

For thermal power plants using water to cool steam, water requirements depend on the cooling technology used. Older thermal-generation assets, and assets located near large water bodies, commonly use once-through cooling systems that draw water and circulate it through pipes to absorb heat from condensers. The water is then discharged back into the environment at a hotter temperature, and with little net loss to the watershed. Newer closed-loop systems use a similar process to cool exhaust steam, they circulate heated water into cooling towers exposed to draft air, leading to water loss through evaporation. Closed-loop cooling draw less water than open-cooling systems, but it involves treating water with chemicals and leads to water loss for the watershed.[2] Where water is scarce, dry-cooling becomes and interesting option. These systems use little to no water; instead, they use air to cool steam. Dry-cooling technology is, however, more expensive to build and is less efficient.

Climate change is expected to disrupt thermal generators around the world in multiple ways. Governments regulate thermal discharges to protect aquatic life (in Canada, through the Fisheries Act).[3] As already experienced in France in 2003 and 2006, and in the United States in 2012,[4] it will be more difficult to comply with temperature limits on thermal discharges of once-through cooling systems. Rising temperatures will increase the risk that peak-power demand (due to increased use of air conditioners) coincides with periods of elevated temperatures in the bodies of water designated to receive discharged water. In August 2012, Dominion Resources was ordered to shutdown a nuclear reactor in Connecticut after high temperatures had been recorded in Long Island Sound, resulting in several million dollars' worth of losses.[5] Another impact of climate change is the in diminishing efficiency of the cooling process due to higher air or water temperature. For dry-cooling, high ambient temperatures can reduce generating capacity by up to 15%, for instance.[6] Northern countries can face an additional challenge: changing ice conditions may increase the quantity and frequency of suspended ice particles in water — also known as frazil ice — resulting in clogged water intakes. Other potential impacts include clogged intakes and filters due to algae blooms, reduced dilution capacity of the receiving water body due to droughts, and increased water restrictions due to reduced water availability.

OPG RESPONDING TO TODAY'S CLIMATE

The impacts of today's climate on nuclear power-plant cooling are already felt in Canada. For example, one of the nuclear stations operated by Ontario Power Generation (OPG) on the shores of Lake Ontario is directly affected by seasonal climate fluctuations and their impacts on lake conditions, because it draws its water from the surface of the lake. During winter, OPG runs, specialized equipment to prevent ice particles suspended in the lake from clogging the main screenhouse and the emergency water system.

"We have also had problems with algae blooms in recent years," says Kimberley Melo, Senior Analyst with OPG's Enterprise Risk Management. The Pickering station recently experienced several episodes of unwanted blooms of *Cladophora* algae during periods of sustained high lake temperatures. In 2007, OPG had to shut down one of its reactors and reduce its power output because of clogged screens and filters in one of its water intakes.[7] In contrast, OPG's other nuclear station draws water from the bottom of the lake, where temperatures are cooler and algae blooms are not a significant issue. Kimberley Melo adds that "climate change can also favour aquatic invasive species, such as zebra mussels, which stick to, and clog, water intakes and outlets." Scientists have linked Zebra mussels with large algae blooms in Lake Ontario because the mollusks filter water enabling sunlight to penetrate more deeply into the water.

In some parts of the United States, power producers face thermal constraints on water discharge. For instance, in August 2012 a nuclear reactor operated by Dominion Resources in Connecticut was forced to shut down after record-high temperatures had been recorded in Long Island Sound. The event resulted in a loss worth several million dollars.[5] In states with warmer climates and water scarcity, such as California, the impacts of rising temperatures have serious implications for energy security.[6]

Overall, the risk to OPG facilities of higher water temperatures and other climate-related hazards remains relatively low because its nuclear stations have large design margins. However, should new nuclear or thermal power-generation assets be commissioned in Canada, rising temperatures could become an important design consideration for cooling systems.

ADAPTATION RESPONSES AROUND THE WORLD

In the European Union, rising temperatures and cooling efficiency are centre stage in upcoming regulatory changes for thermal discharge. The 2010 *Industrial Emission Directive* requires basing industrial water-use permitting on Best Available Techniques (BATs). The European Commission (EC) is planning to start consultations shortly with power producers and other industrial water-users to inform its revision of the 2011 *Industrial Cooling Systems Best Techniques Reference Document* (BREF) containing BATs for industrial cooling design. The EC explicitly decided to take climate change projections into account to identify the cooling techniques that best balance industrial requirements with environmental performance over the long term.

To address the risks associated with changes in climate extremes and normals, French nuclear-power producer Électricité de France (EDF) put in place a four-pronged climate adaptation strategy:

1- Project in a timely manner climate changes by the 2030s for existing assets and by the 2050s for planned projects
2- Assess the vulnerability of existing assets, and strengthen their coping capacity
3- Enhance the resilience of assets and projects to current and future climate risks
4- Integrate knowledge of climate change projections in the design of future projects

EDF also commissioned a research project to quantify and compare various environmental-performance indicators (e.g. water withdrawals, heat emissions, air emissions, energy efficiency and energy use) for a range of cooling technologies in a changing climate.[8] This integrated assessment relies on estimates of future air and water temperatures, relative humidity, and rainfall and streamflow levels, based on downscaled climate-model projections and hydrological models.

EDF is well equipped to implement resilient nuclear-generation cooling practices. Since the historic heat waves of 2003 and 2006, EDF has become a world leader in climate change adaptation by investing in a portfolio of preventive actions. As part of the *Grands Chauds* project, water- and air-temperatures used in the design of cooling systems were revised to account for climate change. Consequently, EDF decided to increase the cooling capacity of two nuclear plants. EDF also benefits from a sophisticated in-house meteorological and hydrologic forecasting system. Finally, a risk-management unit coordinates responses and stakeholder management during climate-related crises. The unit also helps operational teams to determine when exceptional criteria justify temporary derogations from regulatory limits on thermal discharges.[1]

In southern parts of the world, rising temperatures have already justified large investments in alternative cooling-technologies that rely on air rather than water. This is the case with Eskom, South Africa's power utility. Most of Eskom's generation portfolio consumes fossil fuels, and it is one of South Africa's largest consumers of freshwater.[9] In the 1980s, the company made a strategic decision to invest in dry cooling. Dry-cooling technology is more expensive to build and requires more fuel per kilowatt-hour produced. For instance, 2% of the total generating capacity of Eskom's Matimba coal-fired plant is used to operate its cooling fans.[6] Furthermore, generating performance at a dry-cooled plant is sensitive to meteorological conditions. In particular, high ambient temperatures can reduce generating capacity by up to 15%.[6]

Eskom's investments in dry-cooling technologies for its thermo-electric plants began as a response to water scarcity in South Africa. They were later further justified by projected reductions in freshwater resources due to climate change.

In its corporate climate change strategy, Eskom identifies dry-cooling technologies as a short-term adaptation solution for its new thermal power-plants. All new plants powered by fossil fuels incorporate dry-cooling systems. Since the mid-1980s, the company has increased its installed air-cooled capacity by 12,000 MW.[10] Eskom currently operates the world's largest air-cooled power plant, Kendal Power Station, with an installed capacity of more than 4GW.[9] It also plans to add 4.8GW worth of dry-cooled generation capacity through its newly commissioned Medupi coal-fired plant. Medupi will be the first of its kind to combine dry- and wet-cooling technologies.

LESSONS LEARNED

Physical climate change adaptation can usually be implemented during either the design or operational phase of a power asset. One of the only options for coping with the impacts of rising temperatures and water scarcity on thermal generation is to build resilience into asset design. For instance, an appropriate water-intake system or cooling technology can help a power plant accommodate projected climate changes, and avoid output reductions and shutdowns. Locating power plants near the coast enables the use of seawater for cooling. Thermal-generation units can be retrofitted with increased cooling capacity or with a new cooling system, although this is usually a very expensive option.

Taking action on climate change adaptation sometimes requires making trade-offs between economic performance and resilience, especially when power plants draw water from scarce resources. For instance, dry-cooling technologies cost more than conventional wet-cooling technologies to build and operate. They also lower overall power output; they consume more energy for each kilowatt produced.[2] Because reduced access to cooling water is projected to cause disruptions, Eskom has accepted that resilience overrides financial considerations.

In the case of wet-cooling technologies, EDF's research also shows that there are trade-offs between thermal discharges, consumption of water/energy and pollutant release. In a regulated context for cooling-technology performance, as in the European Union, regulators must determine whether climate resilience justifies the reduced environmental performance and/or higher costs associated with closed-loop systems.

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AT A GLANCE

KEY TAKEAWAYS

1. **Resilience to rising temperatures and water scarcity needs to be built into the design of generation assets**

2. **Projected climate change can have an important bearing on the performance of Best Available Techniques**

3. **Astute adaptation investment involves trade-offs between resilience, and environmental and technical performance**

ORGANIZATION(S)
Électricité de France (France), Eskom (South Africa), Ontario Power Generation (Canada)

POWER SUB-SECTOR(S)
- Electricity generation from thermal power plants

ADAPTATION TYPE(S)
- Informational – Monitoring equipment and technology
- Management – Regulatory exemptions and contracts
- Physical – New generation, carrying and transformation capacity

CLIMATE CHANGE IMPACT(S)
- Rising ambient temperatures and number of hot days
- Increased water temperatures
- Changes in surface runoff, aquifer recharge and water levels

ADAPTATION COSTS
- The costs of power-plant slow-down or shutdown to comply with thermal-discharge regulations is high.
- Capital costs of switching to closed-loop or dry-cooling technologies are very high.
- The operational costs of cooling technologies that minimize thermal discharges is high.

ADAPTATION BENEFIT(S)
- Enhanced capacity to cope with hot days and low streamflows
- Better environmental performance

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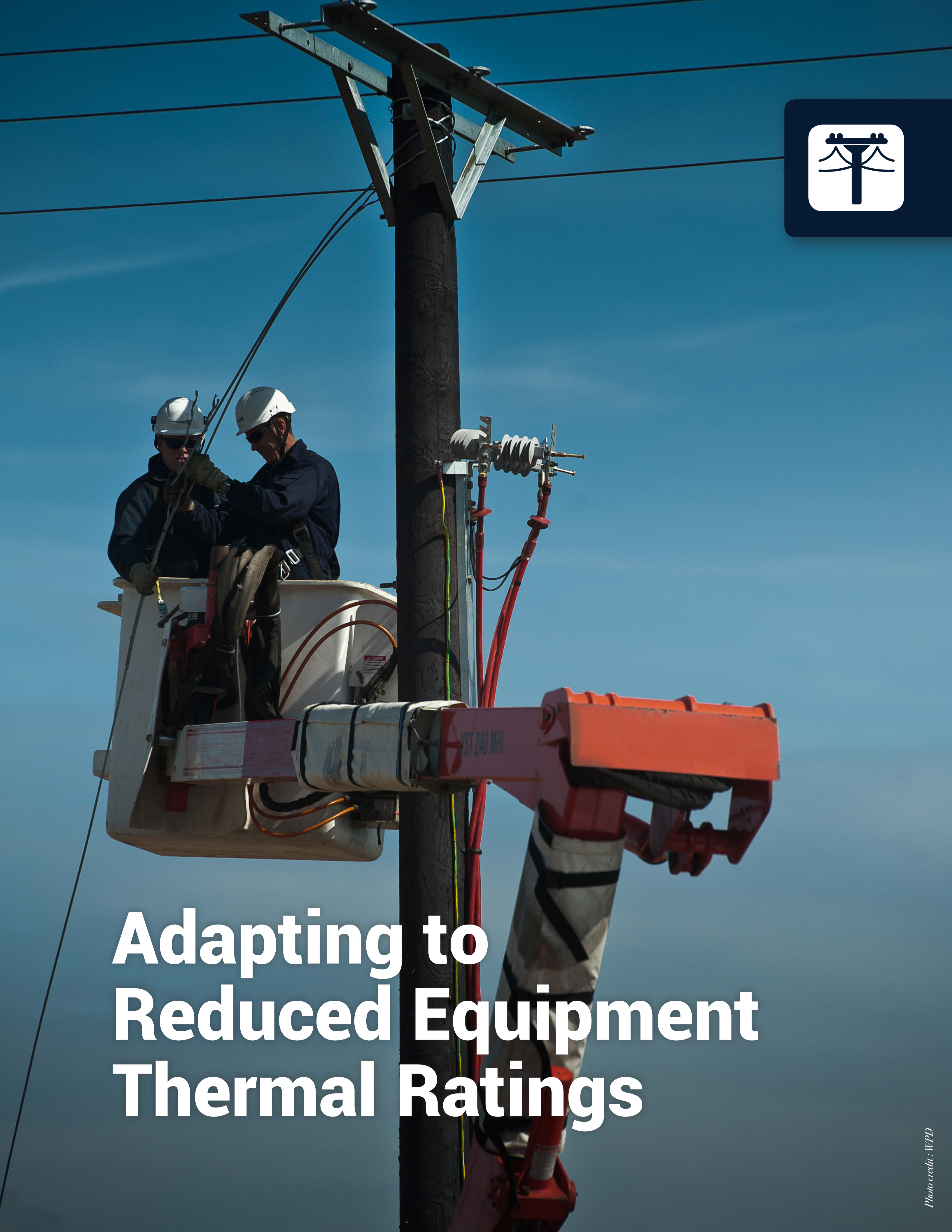
FULL REPORT
https://ouranos.ca/en/programs/energy-adaptation-case-studies/



Adapting to Reduced Equipment Thermal Ratings

Photo credit: WPD

SUMMARY

"What we have done is follow a 'low-regret' approach to take the opportunity of building additional network capacity and resilience as part of planned asset replacement."

Phil West, former Policy Manager, Western Power Distribution [1]

Higher temperatures due to climate change pose a significant challenge for many of the power lines that distribute electricity to homes and businesses. By law, power lines must hang a minimum distance above the ground. Electric utilities operate distribution lines and equipment, and manage minimum clearance requirements on the basis of thermal ratings, which are estimates of the total capacity of an electrical component to carry current at a point in time.

Power lines sag as they heat up, due to two main factors: warmer temperatures and increased amounts of energy transmitted through the lines. As temperatures rise due to climate change, some lines would likely hang below the minimum distance from the ground required by law. This case study describes the approaches taken by several utilities to mitigate this challenge. A cost-effective approach is to adopt improved design standards for new distribution equipment.

CONTEXT

Failure to adapt transmission and distribution lines to increased temperatures may be a source of disruptions and revenue loss. In warmer climates, the likelihood increases that lines will exceed established maximum design temperatures and breach minimum ground clearance because of thermal expansion. Where little network redundancy exists to transfer the loads of overloaded circuits, power interruptions could be experienced, along with increased risk of cascading network failures. The risk of overloads can increase when temperatures rise and more people use air conditioners and fans. A warming climate aggravates these network constraints, especially in the parts of Canada that already experience a larger number of hot days coinciding with peak loads.

Thermal rating refers to the maximum electrical current that the conductor of a transmission or distribution line can conduct. When outside temperatures rise above a certain level, the transmission and distribution capacity of an electricity system decreases — a process known as 'de-rating' or 'reduced thermal rating.'

Historically, the capacity of power transmission and distribution networks has been defined through *static* thermal ratings. These are calculated on the basis of heat-balance equations using extreme seasonal climate values (i.e. solar radiation, temperature, rainfall, wind and cloud cover) observed over long periods of time.[i] Another measure, known as *dynamic* thermal rating, relies on real-time data about weather and/or the state of conductors (e.g. conductor tension).

Several adaptation solutions exist to manage projected de-ratings due to climate change. Increasing the height of the poles that support power lines, for example, helps maintain minimum ground clearance and accommodate higher operating temperatures. A more costly option entails installing conductors with hotter operating limits or novel 'low-sag' conductor material. Another option — the use of dynamic thermal ratings — can help utilities improve both carrying capacity and network efficiency by operating their networks closer to their 'real' capacity limits.

U.K. power utilities already recognize that climate change causes thermal de-rating.[2] An assessment of projected increases in average maximum temperatures by 2040-2069 estimated that carrying capacity will decrease by four to nine percent for typical overhead distribution lines, and by up to three percent for typical overhead transmission lines across the country. (see figure CS9.1). Similar 'de-ratings' are expected in southern Canada, though the impacts on operators have yet to be assessed in detail.[3]

EXAMPLES OF ADAPTATION

B.C. Transmission Corporation (now part of B.C. Hydro) supports the research and development of dynamic (real-time) thermal-rating systems. A key benefit is that these systems can help to prevent power

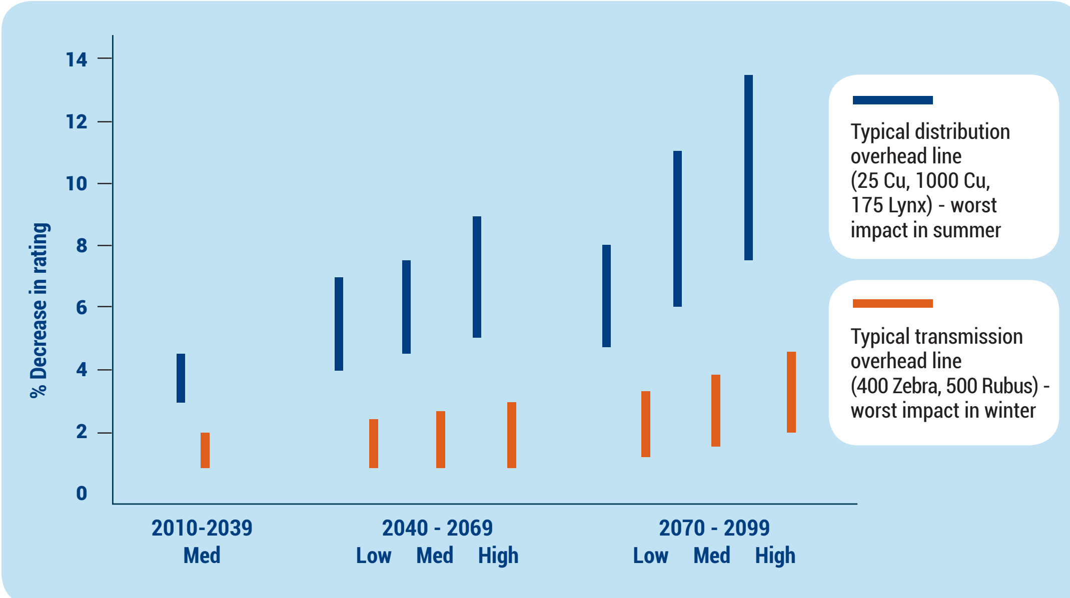


Figure CS9.1 Modeled reductions in overhead line ratings due to increased average daily maximum temperatures projected by UKCP09 under a high greenhouse gas emission scenario (the vertical bars show spread of de-ratings across UK at 25 sq km resolution) (source: Energy Networks Association, 2011)[2]

outages during periods of high loads and ambient conditions close to maximum operating temperatures by leveraging unused capacity within a power system. Other utilities around the world have confirmed the benefits of dynamic thermal-rating technologies. Hydro Tasmania, for instance, relies on observed weather station data, as well as conductor tension data from Transend, Tasmania's transmission asset owner and system operator, to maximize transmission network capacity.

Based on the results of the Met Office study *EP2 Climate Change Impacts on the U.K. Energy Industry Project,* National Grid began to investigate the use of real-time rating, monitoring and management technology to maximize network capacity and realize efficiency gains.[4] The U.K. transmission utility determined that a three percent de-rating of its overhead lines by mid-century is unlikely to considerably affect its operating costs, and therefore does not justify other adaptation investments. The impact of transmission and distribution de-rating of this magnitude pale in comparison with the effects of steady demand growth on transmission and distribution capacity — approximately two percent per decade.

WESTERN POWER DISTRIBUTION'S 'LOW-REGRET' APPROACH

In the U.K., most overhead lines at 132kV and below have been designed to operate at temperatures of up to 50°C. Most distribution equipment, including transformers and switchgear, comply with international standards such as those of the International Electrotechnical Commission (IEC) and the

European Committee for Standardisation (EN). Following several years of collaboration with its industry peers as part of the U.K. Energy Networks Association, Western Power Distribution (WPD) has increased the rated design temperature of newly installed wood pole overhead lines from 50°C to 55°C to accommodate projected increases in sagging.

"This new design standard translates into negligible additional capital expenditures by increasing the required height of wood poles being replaced by 0.5 metres," reports Phil West, former Policy Manager at WPD. "This adaptation solution is a 'low-regret' option as it tags on planned asset replacements, and derives clear and reliable resilience benefits at very low costs. It was an 'easy sell' to corporate executives, and something WPD was able to take on without necessitating increases in user fees."

Between 2011 and 2023, the industry has made financial commitments of CA$330 and CA$300 million, respectively.

In its corporate-wide assessment of climate change risks and adaptation, WPD decided against early re-conductoring whole sections of overhead lines because the associated costs far exceed the anticipated benefits. Furthermore, most conductors have long operating lives and early replacement would carry a very high opportunity cost.

Notwithstanding WPD's 'low-regret' adaptation approach, the U.K. power industry, with support from its regulator, decided to make large investments to manage two other climate change risk areas: pluvial-flooding resilience for substations and vegetation-growth management. Between 2011 and 2023, the industry has made financial commitments of CA$330 and CA$300 million, respectively.[5]

LESSONS LEARNED

WPD, in collaboration with industry peers, began preliminary work on climate change impacts in 2006. The company based its adaptation investment decisions on the 2008 findings of the *EP2 Climate Change Impacts on the U.K. Energy Industry Project* study. The sector-wide study benefited from an innovation-funding incentive by the U.K. energy regulator Ofgem. Technical support from the U.K. Met Office, a highly experienced and credible scientific organization, contributed to the quality of the study. The work was co-ordinated through the UK T&D trade body The Energy Network Association, whose Climate Change Adaptation Task Group is comprised of representatives of each member electricity-network operator, along with government and regulating agencies. The subsequent introduction of a regulatory obligation to report on climate change adaptation helped spur WPD and other utilities to operationalize the EP2 study's findings by implementing adaptation plans.

According to WPD's Phil West, "having a clear and common view across the industry on the mechanisms of assessing risks and solutions" is an important prerequisite for successful collaboration between industry and government on climate adaptation. Many of the risks and solutions to climate change are common across the whole power industry, and in most cases utilities do not consider climate adaptation as a source of competition. As such, adaptation is by nature an issue that is fit for industry collaboration.

For instance, government approvals for adaptation-related rate hikes and capital expenditures have been made possible by the plentiful evidence of costs and benefits shared by all regulated transmission and distribution utilities. Undoubtedly, the already high levels of collaborative research and engagement between utilities and regulators in the U.K. have also played a favorable role. Conversely, WPD's Phil West recalls an instance in Australia where power distribution companies were unable to agree with regulators on the likelihood and consequences of climate change impacts, which led to the rejection of a request to increase rates to fund adaptation projects.[1]

Phil West warns that "using too many climate change scenarios can sometimes prevent progress." In the case of the EP2 study, utilities decided to base their adaptation assessment on a single scenario and probability level to simplify the assessment and avoid diverging views on risk levels. While this approach may not be adequate for other climate change risk areas with highly uncertain projections and/or impacts that are highly sensitive to climate uncertainty, it illustrates that adaptation decisions do not always require multiple complex climate scenarios.

Finally, WPD's work on thermal ratings illustrates another important reality: the return on investment of adaptation projects is always pitted against other capital plans, and in many cases time discounting weakens the business case for adaptation. For example, while the projected distribution de-ratings are significant, they are much smaller than the anticipated impacts of demand growth and increased renewables on the grid. It is only by incorporating an 'adaptation allowance' into its design standard for new overhead distribution lines that WPD managed to reduce its vulnerability to thermal de-ratings. WPD expects that this investment will improve its network resilience at a minimum cost.[1]

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[i] Three basic heat-balance equations are used to calculate static thermal ratings across the world: the Institute of Electrical and Electronics Engineers IEEE 738 Standard, the International Council on Large Electric Systems CIGRE Technical Brochure 207 Standard, (now TB 601, December 2014) and the Electric Power Research Institute EPRI Dynamp Standard.

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AT A GLANCE

KEY TAKEAWAYS

1. For costly adaptation options, with payback exceeding typical planning horizons, collaboration on financing between industry, regulators and government is essential

2. Low-regret' adaptation options, e.g. low-cost upgrades during normal asset replacement, trigger benefits in most future scenarios, and are easy to finance and implement

3. Collaboration between companies, regulators and governments is essential to design and implement adaptation policies in the power sector

ORGANIZATION(S)
B.C. Hydro (Canada); Hydro Tasmania (Australia); National Grid (U.K.); Western Power Distribution (U.K.)

POWER SUB-SECTOR(S)
Transmission and distribution

ADAPTATION TYPE(S)
- Physical – Equipment protection, upgrades and alternative materials

CLIMATE CHANGE IMPACT(S)
- Rising temperatures and number of hot days
- Changes in natural cooling (rainfall, wind and cloud cover)

ADAPTATION COSTS
- The marginal cost of increasing the height of wood pole overhead line support structures during normal asset replacement is low.
- The cost of re-conductoring whole sections of a network is medium to high
- The cost of 'real-time' thermal rating technology is medium to high

ADAPTATION BENEFIT(S)
- Increased network resilience
- Greater transmission and distribution capacity and efficiency

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FULL REPORT
https://ouranos.ca/en/programs/energy-adaptation-case-studies/

OURANOS

Ressources naturelles Canada
Natural Resources Canada
Canada

Increasing Network Resilience with Specialized Weather Forecasts

Photo credit : Frank Weber

SUMMARY

"There is a lot of business-focused knowledge that we provide that informs the decisions made by others in the company."

Stephanie Smith, BC Hydro's manager of hydrology [1]

Electricity assets are vulnerable to extreme weather events—a vulnerability that could grow in the future due to increases in both the frequency and intensity of extreme events. A good way to cope with this vulnerability is to be proactive and take appropriate action before extreme events trigger significant, negative consequences. To achieve this goal, BC Hydro established a system that uses weather and hydrology data to inform the company's decision-making processes. A dedicated team monitors and analyzes relevant data, and alerts company officials when extreme events are likely to occur. The system benefits BC Hydro over both the short and long terms, and improves their capacity to adapt to climate change.

CONTEXT

Extreme climate events threaten energy systems around the world. In British Columbia, Canada, windstorms are a major concern for distribution and transmission lines. In December 2014, a windstorm left 100,000 customers in the province without power. Outages such as this one can have significant impacts on society, shutting down businesses and critical infrastructure such as telecommunication networks and hospitals. Since the key to reducing the impacts of an outage is to act quickly and effectively, advance knowledge of extreme weather events is quite valuable.

> **The IPCC defines climate resilience as the capacity of a system to cope with hazardous events and to respond in ways to maintain its principal function and structure.[3]**

'What would a windstorm be like in the future, considering the impact of climate change?' is a question that many scientists would like to be able to answer with a high degree of confidence. However, extreme events are by nature rare and challenging to analyze. Natural Resources Canada conducted a review of available data related to projected extreme events in the country.[2] The review shows increasing trends in both the frequency and intensity of extreme hot days and in precipitation amounts for most of Canada—variables in which the scientific community has good confidence. For other weather conditions, such as wind and freezing rain—variables that can have significant impacts on energy-system components such as transmission lines—the information is not as robust. Utilities are therefore left with many uncertainties concerning the frequency and intensity of extreme events in the future.

Even with these uncertainties, however, building increased capacity to cope with, and respond to, extreme events—a concept known as climate resilience—helps reduce the overall vulnerability of an energy system. Investments in climate resilience are often profitable right away. According to Stephanie Smith, BC Hydro's manager of hydrology, the company's hydrology forecasting service saves "millions (of dollars) or hundreds of millions!".[1] The service features a weather and hydrology forecasting team able to predict extreme events and help inform business decisions.

FROM CLIMATE RESILIENCE TO CLIMATE CHANGE ADAPTATION

BC Hydro developed in-house weather and hydrology forecasting capacity because it requires more specialized information than what the Government of Canada provides through Environment Canada. "Environment

Canada's main goal in weather forecasting is to protect public safety," explains Smith. "Much of BC Hydro's critical infrastructure and reservoirs are in very remote areas of British Columbia, and are subject to a variety of weather risks."[1] The company's weather and hydrology forecasting team produces information about specific places, such as remote reservoirs and transmission lines.

When an extreme event is expected, the team acts like a watchdog: "Basically when there is a big storm coming," says Smith, "the team can predict how it might impact the business." The team relies on a network of contacts to alert company divisions about the timing, location, severity and the relative certainty of extreme events. Briefing meetings will be organised to communicate as much information as possible on the event that is coming. "We try to give as much as warning and as much knowledge as we can about how certain or uncertain the event is," says Stephanie.[1] This information enables company managers to make appropriate decisions, such as relocating crews or adjusting water levels in reservoirs. In April 2010, for example, the team predicted strong winds in the Strait of Georgia that could lead to the cancellation of ferry service to and from Vancouver Island (see figure CS10.1).[4] Thanks to the warning, BC Hydro dispatched crews before the storm hit to deal with potential outages.

Figure CS10.1 A ferry from Blubber Bay to Powell River in the Strait of Georgia on April 10th 2010

The forecasting team's work goes well beyond extreme storms; it also provides data to support ice modeling and to coordinate the utility's emergency response to summer forest fires. The team tracks current climate and hydrology conditions in all watersheds managed by BC Hydro and gets involved in "basically anything related to weather," according to Smith.[1]

The team of 13 meteorologists, hydrologists, engineers, scientists, technologists and analysts produces a hydrologic forecast every weekday to help company engineers optimize water resources for electricity generation, environmental and recreational flows and other uses. The team consults data from the Canadian Meteorological Centre and the U.S. National Weather Service, and co-manages—with the provincial and federal governments—more than 200 monitoring stations (see figure CS10.2). Thanks to ongoing collaboration with the Weather Forecast Research Team at the University of British Columbia, "UBC is able to provide us with ensembles of point weather-parameter forecasts at exactly the locations that we are interested in" says Smith. The hydrologic forecast is made using the UBC Watershed Model through an integrated platform developed in-house.

Figure CS10.2 Colpitti Creek monitoring station, British Columbia

Of the team's annual budget of $4.5 million, 44 percent goes to hydrometric-monitoring stations, while snow-monitoring stations and climate monitoring account for 13 and 9 percent, respectively.[5]

BC Hydro's current broad strategy for adaptation to climate change grew out of the questions asked by stakeholders in 1994, when the company started to develop water-use plans for the watersheds where it operates reservoirs. The company recognized that more research was needed to develop and interpret future climate scenarios, and to be able to answer questions from external stakeholders.[6] To help analyze the potential impacts of climate change on its assets, BC Hydro began to partner with the Pacific Climate Impacts Consortium (PCIC) in 2007 on a series of studies, published by PCIC in 2010[7] and later summarized in a BC Hydro brochure.[8] In 2010, BC Hydro established an adaptation to climate change strategy that prioritizes vulnerabilities according to the severity of risks and potential business impacts. The company reviews the strategy continually and updates it as needed.

LESSONS LEARNED

After multiple years of efforts concerning adaptation to climate change on a broader scale, this work has slowed a bit at BC Hydro in recent years. The company faces many challenges, including a major restructuring. Stephanie Smith also identifies other issues: "the biggest challenge about integrating adaptation to climate change at BC Hydro is that there are no standard methodologies available yet, and with no staff resources dedicated to climate change; it is a collaboration across the company and with inter-utility working groups to figure out how to do this." Stephanie Smith and Brenda Goehring, Senior Manager of Policy & Reporting at BC Hydro, currently lead the work: "We are bringing people together from across the organization, to talk about how we are going to technically assess the risks from climate change and how does that translate in terms of adaptation or mitigation."[1]

Smith has worked at BC Hydro since 1994 and has headed the Hydrology department for six years. She and her team serve as a centre of knowledge and capacity for the company and reflect BC Hydro's commitment to climate resilience. Smith sees herself more as a "climate coach" than as an "adaptation champion;" she helps every division in the company access the climate information needed to adapt to climate change. "We want to educate the experts [about climate change] for them to incorporate [adaptation to climate change] in the planning activities they are already doing," she says. [1]

Stephanie Smith encounters a certain amount of resistance from others; adaptation to climate change is a task that people must do on top of their regular duties. She says that while she encounters few "climate change sceptics" at BC Hydro, she regularly encounters people who are not sure if they must act on climate change. She explains the potential ways that climate change might impact their work, but recognizes that staff must gauge the relative risks posed by climate change for themselves. Smith says that senior management supports her efforts. "The board of directors and the executive are very focussed on identifying and reducing our climate risk and also in terms of funding the research we need from PCIC and others."[1] Part of what drives this focus on risk is the BC government's climate policy, along with pressure from the BC Utilities Commission and other regulators to ensure that BC Hydro considers climate change impacts in its long-term resource planning and environmental assessments of new projects.

Smith emphasizes that learning how to adapt to climate change is a long and in-depth process. "It's a steep learning curve to figure out how to use this information," she says. "It seems quite straightforward from the outside to run a climate scenario in a hydrological model and to get hydrological scenarios, but then you get stuck. It's much more complex than people realize." Each expert in the company has his or her own model and knowledge; it's often hard to figure out how to incorporate climate information. "We're trying to build this knowledge in-house in a way that it builds on itself rather than hire an outside consultant."[1]

Ultimately, BC Hydro recognizes that adapting to climate change requires timely action informed by accurate data and analysis. Smith's team recently finished a comprehensive study of climate change impacts on water resources that demonstrates that changes in the timing and amount of inflows to reservoirs will be neither sudden nor dramatic. BC Hydro recognizes that it must manage these incremental changes. "It takes some of the pressure off in terms of how quickly we need to incorporate that," says Smith. "We feel we have some time to study this."[1] In the meantime, BC Hydro has developed the skills and tools needed to assess, predict and communicate the potential impacts of extreme weather events.

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AT A GLANCE

KEY TAKEAWAYS

1. **Investments in climate resilience yield benefits over both the short and long terms, and can help achieve larger adaptation goals.**

2. **Development of an in-house weather and hydrology team is a viable option given appropriate time and resources.**

3. **Knowing when to act helps move the adaptation strategy forward.**

ORGANIZATION(S)
BC Hydro (Canada)

POWER SUB-SECTOR(S)
- Hydroelectricity generation, transmission and distribution

ADAPTATION TYPE(S)
- Informational – Climate Services
- Informational – Supply and demand forecasts
- Informational – Monitoring equipment and technology

CLIMATE CHANGE IMPACT(S)
- Extreme events
- Forest fires
- Changing availability of water resources

ADAPTATION COSTS
- The cost of generating and interpreting forecast data is low.
- The cost of maintaining a team of 13 people is medium.
- The cost of maintaining 200 monitoring stations is high.

ADAPTATION BENEFIT(S)
- More effective management and faster response to extreme events
- Minimize or prevent damage during extreme events

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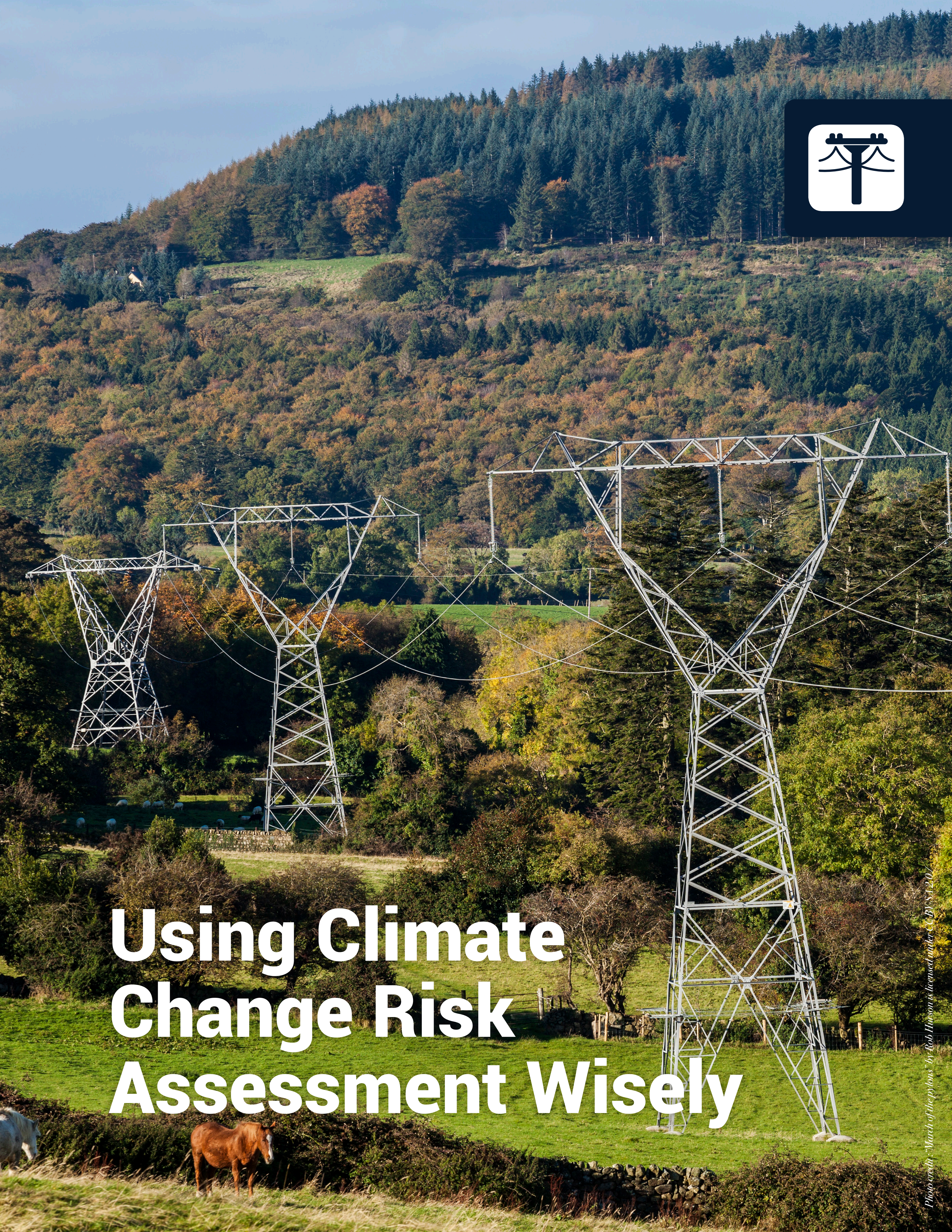
FULL REPORT
https://ouranos.ca/en/programs/energy-adaptation-case-studies/



Using Climate Change Risk Assessment Wisely

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"EirGrid and ESB Networks completed a climate change risk assessment and have identified the key climatic risks faced by individual stations. The results, in conjunction with site-specific screening analysis, are used to determine appropriate remedial measures. Policies and procedures are also being updated to help manage this risk for any future development projects. This should ensure the Irish transmission system is secure and robust for the future."

John McGuckin, Engineer in Transmission Engineering & Maintenance, EirGrid[1]

SUMMARY

Risk assessment, a tool widely used in most industries to identify and manage various potential risks, is proving to be particularly successful in managing climate change risks. Such an assessment was completed by EirGrid, Ireland's public electricity Transmission System Operator (TSO) and ESB Networks (ESBN), Ireland's Transmission Asset Owner (TAO).

Flooding was identified as the main risk for the transmission network, therefore, EirGrid and ESBN have initiated remedial projects to mitigate this risk, basing their investment decisions on screening techniques. The risk assessment also helps the companies develop policies and procedures to ensure that new transmission equipment is robust enough to endure expected climatic conditions, to take climate change into consideration during the site-selection process, and to develop an adaptation plan for the electricity sector, as required by law.

CONTEXT

Does climate change represent a risk for my company? How can my company best manage the risks posed by climate change? Which data—and which climate change scenarios—should we consider? Which investments and initiatives should we prioritize?

These are all important questions that energy companies must answer in the face of climate change. Many Canadian energy companies are at an early stage in addressing these questions. Fortunately, a growing set of helpful tools is available. The PIEVC Protocol from Engineers Canada, for instance, helps assess the risks faced by infrastructure[2], while the *Electricity Sector Infrastructure Climate Change Adaptation Management Planning Guide* from the Canadian Electricity Association outlines a risk-based framework for adaptation planning.

EirGrid, Ireland's electricity TSO, and ESBN, Ireland's Transmission Asset Owner, began to address these questions a few years ago. As part of the process, they conducted a climate change risk assessment — a tool integrated in the ones cited above — to help plan their adaptation strategy.

THE CLIMATE CHANGE RISK ASSESSMENT

EirGrid is a state-owned company responsible for planning, developing, operating and ensuring the maintenance of Ireland's national electricity transmission system, along with overseeing the electricity market. To fulfill its mandate, EirGrid works closely with the Transmission Asset Owner, ESB Networks, in accordance with a contract known as the Infrastructure Agreement. This agreement, as well as a statute, sets out the functions of each organization.

Under the Infrastructure Agreement, EirGrid is responsible for identifying feasible solutions (projects) required to develop the transmission system. EirGrid must design, plan and gain approval for such projects, and negotiate relevant agreements with ESBN.

"To fulfil their mandate, EirGrid and ESBN must be aware of how climate change will impact Ireland, what risks it poses to the transmission system and what adaptation methods are available to reduce these risks."[1] In addition to identifying climate change in its Corporate Risk Framework and recommending that its progress be further evaluated, EirGrid and ESBN launched a climate change risk assessment in 2012. The study aimed to identify appropriate mitigation, adaptation and coping measures over the short, medium and long terms.

EirGrid and ESBN contracted the multinational consulting firm Mott MacDonald to complete their climate change risk assessment and to make evidence-based recommendations for adaptation strategies. Mott MacDonald has worked on many projects on EirGrid's behalf and is therefore very familiar with Ireland's high-voltage power system; the firm can also tap into engineering experts from around the world.[3]

Mott MacDonald suggests to structure climate risk management with the approach described

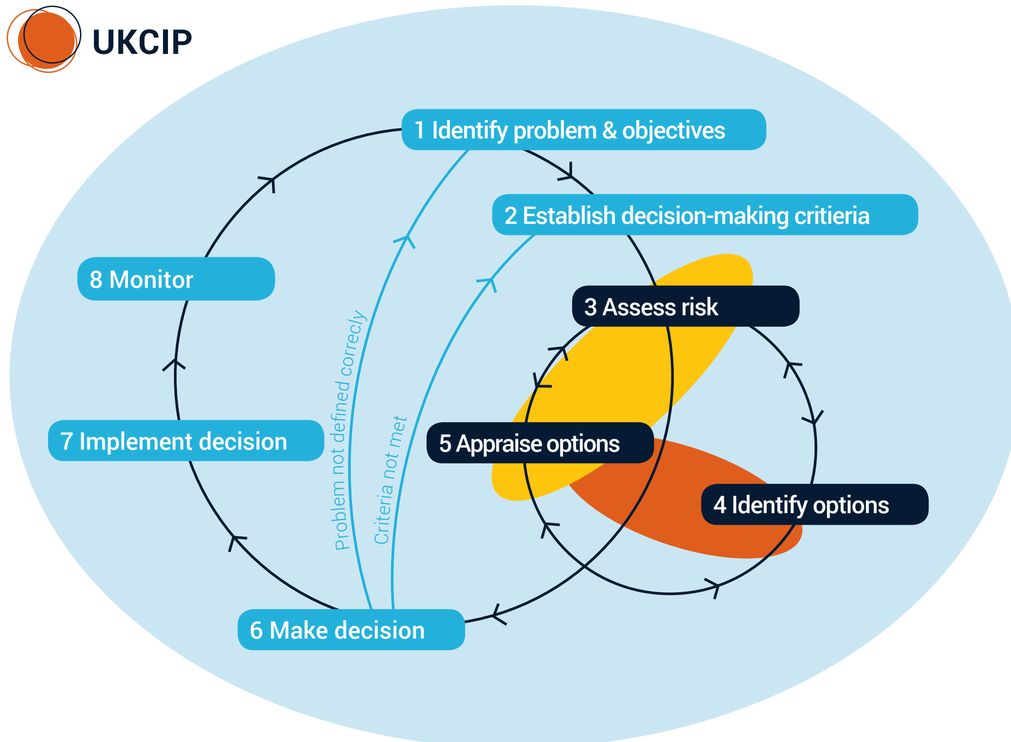

Figure CS11.1 UKCIP risk framework

in the UK Climate Impact Programme (UKCIP) risk framework (see figure CS11.1). This step-by-step approach supports risk-based decision-making.[4] The assessment identified several climate variables with the potential to impact the transmission system, including extreme temperatures and precipitation events, wind, salt fog/spray, lightning, sea-level rise and storm surges. To support the analysis of each variable, the assessment relied on projections developed by the Community Climate Change Consortium Project for Ireland[i]. The projections involved two climate change scenarios: one severe and one moderate. Information from current academic literature helped fill any gaps. The assessment also classified each type of transmission asset for which climate change risks would be evaluated: overhead lines, air-insulated switchgear substations, gas-insulated switchgear substations, cross-linked polyethylene (XLPE) and fluid-filled underground cables.

The assessment projected increases by 2050 in extreme precipitation events, wind, storm surges and lightning, as well as in average and high temperatures. Low-temperature extremes, along with salt fog and spray, were projected to decrease. Overall, the assessment determined that climate change did not significantly threaten transmission infrastructure, and did not increase the risk of a system-wide collapse or partial blackout of the transmission system over the short, medium and long terms. The risk of flood, however, was identified as important and likely to increase in the future, mostly due to extreme precipitation events, as well as sea–level rises and storm surges. Floods can lead to extended outages because they damage control and protection systems in substations, destabilize the ground under transmission towers, limit access to damaged equipment, etc.

Following the assessment, EirGrid and ESBN decided to investigate in greater detail the main risk identified in the assessment: flooding caused by storm surges, sea-level rises and extreme precipitation events.

This investigation assessed the vulnerability of specific substation locations to flooding. An initial targeted group of stations were subjected to successive screening techniques to prioritize the assessment. The investigation comprised:

- Geographical Information Systems (GIS) and other mapping techniques to provide high-level guidance on the vulnerability of sites to flooding from rivers, lakes, estuaries and the sea, but not from direct rainfall.
- Questionnaires to record the knowledge and memory of operational staff regarding flood levels.

Subsequently, EirGrid and ESBN established a five-year plan to carry out flood-alleviation measures at substations deemed to face the highest levels of risk.

EirGrid has decided to budget for investments in flood alleviation at particular sites based on specific risk assessments. A review of the 2012 climate change risk assessment is also planned to assist in the development of adaptation measures based on continuous assessment of the climate change risks. This is to ensure that "the effects of climate change on transmission infrastructure are reviewed and that potential investment decisions will be supported by current climatic trends and events. The information can also be used to develop technical standards and specifications to ensure that transmission equipment being installed is robust enough to endure the foreseen climatic conditions" says John McGuckin.[3]

DEVELOPMENT OF THE ADAPTATION STRATEGY

In January 2015, the Irish Government published a Climate Action and Low Carbon Development Bill. The Bill aims, in part, to provide a statutory basis for the national objective of transitioning to a low-carbon, climate-resilient and environmentally sustainable economy by 2050. The Bill sets out proposed statutory provisions requiring that the Minister for the Environment, Community and Local Government (DoECLG) make a National Adaptation Plan and submit it to government for approval.

The National Adaptation Plan will be built on sectoral plans, prepared by relevant government departments and agencies and adopted by relevant Ministers. EirGrid and ESBN are now engaged in the National Climate Change Adaptation Framework Working Group (WG). This working group aims to ensure that adaptation measures are taken across different sectors and levels of government to reduce Ireland's vulnerability to the negative impacts of climate change.

As part of the National Adaptation Plan, EirGrid and ESBN must develop and submit an adaptation plan for the electricity sector. Given its previous efforts and experience in addressing climate-related issues, both EirGrid and ESBN are well prepared to play an active role in the WG and to continue to explore the evolving risks posed by climate change.

LESSONS LEARNED

The collaboration between EirGrid, ESBN and Mott MacDonald was successful; it has enabled EirGrid and ESBN to launch their joint climate change adaptation initiative and produced a sound risk assessment based on the UKCIP framework. "Prior to this risk assessment, EirGrid reacted to 'events' such as flooding to scope remedial actions. The climate change risk assessment helped identify key risks based on predicted climatic conditions, and to screen and prioritize remedial works to ensure that investment is directed to the most appropriate assets in advance of potential events".[1]

EirGrid and ESBN in Ireland may be at the beginning of the adaptation process, but are already at an advantageous position. The creation of the DoECLG-led working group provides a structural framework and will help to consolidate ongoing efforts.

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[i] The Community Climate Change Consortium for Ireland (C4I) Project was established in 2003. Its main objective is to consolidate and intensify the national effort in climate change research.

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AT A GLANCE

KEY TAKEAWAYS

1. **Many tools, including assessment of climate change risks, are available and helpful to address questions related to climate change and to structure adaptation efforts.**

2. **Collaborating with an external climate-savvy consultant is a good way to start building adaptation capacity.**

ORGANIZATION(S)
EirGrid (Ireland) and ESBN (Ireland)

POWER SUB-SECTOR(S)
Electricity transmission

ADAPTATION TYPE(S)
- Management – Insurance and financial-risk management

CLIMATE CHANGE IMPACT(S)
- Flood events caused by extreme precipitation, sea level rise and storm surge.

ADAPTATION COSTS
- The cost of a risk assessment is low.

ADAPTATION BENEFIT(S)
- Minimization of damages during floods
- Increased network resilience

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FULL REPORT
https://ouranos.ca/en/programs/energy-adaptation-case-studies/

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APPENDIX A: CLASSIFICATION SCHEME OF CLIMATE CHANGE ADAPTATION STUDIES

Practices of energy sector adaptation to climate change can be sorted using various criteria. To classify and analyze the projects reviewed in this study, the researchers used specific criteria, such as the organization's subsector and its energy source, as well as the type of adaptation project and its stage of completion. Using the large sample of adaptation projects, the researchers developed 10 general categories to sub-divide the three adaptation types proposed by Ebinger & Vergara 2011: informational, institutional and physical. The categories provide a way to classify adaptation measures from the perspective of which aspects of energy business need attention in addressing climate change, providing a view at the energy sector from a different angle.

ENERGY SOURCES AND POWER SUBSECTORS

The adaptation projects are classified according to primary energy source and power subsector. Figure A1 shows the relevant categories and icons; the cover page of each case study includes the appropriate icons.

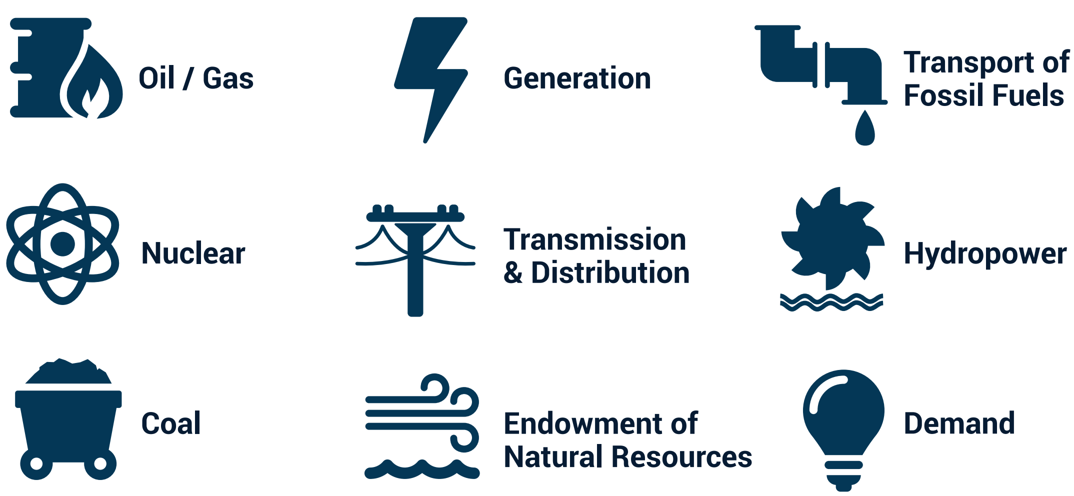

Figure A1: Primary energy source and power subsectors icons

ADAPTATION TYPES AND SUB-TYPES

The classification of adaptation projects according to type (informational, institutional/ management, physical) has been previously used (i.e. Ebinger & Vergara 2011). To further categorize sub-types of energy-sector adaptation projects, the researchers studied the database of 200+ adaptation projects. The sub-types proposed and defined in Table A1 capture the majority of adaptation practices identified. This list of types might not be exhaustive, however, and may expand as a wider spectrum of adaptation possibilities emerges.

Each of the 10 sub-types is covered in at least one of the case studies presented in this report and each case study falls into at least one category. The "at-a-glance section" of each case study lists its categories.

STEPS OF THE ADAPTATION PROCESS

Adaptation frameworks propose a number of project phases or steps toward completion. Charron (2014) proposes the following six steps:

1. Get prepared.
2. Evaluate current vulnerability.
3. Understand climate change.
4. Evaluate future vulnerabilities and opportunities.
5. Develop and prioritize adaptation measures.
6. Establish a plan and put it into action.

The 11 case studies presented here range from step 4 to step 6 of the framework, as the adaptation projects are mostly complete.

Table A1: Types and sub-types of adaptation to climate change in the energy sector

Informational	• Using **Climate Services** Generation and use of data and information on localized climate change projections and related future impacts, and assessments of enterprise, asset or project risks due to climate change • Adapting **Supply and demand forecasts** Changes to load and demand forecast methods and practices to take account of climate change projections • Adaptation of **Monitoring equipment and technology** Investments and plans to invest in climate-related monitoring equipment and technology to understand and respond to climate change impacts
Institutional/ Management	• Adaptation of **Design and operation standards, guidelines, tools and schedules** Changes to standards, guidelines and tools for asset design and operations, and revisions of asset operating, maintenance and replacement schedules to take into account climate change projections. • Adapting **Insurance and financial risk management** Changes to insurance terms or coverage, purchase of additional insurance, and use of financial-risk instruments to absorb all or part of climate change impacts (e.g. contingency budgets or weather derivatives). • Adaptation through **Regulatory exemptions and contracts** Use of regulatory exemptions or contractual arrangements to cope with climate change impacts (e.g. temporary exceedance of maximum water-discharge temperature standards; revisions of the terms of a long-term power-purchase agreement). • Adapting the **Demand management and tariffs** Programs/incentives to reduce power demand and improve reserve margins to account for climate change impacts on peak/baseline loads (e.g. differentiated pricing). • Adaptation by **Re-organization and governance** The creation of dedicated teams/staff and changes to the organizational structure of a company/department to facilitate the adoption and implementation of climate change resilience measures (e.g. Chief Resilience Officer with a climate change mandate).
Physical	• Adaptation through **Equipment protection, upgrades and alternative materials** Asset or system upgrades, relocation or defences, changes to maintenance and repair schedules/expenditures, and investments in alternative materials to cope with climate change impacts • Adaptation through **New generation, carrying and transformation capacity** Investments and plans to invest in additional installed (generation), carrying (transmission) and transformation (distribution) capacity to account for climate change impacts on peak/baseline loads and on natural-resource endowment

APPENDIX B: BARRIERS AND DRIVERS OF ADAPTATION

The successful, sometimes even profitable examples of adaptation to climate change in the energy business cannot hide the existence of the barriers to enhancing climate resilience. The interviews conducted for this study explored these barriers.

A key barrier relates to the **understanding and perception** of climate change. Unfortunately, some sceptics exploit the complexity of science to challenge established knowledge with so-called common sense. Short-term observations (e.g. it was a colder-than-normal summer) may seem to contradict documented long-term trends and suggest that immediate action is not required. While uncertainty and doubt lie at the core of the scientific process, some abuse it to discourage action. As an upside however, our interview partners repeatedly reported that sceptical and zealous scrutiny incited deeper understanding, more careful assessments and ultimately, enhanced the robustness of adaptation projects.

Often businesses do not readily see a rationale for investments in adaptation. A solid understanding of the problem is a prerequisite to **build a rationale for investment** in climate resilience. For some businesses, the financial benefits are evident when climate change provides opportunities for increased production, as with Iceland's plans to boost hydroelectricity production by harnessing increased flows due to melting glaciers (see Case Study 2). But for other businesses, the potential risks to infrastructure and operations go unnoticed until disaster strikes, as when hurricane Sandy struck New York City (see Case Study 5). The losses might then exceed the cost of precautionary investments in climate resilience. Unsurprisingly, many climate-resilience projects were initiated only after extreme weather caused damage.

Once a project is underway, establishing good **communication** between participants was perceived as being a challenge to climate change adaptation processes. A sound approach to adaptation usually involves the contributions of experts from different disciplines, such as climate science and economics. Translating technical jargon, acknowledging the complexity of issues and gaining insight into multi-faceted needs requires sustained dialogue, collaboration and trust between a variety of experts. Finding the common ground and understanding can be a difficult and long process. However, the interdisciplinary effort fosters mutual understanding and may inspire new ideas.

In addressing climate change, there are often no textbook recipes and approaches must be developed. This **lack of guidance** represents another barrier to adaptation, particularly when it comes to technical methods. Frameworks of adaptation practices that build on existing examples must be established to help harden energy-sector assets against changing climate conditions.

Some of our international interviewees deplored a lack of guidance from the regulatory and policy side, which has few incentives in place. Current requirements to consider climate change risk and resilience are marginally embedded in Integrated Resource Assessment Plans (IRA) and Environmental Impact Assessment (EIA) requirements. Efforts to improve guidance, as well as to develop metrics for climate resilience, however, are underway within WMO's Global Framework for Climate Services (GFCS, 2015), at the World Bank and at energy-sector umbrella organizations (IEA, 2015, IHA, 2015, World Energy Council, 2015). At the national level in Canada, the energy working group of Natural Resources Canada's adaptation platform provides support through information, tools and recommendations.

In many cases, the successful implementation of climate change adaptation was the result of the dedicated effort of a champion who took the lead in raising relevant issues and suggesting solutions. These individuals brought the study of climate change within their organizations to a tipping point at which the cost effectiveness or gains in safety and resilience became evident, and inspired the implementation of adaptation efforts. More than once it was obvious that the project would not have been realized without such leadership. On these grounds, **lack of leadership** is indirectly identified as a potential barrier to adaptation.

Many climate change adaptation projects need **access to customised data** from climate-model simulations. Although many climate-simulation data are available in the public domain (e.g. CMIP5, CORDEX), they are enormous in volume, complex in nature and easy for a non-expert in the field to misinterpret. Climate-service providers can help to facilitate data access, processing and interpretation and provide customized data, training or software.

A recurring important element in successful adaptation projects is collaboration with universities, government institutions, consultants or other energy-sector businesses. The **absence of opportunity for collaboration** will likely hamper energy-sector enterprises seeking to advance adaptation efforts, as it isolates them from a community of climate-savvy professionals who work on increasing climate resilience.

One of the largest difficulties in dealing with future climate evolution is the inherent **climate projection uncertainty.** However, one should note that organizations regularly cope with other uncertainties, such as those related to markets and economies, and by regularly taking guidance from historical climate records. Thus, existing methods may help to address climate projection uncertainty and novel approaches that support decision-making under large uncertainty continue to emerge (Lempert et al., 2006; Gregory et al., 2013).

Impact and forecast models applied in current business procedures usually rely on only one observed historical record. To address future climate uncertainty, multiple climate-scenarios must be considered. Implementing the ingestion of climate data in these procedures can be challenging when climate parameters, although relevant, are not yet built into the process. The emerging **need to adapt existing tools** is another hurdle encountered in adaptation efforts. Going through this effort often turns out to be beneficial, however, when it improves business operations. While this study focussed on barriers to adaptation, several drivers of adaptation also emerged. When positive economic impacts can be expected from adaptation, the incentive is obvious. Supportive environments for adaptation exist where companies maintain good connections with universities and research centres, and team with other organizations to address climate change. This usually facilitates access to climate data and information, along with the needed expertise. Finally, the increasing public awareness of climate change can motivate the energy sector to address its potential risks and opportunities.

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