CLIMATE CHANGE & EXTREME WEATHER

A Guide to Adaptation Planning for Electricity Companies in Canada

Canadian Electricity Association | Association canadienne de l'électricité

Climate change and extreme weather pose significant risks and electricity companies.

This Guide offers practical steps for managing the risks.

EXECUTIVE SUMMARY

Canada's climate is changing, as is the frequency, intensity, and duration of extreme weather events. These changes can pose significant risks for electricity companies—risks that must be managed through adaptation. Changing climate and extreme weather patterns have the potential to be enterprise risks. Weather-related risks (and opportunities) have been recognized and managed since the inception of the electrical sector. Most of the risks companies will identify through their adaptation processes will not be new risks so much as existing ones that are exacerbated by climate change.

This guidance document (hereafter "Guide") will address both climate and weather with the following distinction:

Weather refers to the (short-term) state of the atmosphere with regard to temperature, cloudiness, rainfall, wind, and other meteorological conditions.

Climate can be understood as the "average weather"—i.e., the statistical description in terms of the mean and fluctuation of relevant variables such as temperature, precipitation, and wind over a long period of time ranging from months to thousands or millions of years.

It is critical for companies to consider both weather and climate. In terms of weather, the Guide will address extremes, and for climate, it will discuss means.

In response to weather and climate risks, the Canadian Electricity Association (CEA) has set a series of aspirational targets as part of its mandatory Sustainable Electricity™ program. To assist members' activities to adapt to climate change and extreme weather, CEA has committed to providing tools and support by the end of 2020 for companies to create their own adaptation plans. This document is intended to meet CEA member requests for practical guidance that serves the needs of companies navigating the adaptation process.

While CEA's goal is aspirational, the need for robust adaptation planning to help ensure resilience may be driven with greater urgency by each organization's assessment of other factors such as its risk exposure, stakeholder expectations, its desire to demonstrate due diligence in conformity with other requirements such as ISO 14001, and sound asset management strategies.

While recognizing that there is considerable opportunity for diversity in approach, the Guide offers eight steps that provide a framework for developing a climate change adaptation plan (hereafter "Plan"). These eight steps are organized by major activity areas or themes in the chapters ahead as follows:

Figure 1: Flow diagram of the eight-step process

This framework documents the typical steps related to managing the risk. Organizations may choose to incorporate the risk management in existing enterprise risk processes, in asset management programs, or in other risk-based management systems such as ISO 14001.

As is evident from the above steps, and in keeping with directions from the Canadian Electricity Association, this Guide is limited to the development of a Plan and preparation for its implementation. It introduces the principle of review and continual improvement as the final step but does not go into detail on implementation and maintenance of the Plan.

The scope of this project is limited to managing risks associated with equipment and operations, and as such does not constitute a comprehensive adaption plan. Climate and weather impacts on employee health and wellbeing are examples of risks that are outside the scope of this Guide, although the processes described here could also be applied to them.

In the pages that follow, a checklist is provided at the start of each step, providing a quick and convenient way for companies to distill the key actions required throughout the process. Lastly, various appendices, referred to throughout, allow for companies to delve deeper into selected issues. Readers are encouraged to consult individual appendices for (optional) further reading.

The next page provides a summary of the checklist for each step.

TABLE 1: CHECKLIST OF KEY ACTIONS FOR ALL EIGHT STEPS

Phase of Plan development	Step in process	Checklist of key actions by step
Setting the Stage	1. Define objectives and engage leadership	✔ Identify the organization's objectives in pursuing a climate adaptation Plan and define the scope of what the adaptation Plan is intended to address. ✔ Align the adaptation planning objectives with the organization's mission. ✔ Engage leadership by highlighting the economy-wide business case for adaptation and the likelihood that climate change is an enterprise risk. ✔ Recognize potential opportunities associated with climate change. ✔ Obtain a commitment from top management that it will actively participate in the development and subsequent implementation of the Plan.
Risk/Opportunity Assessment	2. Identify critical and vulnerable assets and operations	✔ Identify assets and operations that are critical to the delivery of the corporate mission and mandate (e.g., ensuring reliability of supply). ✔ Determine which of the critical components of the assets and aspects of the operations are vulnerable to climate and weather extremes.
	3. Identify key potential climate impacts	✔ List all relevant potential impacts. ✔ Define parameters required for analysis. ✔ Collect existing data from company and stakeholders. ✔ Identify gaps in needed information. ✔ Collect additional relevant data from external sources. ✔ Select key potential impacts applicable to organization.
	4. Assess risks to critical and vulnerable assets and operations	✔ Assess the significance of potential climate impacts on critical and vulnerable assets and operations. ✔ Characterize each risk by considering its consequence and probability. ✔ Analyze portfolio of risks for critical assets and operations, including interdependent risks. ✔ Summarize significant risks for critical assets and operations.

TABLE 1: CHECKLIST OF KEY ACTIONS FOR ALL EIGHT STEPS

Phase of Plan development	Step in process	Checklist of key actions by step
Risk/Opportunity Response and Adaptation Planning	5. Identify potential adaptation measures (risk controls	✔ Generate a list of adaptation ideas to manage risks. Consider a wide spectrum of possible measures, including strengthening the asset, modifying operations, modifying designs, changes in organization, collaborating with others to address interdependent risks, and strategic shift to new activities (opportunities). ✔ Group and categorize ideas to engage various internal departments, set the stage for filtering ideas, and build a business case for promising ideas.
	6. Develop a business case for selected measures	✔ Decide on criteria for evaluating adaptation measures: cost-benefit measure, time period, discount rate, non-financial measures. ✔ Perform cost-benefit analysis for all potential measures. ✔ Prioritize. Consider using various tools to support prioritization of measures (cost curve, matrix, sensitivity analysis, best practices). ✔ Refine based on potential interactions among measures (synergies or overlap.
Preparation for Implementation	7. Detail and document implementing control actions	✔ Create a summary road map that connects key assets and operations, impacts, risks, and planned adaptation measures. ✔ Identify how the adaptation measures can be integrated into existing risk management systems and governance, and highlight if any changes in systems and governance are necessary. ✔ Identify schedule, budget, milestones, accountabilities, resourcing, etc. for any proposed organizational changes and incremental investments. ✔ Determine the right metrics across the organization to track and evaluate both the planned actions and their outcomes. ✔ Determine what forms of external reporting might be necessary (for legal/compliance reasons) or appropriate (as a voluntary commitment).
	8. Establish a process to review and improve Plan	✔ Determine the ongoing project management requirements of the Plan—what will be measured, monitored, and reported. ✔ Establish a process or principles that will be used to monitor the Plan, after it goes into effect, for its suitability, adequacy, and effectiveness. ✔ Present implementing control actions and any proposed governing document changes for senior management's approval.

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- With input from Mantle314 Inc. (formerly Zizzo Strategy Inc.)—Olena Kholodova, Anton Tabuns, Laura Zizzo, and Joanna Kyriazis
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- The Canadian Standards Association (operating as CSA Group), whose work on climate change adaptation solutions within the framework of the CSA Group Canadian Electrical Code has provided useful background and supporting information for this Guide;
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- Several companies that provided feedback on earlier drafts of this Guide, such as Manitoba Hydro, OPG, Hydro One, ENMAX, and Nalcor Energy.

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Disclaimer

The collaboration process has reflected a range of views and possible approaches, at times leading to compromises among the various contributors on specific points. The document reflects a broad consensus. The inclusion of the above- mentioned names of individuals and organizations is for acknowledgement purposes only and does not necessarily constitute an endorsement of the material.

The scope of this Guide is limited to physical assets and operations (including consideration of supply chain). It is not intended to be comprehensive; for example, it does not directly address potential risks to human resources. The steps in the Guide can be used to broaden the scope to create a comprehensive Plan.

While every attempt has been made to ensure that the information contained in this document is accurate, all information is provided "as is", with no guarantee of completeness, accuracy, and without warranty of any kind.

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INTRODUCTION

Climate change is causing profound changes to seasonal and annual patterns in terms of precipitation, temperature, and numerous other variables. It is also changing the frequency, intensity, and duration of extreme weather events. These changes can pose significant risks for electricity companies—risks that need to be managed through adaptation.

This Guide offers practical steps for managing risks caused by changing weather and climate patterns. Weather refers to the conditions in the atmosphere over a short period of time, while climate refers to patterns in the atmosphere over longer time periods.[1] While the Guide may at times refer to adaptation to specific weather events, and at other times refer to climate adaptation, the intent throughout is to provide a framework for managing both types of risk.

Why is this guide needed?

The Canadian Electricity Association (CEA) has coordinated past climate change adaptation initiatives, funded and supported by Natural Resources Canada (NRCan), to build capacity and advance climate adaptation in the electricity sector, including the following reports:

a. Understanding Canadian Electricity Generation and Transmission Sectors' Action and Awareness on Climate Change and the Need to Adapt, Zizzo, Allan, and Kyriazis, 2014

b. Adapting to Climate Change: State of Play and Recommendations for the Electricity Sector in Canada, Canadian Electricity Association supported by Haffner Group and Environment and Risk Assurance Services Inc. (ERASi), 2016

c. Adapting to Climate Change: A Risk Management Guide for Utilities, Canadian Electricity Association supported by Environment and Risk Assurance Services Inc. (ERASi), 2017[2]

This Guide will build on these past reports. Through surveys, meetings, and other forms of consultation, companies in the electricity sector have indicated their interest in obtaining additional guidance on adaptation. The need for companies to have climate change adaptation plans in place is real and immediate. To this end, and with support from NRCan the Canadian Electricity Association has committed to producing this Guide and to providing related support to member companies in the form of training workshops.

This Guide is limited to the development of a Plan and preparation for its implementation. It discusses foundational principles, climate impacts and risks, adaptation measures, ways to evaluate such measures, and the importance of monitoring and continual improvement. This Guide provides a flexible framework to inform decisions each company will need to make. Each company is free to decide how to develop and implement its Plan.

While CEA recognizes the importance of planning for and adapting to extreme weather events, the need for robust adaptation planning to help ensure resilience may be driven with greater urgency by each organization's assessment of other factors such as its perceived risk exposure, consideration of stakeholder expectations, its desire to demonstrate due diligence in conformity with other requirements such as ISO 14001, and sound asset management strategies.

Companies have asked for clarity on how they can ensure their Plans conform to CEA's minimal expectations, and to better understand such expectations. A companion document to this Guide, entitled "Verification Process for Reporting Progress in Adaptation Planning for Electricity Companies in Canada" (hereafter "Verification Process"), can be used in conjunction with this Guide. The Verification Process provides a series of yes-or-no questions accompanied by explanatory discussions. Companies may use the Verification Process both to clarify expectations for adaptation planning and to assess the status of their Plans.

Audiences for This Guide

In response to member feedback, this Guide has been written as a single source of information to support both companies with limited experience in adaptation planning and companies that are already advanced in this area

Companies that are beginning their climate change adaptation planning would like to understand the fundamental steps in developing a Plan. More advanced companies have indicated that they would like additional guidance in areas such as climate modelling and how to develop a business case for adaptation-related investments. Both types of companies have indicated that they could benefit from more discussion of challenges, best practices, and case studies for aspects of the adaptation process.

A note on terminology

Electricity companies that are members of CEA range in structure and ownership, from vertically integrated to concentrated within subsectors (such as generation, transmission, and/or distribution),from publicly held to government owned, and from local to international. For simplicity, we will refer generically to "companies," "utilities," or "organizations" throughout the document. Companies that generate, transmit, and/or deliver electricity are the primary intended audience for this Guide.

Components of Plan

While there is considerable opportunity for diversity in approach, the following eight steps provide an overarching framework for developing a Plan. They are organized by broader activities or themes as follows:

TABLE 2: EIGHT-STEP FRAMEWORK FOR DEVELOPING A PLAN

Phase of Plan development	Step in process
Setting the Stage	**Step One:** Define objectives and engage leadership
Risk/Opportunity Assessment	**Step Two:** Identify critical and vulnerable assets and operations **Step Three:** Identify key potential climate impacts **Step Four:** Assess risks to critical and vulnerable assets and operations
Risk Response and Adaptation Planning	**Step Five:** Identify potential adaptation measures (risk controls) **Step Six:** Develop a business case for selected measures
Preparation for Implementation	**Step Seven:** Detail and document implementing control actions **Step Eight:** Establish a process to review and improve Plan

At the start of each step, we also provide a checklist of key issues to be considered for that step. For further ease of reference, **Table 1** in the Executive Summary summarizes the full checklist for all eight steps. The checklist does not lead to any formal accreditation process and is offered as (non-prescriptive) guidance.

In addition to addressing key risks to vulnerable and critical assets and operations, the Plan may help companies meet ISO climate change requirements and expectations such as those found in ISO 14001 (as discussed in **Figure 1**). Finally, various appendices, together with a glossary of key terms, allow companies to obtain additional information and delve deeper into selected issues.

Figure 2: Connecting Adaptation Plans to ISO

Electricity companies are experienced in identifying and managing risks. In addition, they already have in place management systems within which they determine risks and associated risk controls. Among CEA member companies, most—if not all—have ISO 14001-conforming systems. With this context in mind, it is important for companies to understand that climate change can be managed in the same way as other risks are managed. Adaptation planning may require new information and knowledge, but for many companies, the most efficient path forward will be to integrate Plans into their existing managed systems. Compared to developing a standalone adaptation process, an integrated approach may present additional challenges to start: it will require siloed companies to break down barriers, and may require the involvement of a broader cross-section of staff to capture linkages and interdependencies. But the additional effort will reap dividends, as integration also allows for consistency with ISO 14001 expectations, stronger alignment with strategic planning, and an improved ability to create holistic business cases. We have prepared a comparison chart in Appendix 1 entitled "Alignment of Guide with ISO 14001 and ISO 14090," which shows in aggregate how the adaptation planning steps outlined here can be aligned with and integrated into an ISO approach.

Climate change is causing profound changes to seasonal and annual patterns in terms of precipitation, temperature, and other variables.

01 PHASE I: SETTING THE STAGE

Phase of Plan development	Step in process
Setting the Stage	**Step One:** Define objectives and engage leadership
Risk/Opportunity Assessment	**Step Two:** Identify critical and vulnerable assets and operations **Step Three:** Identify key potential climate impacts **Step Four:** Assess risks to critical and vulnerable assets and operations
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STEP ONE: DEFINE OBJECTIVES AND ENGAGE LEADERSHIP

Summary:

Clearly defining the objectives associated with controlling climate-related risk(s) is essential in order to maintain focus on the outcomes, ensure consistent understanding, and align with existing corporate objectives, such as reliability.

To achieve success, it is essential to engage the organization's leadership early in the planning stages for the following reasons:

- The leadership team is ultimately accountable for the sound management of risk and opportunity. Adaptation planning is about risk management, asset protection, reasonable care, and fulfilling accountabilities—all points that will typically resonate with senior management.
- Success is dependent on commitment from all levels and functions within an organization, led by top management.

Top management can:

- Effectively address risks and opportunities by ensuring the integration of adaptation into corporate strategy and business processes, as well as alignment with other business priorities.
- Ensure that resources are available.
- Ensure that the program meets the intended outcomes.

Checklist for Step One

- ✔ Identify the organization's objectives in pursuing a climate adaptation plan and define the scope of what the adaptation Plan is intended to address.
- ✔ Align the adaptation planning objectives with the organization's mission.
- ✔ Engage leadership by highlighting the economy-wide business case for adaptation and the likelihood that climate change is an enterprise risk.
- ✔ Recognize potential opportunities associated with climate change.
- ✔ Obtain a commitment from top management that it will actively participate in the development and subsequent implementation of the adaption Plan.

Define Objectives

The overall objective for a company in developing a Plan is to **improve resilience** to key risks from climate change and extreme weather, and to ensure that such risks do not adversely impact the organization's ability to **deliver on its core mission** and mandate.

Figure 3: Federal Energy Regulatory Commission 's (FERC) proposed definition for bulk power system resilience (January 2018)

"The ability to withstand and reduce the magnitude and/or duration of disruptive events, which includes the capability to anticipate, absorb, adapt to, and/or rapidly recover from such events."[3] Obtain a commitment from top management that it will actively participate in the development and subsequent implementation of the adaption Plan.

In addition to confirming the overall objective, companies may also want to identify subordinate objectives that set boundary conditions or provide more operational clarity in adaptation planning. Such objectives might include the following:

- A target date for starting to implement identified actions;
- A target level of knowledge within the company on climate (and weather) risks and adaptation;
- A maximum budget or some other aggregate economic threshold that identifies actions need to be met (e.g., budget neutrality);
- Process objectives such as integration with ISO 14001 or integration with business reporting or annual reporting;
- An articulation of what improved resilience would really mean for the organization—could it be operationalized with existing, modified, or new key performance indicator (KPI) targets?

Companies may consider setting additional objectives beyond the above examples, and then finalizing the objectives together with the organization's leadership or top management. Such objectives can be general or high level to start, with the understanding that they could be refined in subsequent iterations of the Plan.

The objective setting for adaptation planning should be framed against the background of the organization's core mission and mandate. **Table 3** has some examples of mission/mandate statements by Canadian electricity companies (bold added to key phrases for emphasis):

TABLE 3: EXAMPLES OF MISSION/MANDATE STATEMENTS BY ELECTRICITY COMPANIES

Organization	Statement
Alectra Utilities	"Alectra Utilities is shaping the future of energy as we know it. We are writing the next chapter in the changing face of energy in Ontario based on our strong legacy from the past. We are moving forward—as one organization—**to provide safe, reliable, and innovative energy solutions** to families and businesses across the greater Golden Horseshoe area."[4]
BC Hydro	"BC Hydro is one of the largest energy suppliers in Canada … That's a big responsibility that demands a simple, clear, and straightforward mission and vision. Our mission is to **safely provide reliable, affordable, clean electricity** throughout BC. Our vision is to be the most trusted, innovative utility company in North America by being smart about power in all we do."[5]
Ontario Power Generation	"OPG's mission statement encapsulates our overall goals: Power with purpose—providing low-cost power in a **safe, clean, reliable, and sustainable manner for the benefit of our customers and shareholder**."[6]

Engage Leadership

Leadership should be engaged in the setting of objectives. Support from top management for the project is essential for success. Two themes may be helpful in capturing the attention and support of top management: the economy-wide business case for adaptation, and climate change as an enterprise risk.

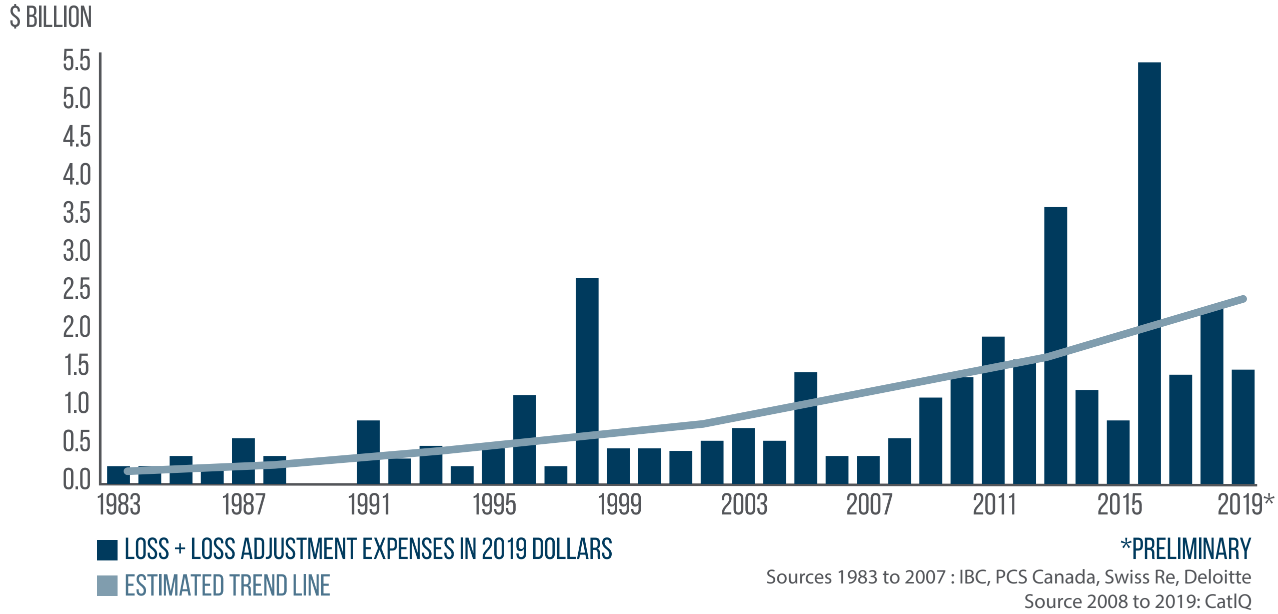
Economy-wide business case for adaptation

In multiple jurisdictions worldwide, there are compelling analyses and data on growing climate risks going back decades that help illustrate why adaptation must become part of the new normal for business across all sectors.[7] In the World Economic Forum's 2019 Global Risks Report—which assesses a wide range of risks, from asset bubbles to infectious diseases—the top two risks in terms of likelihood were "extreme weather events" at number one and "failure of climate change mitigation and adaptation" at number two.[8]

Both the 2016 Fort McMurray and 2017 British Columbia wildfires have been connected to climate change in two separate research papers published by Environment and Climate Change Canada scientists. According to University of Alberta wildland fire professor Mike Flannagan, climate change increased the likelihood of the Fort McMurray fire by 1.5–6 times, and the 2017 record-breaking fire season in British Columbia by 7–11 times.[9]

More broadly, the Insurance Bureau of Canada has prepared a chart (**Figure 4**) depicting a clear trend of increases in billion- dollar catastrophic loss claims from 1983 to 2017.[10]

Figure 4: Increases in billion-dollar catastrophic loss claims in Canada, 1983–2017



Sources 1983 to 2007 : IBC, PCS Canada, Swiss Re, Deloitte
Source 2008 to 2019: CatIQ

In the United States, there are similar climate-related loss trends. The National Oceanic and Atmospheric Administration (NOAA) of the US Department of Commerce updates a chart annually (see **Figure 5** below) depicting trends in increased billion-dollar wildfire, drought, winter storm, freeze, flooding, tropical cyclone, and severe storm events from 1980 to 2017. In 2017, these disasters totalled more than US$300 billion in costs."[11]

Figure 5: Increases in billion-dollar climate/weather events in the US, 1980-2017

Select Time Period Comparisons of United States Billion-Dollar All Disasters, Drought, Flooding, Freeze, Severe Storm, Tropical Cyclone, Wildfire, and Winter Storm Statistics (CPI-Adjusted)

Time Period	Billion-Dollar Disaster	Event/Year	Cost	Percent of Total Cost	Cost/Year	Deaths	Deaths/Year
1980s (1980-1989)	29	2.9	$177.2B	9.9%	$17.7B	2,870	287
1990s (1990-1999)	53	5.3	272.3B	15.2%	$27.2B	3,045	305
2000s (2000-2009)	62	6.2	$517.1B	28.9%	$51.7B	3,091	309
2010s (2010-2019)	119	11.9	$807.3B	45.1%	$80.7B	5,217	522
Last 5 Years (2015-2019)	69	13.8	$535.6B	29.9%	$107.1B	3,862	772
Last 3 Years (2017-2019)	44	14.7	$460.4B	25.7%	$153.5B	3,569	1,190
1980-2020*	**273**	**6.7**	**$1,791.5B**	**100%**	**$43.7B**	**14,303**	**349**

*Statistics valid as of July 8, 2020

These graphical representations help highlight the growing risks to the economy as a whole (including electricity stakeholders and consumers) that point to the need for adaptation, and they may be useful in helping top management in a company grasp the importance of adaptation.

In addition, analyses both internationally and in Canada have demonstrated that adaptation can provide significant benefits in the form of future cost avoidance (see **Figure 6** below).[12] The take-away from such analyses is that adaptation can help avoid or dramatically reduce costs from climate change impacts. This framing of the problem is important from the start, because the business case for adaptation (as we will see in Step Six) often depends on understanding and committing to the logic of avoided costs.

Figure 6: Estimating the economy-wide payoff from adaptation investments

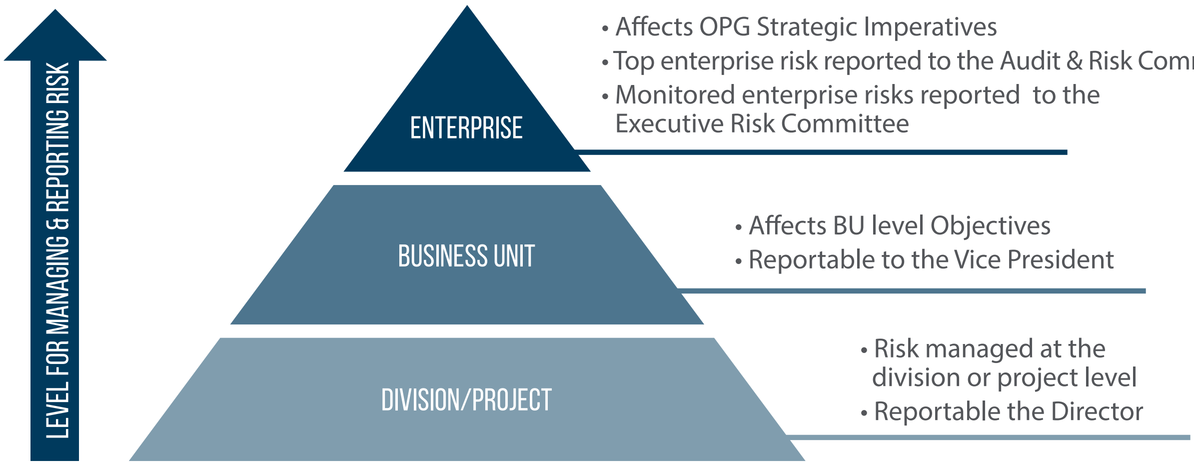
The issue of how to estimate the payoff from adaptation investments is a difficult area and has generated much debate among economists, climate scientists, and even moral philosophers. The controversy is driven by the complexity of climate science, the long timeframes involved, and varying methods and assumptions (e.g., appropriate discount rates) for translating risk into economic impacts.

As one notable example of such an estimate, in 2012, the National Round Table on the Environment and the Economy completed an adaptation cost-benefit analysis for Canada. The analysis estimated ratios for economy-wide adaptation ranging from 9:1 to 38:1—that is, for every adaptation dollar spent, there would be future cost avoidance of between $9 and $38 (depending on growth and climate change scenarios).[13]

Climate change as an enterprise risk

Top management should understand that climate change and extreme weather may represent an enterprise risk to the company. This characterization is an important way to highlight the importance of the risks in question and why they deserve the attention of the leadership. Effective management of business risk has always been a strategic imperative in the electricity sector. Among business risks, enterprise risks are those that could adversely impact an organization's ability to deliver on its core mission and mandate. Identifying and managing enterprise risk is critical for ensuring the success of the organization. At Ontario Power Generation (OPG), for example, as illustrated in **Figure 7**, the company has a classification system that differentiates among division/project risks, business unit risks, and enterprise risks, with corresponding implications for risk management and internal reporting.

Figure 7: Example of risk classification at OPG



Climate change is more of an enterprise risk now than it was ten or twenty years ago—and not only because of the growing risk of damage and harm to core assets and operations. Legal and regulatory risks are also increasing for companies that fail to reduce such risks and build resilience:

1. Pacific Gas and Electric Company (PG&E)'s declaration of bankruptcy in January 2019 was partly in response to "$30 billion in liability [claims it faced] after record-breaking deadly wildfires in 2017 and 2018."[14] Reportedly, "investigators have attributed more than 1,500 fires to PG&E power lines and hardware."[15,16]
2. The British Columbia Utilities Commission (BCUC) sent a letter in February 2019 to major public utilities in California asking for information on their plans and strategies to address extreme events.[17] It is notable that the BCUC inquiry was sent in the wake of the PG&E bankruptcy, and makes reference to the California Public Utilities Commission introducing "a new risk evaluation framework" in 2018.[18] **Figure 8** below provides additional details on the BCUC letter.
3. An April 2019 report by BlackRock, the world's largest asset manager with $6.5 trillion in assets under management, examines "the exposure to climate risk of 269 publicly listed US utilities based on the physical location of their plants, property, and equipment."[19] The report found significant variations in risk exposure based on the above variables, the specific type of extreme weather event relative to the utility profile (e.g., drought presents higher risk for a hydro power plant), and lastly, the climate resilience of the utility itself. Its overall finding was that the "the risks are underpriced." It cautioned that these risks "are likely to intensify in frequency and magnitude in the decades ahead."[20]
4. The New York State Common Retirement Fund, which manages more than $207 billion in assets, released a report from its Decarbonization Advisory Panel in April 2019. The report "examines the financial impacts of climate change" on the fund.[21] Among its key messages, the report cautions that physical risks from climate change will impact the fund's assets as "chronic and acute changes in climate patterns … create disruptions to supply chains, real assets (including land and agriculture), health, and movement of people … Legal liabilities for companies and investors may play a role here as well."[22]
5. Financial institutions increasingly want assurance that climate change and extreme weather risks are appropriately assessed and managed.

Figure 8: Letter from BCUC to major public utilities

In a February 2019 letter to major public utilities, the BCUC references recent extreme events in British Columbia—including wildfires, landslides, and severe windstorms—and highlights "potential risks such as earthquakes, ice storms, or cybersecurity attacks."[23] Noting that such events can damage infrastructure and present risks to the provision of "safe and reliable energy," the BCUC asks the utilities to explain how they "plan for and manage operations during such events, and how they consider strategies … in relation to risk management and emergency preparedness," including mitigating "the potential impact on customers and stakeholders."[24] The commission outlines ten categories of information it would like from each utility, including its emergency plans in response to infrastructure risks, its assessment of key safety and reliability risks, and its plans or strategies to manage such risks.

The trend is clear: as the climate continues to change at a rate not previously anticipated, as scientific knowledge improves, and as stakeholder expectations increase, indirect risks through legal exposure from claims of negligence are also increasing for companies that fail to adapt appropriately.[25] Conversely, as discussed in **Figure 9**, companies that develop robust adaptation plans are finding benefits in doing so.

Figure 9: Climate change as an enterprise risk at Horizon Utilities

The distribution company Horizon Utilities (now part of Alectra) started work on adaptation in 2008 and introduced an Enterprise Risk Management (ERM) system in approximately 2009.[26] The company developed a vulnerability assessment and initial adaptation strategy in 2012. In July 2013, nearly 20,000 customers of Horizon Utilities lost power after a summer storm.[27] Then in December 2013, an ice storm left more than 30,000 customers without power.[28] The two storms highlighted the importance of Horizon's efforts to ensure that its weather and climate risks are given proper attention. In its ERM system, "climate change is a stand-alone indicator," and risks are prioritized according to their likelihood and impact.[29] In particular, the system categorizes "major disruptions due to weather … as a hazard risk; it has been assessed by management as a major risk for the organization."[30]

Horizon introduced a long-term adaptation plan in 2015. As Horizon's director of supply chain management, Joseph Almeida, explained in a 2016 case study prepared with funding from Natural Resources Canada: "As a company, we felt that we needed to understand the climate trends, identify our gaps, measure those trends, and put a long-term plan together to reduce our risk going forward."[31] Key climate impacts that the organization foresees needing to manage include warmer temperatures, more extreme weather events, heavy precipitation in a short time, more total annual precipitation, and increased vegetation, which in turn is attracting more animals onto the wires.[32]

Brian Lennie, Horizon's policy advisor, aptly summed up the initiative and its objectives: "We are trying to plan ahead so we have fewer instances where our customers are negatively impacted by climate change, both in terms of service disruptions and rate increases due to the significant damage caused by more frequent storms."[33]

In general, electricity companies in Canada recognize the new reality. In summer 2018, to establish a baseline for this Guide and related training, CEA conducted a survey of member companies on adaptation issues. CEA found that 87% of technical experts and 100% of senior management regard climate change and extreme weather as a potential enterprise risk.

These trends, reports, and CEA survey results may be worth highlighting to top management in any company when framing the importance of the adaptation initiative.

100% of senior management surveyed regard climate change and extreme weather as a potential enterprise risk.

02 PHASE 2: RISK ASSESSMENT

Phase of Plan development	Step in process
Setting the Stage	**Step One:** Define objectives and engage leadership
Risk/Opportunity Assessment	**Step Two:** Identify critical and vulnerable assets and operations **Step Three:** Identify key potential climate impacts **Step Four:** Assess risks to critical and vulnerable assets and operations
Risk Response and Adaptation Planning	**Step Five:** Identify potential adaptation measures (risk controls) **Step Six:** Develop a business case for selected measures
Preparation for Implementation	**Step Seven:** Detail and document implementing control actions **Step Eight:** Establish a process to review and improve Plan

STEP TWO: IDENTIFY CRITICAL AND VULNERABLE ASSETS AND OPERATIONS

Summary:

To narrow the analysis to the most material issues, thereby creating a manageable scope, it is recommended that companies ascertain which assets and operations are both critical to fulfillment of the objective and vulnerable to climate and weather.

It should be noted that not all critical assets, processes, goods, and services are vulnerable. For example, conductors are critical, but if buried they may not be vulnerable to typical weather or climate impacts such snow and ice accretion or wind. Similarly, not all assets that are vulnerable to climate impacts are critical to the fulfillment of the company's overall objective.

Critical operations may include consideration of supply chain.

Top management can:

- Effectively address risks and opportunities by ensuring the integration of adaptation into corporate strategy and business processes, as well as alignment with other business priorities.
- Ensure that resources are available.
- Ensure that the program meets the intended outcomes.

Checklist for Step Two

- ✔ Identify assets and operations that are critical to the delivery of the corporate mission and mandate (e.g., ensuring reliability of supply).
- ✔ Determine which of the critical components of the assets and aspects of the operations are vulnerable to climate and weather extremes.

Table 4 provides examples of the kinds of assets and/or operations that might be identified by companies as critical and vulnerable:

TABLE 4: EXAMPLES OF ASSETS AND OPERATIONS THAT MAY BE CRITICAL AND VULNERABLE

Type of asset or operation	Explanation
Conductors	Conductors are both critical assets for the core business and vulnerable to climate in general and extreme weather. Different types of conductors—overhead, surface, and underground —will also have notable differences from one another. For instance, overhead conductors are more susceptible to wind and icing issues, while surface and underground conductors may have risks of overland and subterranean flooding.
Vegetation management (an operation that supports the integrity of overhead conductors)	Vegetation management may be a critical operation both for transmission and distribution companies.[34] The operation may also be vulnerable. For example, maintenance workers may need to access remote locations according to predetermined schedules, but access routes could be compromised by extreme weather, raising increased maintenance challenges, and reliability risks. Vegetation management may become more challenging as growing seasons increase in duration, as potential stresses from insects and disease increase, and as the risk of wildfire increases.
Generation cooling water intake systems	Thermal and nuclear generation stations withdraw, use, and discharge significant amounts of water for cooling purposes. As air and water temperatures increase, stations may need more water for cooling, but they may also be more constrained in how they can discharge water, potentially leading to de-rating or shutdowns. Water filtration systems may also be compromised.
Water availability for hydro generation	Lower water availability may reduce a company's ability to generate electricity, which impacts electricity sales and revenues; higher water availability may be an opportunity for additional generation and export or may present a risk of flooding. Also, hydro generation relies on a resource that often has competing uses: lakes and rivers are also used for fishing, recreation, transportation, water consumption, irrigation, etc. A change in water availability or level (e.g., an extended drought in the summer) may impact several uses at once, creating the potential for conflict.
Critical components at ground level or underground	All electricity subsectors (distribution, generation, and transmission) should examine whether they have essential system components at ground level or underground to determine whether these components may be vulnerable to floods, storm surges, and/ or sea level rise. Generation examples may include generators (e.g., pad mount gas turbines), transformers, switchgear, pumps, etc. Transmission examples may include transformers, switchgear, and protective and control instrumentation.

For a longer list of assets and operations that may be critical and vulnerable, **see Appendix 2.**

STEP THREE: IDENTIFY KEY POTENTIAL CLIMATE IMPACTS

Summary:

The third step is to identify key potential climate (and weather) impacts. The focus in this step is to identify existing and potential impacts that could affect critical and vulnerable assets and operations, i.e., affect an organization's ability to deliver its core service.

- An organization should include both **acute** (extreme weather related) and **chronic**. While average temperature or precipitation may not change dramatically year to year, over time the change may be significant.
- Impacts may include such things as mean annual and seasonal temperature; changes to the type, timing, and intensity of precipitation; and changes to the extent of snow cover. Precipitation impacts can range from reservoir recharge to overland flooding.
- Organizations should be wary of "**average** annual data," as this may obscure important changes in frequency, severity, or type of precipitation. Such changes may alter the risk.
- Impacts can exhibit **direct** cause and effect (e.g., damage due to high winds, or flooding due to precipitation) or indirect cause and effect, including intermediate steps. An example of an **indirect** impact is warmer air temperature resulting in warmer water, which may in turn lead to cooling challenges and/or increased growth of invasive species such as zebra mussels. Or as another example, warmer air temperatures may result in permafrost melt, which may then lead to infrastructure integrity issues.
- Different impacts may combine as a force multiplier, such as ice accretion and wind gusts.
- Impacts may also accumulate: lack of rain, high temperature, drought, and electrical storms may all contribute at the same time to increased wildfire.
- The impacts of concern should relate to vulnerabilities of critical assets and operations.

Checklist for Step Three

- ✔ List all relevant potential impacts.
- ✔ Define parameters required for analysis.
- ✔ Collect existing data from company and stakeholders.
- ✔ Identify gaps in needed information.
- ✔ Collect additional relevant data from external sources.
- ✔ Select key potential impacts applicable to organization.

List Relevant Potential Impacts

To begin with, companies should identify and list potential climate and extreme weather impacts that could be relevant to their core objectives and their critical assets and operations. Impact examples include temperature, precipitation (as snow, ice, and rainfall), winds, etc. Broadly speaking, these impacts fall into the following three categories:

1. **Changes in frequency, intensity, and/or duration of extreme events.** As part of a changing climate, extreme events are changing in frequency, intensity, and duration. In cases where extreme events become more frequent (for example, one model's IDF curve projects a historic 1:100-year storm may become a 1:20-year storm), or they increase in intensity and/ or duration, the associated risk may increase.[35]
2. **Changes in annual and/or seasonal patterns.** Average changes in precipitation or temperature may not always seem significant in a given year. Over the next few decades, however, such changes can add up to significant changes impacting earlier assumptions and forecasts on such fundamental considerations as the demand-supply picture and the lifespan and resilience of infrastructure. Over the timeframe of recorded global temperatures, twenty of the warmest years have occurred in the last twenty-two years, and the years between 2014 and 2019 were the hottest on record.[36] It is expected that this trend will continue, resulting in significant changes to average and seasonal patterns in all of the above categories.
3. **Changes to ecosystem/biodiversity/invasive species.** Potential impacts in the broader ecosystem, including changes to biodiversity and invasive species, could also significantly impact critical organizational assets and operations. For example, some generation companies are concerned about warming lake temperatures, which could favour algal blooms as well as result in the spread of zebra mussels. Vegetation management programs may require adjustment to address changes in growing seasons and stresses to vegetation due to drought, disease, or insects (such as pine beetles). Such stresses adversely affect the health of vegetation and may alter the composition of wood to make it more combustible or increase the fuel base.

Weather vs. climate: What is the difference?

As a reminder, climate and weather are distinct (but related) concepts. Weather refers to the day-to-day state of the atmosphere and its short-term variations expressed in minutes or days, whereas climate can be thought of as the "weather" of a place averaged over a long period of time (from several years to decades). More concretely, climate refers to the composite or generally prevailing weather conditions of a region throughout the year—as manifested in its temperature, air pressure, humidity, precipitation, sunshine, cloudiness, and winds—and averaged over a series of years. While weather forecasts are limited to projecting a few days into the future, climate models can make credible projections many years into the future. It is important that decision makers (top management) have assurance that models can produce credible and actionable results.

TABLE 5: CATEGORIES AND SUBCATEGORIES OF POTENTIAL CLIMATE IMPACTS

Category of potential impact	Subcategory
Increasing frequency, intensity, and/or duration of extreme events	1. Heat waves 2. Droughts and wildfires 3. Wind events including hurricanes, tornadoes, microbursts, and gusts 4. Major precipitation events and overland flooding 5. Sea level rise and storm surges 6. Ice storms, freezing rain, snow, and ice load events
Changes in annual and/or seasonal patterns	1. Changes in mean annual and/or seasonal temperature (air and water) 2. Changes in water availability (both spatial and temporal changes) 3. Changes in type, timing, and intensity of precipitation (seasonal and annual changes) 4. Changes in humidity and pressure 5. Changes in runoff and ground condition 6. Changes to annual extent and duration of snow cover (e.g., timing of spring melt), permafrost melt and changes in ice conditions (e.g., deepening of annual thaw
Changes to ecosystem/ biodiversity/invasive species	1. Increases in or redistribution of insect- and rodent-borne disease vectors 2. Changes in duration of growing season and stresses on vegetation 3. Shifts in species' range and/or reproductive patterns (e.g., migratory birds, species at risk, and invasive species).[37]

Companies may find it helpful to start with the list of potential risks summarized in **Appendix 3**, in which the types of impacts listed in **Table 5** are further elaborated upon with examples. This list can be used as a broad starting point to ensure key potential issues are identified. Climate (and weather) events and phenomena can have direct, indirect, and combined impacts on a company's assets and operations:

- **Direct impacts:** Some climate events and phenomena have direct—i.e., unmediated—effects on assets and operations. For example, snow and ice accretion on overhead lines may result in line failure; high winds could damage overhead conductors; lightning strikes may damage components.
- **Indirect impacts:** Some climate events and phenomena initiate a chain of events that ultimately impact assets and operations. For example, a buildup of ice or snow on trees may cause a tree or part of it to fall on overhead lines; high winds may result in flying debris or downed trees, resulting in asset damage; electrical storms may ignite wildfires, which in turn may damage overhead conductors and poles.
- **Combined impacts:** As the above examples suggest, a single event may have both direct and indirect impacts. For example, designing overhead conductors for greater projected radial ice accumulation may not adequately reduce risk if tree failure can also damage the lines.

Figure 10 provides an example of how OPG is reducing zebra mussel infestations within its Darlington Nuclear Generating Station refurbishment project.[38]

Figure 10: Zebra mussels and OPG's Darlington Nuclear Generating Station refurbishment project

Zebra mussels arrived in the Great Lakes in Ontario around 1988, and studies suggest warming lake temperature from climate change is facilitating the growth of the population.[39] According to a 2002 report, OPG "estimates that as a direct consequence of zebra mussels, its operating costs increased by between $500,000 and $1 million per year at its Darlington and Pickering nuclear stations."[40] Zebra mussels have also proven to be a significant cost and nuisance for its fossil and hydroelectric stations.[41]

In the case of the $12.8 billion Darlington refurbishment project, the issue of zebra mussels was raised as part of its environmental assessment screening with stakeholders. According to Brandon Wyatt, a steamfitter who works on reducing zebra mussel pipe infestation, OPG puts sodium hypochlorite in the cooling water it draws from the lake to prevent the mussels from breeding in the pipes. The sodium hypochlorite is then removed as part of a water treatment process so the water can safely be returned to the lake.[42]

Define Parameters Required for Analysis

Having identified potential impacts (e.g., snow and ice), the organization should next define the associated information needed to assess the potential impacts, such as future time period of interest, the baseline data for comparison, the required degree of detail (resolution), inclusion of both means and extremes as required, and return periods. **Table 6** below defines the key parameters within which each company will need to define the scope of the analysis it requires. The analysis should not aim to be exhaustive, but to focus on the variables and outcomes of greatest interest to the company.

TABLE 6: KEY PARAMETERS TO DEFINE SCOPE OF CLIMATE ANALYSIS

Category of potential impact	Background/explanation	Decision(s) required by each company
Baseline period	When using climate model results for scenarios, the baseline period serves as the reference period from which the modelled future change in climate is calculated.	The chosen interval should be long enough to smooth out rare, extreme single events and short enough to be sensitive to rapidly changing conditions. The baseline period is often as long as thirty years but can be as short as ten years. In **Figure 11** below, the baseline of 1976–2005 is compared to the future period of 2051–2080 to show a significant increase in days with an average temperature above 30 degrees Celsius.
Timeframe for future scenarios	In climate models, the "near-term" period typically refers to the current period until about 2040, the "mid-term" to the 2040–2070 period, and the "long- term" to the 2070–2100 period.	Companies should select the timeframes most relevant to infrastructure risks of interest, bearing in mind the service life of equipment and potential for design changes and equipment replacement. For many companies, the mid-term period will align with the service life of many components.
Resolution (spatial and temporal)	Resolution refers to the granularity of the model. Spatial resolution should take into account local climate modifiers, extreme weather, and whether critical and vulnerable equipment requires detailed knowledge of site-specific conditions. Temporal resolution refers to the size of time steps (i.e., how close together in time variables are archived and available).	The higher the spatial resolution, the more specific climate information a model can produce for a particular region—but this comes with the trade-off of taking longer to run (more costly) because the model has more calculations to make. Higher spatial resolution may be more warranted in areas with complex terrain. For temporal resolution, extreme weather events such as microbursts and electrical storms are often of short duration, justifying the need for shorter intervals (i.e., one hour or less) than other parameters (such as temperature) that typically change more gradually.
Key potential climate impacts to include in analysis	Some of the key potential climate impacts summarized in **Table 4** may serve as criteria of interest for the climate analysis. But analyzing some of these potential impacts may require the use of surrogates, as discussed in **Appendix 4**. Also discussed in **Appendix 4**, the Global Climate Observing System has identified a range of climate variables "that are key for sustainable climate observations."[43] Some of these variables are directly or indirectly related to criteria used in climate models in Canada.	Many companies may choose to limit their analyses to those potential climate impacts that relate to their critical and vulnerable equipment and operations. Such criteria may include precipitation, electrical storms, temperature, snow and ice loading, permafrost, and growing season. Criteria may be examined singly or in combination (e.g., ice/snow loading combined with wind gusts). Ouranos has a guidebook focused specifically on climate scenarios that discusses differences among basic, intermediate, and detailed scenarios, including the climate variables typically considered at each level of complexity. See **Appendix 4**.

TABLE 6: KEY PARAMETERS TO DEFINE SCOPE OF CLIMATE ANALYSIS

Category of potential impact	Background/explanation	Decision(s) required by each company
Means and extremes	Climate change is causing changes in both means (averages) and extremes.	Most companies will want to identify projections for both means and extremes. Extremes may capture more headlines, but they are also typically associated with more uncertainty (i.e., less confidence) and changes in mean patterns can also raise significant issues for companies.
Return periods	Return period is an estimate of the likelihood of an event to occur, showing the average recurrence interval over an extended period of time. For example, a 100-year event may occur once or more often in a 100-year period, or not at all.	Return periods are often a consideration in establishing design and/or siting criteria for infrastructure that will be exposed to weather extremes. For example, overhead conductors have specific design criteria related to such risks as snow loading and/or wind gusts. Return periods can be used both to select the specific model criteria based on existing designs, and as an input for future risk management (including how designs may need to be changed). Companies may need to decide how likely an event needs to be—or how much the likelihood of an event needs to have changed—for it to be relevant for further analysis.

Table 7 below illustrates how wires and generation companies respectively may define the scope of their analyses at a first pass (examples are not intended to be exhaustive).

TABLE 7: HOW WIRES AND GENERATION COMPANIES MIGHT DEFINE THE SCOPE OF THEIR CLIMATE ANALYSES

Parameter	Transmission/distribution company	Generation company
Baseline period	10–30 years	10–30 years
Timeframe for future scenarios	If assets typically have 30–60 years of asset life, with 10–50 years of asset life remaining, then mid-term models would seem appropriate.	If assets typically have 50–100 years of asset life, with 30–60 years remaining, then mid-term models would seem appropriate.

TABLE 7: HOW WIRES AND GENERATION COMPANIES MIGHT DEFINE THE SCOPE OF THEIR CLIMATE ANALYSES

Parameter	Transmission/distribution company	Generation company
Resolution (spatial and temporal)	**Spatial resolution:** Regional climate models (RCMs) may suffice except for key nodes such as switchyards. If the switchyards are vulnerable to extreme weather or flooding, local climate models (LCMs) may be required for those specific locations. **Temporal resolution:** If vulnerabilities include electrical storms, tornadoes, and microbursts, they typically operate over shorter timeframes and therefore require shorter intervals.	**Spatial resolution:** Generating stations typically have discrete footprints, therefore if extreme weather is of concern, LCMs would seem appropriate. For hydroelectric water availability, the size of the watershed will help determine whether global climate models (GCMs) or RCMs are appropriate for precipitation issues. Note that there are methods to bring GCM and RCM data to finer spatial resolutions. **Temporal resolution:** If vulnerabilities include electrical storms, tornadoes, and microbursts, they typically operate over shorter timeframes, therefore requiring shorter intervals.
Key potential climate impacts to include in analysis	For Canadian wires companies, key criteria may include air temperature, wind speed (including gusts, tornadoes, and hurricanes), precipitation, freezing rain, snow, permafrost, flooding, and wildfires.	For Canadian companies with thermal, nuclear, and/or hydroelectric generation, key criteria may include air and water temperature, precipitation (including rain, freezing rain, and snow), and flooding. These examples are not intended to be exhaustive.
Means and extremes	Companies will want to examine both means (for chronic impacts) and extremes (for acute impacts).	Companies will want to examine both means (for chronic impacts) and extremes (for acute impacts).
Return periods	Knowledge of this will help inform risk assessment, especially related to precipitation. If designing for a 1:500-year storm is more costly than designing for a 1:200-year storm, each organization will need to balance its risk tolerance against the cost.	Knowledge of this will help inform risk assessment, especially related to precipitation. If designing for a 1:500-year storm is more costly than designing for a 1:200-year storm, each organization will need to balance its risk tolerance against the cost.

Once the scope for the required analysis has been determined, organizations will next need to determine, as described below, whether such information already exists internally or must be obtained from external sources.

For a more detailed discussion of climate models and some of the above issues, see **Appendix 4**.

Collect Existing Relevant Data from Company and Stakeholders

The organization should next collect existing relevant data on extreme weather and climate change impacts of interest. Many companies may already have useful information and data on extreme events and climate scenarios from various credible sources, and these should be leveraged for efficiency and insight. It is important to identify both external and internal stakeholders who may already possess relevant information. Once sources are identified, the data and projections should be reviewed for their validity and applicability to the scope of analysis required (as discussed and elaborated above in **Table 6** and **Table 7**). For example:

- The relevant system operator may have already provided long-term peak demand assumptions for the electricity market that incorporate projected temperature changes from climate models.
- The hydroelectric side of the organization may have obtained or have access to water-related scenarios from government or from other stakeholders (e.g., International Joint Commission).
- Transmission companies may have access to information on climate scenarios related to forests where they operate.
- The finance and risk functions may be in contact with insurers who have assembled historical data for weather-related catastrophic losses (which will help highlight key potential impacts).
- It may also be useful for companies to reach out to peers with similar profiles—for instance, distribution companies in close proximity may want to compare notes in identifying relevant potential impacts and in sources of information so as to avoid unnecessary duplication. In the Durham region, for example, the three local distribution companies have shared the results of one climate model.
- Companies in the Pacific and Yukon regions in Canada have access to information through the Pacific Climate Impacts Consortium (PCIC).
- A number of companies in Canada have already taken steps in the past few years to develop return period loading maps for wind and ice (individually and in combination).[44]

Companies need to engage a cross-section of well-informed internal and external stakeholders to identify relevant data. The nature of this engagement can vary, from a standing working group that meets at predetermined intervals to reforming the group as required to address evolving areas of emphasis. See **Step Seven** for further discussion of governance considerations.

By eliciting input broadly, the organization may find there is more information already available than was first apparent or assumed.

Identify Gaps in Needed Information

Companies should next identify if there are any important gaps in the information they require. In particular, they should identify which potential impacts may require additional information and analysis. Existing sources may already provide adequate data on some impacts of concern (e.g., temperature and precipitation), while others may require further analysis and data (e.g., ice load events). For example, freezing rain events may require analysis of events over a 72-hour period in which the temperature never exceeds zero degrees Celsius and there are periodic wind gusts. See **Appendix 4** for an elaboration of this issue.

Collect Additional Data from External Sources

With the model characteristics and criteria identified based on critical and vulnerable equipment and operations, and any important gaps in existing sources of information identified, the organization can further investigate whether such data can be obtained from public resources and databases, such as those listed in **Table 8** below, or whether it may want to commission third parties to provide customized projections. For many companies, a search of publicly available information (especially when combined with the information they have already collected internally) may prove to be adequate for the purpose of aggregating relevant climate impact data. The data does not have to be perfect, but it should be sufficiently precise to allow for a meaningful risk assessment.

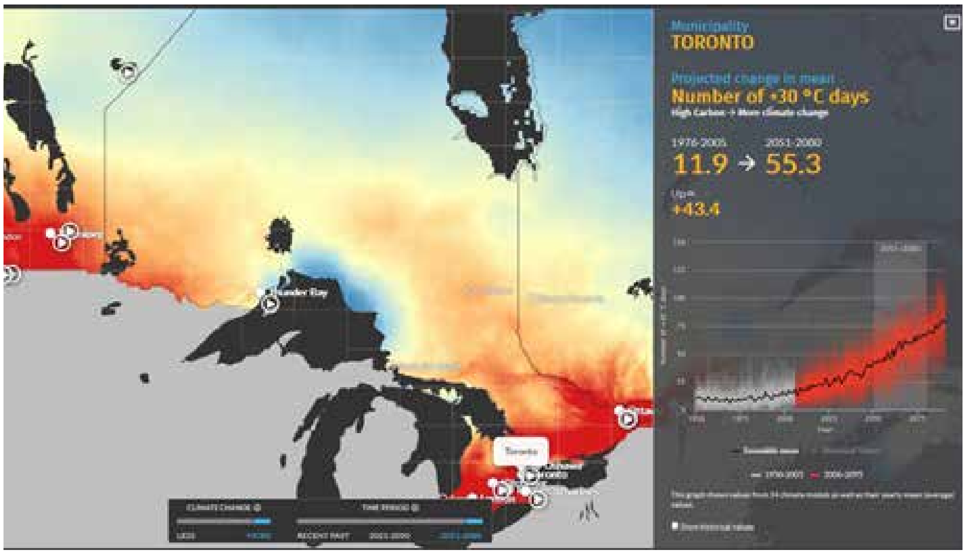
TABLE 8: PUBLIC RESOURCES FOR CANADIAN CLIMATE INFORMATION

Organization/website	Mandate and information available
Canadian Centre for Climate Modelling and Analysis (CCCma)	CCCma develops numerous versions of the Canadian global climate model, provides climate data for these models, and carries out climate model experiments in support of the Intergovernmental Panel on Climate Change (IPCC).
Canadian Centre for Climate Services (CCCS)	CCCS provides access to climate tools and information. It helps Canadians become more resilient to climate change by delivering climate services driven by user needs, providing access to climate information, building local capacity, and offering training and support.
Canadian Climate Data and Scenarios (CCDS)	The Canadian Climate Data and Scenarios (CCDS) site is an interface for distributing climate change information. It supports climate change impact and adaptation research in Canada through the provision of climate model and observational data.
Climate Atlas	Climate Atlas is an interactive tool combining climate science, mapping, and storytelling. The site allows the user to explore aspects of climate change using maps, graphs, and climate data for provinces, local regions, and cities across Canada. The data on the website is, for the most part, statistically downscaled GCM data produced by Pacific Climate Impacts Consortium (see below).[45]
Climate Change Hazards Information Portal (CCHIP)	CCHIP is a project of Risk Sciences International, an Ottawa-based company specializing in risk management consulting. CCHIP is a web-based tool that helps empower organizations to integrate climate change impacts into their planning and design decisions to help protect private and public infrastructure, resources, and public health. It welcomes dialogues with electricity companies and other organizations.
Google Earth Engine	Google Earth offers earth science data and analysis, including weather data sets and climate models.
Ouranos Consortium on Regional Climatology and Adaptation to Climate Change	Ouranos is a platform for innovation and consultation focused on climate change adaptation in Quebec. It includes a network of 450 researchers and experts from a variety of disciplines.
Pacific Climate Impacts Consortium (PCIC)	PCIC is a regional climate service centre at the University of Victoria that provides practical information on the physical impacts of climate variability and change in the Pacific and Yukon region of Canada. PCIC collaborates with climate researchers and regional stakeholders to produce knowledge and tools in support of long-term planning. PCIC's data portal makes data publicly available, notably including "statistically downscaled Canada-wide climate data for precipitation, minimum and maximum temperature [with] both historical hind-casts and projections to 2100."[46]

There are multiple sources of credible climate information readily available. **Figure 11** below provides one example of information available from the Climate Atlas website—a projection of the increase in the number of +30˚C days for Toronto in the 2051–2080 timeframe under a "high-carbon scenario" relative to a baseline of 1975–2005.

Where companies have determined, however, that such sources do not provide adequately granular or precise information on key climate impacts and scenarios of concern, they may decide it is necessary to work with researchers to obtain additional information on variables of interest that may not be available in the public domain. Also, as discussed in **Appendix 4**, there may be times when the parameter of interest (e.g., lightning or microbursts) cannot be directly modelled but can be simulated through the use of surrogates.

Figure 11: Climate projection example available from Climate Atlas



It is important that organizations base their decisions on data in which they have sufficient confidence. A number of factors affect the degree of assurance associated with projections. First, there is typically more uncertainty associated with long-term projections than nearer-term ones. Second, the degree of assurance may change with the parameters being modelled—for example, greater assurance may be attributed to temperature projections than to precipitation. Third, risks can change over time—for example, as temperature in a given area warms through the zero-degree mark, the incidence of freezing rain may first increase then decrease as the temperature increases. Lastly, projections of extreme events often introduce additional sources of uncertainty due to the events often being isolated, localized, of short duration, and modelled indirectly (e.g., using vertical cloud height or the movement of tiny ice particles that form and move within clouds to project electrical storms).

Select Key Potential Impacts Applicable to Organization

Regardless of how the information is identified or collected—whether it already exists within the organization, is researched and retrieved from public sources, or is obtained through additional work with researchers—the organization will want to narrow the broad list of all originally identified relevant potential impacts to those that could entail significant risks for the organization.

With the information collected up to this point, it should be possible to answer the following question: What are the major potential impacts that could raise significant risks for the organization's core mission and critical assets and operations?

Figure 12 illustrates how one US utility, Seattle City Light, identifies key potential impacts of concern in its Climate Change Vulnerability Assessment and Adaptation Plan.[47]

Figure 12: Seattle City Light's key potential impacts of concern

This highlighting of key potential impacts sets the stage for the risk assessment to follow.

STEP FOUR: ASSESS RISKS TO CRITICAL AND VULNERABLE ASSETS AND OPERATIONS

Summary:

Once the impacts of climate and extreme weather on critical and vulnerable assets and operations have been identified and information regarding future projections has been obtained, the next step is to determine the degree to which critical and vulnerable assets will be able to continue meeting their design intent and key systems and processes will be able to withstand identified risks according to their current operational protocols.

This process is the same probability/consequence approach used to assess any risk. It may be quantitative or qualitative. Existing processes may be applicable or the consequence scale may require amendment. Typically the consequence assessment should align with the business planning criteria.

Risks should be assessed both with (residual risk) and without (inherent risk) control measures applied. In this way, the effectiveness of the controls can be assessed.

Once risk has been assessed, determine those risks that exceed management's risk tolerance.

NOTE: Many of the risks identified may not be new—climate change and extreme weather may simply exacerbate existing risks.

Checklist for Step Four

- ✔ Assess the significance of potential climate impacts on critical and vulnerable assets and operations.
- ✔ Characterize each risk by considering its consequence and probability.
- ✔ Analyze portfolio of risks for critical assets and operations, including interdependent risks.
- ✔ Summarize significant risks for critical assets and operations.

Characterize Each Risk by Considering its Consequence and Probability

Ideally this risk assessment should be done twice, the first assessment assuming that no adaptation measures (risk controls) are in place, and the second with controls in place (i.e., assessing residual risk). Probability and consequence rating criteria may be qualitative or quantitative. While quantitative scales have greater precision and measurability, qualitative scales may be used when the risk does not lend itself to quantification, the data is not available, or data analysis is not cost effective. Either way, it is important to identify the timeframe for the risks under consideration.

There are a variety of consequence and probability scales, varying both in granularity and in type of consequence(s) of interest. The company should select a scale that on the one hand has sufficient granularity for discrimination of risk, and on the other hand does not create unnecessary categories that will simply add effort without value. Experience has shown that a scale of one to five often works well. **Table 9** provides an example of a consequence scale, and **Table 10** provides an example of a probability scale.

TABLE 9: EXAMPLE OF CONSEQUENCE SCALE

Score	Type of consequence		
	Financial	Stakeholder/reputational	Regulatory
1: Very low	• Does not affect asset value • Impact up to $10,000—negligible or minor shortfalls • Little to no impact on economic growth, employment	• Relatively unimportant, stakeholders either unaware or aware but not concerned • No threat to image • Minor reputational consequence • Media not involved	• Unimportant/little to no potential for regulatory action
2: Low	• Impact greater than $10,000, up to $100,000 • Isolated areas of reduced economic growth relative to forecasts	• Stakeholder concerns/ complaints limited to individuals or local groups	• Notification to regulator required • Warning from regulator
3: Moderate	• Impact greater than $100,000 , up to $500,000 • Reduction in economic growth relative to forecasts	• Somewhat important to stakeholders	• Regulatory sanction, fine, regulatory involvement, potential for increased reporting
4: Major	• Impact greater than $500,000 , up to $1 million • Business health and employment affected	• Significant local concern for stakeholders, media attention	• Conviction, potential loss of licence, potential for regulatory orders, potential for additional licence requirements
5: Extreme	• Potential to significantly affect value of assets • Impact greater than $1 million • Significant economic impact, loss of employment, business failure	• Permanent, significant reputational loss, very damaging with stakeholders	• High potential for regulatory action • Subject to past regulatory action/ compliance problems • Intrusive involvement by regulator • Loss of regulatory approval to operate

Consequence categories can be tailored to reflect the organization's objectives and areas of concern. Health, safety, reliability, and environmental responsibility could also be potential categories, and stakeholders could be disaggregated into various constituencies if helpful (e.g., government, economic regulator, customers, etc.)

The company should identify both the inherent and residual risk of each potential impact for the asset or operation. Inherent risk refers to the risk without mitigating controls applied. Residual risk refers to the extent of risk that continues to exist after controls have been applied. The purpose of this step is to assess whether existing controls are adequate to decrease the risk to within an organization's risk tolerance. It is conceivable that an organization may deem existing controls adequate to meet future projected climate risk—i.e., existing design specifications or operating protocols may be more than adequate to address the issue in question. For example:

- Dams may be likely to experience higher flows, but existing design parameters may already be sufficient to absorb the projected change.
- The operating protocol for vegetation management may continue to be adequate under a changed growing season, as it often has built-in feedback mechanisms to determine if it is meeting objectives or if adjustments may be required in the frequency and (seasonal) duration.

The residual risk may be acceptable (negligible or non-existent) or unacceptable—for instance, in those cases where the existing design or operation will not adequately control future climate or extremes. For example:

- A dam may identify a significant risk of flooding or damage to spillways given the projection of higher precipitation levels.
- Access for maintenance, repair, or reprovisioning may be impacted by shorter winter road seasons and storm (flooding) events rendering them impassable.

The consequence assessment should be aligned with each company's specific business plan: a $1 million impact might be scored as a high five for one company and only a moderate three for others. The consequence assessment can also be adjusted to match the significance of the organizational level being considered; what may be ranked a three in financial terms from a corporate perspective may be a five at a business unit or divisional level. Similarly, something of significant concern to local stakeholders may have a lower rating from a corporate standpoint. This cascading approach enables relevant issues to be mapped at all business planning levels. Risks can also be grouped together in terms of their types of consequence for analysis by relevant functions within the company (e.g., all reputational risks, all regulatory risks, etc.).

The probability assessment will vary considerably based on the location and time period considered. For example, some areas experience hurricanes or ice storms more frequently than others, and microburst and tornado activity are ramping up in many areas. **Table 10** below shows a standard example of a probability scale.

TABLE 10: EXAMPLE OF PROBABILITY SCALE

Score	Description
1	Very unlikely to occur in the timeframe related to the objective. Extremely remote, highly improbable, very infrequent, rare, occurring less than once every 25 years.
2	Unlikely to occur in the timeframe related to the objective, not negligible. Remote possibility, low probability but noticeably greater than zero (i.e., may arise once in 10 to 25 years).
3	As likely as not to occur in the timeframe related to the objective. Moderate probability, reasonably likely, 50/50 chance, occasional, periodic (i.e., may arise once in 10 years).
4	Likely to occur in the timeframe related to the objective. Greater than 50% probability but lower than 90% probability (i.e., may arise about once per year).
5	Very likely to occur in the timeframe related to the objective. Virtually certain, frequent, routine or ongoing, could occur several times per year, greater than 90% probability.

Analyze Portfolio of Risks for Critical Assets and Operations

It may be easiest for companies to start by assessing the consequence and probability of each significant impact in isolation. It is also important, however, to consider key risks in combination, and to consider the portfolio of risks to specific assets and operations. Many of the risks companies identify will not be new risks so much as existing ones that are exacerbated by climate change.

Interrelationships among potential significant impacts (combined effects, multiplier effects, cascading effects)—as well as interdependencies among the electricity sector, other infrastructure sectors, and municipalities—should also be considered. When considered in aggregate, the risk profile may be significantly different than if each impact is viewed in isolation. For example:

- **Two impacts could occur as a combination event.** Higher wind and ice or snow accretion in combination could present a much more significant risk than either impact alone.
- **Two or more impacts could have multiplier effects or cascading consequences.** Increased ambient air temperature combined with increased frequency and severity of drought and insect-borne disease could stress trees more than otherwise projected, making them more susceptible to wind and ice. Increased forest mortality could also increase the fuel base, thereby increasing the extent of damage caused by wildfire. Elevated ambient air temperatures could reduce the efficiency of conducting electricity and the ability to cool equipment (such as transformers) at the same time as that there may be additional demand; higher air temperatures could lead to higher water temperatures and impair the ability to reject waste heat. The warmer water may also increase the incidence of algal blooms, further impairing the ability to cool.
- **Year-round exposure to multiple impacts could accelerate asset degradation.** A company could be exposed to ice accretion in the winter, flooding in the spring, higher temperature in the summer, and more frequent higher wind/ precipitation events throughout the year. A robust approach to strengthening the asset will need to consider the probability and consequence of impacts both individually and in combination, and over the life of the asset.
- **Climate change could have cascading impacts on interconnected infrastructure systems.** As a recent C40 Cities report on climate risks and infrastructure interdependencies demonstrates, multiple sectors are highly interdependent in the provision of essential goods and services—in particular, the food, energy, water, transportation, wastewater, telecommunication, and solid waste sectors.[48] The report notes that climate change "is projected to cause adverse ripple effects in these systems," and highlights the examples of various "city governments and other public agencies … to understand the cascading impacts of climate change on interconnected infrastructure systems at the urban scale," including discussions of the City of Toronto.[49] The key take-away of the C40 report is that is that when assessing climate risks, infrastructure interdependencies must be considered.[50] **Figures 13, 14, and 15** illustrate risk interdependencies for the City of Toronto among major stakeholders and infrastructure providers, including Toronto Hydro and Hydro One.[51] **Figure 13** was adapted by the City of Toronto with permission from MUST Urbanism (2016).

Figure 13: Toronto risk assessment interdependencies mapping exercise

This diagram illustrates some interdependencies and reinforces the message that to be successful, robust control systems must account for such interdependencies. This exercise identified that Toronto Hydro (a distribution company) relied on Hydro One (the transmission company), the City of Toronto (for water and sewerage), and those charged with responsibility for transportation services (all government levels, rail and road transport, etc.)

High Level Risk Assessment: Dependency Diagram

Source: C40—Concept adapted by the City of Toronto with permission from MUST Urbanism (2016).

An integrated approach to examining potential impacts helps set the stage for companies to consider which adaptation responses (risk controls) may be optimal in addressing or managing all such risks as discussed in **Step Five**. Once the portfolio of risks has been identified for an asset or operation, key linkages can be mapped together in a concise manner. Doing so ensures organizational focus and will be helpful in communicating key risks to top management.

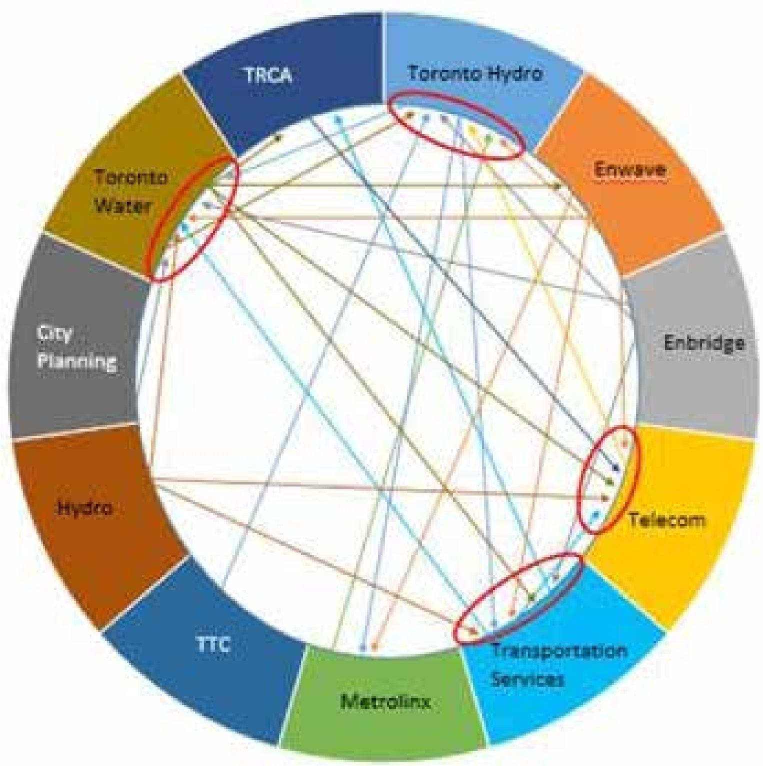


Figure 14

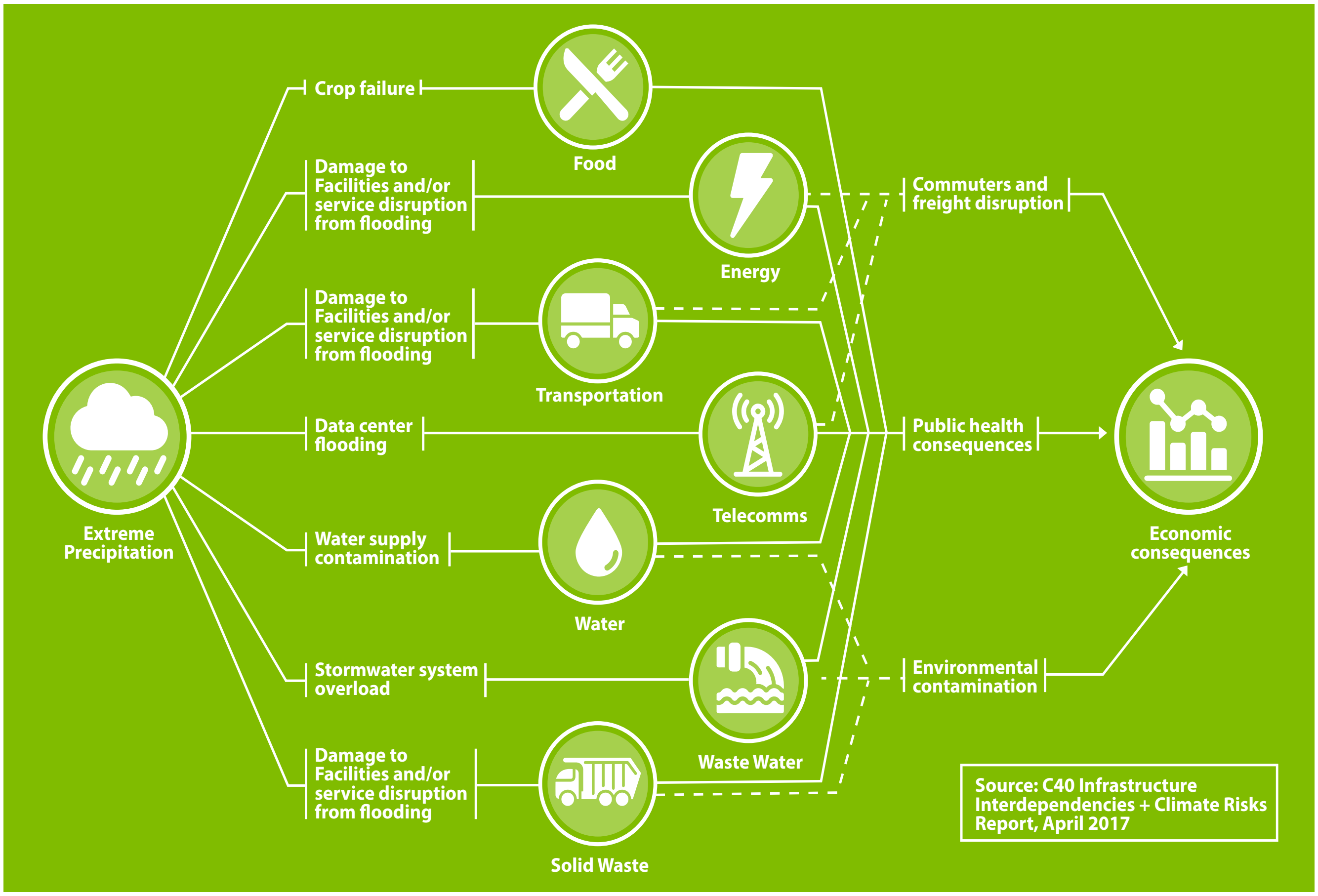
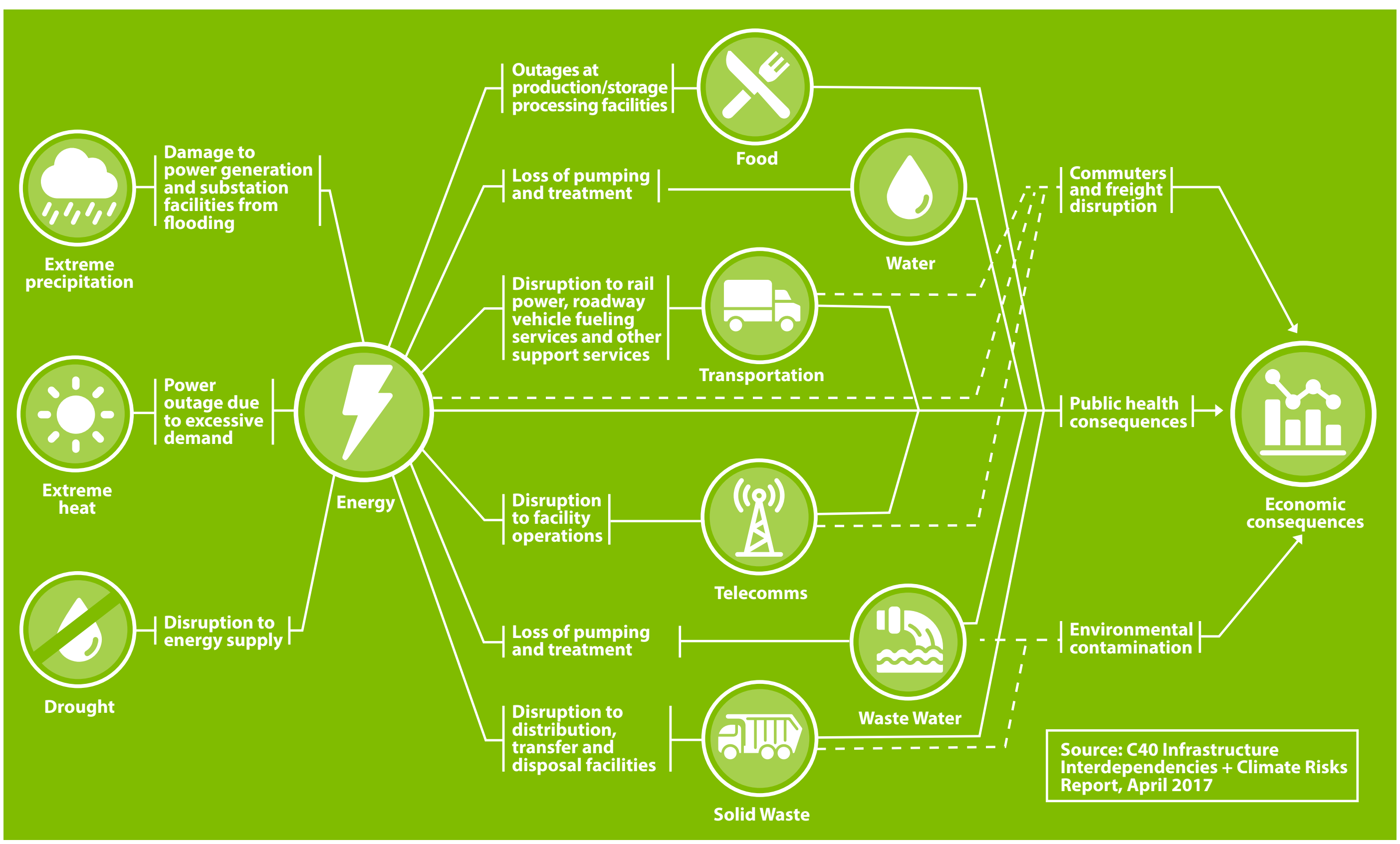
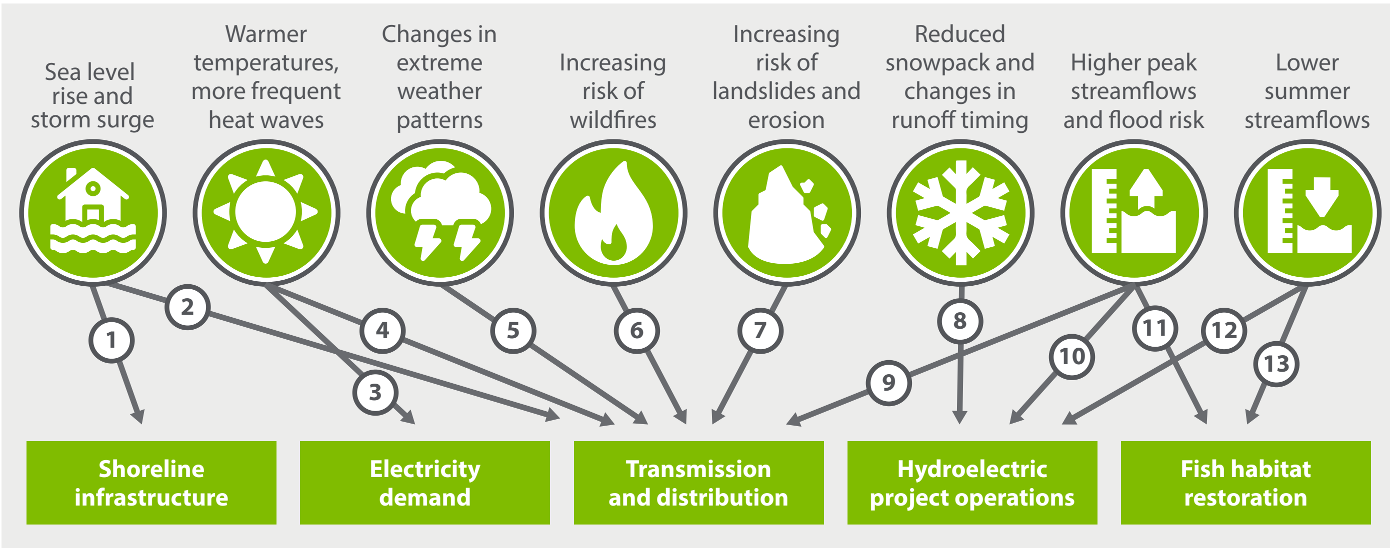


Figure 15



Returning to Seattle City Light's Climate Change Vulnerability Assessment and Adaptation Plan, the company connects projected changes in climate and weather to its key assets and operations. It is important to notice in **Figure 16** that the relationship is not one-to-one—as would be expected of a portfolio approach to risks, an asset may face more than one risk (for instance, transmission and distribution face multiple risks), and conversely, a single climate change impact (e.g., flood risk) may raise risks for more than one asset or operation.[52]

Figure 16: Seattle City Light's linking of key impacts to assets and operations



Summarize Significant Risks for Critical Assets and Operations

Lastly, the risk assessment should include a prioritization step, to determine the subset of risks that exceed top management's tolerance. These risks form the basis for the adaptation planning in **Step Five**, to follow. The summary may include not only potential enterprise risks, but also other notable risks, as these may also form part of the adaptation response. A consequence-probability matrix (as illustrated in **Table 11**) is helpful for identifying which of the risks identified are of greatest concern.[53]

TABLE 11: EXAMPLE OF CONSEQUENCE-PROBABILITY MATRIX (CONCEPTUAL)

Consequence					
Extreme		High risk	High risk	Extreme risk	Extreme risk
Major			High risk	High risk	Extreme risk
Moderate				High risk	High risk
Low					High risk
Very low					
	Very unlikely	Unlikely	As likely as not	Likely	Very likely
	Probability				

Continuing with the Seattle City Light example, **Figure 17** shows how the company identifies risks from climate change impacts for each critical asset or operation (in their terminology, utility function). Note that the excerpt below does not include two other key functions: hydroelectric project operations and fish habitat restoration. For additional information, the full report can be downloaded here.[54]

FIGURE 17: EXCERPTS FROM SEATTLE CITY LIGHT'S SUMMARY RISK ASSESSMENT

			Vulnerability			**of Impact to**			
Utility function	Impacts caused by climate change*	Time	Exposure	Sensitivity	Capacity to Adapt	Financial Cost	Safety	Reliability	Environmental Responsibility
Coastal properties	• Tidal flooding due to higher storm surge and sea level rise	2030	🟢	🟠	⚫	Low			Low
		2050	🟠			Med			Low
Transmission and distribution	• Tidal flooding and salt water corrosion due to higher storm surge and sea level rise	2030	🟢	🟢	🟠	Low		Low	
		2050	🟠			Low		Low	
	• Reduced transmission capacity due to warmer temperatures	2030	🟠	🟢	🟢	Low		Low	
		2050	🟠			Low		Low	
	• More frequent outages and damage to transmission and distribution equipment due to changes in extreme weather***	2030	🟢	🟠	🟠	Low	Low	Low	
		2050	🟢			Low	Low	Low	
	• More damage and interruptions of transmission and generation due to wildfire risk	2030	🟠	⚫	🟠	High	High	Med	
		2050	⚫			High	High	Med	
	• More damage to transmission lines and access roads due to landslide risk	2030	🟠	🟠	🟠	Med	Low	Med	
		2050	🟠			Med	Low	Med	
	• More damage and reduced access to transmission lines due to more frequent river flooding and erosion	2030	🟠	🟠	⚫	Med		Low	
		2050	⚫			High		Low	
Energy Demand	• Reduced electricity demand for heating in winter due to warmer temperatures	2030	🟠	🟠	⚫	Med		Low	
		2050	⚫			High		Low	
	• Increased electricity demand for cooling in summer due to warmer temperatures	2030	🟢	🟢	⚫	Low		Low	
		2050	🟠			Med		Med	

**The impacts are those caused by climate change in addition to historical conditions; most existing hazards (such as windstorms) will continue.*
***Magnitude refers to the average event or normal condition for the timeframe, not the worst possible year or event that could occur.*

Component of vulnerability	Rank	Description
Exposure (the expected change in the climate)	● (green)	Projected change in the climate is small within the timeframe and unlikely to be distinguishable from historical variability.
	● (orange)	Projected change in the climate is moderate and more likely to be distinguished from historical variability.
	● (dark grey)	Projected change in the climate is significant and likely to be distinguishable from historical variability.
Sensitivity (the susceptibility of the system to the change)	● (green)	Current conditions greatly reduce sensitivity to the expected change.
	● (orange)	Current conditions provide some buffer to the expected change.
	● (dark grey)	Current conditions are highly sensitive to the expected change if no action is taken.
Capacity to adapt (current processes or procedures that provide capacity to adapt)	● (green)	Existing capacity to prepare is high and can significantly reduce vulnerability.
	● (orange)	Some capacity exists that can be leveraged to reduce vulnerability.
	● (dark grey)	Limited capacity exists that can be leveraged to reduce vulnerability; there is significant room for enhancing capacity.

Risks should be assessed both with (residual risk) and without (inherent risk) control measures applied.

PHASE 3: 03 RISK RESPONSE AND ADAPTATION PLANNING

Phase of Plan development	Step in process
Setting the Stage	**Step One:** Define objectives and engage leadership
Risk/Opportunity Assessment	**Step Two:** Identify critical and vulnerable assets and operations **Step Three:** Identify key potential climate impacts **Step Four:** Assess risks to critical and vulnerable assets and operations
Risk Response and Adaptation Planning	**Step Five:** Identify potential adaptation measures (risk controls) **Step Six:** Develop a business case for selected measures
Preparation for Implementation	**Step Seven:** Detail and document implementing control actions **Step Eight:** Establish a process to review and improve Plan

STEP FIVE: IDENTIFY POTENTIAL ADAPTATION MEASURES (RISK CONTROLS)

Summary:

As with any risk management process, top management has the authority to assume some degree of risk. Typically, either the inherent or residual risk should fall within top management's defined risk tolerance. In the event that controls do not reduce the risk to a level that is within this tolerance limit, this must be clearly identified, the reasons documented, and approved interim actions applied. The relative success of actions controlling risks must be clearly communicated to those with accountability, i.e., top management.

When identifying potential adaptation measures, organizations should consider the range of possible actions—for example, adaptation measures can range from hardening the asset to modifying design or modifying operations.

Certain adaptation measures may address multiple risks—for example, burying conductors would address issues related to wind (gallop, failure of conductors or supports), temperature (sagging, annealing, and premature aging), and/or snow and ice accretion. Each potential action needs to be viewed from the standpoint of effectiveness in controlling risk, whether it introduces other risks, and whether it can be supported with an effective business case. For example, burying lines may address key climate-related risks, but the incremental costs may not support the business case.

In this step, the process shifts from risk identification and prioritization to adaptation action planning.

Checklist for Step Five

- ✔ Generate a list of adaptation ideas to manage risks. Consider a wide spectrum of possible measures, including strengthening the asset, modifying operations, modifying designs, changes in organization, collaborating with others to address interdependent risks, and strategic shift to new activities (opportunities).
- ✔ Group and categorize ideas to engage various internal departments, set the stage for filtering such ideas, and build a business case for promising ideas.

Adaptation reminders

- Not all risks need to be eliminated. As with other aspects of risk management, some climate and extreme weather risks may be accepted, taking into account their consequence, probability and the organizational context (i.e., risk tolerance, resource constraints, etc.)
- The overarching objective of adaptation planning is resilience to risk, and the concept of resilience encourages companies not only to survive, but to prosper. Adaptation to climate change may also therefore generate opportunities and potential for competitive advantage, e.g., through modifications in reservoir management or demand response strategies (as discussed below).

Generate a List of Adaptation Ideas

Companies should aim at first to be creative and capture as many adaptation options as possible for significant risks identified. Adaptation responses can be grouped into various buckets. **Table 12** illustrates some potentially useful categories with examples.

TABLE 12: CATEGORIES OF ADAPTATION OPTIONS

Adaptation category	Examples
Strengthening or hardening the asset	• Elevating critical equipment so it is less susceptible to flooding • Upgrading insulators to address potential risks from higher temperatures • Ensuring backup generators powering sump pumps are above the expected flood levels
Replacing the asset	• Upgrading old equipment such as transformers and wires with equipment designed to higher rating requirements • Replacing poles to withstand greater loads, including replacing wood with concrete or steel • Replacing power conductors with stronger steel-core lines • Replacing non-submersible equipment with submersible-type equipment
Modifying operations	• Improved/proactive vegetation management practices to reduce the risk of line failure • Modified timing for outages or maintenance to address changes in seasonal durations or patterns • Modifications in reservoir management to reduce risks and increase revenues • Monitoring temperatures and reducing loading on transformers on hotter days • Installing an ice monitoring and removal technology that is triggered when ice thickness on conductors reaches certain thresholds
Modifying designs and standards	• Designing new poles to withstand greater loads • Upgrading standards for buildings, building foundations and drainage systems to accommodate changing conditions such as permafrost melt and changing snow load risk • Including lightning protection (e.g., earth wires, arrestors) in new designs and standards • More stringent flood standards, including safety margins for critical infrastructure • Upgrading design standards for transmission hardware to address maximum ice and hourly wind loads and cumulative ice and wind loads
Changes in organization and staffing	• Expanding contracts to bring in additional resources, e.g., response crews from outside the region when needed • Designating and training certain employees to act as community liaisons to strengthen community resilience
Collaborating with others to address interdependent risks	1. See C40 Infrastructure Interdependencies + Climate Risks report for multiple detailed examples of interdependencies among key infrastructure sectors and municipalities 2. Working with a municipality to coordinate flood mitigation efforts 3. Working with customers to provide incentives for them to reduce demand during high-temperature days 4. Mutual assistance agreements whereby two or more companies agree to help each other in the event of a disaster (these can include terms for sharing human resources, materials, and equipment) 5. Collaborating with trade associations and best practice sharing committees

TABLE 12: CATEGORIES OF ADAPTATION OPTIONS

Adaptation category	Examples
Devising or modifying communication strategy	1. Establishing or modifying communication strategies to advise customers and other key stakeholders of the organization's response to emergency weather events 2. Grid modernization to provide data and communicate with customers, facilitating priorities for directing repair crews based on clear customer prioritization.
Strategic shift to new activities (opportunities)	1. A company could decide to make new investments and capitalize on new market opportunities, potentially alongside selling part of its existing portfolio of assets to reduce exposure to risks. Examples of such a shift might include investment in demand-side, digital, battery, and micro-grid technologies to meet increased market demand during high-temperature days and increased grid demand for storage. Some of these activities might be pursued for independent reasons, but adaptation considerations may provide additional justification for the shift.

It is worth making five observations. First, some ideas may be mutually exclusive—for instance, hardening an existing asset or replacing it with a new one—but many other ideas could be complementary. For example, a company may decide:

- To harden or replace an existing asset (reactive adaptation) while also modifying design standards for a new asset (proactive adaptation), at the end of service life replacing the asset with a new design to address climate projections;
- To modify vegetation management practices (operations) while also modifying or replacing the wires (assets);
- To ensure that additional response crews can be accessed from outside the region when needed, while also improving the capacity of the organization's own response crews to prioritize its efforts effectively.

Second, the ideas fall on a spectrum in terms of their cost implications. Some adaptation responses involve minimal to no cost (e.g., mutual assistance agreements); others may entail significant cost (asset replacement); and others may generate new or additional forms of revenue (strategic shift to new opportunities).

Third, it may also be the case that a single adaptation response (e.g., a design change) addresses more than one risk. For example, an asset can be hardened in such a way as to address both flooding and fire risks.

Fourth, adaptation responses should also carefully consider infrastructure interdependencies, cascading consequences and multiplier effects, as discussed above in **Step Four**, and therefore the potential benefits of cooperation with key stakeholders such as municipalities and other infrastructure sectors.

Lastly, the above categories may not be exhaustive of issues for all companies. Although outside the scope of this guide (which focuses on physical assets and operations), some companies may also decide to review and, where appropriate, modify health and safety policies to address issues related to thermal comfort, prevention and treatment of vector-borne diseases, and pollen and allergies.[55] It is helpful in the first instance to brainstorm widely so as to identify the full spectrum of possible responses. For a longer list of potential adaptation responses that can be used for such brainstorming purposes, see **Appendix 5**.

Figure 18 describes some of the measures that Toronto Hydro is considering or has undertaken to incorporate climate projections into construction and maintenance plans to protect assets and make the grid more resilient.

Toronto Hydro is either looking at or installing equipment with extreme weather in mind. That includes stainless steel transformers that are more resistant to corrosion and breakaway links for overhead service connections, which allow service wires to safely disconnect from poles, and prevent damage to service masts.[56]

Further, by incorporating climate projections for temperature, rainfall, and freezing rain into construction and maintenance plans, Toronto Hydro is looking for ways that new equipment can withstand the stronger elements. It's investing in flood mitigation systems in stations and using submersible equipment such as stainless steel transformers to protect against flooding.

To help combat high winds and freezing rain, the utility is raising the height of its overhead poles to clear tree branches and installing breakaway service wires to help limit the damage sustained to overhead equipment. While these investments won't prevent outages from large trees toppling onto overhead lines, they will help crews and system controllers restore power more quickly.[57]

Group and Categorize Adaptation Ideas

Once a list of potential controls and other responses has been generated, these ideas can be grouped in several ways to engage appropriate stakeholders, departments, and functions:

- They can be grouped as above under types of adaptation responses (e.g., asset hardening, modifying operations, etc.). Public affairs may have a role in supporting all communication strategies, while an engineering group could look at all relevant design-related issues.
- They may be grouped as internal only, both internal and external, or external only actions. Some adaptation responses may be undertaken entirely within the company itself, while others, given the interdependencies involved, may be
- best pursued in collaboration with stakeholders, partners, and customers (e.g., demand response and peak shaving programs with customers). And still others may be up to an external party to implement, and the company will only play a monitoring role (e.g., a company may want to monitor a municipality's planned sewer upgrade to track progress).
- They can be grouped together as potential responses to specific (critical and vulnerable) assets and operations. For example, all potential adaptation options for the range of climate risks to substations or reservoirs can be grouped together and examined by relevant experts.
- They can be grouped in terms of their potential to generate costs or revenues or both, whether they are competing or complementary to each other, and in terms of the timeframes they would require—some can be implemented quickly, while others could take years to implement.
- There can be hybrids and combinations of the above potential groupings.

STEP SIX: DEVELOP A BUSINESS CASE FOR SELECTED MEASURES

Summary:

Actions identified to control climate-related risks may require the development of a business case for adaptation-related expenditures/investments. A business case typically refers to an economic assessment of the costs and benefits of taking certain actions or initiatives. Wherever possible, organizations should make use of their existing processes for making the business case around new investments and/or changes to resource allocations in business operations. Where existing processes lack clearly defined mechanisms for addressing new risks and opportunities—or for addressing changes in risks and opportunities as a result of climate change impacts and risks and the need for adaptation—they will need to be modified. The business case should consider both risks and opportunities.

Checklist for Step Six

- ✔ Decide on criteria for evaluating adaptation measures: cost-benefit measure, time period, discount rate, non-financial measures.
- ✔ Perform cost-benefit analysis for all potential measures.
- ✔ Prioritize. Consider using various tools to support prioritization of measures (cost curve, matrix, sensitivity analysis, best practices).
- ✔ Refine based on potential interactions among measures (synergies or overlap).

Boundary Conditions and Evaluation Measures

Companies will need to define the boundary conditions and evaluation criteria for adaptation business cases. Taking into account existing policies and practices for business cases generally, companies should evaluate and decide on the following key considerations that will frame the boundaries of the analysis, as elaborated in **Table 13**.

TABLE 13: BOUNDARY CONDITIONS/EVALUATION CRITERIA FOR ADAPTATION MEASURES

Condition or criterion	Explanation
What comparison measure to use	The optimal approach to evaluation may vary by organization and risk. Cost-benefit measures used in business cases typically include net present value (NPV), return on investment (ROI), payback period (PBP), and benefit-cost ratio (BCR). These measures provide analytical tools that are part of standard business practices. The challenge is in estimating and forecasting the variables necessary to do these calculations in the context of adaptation measures. Other approaches include real options value analysis and extreme value analysis.
What time periods to consider	Many climate change risks become more pronounced over long time horizons—horizons which may in some cases exceed the timeframe used in business planning and in justifying new investments. Put differently, the benefits of adaptation measures may not be fully realized in a given business timeframe. Any disparity between cost and benefit timeframes needs to be considered and acknowledged as part of the overall business case. The effective lifetime of critical assets is a useful timeline to use when evaluating potential impacts and then adaptation measures related to the asset. However, when prioritizing adaptation measures across all assets and operations, companies might want to consider consistent time periods for the short-, medium-, and long-term horizons.
Discount rate	For NPV analysis, the discount rate will need to be considered. Companies tend to have standard discount rates as part of existing procedures and policies. When considering longer time horizons and more critical risks, lower discount rates tend to be appropriate. This approach also aligns with the scientific consensus that uses lower discount rates for critical climate issues (e.g., in IPCC reports). Still, institutions need to decide whether to align completely with low discount rates used in assessing critical long-term climate risk, or whether companies— given their more limited role and reach—should take their own approach. This is also a decision where input from key stakeholders (government, regulators) would be beneficial.
Non-financial measures to consider	In addition to financial considerations, it is important to assess adaptation measures in terms of their non- financial implications, including reputational risk/benefit, ease of implementation, time until implementation, upfront investment, geographical distribution, technology fit in the overall system, etc. These measures can play a significant role in determining if a specific measure is the right decision for a given organization.

Cost-Benefit Analysis

There are a range of approaches to evaluation of capital investment decisions that can be used to evaluate adaptation measures, including net present value (NPV), return on investment (ROI), payback period (PBP), benefit-cost ratio (BCR), extreme value analysis (EVA), and real options value analysis (ROV).

Each adaptation measure will have a unique cost profile in terms of its capital investment and operational cost impacts. Some measures will require altogether new investments, while others will change the scope and timing of planned investments, and still others will require reallocations of committed resources for operations—including, for example, maintenance cycles (human resources, technology use, etc.). This variation in cost structure and potential cost allocation should be kept in mind—i.e., there is no single one-size-fits-all way to allocate adaptation costs, given the wide range in potential adaptation measures that may be pursued.

The benefits of adaptation measures, meanwhile, can be expressed and evaluated primarily in terms of their avoidance benefit—i.e., how they may help the company avoid direct and indirect costs, as well as the non-financial impacts that would occur in the absence of such measures. **Table 14** below elaborates on potential benefits of various adaptation measures.

This analysis should start with lifetime costs of the climate risk to selected assets and the company as a whole in the absence of any adaptation measure. The task of estimating such future costs can be challenging and complex. Part of the business case will need to involve making explicit both the probability and the impact of potential costs in the absence of adaptation. In other words, this analysis should be explicitly tied to the risks of potential climate impacts on the company. In addition, the estimation of future costs can be informed by the company's own historical costs as well as reasonable extrapolations from similar events in other companies, where such information is publicly available.

TABLE 14: BENEFITS OF ADAPTATION MEASURES

Type of benefit	Explanation and examples
Direct financial benefits: Avoidance of potential costs that may be directly incurred by companies from climate change impacts in the absence of adaptation measures	• Restoration and repair costs, including parts and labour • Replacement costs for damaged assets, including parts and labour • Replacement costs for equipment that cannot be relocated • Administrative costs for restoration and repair activities, including inspections, procurement, and installation/ removal of temporary measures • Relocation costs, including property, infrastructure, engineering, and installation • Costs to connect relocated assets and supporting infrastructure • Lost revenue (economic loss) as a result of damage and disruption to assets • Reductions in worker productivity • Potential legal liabilities[58]
Indirect financial benefits: Avoidance of financial costs to the organization's stakeholders as a result of a climate/weather impact on the company's own assets and operations	The electricity sector is highly interconnected and climate impacts in one part of the grid can have ripple effects elsewhere. For example, a loss in electrical service or forced outage as a result of a climate impact to a company in one subsector could entail significant financial costs to stakeholders in other subsectors, as well as financial costs to the residential, commercial, and industrial customers of the grid arising from interrupted power, damage to equipment, spoilage, and opportunity costs from idle resources.[59] Given the central importance of a reliable electricity grid—not to mention legal obligations under NERC reliability standards—it may be legitimate for the business case for certain adaptation investments to factor in such indirect financial benefits.[60]
Non-financial benefits	Some measures may also have non-financial benefits. Such non-financial considerations may include reputational risks and benefits (e.g., changes in customer satisfaction, organizational credibility) and ease of implementation (e.g., geographical distribution and resource availability).
Co-benefits: Benefits beyond adaptation considerations	Some measures may have beneficial impacts beyond the avoided costs and non-financial measures considered. For example, the installation of batteries to provide protection against disruption may also help with reducing peak power costs. Such co-benefits could also be highlighted.

The cost-benefit analysis should combine the above-mentioned estimated costs and benefits. The best approach would be to have one main financial measure that can objectively combine multiple impacts, including, at a minimum, direct expenses and avoided direct costs. NPV and internal rate of return (IRR) are two of the available methods to aid in such analysis. When the NPV is positive or when an IRR exceeds the hurdle rate, the initiative should on principle be considered.

The next issue is how to treat indirect avoided costs and indirect benefits. Depending on the organizational culture and the extent of uncertainty surrounding these considerations, companies may aim to include them as well into a single NPV or IRR measure. This approach has the advantage of combining all elements into one intuitive and generally accepted financial measure, allowing for a comprehensive comparison across measures. The disadvantage, however, is that translating indirect benefits or risks into one financial measure might require making a range of assumptions, and there could be disagreements on how those benefits should be calculated. The recommended practice is to include both the most basic, stripped-down NPV and an all-inclusive NPV and to be explicit about the assumptions.

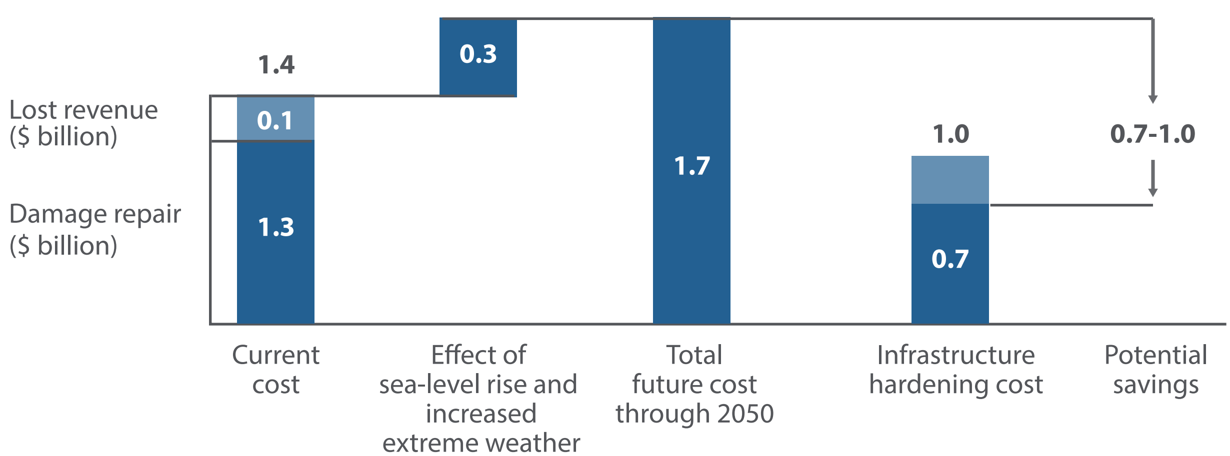
Once priority measures are selected (see below), companies should translate them into direct budget impacts over time. It is important to note that, even when only pursuing NPV-positive measures, cash outlays could increase markedly for some time, with the benefits mostly in the form of avoided future costs. Top management (and shareholders) need to be prepared to address the strategic nature of the investment and the possible misconception that the measures did not pay off economically.

In a 2019 article on climate change risks for utilities, the consultancy McKinsey analyzed extreme weather risks and found there is "a strong case for utilities to start now to take steps on climate change adaptation." The analysis examined "the financial records of ten large power utilities in seven states where hurricanes are common." It found that, over a 20-year period, a typical utility among those examined "saw $1.4 billion in storm-damage costs and lost revenues due to outages." Next, drawing on climate change scenarios, it made a (conservative) calculation that by 2050, the cost of extreme weather events and infrastructure damage would increase by $300 million on average for a total of approximately "$1.7 billion in economic damage." Lastly, the analysis determined that the cost of adaptation and making assets more resilient for the typical utility would be about $700 million to $1 billion—significantly less than the $1.7 billion figure for damages and lost revenues in the absence of such adaptation. The analysis recognized that the cost-benefit would vary based on the unique risk profile of each utility, and that there could be potential co-benefits for adaptation measures (e.g., improved reliability and enhanced diversity of supply). **Figure 19** summarizes the analysis and its key findings.

Figure 19: Cost-benefit of climate change adaptation

Taking action on resiliency can be cost-effective, especially when future climate-change risks are taken into account.

20-year storm-damage costs compared with adaptation costs for a Southeastern utility*



*Estimated costs for a typical Southeastern utility.
Source: Energy Information Administration: National Climate Assessment - Utility Financial Statements

Evaluation and Prioritization

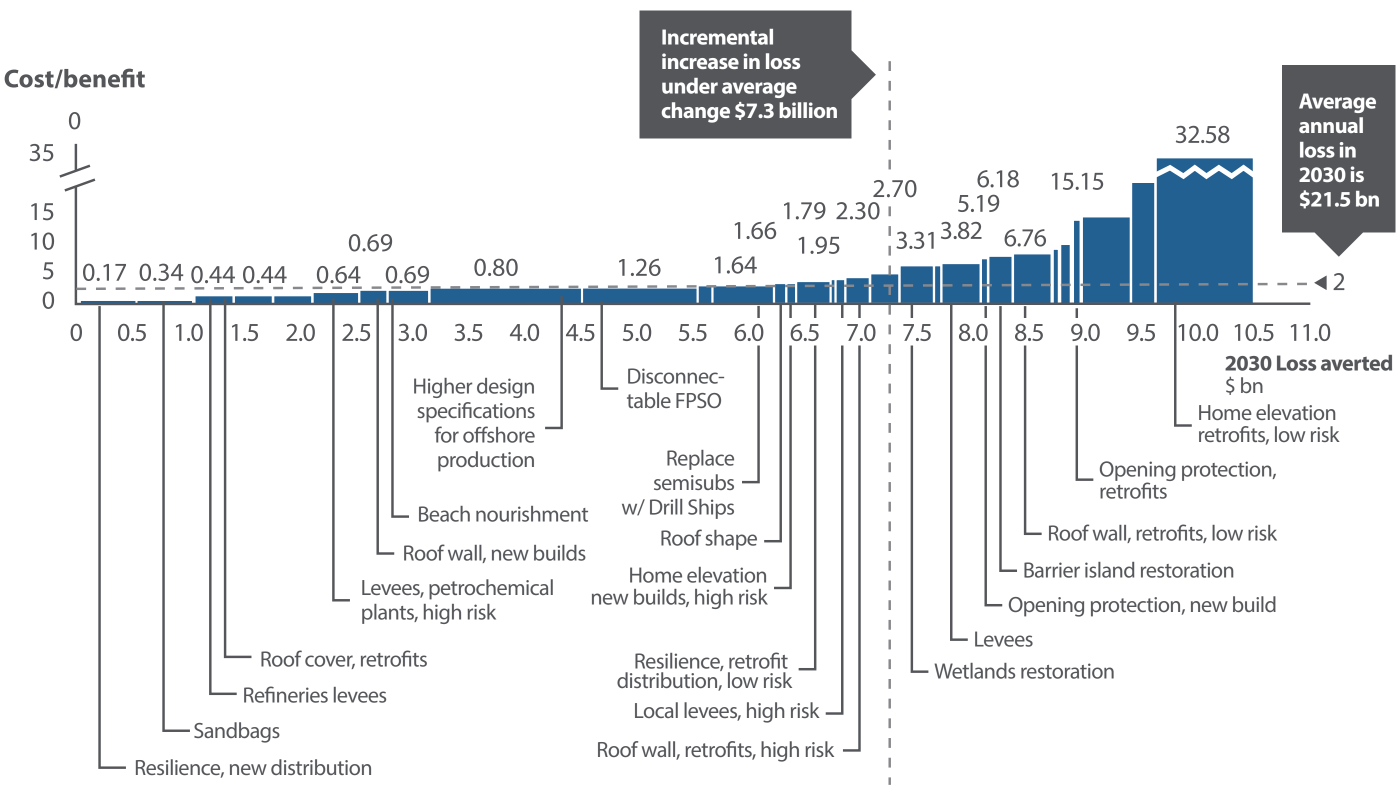
Companies will need to define the boundary conditions and evaluation criteria for adaptation business cases. Taking into account existing policies and practices for business cases generally, companies should evaluate and decide on the following key considerations that will frame the boundaries of the analysis, as elaborated in **Table 13**.

- A **cost curve** is a relative ranking of the cost of each adaptation option plotted on an intuitive and easy-to-understand curve.

Figure 20: Entergy's cost curve

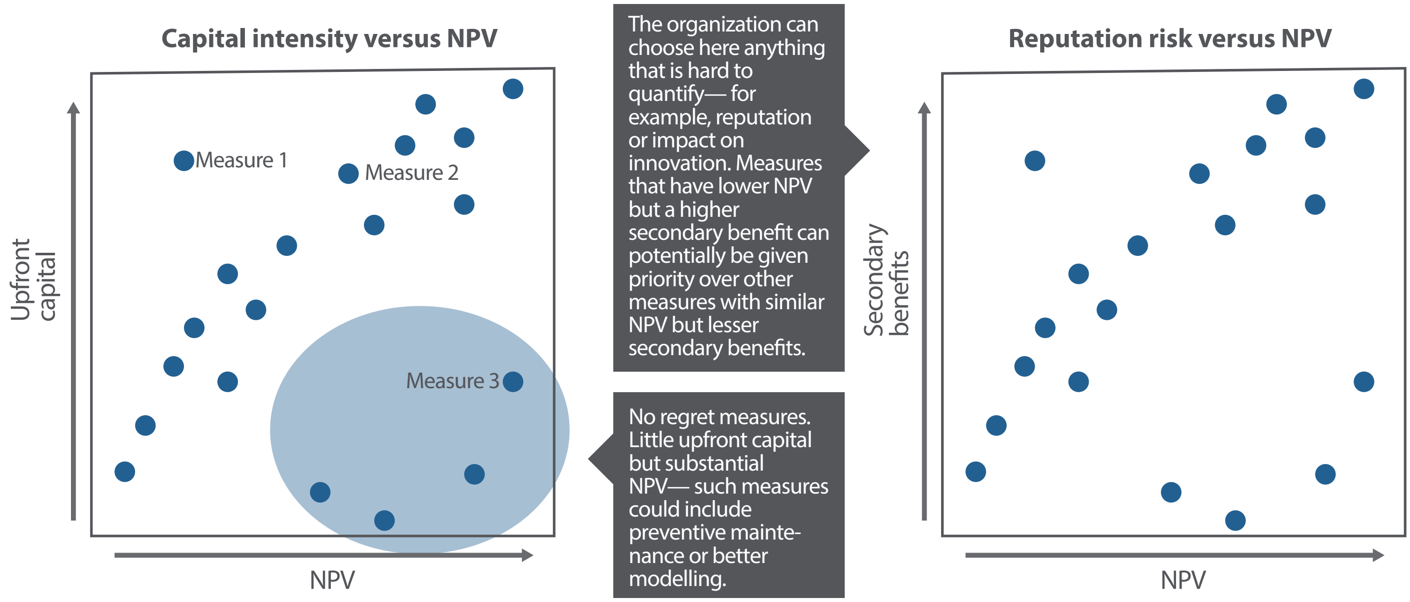
Entergy developed a cost curve as part of its project to build a more resilient Gulf Coast.[61] The analysis identified a "range of attractive measures [to] keep the risk profile of the region constant" between 2010 and 2030.[62] In the chart below, "the width of each bar in a cost curve represents the total potential of that measure to reduce expected loss up to 2030 for a given scenario," while "the height of each bar represents the ratio between costs and benefits for that measure."[63]

Entergy's Gulf Coast measures to keep risk profile of region constant between 2010 and 2030



- A **matrix** or matrices can be used to compare adaptation measures using multiple key criteria. Matrices can allow for useful comparisons among potential adaptation measures focused on two key criteria, such as capital intensity versus NPV or reputation risk versus NPV. Such focused comparisons may allow priorities to emerge with greater clarity among various options. **Figure 21** illustrates what such matrices could look like.

Figure 21: Matrices comparing measures using two criteria



- A **sensitivity analysis**, also called a **robustness analysis**, demonstrates how the impact of various measures might change as a single variable changes (e.g., CO2 pricing, higher or lower capital costs than expected, etc.), and the implications under various scenarios (more pessimistic and more optimistic than the base case). Controlling for a variable is commonly called a sensitivity analysis and examining scenarios is more commonly referred to as a robustness analysis, but they are similar and overlap in their analyses.
- An **extreme value analysis** was applied by a CEA member organization (**Figure 22**) to carry out and support quantitative resilience analyses, recognizing that natural hazards of interest are extreme events. Many published resilience analysis frameworks gravitate toward conventional risk management frameworks, which may or may not be adequate. Recognizing the low-probability/high-consequence (LP/HC) trait, the organization applied extreme value analyses (EVA) in support of its grid resilience work.

Key Challenges and Best Practices

There are two challenges worth keeping in mind when developing a business case for adaptation measures. First, some measures might overlap or be interdependent. Consider, for example, a risk of power line disruption due to storms. One adaptation method might be an automated early warning system, while another one is putting all power lines underground. Each might provide significant benefits, but the benefits cannot be double-counted. Also, a single measure can reduce more than one risk (e.g., burying lines addresses wind, snow and ice accretion, and premature aging), making other measures look less attractive. These interconnected considerations can become very complex and should be evaluated with care.

Second, as discussed earlier, there may be interdependencies across sectors. On the one hand, the electricity sector impacts every sector and the overall communities where it operates. On the other hand, electricity companies may also be impacted by other key sectors (e.g., telecommunication, municipal infrastructure). The rationale and resiliency of proposed measures should be tested and, if necessary, adjusted in light of these broader interdependencies.[64]

Figure 22: Extreme value analysis for low-probability/high-consequence events

For certain analyses, one must consider certain aspects of resilience and reliability characterizations, including:

- Resilience involves low-probability/high-consequence (LP/HC) grid outage events.
- Reliability involves high-probability/low-consequence (HP/LC) grid outage events.

Transmission resilience impact measure: In the absence of an electricity-sector-accepted resilience measure, the utility examined conventional transmission reliability statistics (transmission SAIDI and SAIFI), focusing on LP/HC impacts of natural hazard on the integrated grid. In statistics, variability is measured by standard deviations. The utility's EVA exploratory work on variance continues, and one approach to account for uncontrollable events is the exclusion of major events criteria, referred to as the "2 Beta Method"—specifically, the exclusion of any event impacting 10,000 MW- minutes or more of unsupplied energy at transmission delivery points (DPs). The threshold is about 1.95 (log normal and rounded to 2) standard deviations above the average. For this grid resilience work, the utility applied EVA for grid impact events of 10,000 MW-minutes or more; it should be noted that this threshold would be different for other utilities.

Distribution resilience impact measure: For distribution system grid resilience analyses (noting the absence of electricity-industry-accepted resilience measures), the utility considered the LP/HC events for the distribution system. For the utility's distribution system reliability work, an extreme or force majeure event is the loss of electricity supply to 10% or more of customers simultaneously. For distribution grid resilience work, the utility used this historical criterion.

See Appendix 6 for a more detailed discussion of these evaluation tools. With respect to best practices, the following points may be helpful:

- Start simple. Use simplified calculations and assumptions and a limited number of financial evaluation criteria or only a single financial evaluation criterion (the rest can be qualitative considerations). After this first round, decide on where to make assessment more sophisticated.
- Prioritize key measures early. Those measures that help reduce risks to critical and vulnerable assets and operations should receive priority attention. Other measures may also be included where appropriate but should be understood as having lower priority.
- Make use of climate-related analytical tools. Sophisticated climate-related analytical tools have been developed, including ways of calculating the value of lost load (VOLL)—a quantitative estimate of indirect costs to customers from climate change impacts[65]—and the interruption cost estimate calculator (ICE).[66] These analytical approaches are explained in **Table 15** below.

TABLE 15: ANALYTICAL TOOLS FOR QUANTIFYING INDIRECT COSTS OF CLIMATE CHANGE IMPACTS TO CUSTOMERS

Analytical tool	Explanation	Example
VOLL	VOLL represents "the value that customers place on reliable electricity service."[67] It "is usually measured in dollars per unit of power," and depends on a range of factors, including customer profile, economic conditions, time and duration of outage, etc.[68] VOLL can be calculated using proxy methods, historical data, macroeconomic analysis, and customer surveys.[69] Companies may estimate both marginal VOLL ("the value of the next unit of unserved power at peak periods") and average VOLL over a given period.[70]	Lawrence Berkeley National Laboratory (LBNL) "analyzed VOLL for different classes of customers in the United States in 2009 and updated the study in 2015."[71] The estimates produced by this study are summarized in a US Department of Energy Report, Climate Change and the Electricity Sector: Guide for Climate Change Resilience Planning (2016), including estimated interruption cost—per event, average kilowatt (kW), and unserved kilowatt-hours (kWh) by duration and customer class.[72]
ICE	LBNL developed ICE as "an econometric model that can calculate customer interruption costs by season, time of day, day of the week, geographical region … and customer class." ICE is "part of a publicly available tool" and uses "model results to calculate value of service reliability, which is substantially equivalent to VOLL."[73]	Central main power (CMP), in a 2014 rate case, "proposed to automate substations and line reclosers across its entire service territory … improving reliability with a 15-minute reduction in customer average interruption duration index (CAIDI). Using the ICE calculator, CMP calculated that the first six years of automation investments would deliver to CMP customers a net present value of $20.7 million in avoided outage costs, more than double the NPV of the investment ($10.1 million)."[74] For a chart encapsulating CMP's avoided customer outage cost estimation methodology, see **Appendix 6**.

- Leverage existing investment and planning processes. Ensure that finance and risk personnel participate in or are consulted as part of adaptation planning to ensure the form and content of adaptation-related investments and resource decisions are properly situated within existing organizational processes, analyses, metrics, and financial models. Just as adaptation planning in general should leverage and build on existing risk management processes, the business case for incremental adaptation measures will be most effectively and efficiently formulated if it is situated within already identifiable investment and planning processes.
- Incorporate climate adaptation measures into other projects or developments. Look for opportunities to combine business-as-usual projects or developments—i.e., planned upgrades and expansions—with adaption actions. For example, a certain asset that is due for replacement in any case can be replaced with a more climate-resilient design. The cost of implementing adaptation measures might be lower when implemented in conjunction with more general asset upgrades or expansions that are likely to happen anyway. The adaptation measure in question may reinforce the business case that already exists as part of that future replacement or upgrade, and it may represent an argument to take the action earlier.
- Educate and engage stakeholders across the business. Education and awareness of climate-change-related impacts for each company can help to build overall support for adaptation planning. The finance or accounting department in particular should be engaged as a key stakeholder to help ensure the costs and benefits of adaptation are communicated and quantified in ways that will align with business planning and resonate with top management.

Table 16 provides highlights from notable adaptation business case examples in the electricity sector.

TABLE 16: ADAPTATION BUSINESS CASE EXAMPLES IN ELECTRICITY SECTOR

Organization	Business case overview and highlights
Manitoba Hydro	In 1984, an ice storm caused a significant number of broken poles, and it took two weeks for Manitoba Hydro (MH) to restore service to all customers. In response, MH developed an Ice Removal Management System (IRMS) and technology upgrades. This system helps it manage the impacts of severe snow and ice storms that cause significant ice accretion on its infrastructure and are typical in the region. IRMS includes ice-visioning technology that determines the level of ice accumulation, melting and rolling technology to remove the ice, and underground supply and communication lines to avoid ice damaging the lines. Manitoba Hydro was able to compare the cost associated with restoring services following the 1984 storm to a storm of comparable magnitude and impact that occurred in 2000. This comparison provided a quantitative basis for evaluating the business case.
Con Edison	After the "one-two punch from Hurricane Sandy on October 29, 2012, and a Nor'easter that followed the next week," Con Edison had to contend with a "record 1.1 million customer outages in New York City and Westchester County."[75] In 2013, Con Edison initiated a four-year "Fortifying the Future" storm hardening program."[76] The program included "the installation of more than 1,000 'smart' switches on its overhead system, submersible equipment that can withstand flooding, redesigned underground electrical networks, and numerous other steps to avoid outages."[77] According to Con Edison's analysis, "more than 250,000 electric outages have been prevented as a result of these stringent improvements."[78]

Wherever possible, organizations should make use of their existing processes for making the business case around new investments and/or changes to resource allocations in business operations.

04 PHASE 4: PREPARE FOR IMPLEMENTATION

Phase of Plan development	Step in process
Setting the Stage	**Step One:** Define objectives and engage leadership
Risk/Opportunity Assessment	**Step Two:** Identify critical and vulnerable assets and operations **Step Three:** Identify key potential climate impacts **Step Four:** Assess risks to critical and vulnerable assets and operations
Risk Response and Adaptation Planning	**Step Five:** Identify potential adaptation measures (risk controls) **Step Six:** Develop a business case for selected measures
Preparation for Implementation	**Step Seven:** Detail and document implementing control actions **Step Eight:** Establish a process to review and improve Plan

STEP SEVEN: DETAIL AND DOCUMENT IMPLEMENTING CONTROL ACTIONS

Summary:

Once adaptation measures have been evaluated and prioritized, selected adaptation measures should be summarized and synthesized into a documented set of implementation actions for approval by senior management. Companies should consider the extent to which existing process governance supports the actions or whether governance changes are required.

The degree of documentation should be such that it is adequate to support effective management, and that it can be used to demonstrate the rigor of the process. The Plan can be part of other plans or programs. There may be a need to create records documenting key activities such as the determination of critical and vulnerable assets and operations. The Guide identifies these key activities.

If the Plan is comprised of a suite of existing management plans, programs, or processes, organizations may wish to consider creating a simple road map. The road map is a means of ensuring that the process steps have been adequately addressed, and demonstrating this to others.

The documentation may be of any appropriate format or media and should be managed in accordance with sound document control processes—i.e., available, protected, periodically reviewed, uniquely identified, approved, and version controlled.

Checklist for Step Seven

- ✔ Create a summary road map that connects key assets and operations, impacts, risks, and planned adaptation measures.
- ✔ Identify how the adaptation measures can be integrated into existing risk management systems and governance and highlight if any proposed changes in systems and governance are necessary.
- ✔ Identify schedule, budget, milestones, accountabilities, resourcing, etc. for any proposed organizational changes and incremental investments.
- ✔ Determine the right metrics across the organization to track and evaluate both the planned actions and their outcomes.
- ✔ Determine what forms of external reporting might be necessary (for legal/compliance reasons) or appropriate (as a voluntary commitment).

The extent of documentation is largely organization specific. Documentation must comply with requirements (internal or external, e.g, regulatory or ISO). The extent of documentation should be sufficient to support decision making and demonstrate the identification, determination, and assessment processes that underlie the selected controls. At a minimum, a concise document capturing approved implementation actions should be maintained. This list will enable tracking of implementation and support metrics and management review (as discussed in **Step Eight**, the final step, below). The goal of documenting implementation actions is to provide assurance that the identified risks and opportunities are being adequately managed. It is up to each company to decide how it will want to provide and communicate this assurance.

Table 17 outlines a set of issues companies may consider in reviewing governing documents and preparing documentation.

TABLE 17: RECOMMENDED ELEMENTS OF DOCUMENTED (ADAPTATION) PLAN

Key issues	Explanation
Road map	A road map establishes the linkages among potential impacts and risks, key assets and operations, and planed adaptation responses—all in one place—and can be a very helpful tool for distilling the project and communicating its overall scope to senior management.
Categorization of risks	A process for identifying and categorizing risks, including determination of how many of the risks constitute enterprise-level risks (the priorities), how many can be managed and monitored within existing controls, and how many need additional controls and adaptation measures to be acceptable.
Prioritized adaptation measures	Discussion of recommended adaptation measures in response to such risks, including the business case conclusions for the selected adaptation measures.
Extent of integration with existing risk management systems and governance	There should also be an explicit discussion of how and to what degree the range of proposed measures can be integrated into the existing risk management system and governing documents. Where any changes are proposed for risk management systems and governance, these should be clearly highlighted.
Project management essentials	These include an estimated budget, timeline, resource requirements, and identification of those with the accountability and authority to implement the selected measures. For large companies, it may be appropriate to have cascading activities and milestones—i.e., an overall schedule for the organization as a whole, supported by more granular activities for divisions or business units.
Identify key metrics for evaluation, reporting, and potential disclosure	Ensure that the right things will be measured, monitored, and reported at the right organizational level and the right frequency (i.e., enterprise risks and responses to top management). For companies integrating climate change risk management into broader management systems such as ISO 14001, reporting can form part of management review. The plan should identify what forms of external disclosure might be necessary in light of legal/compliance requirements and appropriate where the company would like to commit to voluntary reporting.

Some companies may choose to develop detailed documentation that could be the basis for public disclosure. Others may choose to keep the documentation brief, highlighting for the most part the degree to which the above issues are mostly covered through integration with existing controls and risk management.

Metrics

Companies should have a monitoring and evaluation (M&E) framework in place, including appropriate metrics to track progress against targets and to allow management to evaluate and act. The framework should provide a basis for tracking the adaptation Plan both in terms of it its implementation progress and in terms of its results against the objectives (**Step One**) it was intended to achieve.

Metrics to track implementation

There should be measures tracking progress toward building adaptive capacity and implementing adaptation actions. These metrics should be explicitly linked to the prioritized adaptation measures that form part of the integrated adaptation Plan. Many such metrics could be process based. For example, if one of the adaptation measures is to raise awareness by training 1,000 people on climate adaptation within a certain timeframe, the metric could be to track the percentage of those people trained at predefined intervals. Especially at the start of the adaptation process, there may be a series of self-contained actions (e.g., set up a new reporting system, analyze low-probability/high-consequence risks, upgrade a critical asset) that need to be monitored at the start and will be central to success. There could therefore be an overall metric tracking the percentage of measures from climate adaptation actions that are implemented, but there should also be metrics for each individual measure.

Metrics to evaluate results

In addition to metrics focusing on tracking the progress of the adaptation actions for implementation, there should also be metrics to focus on the results achieved. Is the Plan achieving its objectives as defined in **Step One**? This suite of metrics is intended to determine whether the overarching objective of adaptation is being met—i.e., whether the organization has become more resilient. While it may be challenging to determine meaningful metrics for this, they form the basis of the conclusion that will interest top management and other stakeholders.

ISO 14090 Adaptation to Climate Change section 8.2 suggests that due to the long-term nature, variables, and uncertainties of climate change, the outcome of a plan cannot always be assessed within short timeframes. Instead, it suggests that organizations develop indicators and monitor progress to confirm the plan is on track, so that corrective actions can be done when necessary.

Verification Process

As mentioned in the Introduction, a Verification Process has been developed to allow organizations to self-assess the status and adequacy of their Plans. The process combines yes-or-no questions with discussions of expectations. Companies may use the Verification Process both to clarify expectations for adaptation planning and to assess the status of their Plans.

Integration with Existing Risk Management Systems

All electricity companies already have monitoring and evaluation (M&E) frameworks for measuring performance and outcomes, and ISO and CSA management system standards require measuring and monitoring to ensure that programs are meeting desired outcomes. Leaving aside climate adaptation for the moment, companies already have fundamental outcome-based metrics that focus on how well the company is executing its mission. For most companies, the reliable provision of electricity is at the heart of that mission, and there are multiple metrics tracking reliability: system average interruption duration index (SAIDI), including and excluding significant weather events; system average interruption frequency index (SAIFI), including and excluding significant weather events; customer average interruption duration index (CAIDI); and forced outages. Companies can also track costs from extreme weather and climate impacts and monitor customer satisfaction levels.

While such measures are potentially very suitable for tracking outcomes, it can be difficult to demonstrate the effectiveness of adaptation measures in relation to any changes in reliability metrics for several reasons. First, large natural variability in weather already presents a continuously changing baseline, so the goal line is moving. Second, some adaptation measures may be focused on minimizing risks from rare, high-impact events. In some such cases, the extreme events for which avoided costs were calculated may not materialize within any relevant timeframe. As long as these events do not occur, there is nothing to measure and no outcome to assess. Third, causes might be interconnected. The grid going down could be caused by a failing high-voltage line, a slow warning system, and a failing backup system at the same time. Determining cause and effect may be complex.

Each company should therefore do in-depth customized analysis of its reliability measures to understand—qualitatively and, where possible, quantitatively—what is driving the trends, or if they even stay constant under varying climate conditions. By building an understanding of how climate change risks and related adaptation actions influence these measures, it can use those lessons for adjustments. For example, if reliability metrics indicate performance is getting worse, or if costs from extreme weather and climate impacts are increasing, these changes could be driven by a failure to implement adaptation measures effectively, the effect from implemented adaptation measures turning out to be lower than envisioned, or other effects—or they could be wholly unrelated to the adaptation measures and extreme events might have been unusually frequent or extreme. In short, only a dedicated analysis of underlying drivers will allow for continual improvement as discussed in **Step Eight**.

Reporting

Reporting on the extent to which controls implemented are managing risks and on the significance (or materiality) of residual risks to stakeholders is essential. Key stakeholder expectations and requirements in terms of reporting (what, when, to whom) should be determined and will help inform what metrics and processes are required to ensure conformance. **Internal** to the organization, reporting to top management will help determine whether the system is meeting the intended outcomes or whether adjustment or refinement is required. In this manner, it will set the stage for the process of continual improvement. **External** to the organization, reporting of material risks may be a regulatory obligation for some companies, while others may choose to voluntarily disclose such risks.

Mandatory reporting

Some companies are reporting issuers under Canadian securities law. All reporting issuers are required to disclose information material to investor decision making, including material environmental issues.[79] Generally, information is considered material if it might impact the market price or value of an issuer's securities, or if a reasonable investor's decision to buy, sell, or hold securities would likely be influenced or changed if the information were omitted or misstated. As **Figure 23** illustrates, even medium- to long-term risks that might reasonably be considered as material should be disclosed.

Figure 23: CSA staff notice on climate-change-related risk

"An issuer's materiality assessment should not be limited to risks that might reasonably be expected to have an impact upon an issuer in the near term, to the exclusion of risks that may only crystallize over the medium to long term. If an issuer concludes that a climate-change-related risk could reasonably be expected to have a potential material impact on the issuer at some point in the future, it should be disclosed, even if it may only arise over the medium or long term"[80]

Voluntary reporting

Some companies—whether subject to mandatory reporting obligations or not—may choose to provide climate-related disclosures voluntarily via various means (e.g., sustainability reports, survey responses, on their company websites, or through various reporting initiatives). There are several voluntary reporting initiatives and frameworks relevant to sustainability and climate change.[81] In 2015, Financial Stability Board Chair and Bank of England Governor Mark Carney appointed Michael Bloomberg to head an industry-led Task Force on Climate-Related Financial Disclosures (TCFD).[82] The TCFD's mandate is to develop voluntary, consistent, climate-related financial disclosures for use by companies when providing information to lenders, insurers, investors, and other stakeholders.[83] Disclosing in line with TCFD is now considered best practice in the voluntary space—although metrics for adaptation are still under development by stakeholders supporting TCFD implementation—and can help companies prepare for mandatory reporting.[84]

Leading electricity companies In the United Kingdom and the United States are starting to disclose under TCFD:

1. **SSE:** Based in the United Kingdom, SSE "is involved in the generation, transmission, distribution, and supply of electricity; in the production, storage, distribution, and supply of gas; and in other energy services."[85] In November 2017, it "committed to meeting [TCFD's] voluntary recommendations in full by 2021," making it among the first electricity companies to do so.[86] In its 2018 Annual Report, SSE provides its "initial response to the four themes of the TCFD recommendations—strategy, metrics and targets, governance, and risk management."[87]
2. **Duke Energy:** In its 2017 Climate Report to Shareholders, Duke Energy outlines a risk management process for managing physical risks focused on three main activities: system hardening; emergency planning, response, and recovery; and managing water scarcity, as elaborated upon in Table 18 below.

TABLE 18: DUKE ENERGY'S DISCLOSURE OF HOW IT MANAGES PHYSICAL RISKS

Activity	Highlights
System hardening	"As part of Duke Energy's plan to invest $25 billion over 2017–2026 to create a smarter, more modern grid, nearly $7 billion is included over the first five years specifically for storm hardening and targeted undergrounding. These investments are aimed at improving resiliency and hardening the grid against extreme weather to make the grid less likely to experience outages or equipment failure, and to minimize impacts to customers from outages when they do occur. Investments will include substation and transmission line upgrades, increased system automation, equipment modernization, elevating substations in flood-prone areas, replacing and strengthening utility poles, and relocating miles of hard-to-access overhead power lines underground. These investments will help prevent outages, especially during storms, and provide faster restoration times."[88]
Emergency planning, response, and recovery	"[Duke Energy] formed a new storm event organization to increase our ability to quickly handle surges in customer inquiries, increased the number of storm restoration staging areas to more quickly distribute resources, and employed improved communications technologies to provide proactive outage alerts and power restoration updates to affected customers. We also conduct systematic tree trimming to reduce the risk of damage to our power lines. In addition, almost all new residential lines are being installed underground to protect them from storm damage … We are active participants in regional utility grid response and recovery companies, such as Grid Assurance, to enable effective utility collaboration and resource sharing during major outage events … Our experiences preparing for and responding to the impacts of severe weather events help us plan and prepare for future events to reduce their operational and economic impacts."[89]
Managing water scarcity	"Because of the importance of water to generating electricity, prolonged drought poses a risk to our operations … In response to the 2007 drought, we established an in-house Drought Mitigation Team to monitor and forecast drought effects on the lake system storage. We also implemented equipment and operational changes at nuclear and coal-fired generating plants to reduce drought- related risks. The experience Duke Energy gained from the 2007 drought will help us respond effectively to potential similar events in the future … Since 2011, we've been steadily reducing our water intensity, defined as the amount of water consumed per MWh generated … Much of the coal generating capacity Duke Energy has retired since 2011 has been replaced with natural gas combined-cycle generation, which withdraws significantly less water than coal-fired units for cooling purposes."[90]

Appendix 7 provides additional examples of risks that may be material for reporting and disclosure.

STEP EIGHT: ESTABLISH A PROCESS TO REVIEW AND IMPROVE PLAN

Summary:

Periodically, the Plan should be reviewed against the overall objective as well as specific performance metrics. The overall question is whether the climate change adaptation planning components and associated controls continue to meet the intended outcome.

Additionally, the Plan should be periodically assessed from the standpoint of continued suitability, adequacy, and continual improvement. The field of climate change adaptation is ever changing—science will continue to evolve, modelling will become more sophisticated, technology will advance, and interested party expectations will change. Top management must be involved in such reviews and should determine the ongoing suitability, adequacy, and effectiveness.

Checklist for Step Eight

- ✔ Determine the ongoing project management requirements of the Plan—what will be measured, monitored, and reported.
- ✔ Establish a process or principles that will be used to monitor the Plan, after it goes into effect, for its suitability, adequacy, and effectiveness.
- ✔ Present implementing actions and any proposed governing document changes for senior management's approval.

There are two straightforward and important reasons for ensuring such a process of continual improvement. First, continual improvement is a fundamental feature of risk management systems—it is intended to help manage risks effectively, improve performance, and fulfill compliance obligations. The process of reviewing and improving the Plan is a stakeholder expectation (as well as an ISO requirement). Stakeholders have come to expect that those with accountability and authority exercise reasonable care in managing risks, an expectation that also applies to climate change and extreme weather risks. The review and continual improvement of a plan-do-check-act (PDCA) cycle is intended to periodically test whether controls and adaptation measures are meeting objectives or whether changes are required in light of evolving circumstances.

Second, climate change—the core challenge the Plan is meant to address—is itself changing, and therefore so are the potential responses to it to ensure resilience. The pace of climate change is accelerating in comparison with older forecasts, government policies and corporate strategies are evolving in myriad ways, and there are technological innovations occurring (e.g., in artificial intelligence and energy storage, among other areas) that could impact the adaptation options available in response to specific risks as well as their costs and benefits relative to each other.

Continual monitoring, updating, and improvement are therefore required to incorporate relevant developments in climate science, policy, technology, and best practices to course correct as needed; and to ensure continued success.

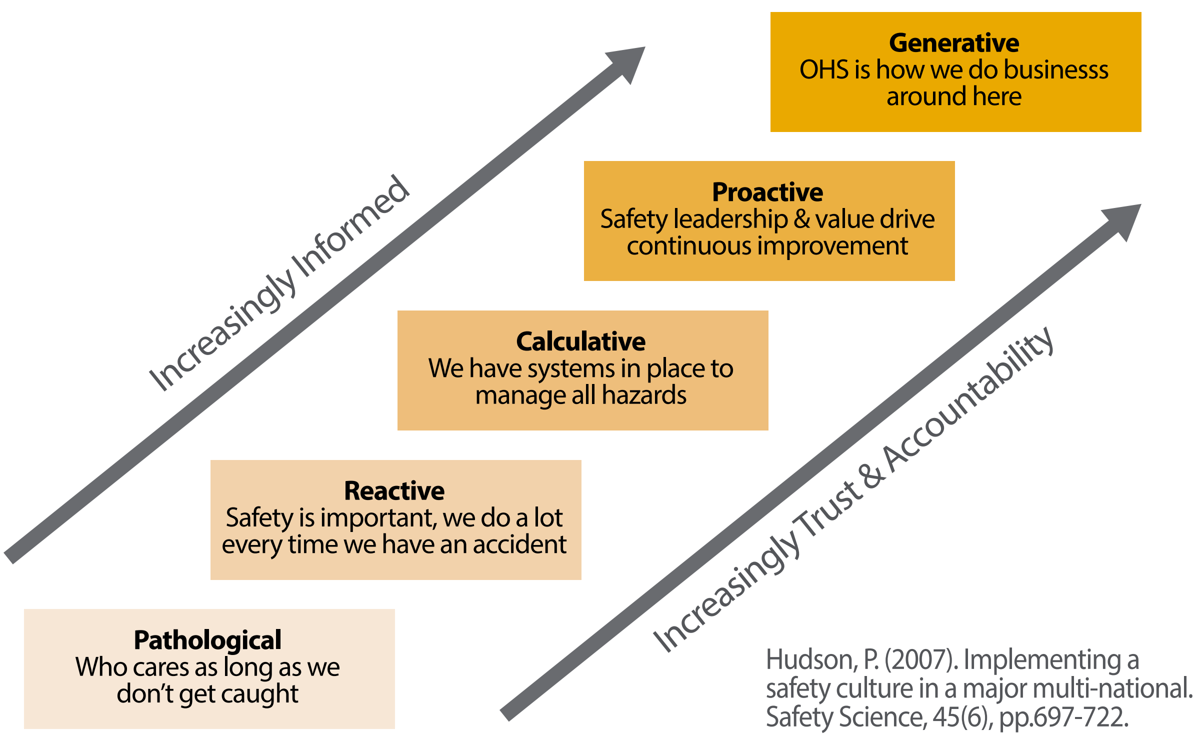
Climate adaptation Plans should be regularly reassessed through the M&E framework discussed in **Step Seven**. If adaptation actions are facing implementation difficulties, and/or if they are not producing the intended outcomes, companies will need to consider modifications to determine whether different or additional adaptation measures are required. And even if the Plan appears to be achieving intended outcomes, the risk profile may be changing beneath the surface, so assumptions must be periodically renewed and refreshed.

Companies should exchange information regularly with important stakeholders including municipalities and interdependent sectors, as these stakeholders may help them identify reasons for revising risk assessments or for how they assess the relative merits of various potential adaptation responses. It is also important to ensure that top management remains engaged and supportive through periodic discussions with them, and if deficiencies are identified, to determine how to resolve such deficiencies. Indeed, given the importance of continually engaging top management and reassessing the objectives of adaptation planning, the considerations in **Step Eight** come full circle back to **Step One**.

The ultimate aspiration for adaptation planning should be that it achieves such **maturity** that it becomes an integral part of the company's business culture, standards, and processes.[91] An analogy can be found in the evolution of safety culture in Canada and other mature economies over the last fifty years. At an early stage of improving safety culture, new safety programs and initiatives of various kinds were introduced to companies in electricity and other sectors. As companies progressed in their understanding of safety issues and processes, their safety cultures went through step changes in maturity, as illustrated conceptually in the ladder in **Figure 24** below. Among electricity companies in Canada today, safety should be intrinsic to and embedded in all activities and decisions (if safety is not so embedded, the company is on a lower rung of the ladder). In a similar manner, improving resilience from climate change and extreme weather risks will be an ongoing imperative and should eventually become fully embedded in the culture of Canadian electricity companies.

Figure 24: The evolution of safety culture

The chart below illustrates a spectrum of possible safety cultures in companies, from "pathological" at one extreme to "generate" at the other.[92]



The field of climate change adaptation is ever-changing—science will continue to evolve, modelling will become more sophisticated, technology will advance, and expectations will change.

APPENDIX 1: ALIGNMENT OF GUIDE WITH ISO 14001/14090

The numbers in parentheses in the following table reference clauses in ISO 14001:2015 and ISO 14090:2019.

General alignment

ISO 14001: Environmental Management Systems —Requirements and Guidance for use

Climate change and extreme weather can be managed as other risks, using standard processes for risk identification, characterization, assessment, and control such as those found in environmental (ISO 14001) and other management systems. Some existing controls in some companies may already be adequate to address climate considerations, e.g., reservoir and vegetation management. ISO management system standards are risk based (0.5); they recommend integration (0.5), and they require competency and awareness. Climate change mitigation and adaptation are explicitly referenced—(0.1) background; (4.1) context; (A4.1).

The plan-do-check-act (PDCA) approach is also consistent between the Guide and ISO. PDCA is fundamental to ISO and is also the basis of the Guide. The Guide focuses on planning (plan) to set the stage for future implementation (do), but it also references monitoring, measurement, analysis, and evaluation (check) and continual improvement (act).

ISO 14090: Adaptation to climate change—Principles, requirements and guidelines

Climate change is recognized as impacting organizations in various ways and therefore adaptation is required to reduce the threats and maximize the opportunities. Further, ISO 14090

- introduces the concepts of hazards, impacts, and vulnerability related to both climate change and weather extremes,
- recognizes that adaptation measures are most effective when integrated into existing processes (mainstream and embedded), and
- requires that organizations assemble adaptation plans and establish climate change adaptation priorities.

Phase of Plan development	Step in process	Alignment/integration with ISO 14001	Alignment with ISO 14090
Setting the Stage	1. Define objectives and engage leadership	**(0.3) Success factors:** Success depends on commitment from all levels and functions of a company, led by top management. Companies can leverage opportunities to prevent or mitigate impacts and enhance opportunities. Top management can effectively address risks and opportunities by integrating environmental management into the organization's business processes, strategic direction, and decision making, aligning them with other business priorities. **(1.0) Scope:** The standard helps companies achieve their intended outcomes (see 4.4, A.3). The standard is applicable to any organization. (4.1) Understanding context: "The organization shall determine internal and external issues that are relevant to its purpose and that affect its ability to achieve the untended outcomes—such issues shall include environmental conditions being affected by or capable of affecting the organization." (**4.2)** Understanding the needs and expectations of interested parties **(4.4) EMS:** To achieve the intended outcomes (improved performance, compliance, and achieving objectives), companies shall establish, implement, and continually improve the management system (MS) **(5.1) Leadership and commitment:** Top management shall demonstrate leadership by taking accountability for the effectiveness of the system; ensuring objectives are established and are compatible with the strategic direction and context of the company; ensuring integration of the EMS into business processes; ensuring required resources are available; communicating the importance of the MS; ensuring that the intended outcomes are met; directing persons to contribute to the effectiveness of the MS; and promoting continual improvement. **(5.2) Policy:** Includes commitment to protection of environment, including climate change mitigation and adaptation, and continual improvement. **(6.2.1) Environmental objectives:** The company shall establish objectives at relevant levels and functions, taking into account environmental aspects, compliance obligations, and its risks and opportunities. Objectives shall be consistent with policy, measurable (where practicable), monitored, and updated as appropriate.	Introduction: Climate change is and will continue to impact organizations; it represents both a threat and an opportunity; climate change adaptation is required. **(7.3.4)** The organization shall take into account internal and external interested parties that influence or are influenced by the long-term climate- relevant decisions. 1. The adaptation Plan shall state the objectives that the organization aims to meet by implementing the Plan. 2. The Plan shall specify the scope and boundaries of the organizational system being addressed. **(7.4.6)** The organization shall state the adaptive capacity it requires to effectively implement and manage the identified adaptation. It shall state how the climate change adaptation process is to be embedded. **(7.4.9)** Where the climate change adaptation Plan includes activities relating to interested parties, these shall be described. **(8.1)** Top management shall demonstrate leadership of, commitment to, and accountability for implementation by taking accountability for effectiveness of the Plan, ensuring policies and objectives are established, ensuring integration of the climate change Plan into the organization's business processes, ensuring that the adaptation Plan meets its intended outcomes, promoting continual improvement, etc.

Phase of Plan development	Step in process	Alignment/integration with ISO 14001	Alignment with ISO 14090
Risk Assessment	2. Identify critical and vulnerable assets and operations 3. Identify key potential climate impacts	**(6.1) Actions to address risks and opportunities:** The company shall establish, implement, and maintain processes to address environmental aspects and compliance obligations, and determine risks and opportunities related to its issues and requirements. **(6.1.2) Environmental aspects:** The company shall determine its environmental aspects that it can control and those that it can influence. It shall take into account change and normal, abnormal, and reasonably foreseen emergency situations.	Introduction: Impacts can be either direct or indirect. **(6.1)** Climate parameters can include temperature, precipitation, humidity, sea level, wind speed and direction, and freeze-thaw cycles. **(7.3.4)** The organization shall assess adaptation option)s over the expected lifespan of the decisions' consequences—e.g., decisions with consequences that last >20 years require a high decision-making capability due to the uncertainty that has to be managed in the decision. **(7.4.5)** The Plan shall describe past, present, and future impacts both positive and negative, and direct, indirect, and cross-cutting (systemic) impacts that climate change poses.
	4. Assess risks to critical and vulnerable assets and operations		**(6.1)** The organization shall assess how its activities, products, and services might be impacted by climate change. Consider both chronic (slow onset) and acute (extreme events). **(6.2)** Impact assessment methods can include risk assessment, vulnerability assessment, and threshold analysis. These techniques capture vulnerabilities exposure, likelihood and consequence, consideration of the organization's ability to manage the impacts, dependencies and interdependencies, and systemic thresholds. **(6.3)** Assess adaptive capacity. **(7.3)** The organization shall identify and use reliable and appropriate sources of information. Information can be science based, expert opinion, feedback, and views from interested parties.

Phase of Plan development	Step in process	Alignment/integration with ISO 14001	Alignment with ISO 14090
Risk Response and Adaptation Planning	5. Identify potential adaptation measures (risk controls)	**(6.2.2) Planning actions to achieve objectives:** In planning how to achieve its objectives, the company shall determine what will be done, by whom, when it will be completed, and how the results will be evaluated, including indicators for monitoring progress toward achieving its objectives.	**(5) Pre-planning:** Organizations shall determine leadership and broader governance required for the climate change adaptation process. **7.3.2** Some climate change actions imply incremental changes within current systems and operations while others imply more fundamental transformation.
	6. Develop a business case for selected measures		**7.1** The organization shall establish climate change adaption priorities. **7.3.3** Decision-making approaches can include such things as a cost-benefit analysis.
Preparation for Implementation	7. Detail and document implementing actions	**(6.1.4) Planning action: The company shall plan:** a) to take actions to address its significant aspects, compliance obligations, and risks and opportunities; b) how to integrate and implement actions into its EMS or other business processes (see 6.2, 7, and 9.1); and c) evaluate the effectiveness of the actions. Technological options and financial and business requirements shall be considered. ISO speaks more to overall integration.	**(7.1)** The organization shall assemble a climate change adaptation Plan, and shall incorporate and embed climate change adaptation into policies, strategies, and plans. **(7.2)** The organization shall state the relationship of adaptation Plans with other internal policies, strategies, codes, legal and other requirements, etc. (7.4.1) Objectives shall be stated; uncertainties shall be noted; decision-making approach shall be documented; prioritization process shall be described; etc. **(7.4.3)** Where baselines are used, they shall be clearly defined. **(7.4.4)** The Plan shall state climate change information past, present, and future; underlying GHG scenarios; and any other scenarios used, e.g., socio-economic demographic. **(7.4.7)** The climate change adaptation Plan shall document actions to be implemented along with explanations of why some actions were adopted and others not. Each documentation shall include objective, description, indicators, and time scales, and should include cost-benefit barriers, capacity, etc. **(8.2)** The organization shall prepare a plan that documents the processes, including inputs and outputs, which ensure actions identified in the adaptation Plan are delivered. Developing an implementation plan is critical to the delivery of the adaptation Plan and the preparation of the monitoring and evaluation plan.

Phase of Plan development	Step in process	Alignment/integration with ISO 14001	Alignment with ISO 14090
Preparation for Implementation	8. Establish a process to review and improve Plan	**(4.4)** EMS (requirement to continually improve **(6.2.2)** Planning action (includes timelines and how results will be evaluated, including indicators) **(7.4)** Communication **(7.4.2)** Reporting (internal and external communication) **(9.1)** Monitoring, measuring, analysis, and evaluation: The company shall monitor, measure, analyze, and evaluate its performance by determining what needs to be monitored and measured, the methods to ensure valid results, the criteria against which to measure, appropriate indicators, when the monitoring and measuring will be performed, and when the results are to be analyzed and evaluated. **(9.1.2)** Evaluation of compliance **(9.2)** Internal audit **(9.3)** Management review: Top management shall review the system at planned intervals to ensure its continuing suitability, adequacy, and effectiveness. **(10.3)** Continual improvement: The system shall be continually improved to enhance performance.	**(4.10) Transparency:** Reports reports and communication are based on open, understandable, and appropriate presentation of information for interested parties. (7.2) The organization shall adopt an adaptive management approach that enables the capture of new knowledge and learning to inform future decision making. **(7.4.6)** Indicators should be determined to measure how adaptive capacity evolves over time. The same indicators can be used for monitoring and evaluation. **(7.4.8)** The organization shall prepare an implementation plan, a measuring and monitoring plan, and arrangements for communication. **(8.2)** Due to the long-term nature, variables, and uncertainties of climate change, the long-term outcome of the Plan cannot always be assessed within short timeframes. Instead, monitor processes and use proxies that better capture the Plan's likely impacts—i.e., develop indicators that can be used to confirm a trajectory for the adaptation Plan such that monitoring and evaluation can be used to initiate corrective action if necessary. **(9.)** Monitoring and evaluation are used to assess, inform, and review the adaptation Plan so that satisfactory progress is confirmed and indications of unsatisfactory progress are identified early enough for corrective action to be taken. Indicators can be quantitative or qualitative. **(10.)** Organizations shall communicate their climate change adaptation to external interested parties. The communication shall be accurate, verifiable, and relevant (not misleading). The scope of the Plan shall be clearly communicated. Reporting shall be characterized as open, comprehensive, and understandable.

APPENDIX 2: LIST OF KEY ASSETS AND OPERATIONS

This list identifies some assets and operations that might be critical and/or vulnerable; companies may identify others beyond those provided here. Where an item on the list below is also included in **Step Two**, an asterisk is provided.

Asset or operation	Explanation
Conductors	Conductors are critical for the core business and vulnerable to climate in general and extreme weather. Different types of conductors—overhead, surface, and underground—have notable differences. For instance, overhead conductors are more susceptible to wind issues and icing issues, while surface and underground conductors may have risks of overland and subterranean flooding.
Support structures for conductors: towers and poles	Downed poles or towers (or masts) are often the cause of power outages. If above-ground conductors (wires) are critical, then by extension the support structure is as well. Any impact (e.g., wind, ice, electrical storms, fires, infestation) that could damage support structures is a risk.
Transformers	Heat waves may lead to faster transformer insulation breakdown, increasing maintenance needs, and shortening lifespans of power transformers.
Vegetation management*	Vegetation management may be a critical and vulnerable operation.[93] Maintenance workers may need to access remote locations, but access routes could be compromised by extreme weather, raising maintenance challenges and reliability risks. Other potential challenges include lengthened growing seasons, increased potential stresses from insects and disease, and increased wildfire risks.
Substation assets	Assets include circuit breakers, grounding structures, transformers and cooling systems (see above), bus bars, underground cables, and protection/control equipment. Could be vulnerable to flooding.
Generation cooling water intake systems*	Thermal and nuclear generation withdraw, use, and discharge significant amounts of water for cooling purposes. As air and water temperatures increase, plants may need more water for cooling, but they may also be more constrained in how they can discharge water, potentially leading to plant de-rating or shutdowns. Water filtration systems may also be compromised.
Water intake systems (general)	Warmer environments may support increased growth rates in biota, including algae, and in invasive species such as zebra mussels. Algal blooms and zebra mussels can in turn jeopardize plant operations by impairing water intakes or restricting flow by accumulating in pipework.
Service water	Service water is any water used in the plant other than cooling water or potable water. Typically used for such purposes as fire water and process water. Could be impacted by invasive species such as zebra mussels.
Water for hydro generation*	Lower water availability may reduce a company's ability to generate electricity, which impacts electricity sales and revenues; higher water availability may be an opportunity for additional generation and export. Hydro generation also relies on a resource that often has competing uses: lakes and rivers are also used for fishing, recreation, transportation, water consumption, irrigation, etc. A change in water availability or level (e.g., an extended drought in the summer) may impact several uses at once, creating the potential for conflict.
Dam safety and integrity	Record-setting rainfall could damage or, in an extreme case, even undermine emergency spillways.
Fuel supply chains	If the time to replenish inventory exceeds the number of days of inventory on hand, and the inventory is critical (e.g., diesel generation), the plant may be forced to shut down.

Asset or operation	Explanation
Overhead conductors*	Issues that relate to overhead conductors for distribution and transmission (see above) also apply to generating facilities.
Solar panels	Solar panels have the potential to be damaged by flying debris from hurricanes, tornadoes, microbursts, and gusts, and potential vulnerability if they are installed in flood plains.
Key system component at ground level or underground*	Any essential system components at ground level or underground may be vulnerable to floods, storm surges, and/or sea level rise.
Work access during extreme weather events	Extreme weather events may prevent critical staff from travelling to work when needed.

APPENDIX 3: LIST OF POTENTIAL CLIMATE IMPACTS

Below is a list of potential climate impacts for the electricity subsectors (distribution, generation, and transmission) and some specific assets within those subsectors. They are organized within the three categories of impact discussed in **Table 4**:

1. Changes in annual and/or seasonal patterns
2. Increasing frequency, intensity, and/or duration of extreme events
3. Changes to the ecosystem

This (non-exhaustive, but broadly illustrative) list may be useful in each company's efforts to identify key potential climate impacts.

1. Changes in annual and/or seasonal patterns

Changes in mean annual and/or seasonal temperature	• **Higher ambient temperature** impacts electricity demand and associated pressures on the grid—potentially an issue for **all three subsectors**. • **Higher ambient temperature** may entail increased maintenance requirements—potentially an issue for **all three subsectors**. • **Higher ambient temperature** may raise occupational health and safety issues (e.g., comfort levels and humidex readings) for maintenance and operating personnel—potentially an issue for **all three subsectors** (and, in theory, could impact critical assets and operations with outdoor workers). • As **summer peaks increase** in certain jurisdictions, the balance of long-term energy contracts could be impacted (e.g., the mix of "diversity agreements" between winter-peaking and summer-peaking jurisdictions)—potentially an issue for all three subsectors. • Higher ambient temperatures may reduce distribution efficiency and increase line losses. • Higher ambient temperatures may reduce transmission efficiency and increase line losses. • Premature aging: increased heat may cause conductor sag and annealing (for distribution and transmission). Sagging may lead to issues of phase-to-phase shortages or affect safe limits of approach. • Higher ambient temperatures may reduce efficiency of thermal and nuclear generation plants as well as combustion turbine units. • Thermal and nuclear stations withdraw, use, and discharge significant amounts of water for cooling purposes. As air and water temperatures increase, plants may need more water for cooling, but they may also be more constrained in how they can use and discharge water, potentially even leading to plant de-ratings or shutdowns. Plants will need to adjust operations in order to reject the same amount of thermal energy, for instance by increasing flow rates, increasing maximum discharge temperatures, or improving cooling infrastructure such as condensers.
Changes in water availability	• About 60% of Canada's electricity production is hydroelectric, so major changes in water availability could potentially have significant supply, reliability, ancillary services, and planning impacts on the electricity system, especially in provinces where hydroelectric generation plays a central role. • Changes to water availability in the United States could impact the electricity trade balance and potentially also reliability across the system (all three subsectors). • Hydro generation relies on a resource with competing uses: lakes and rivers are also used for fishing, recreation, transportation, water consumption, irrigation, etc. A change in water availability (e.g., an extended drought in the summer) may impact several uses at once, creating the potential for tensions and conflict. • Hydroelectric operations may need to be modified to address increased risk of upstream or downstream flooding.

Changes in type, timing, and intensity of precipitation	• Wind/rain combination can cause damage to structures (all three subsectors). • Heavy precipitation may lead to flooding, resulting in oil/chemical spills (all three subsectors). • Potential to overburden storm drainage, leading to flash flooding (flooding of underground vaults and surface infrastructure) and related damage and outages (also see overland flooding discussed below) (all three subsectors, especially distribution). • Potential to accelerate corrosion of steel components. • Precipitation can cause changes in asset maintenance and cleaning needs (e.g., corrosion of transformers made with regular steel, rotting of wood structures due to increased moisture, etc.). • May impact reservoir management (hydroelectric generation). • Freezing rain may cause ice accretion on overhead conductors (transmission and distribution).
Changes in runoff and ground conditions	• Erosion can cause infrastructure damage (all three subsectors). • Saturation or destabilization of soil can impact slope stability, causing landslide risk (all three subsectors).
Changes in extent and duration of snow cover (e.g., timing of spring melt), permafrost melt, and ice conditions (e.g., deepening of annual thaw)	• Changes to winter conditions in remote locations, including ice/thaw freezes, could raise maintenance and/or safety issues (all three subsectors). • Ice roads—access, quality, and duration—are a potential issue for all three subsectors. • Ground shifting, e.g., from thaw sensitivity and settlement of permafrost, may impact ground and integrity of structures—e.g., physical damage to asphalt and concrete; failure of dykes and containment; and compromised stability of pole foundations, power line towers, vaults, and cable chambers (all three subsectors). • Could impact on reservoir recharge and timing of recharge relative to summer peak demand (hydroelectric generation). • Conductor supports can sink, tilt, or both (transmission and distribution). • Ground shifting and lack of slack can cause damage to transmission tower footing—e.g., some parts may be frozen while others are not, leading to steel buckling. • Can lead to frost heave—i.e., vertical lifting of piles due to freezing of water in the active layer soils—lifting pole foundations and necessitating expensive repairs (transmission and distribution). • Can shift buildings and foundations so ground electrode conductors need to be changed and new conductors must be installed (transmission and distribution). • An increase in freeze-thaw cycles accelerates degradation.

2. Increasing frequency, intensity, and/or duration of extreme events

Heat waves	• Bulk power system may be challenged in its ability to respond to peak load (all three subsectors). • Can cause risks to safety and comfort of workers (all three subsectors). • Can cause threats to human health from lengthy power outages (all three subsectors). • Increased ambient air temperature may reduce the maximum electrical current that can safely pass through lines (distribution and transmission). • May jeopardize critical design thresholds and lead to unacceptable efficiency ratios, increasing likelihood of failure (distribution and transmission). • Could impact accuracy of power line current and voltage sensors (distribution and transmission). • Reduced capacity of transformers may lead to faster transformer insulation breakdown, increasing maintenance needs, and shortening lifespans of power transformers and batteries (all three subsectors).

Drought and wildfire	• Can cause damage to infrastructure from wildfires and increased costs of maintenance (all three subsectors). • Associated heat, smoke, and soot can affect transmission line capacity. • May create a "flashover" from electricity infrastructure—i.e., when smoke and particulate matter ionize the air, creating an electrical path away from transmission lines. • Firefighting may negatively affect transmission operation by aircraft dumping loads of fire retardant that can foul the lines or through preventive shutdowns for safety measures. • Can block access to equipment in need of response or repair (all three subsectors). • Can threaten employee and community safety, including primary threat from event and secondary threats from evacuation (all three subsectors).
Wind events	• Galloping lines, leading to failure (transmission and distribution). • High winds (70 km/h+) may cause tree branches and flying debris to interfere with electrical lines and/or damage overhead conductors (transmission and distribution). • Fallen lines have the potential to cause fires or other public safety hazards (transmission and distribution). • Flying debris can cause damage to solar panels. • Tornadoes could damage concrete poles and other permanent structures (all three subsectors).
Major precipitation events, overland flooding, and storm surges	• Flooding could jeopardize the backup generation that provides emergency power (all three subsectors). • Major rainfall could compromise the effective containment volume (all three subsectors). • Potential for landslides, erosion, and accumulation of mud and debris flow, leading to infrastructure damage and impacting slope stability (all three subsectors). • Can cause water treeing in electrical cables and cracking of cable insulation (all three subsectors). • Flash floods may result in accumulation of muck and debris in dam reservoir. • Flooded basements or installations can lead to infrastructure damage—e.g., flooding of underground vaults and surface infrastructure; damage to batteries, switchgear, underground feeder assets, and low-lying substations; and related damage and outages (all three subsectors). • Can cause increased risks of landslides, coastal erosion, and infrastructure damage (all three subsectors). • Can compromise stability of foundations of towers and cause damage due to land movement (all three subsectors). • Saturation or destabilization of soil can impact slope stability, causing landslide risk (all three subsectors). • Can cause difficulty accessing equipment and impaired ability of repair crews to respond and restore service (all three subsectors). • Increased exposure of low-lying coastal substations to inundation during storm surges can damage controllers, switches, and other components of substations (distribution). • Could hamper the ability of emergency teams to respond quickly and effectively (all three subsectors). • Can have impacts on infrastructure, including damage to drainage and sewage systems (all three subsectors).
Ice storms and freezing rain	• Ice accretion directly on towers, insulators, cable lines, and tower arms, can cause lines to drop or poles to break under the weight of ice (transmission and distribution). • Tree and branch failure due to ice/snow accretion can lead to significant increase in tree contacts with lines, causing widespread infrastructure damage and power loss—e.g., snapping power lines and breaking or bringing down utility poles (transmission and distribution). • Increased salt use causes equipment to corrode faster, leading to premature aging and the need for additional cleaning and maintenance (all three subsectors). • Can cause severe service impacts to customers (distribution, all three subsectors). • Power outages can cause threats to human health (all three subsectors).
Electrical storms	• Increased potential for lightning strikes can result in equipment damage and/or disruption of supply.

3. Changes to ecosystem

Shifts in species range or reproductive patterns for plants and animals	• Warmer environments may result in conditions that support increased growth rates in biota, including algae, and in invasive species such as zebra mussels. Algal blooms and zebra mussels can in turn jeopardize plant operations by impairing water intakes or restricting flow by accumulating in pipework. • Changes to water temperature and levels may also impact fish populations, leading to regulatory changes for hydroelectric plants. • Changes in migratory bird or species-at-risk migrations may impact siting, regulation and operations (e.g., vegetation management, "incidental take" regulations), and/or public acceptance of projects (all three subsectors, especially transmission). • Changes in the amount of pollen produced per plant and the potency of each pollen grain could impact allergies among personnel (all three subsectors).
Pathogens, pests, and diseases	• Vector-borne diseases can emerge or re-emerge, increasing exposure of outdoor workers to West Nile virus, Lyme disease, etc. (all three subsectors). • Zoonotic (e.g., rodent-borne) diseases can emerge or re-emerge (all three subsectors). • Water-borne diseases can emerge or re-emerge (all three subsectors).
Duration of growing season	• May impact vegetation management—maintenance, operations, and reliability (transmission and distribution).[94]
Sea level rise	• Salt water has the potential to cause damage (all three subsectors). • The United States has multiple facilities located on low-lying lands vulnerable to sea level rise and flooding. Damage to such facilities could impact reliability of North American grid (all three subsectors). • Increased coastal erosion and flooding has the potential to cause large-scale loss of coastal property and infrastructure. A rise in sea level could impact facilities in coastal areas (all three subsectors). • Could impact current clearance distance between water and lines (all subsectors). • Increased risk of flooding and erosion of coastal areas may exacerbate other hazards, such as ice ride-up and pile-up (all three subsectors).

APPENDIX 4: ADDITIONAL INFORMATION ON CLIMATE MODELS

Companies may also want to consider the following issues with respect to climate models.

Ouranos's Guidebook on Climate Scenarios

Ouranos has prepared a guidebook on climate scenarios that discusses differences among basic, intermediate, and detailed scenarios, including the climate variables (and the level of spatial and temporal resolution) typically considered at each level of complexity:

1. A basic assessment may examine precipitation and temperature.
2. An intermediate assessment may examine more complex indices derived from temperature and precipitation, such as freeze-thaw cycles.
3. A detailed assessment may investigate "numerous climate indices simultaneously," or may entail "studies that analyze the projected changes in extremes. In terms of single indices, the analysis of indices that are not derived from temperature and precipitation and for which there is less confidence, such as wind, humidity, streamflow, and snow on the ground, to name a few, would be included in this category."[95]

See "A Guidebook on Climate Scenarios: Using Climate Information to Guide Adaptation Research and Decisions, available" here.

Degree of spatial and temporal resolution

If the organization is seeking highly granular data, consider whether the need for such greater detail and shorter-interval time steps applies only to discrete areas or to the full territory of operation, bearing in mind that "as a general rule, increasing the resolution of a model by a factor of two means about ten times more computing power [and associated cost] will be needed."[96]

Uncertainty about future emissions

Uncertainty about future emissions and their impacts increases as the projected timeframe extends into the future. The consequence of uncertainty in emissions for climate projections is much less for the near-future climate (2020s) than it is for the distant future (2080s). The near-term climate is dominated by historic emissions of greenhouse gases and natural climate variability, while climate projections of more than fifty years become less certain due to inherent uncertainties associated with political decisions and economic and technological development.

Climate variables and criteria of interest

For the sake of completeness, it is worth noting that the Global Climate Observing System (GCOS) maintains a list of essential climate variables (ECVs). An ECV is defined as a "physical, chemical, or biological variable or a group of linked variables that critically contributes to the characterization of Earth's climate."[97] GCOS presents ECV data sets to the United Nations Framework Convention on Climate Change to "provide the empirical evidence needed to understand and predict the evolution of climate, to support evidence-based decision making on climate change, and to manage associated risks."[98] GCOS currently identifies 54 ECVs as follows:

Atmospheric

Surface: air temperature, wind speed and direction, water vapour, pressure, presipitation, surface radiation budget

Upper-air: temperature, wind speed and direction, water vapour, cloud properties, Earth radiation budget, lighting

Composition: carbon dioxide, methane, other long-lived greenhouse gases. ozone, aerosol, precursors for aerosol and ozone

Oceanic

Physics: temperature, sea surface and subsurface; salinity: sea surface; currents, surface currents, sea level, sea state, sea ice, ocean surface stress, ocean surface heat flux

Biogeochemistry: inorganic carbon, oxygen, nutrients, transient tracers, nitrous oxide, ocean colour

Biology/ecosystems: plankton, marine habitat properties

Terrestrial

Hydrology: river discharge, groundwater, lakes, soil moisture, evaporation from land

Cryosphere: snow, glaciers, ice sheets and ice shelves, permafrost

Biosphere: albedo, land cover, fraction of absorbed photosynthetically active radioation, leaf area index, above-ground biomass, soil carbon, fire, land surface temperature

Human use of natual ressources: water use, greenhouse gas fluxes

Some (but not all) of these variables are directly or indirectly related to climate criteria of interest (key potential climate impacts) for Canadian electricity companies. The following are examples of ECVs that may be relevant:

1. Atmospheric—Surface: air temperature, wind speed (including gusts, tornadoes, and hurricanes), precipitation (including rain and freezing rain); Upper-air: lightning.
2. Oceanic—Physics: sea level, sea ice, ecosystems.
3. Terrestrial—Hydrology: river discharge, groundwater, lakes; Cryosphere: snow, permafrost; Biosphere: leaf area index, above-ground biomass, fire, human land and water use.

There are, however, some conspicuous omissions on the ECV list from the standpoint of adaptation planning for electricity companies. For example:

1. Ecosystems in rivers and lakes (e.g., zebra mussels, algae) may be of interest to electricity companies, but the ECVs only refer to "oceanic" ecosystems.
2. Vegetation management is a key concern for electricity companies, but "leaf area index" and "above-ground biomass" may not capture this concern.

In short, while the ECVs provide useful scientific context for the variables being considered in climate models, companies may find it easier to identify their key criteria of interest from the list of potential climate impacts (as discussed earlier in **Step Three**).

Criteria of interest (key potential climate impacts) and surrogates

Certain criteria of interest may be difficult to model directly, e.g., tornadoes and electrical storms. Where the model does not capture parameters of interest directly, surrogates may be used—for example, the Energy Helicity Index (EHI) has been used to correlate to storm and tornado prediction. Electrical storms may use modelled vertical cloud height.

When searching for existing data or commissioning a model, companies need to be clear about their parameters of interest. For example, if the issue is ice accretion on overhead lines, projections of the number of freezing rain events per year will not provide required information. As dramatically demonstrated by the 1998 ice storm, the concern is the buildup of ice over the duration of the storm. Storm fronts are typically of 72-hour duration. The desired model outcome therefore may be to know the amount of freezing rain over 72 consecutive hours with no temperatures exceeding zero degrees (i.e., no melting). This information enables assessment of the risk based on the design criteria for the lines. There may not be a direct correlation between the model result (amount of freezing rain over a 72-hour period) and the extent of accretion on the lines—which is influenced by shape and temperature of the surface— but modellers can make a correlation between the amount of freezing rain that falls and the extent of buildup by determining the ratio based on past events.

In recognition that different line voltages have different criteria, the values specified to modellers will vary. In addition to freezing rain, the conductors are also designed with wind gusts taken into account, therefore knowledge of the extent of accretion over a 72-hour period may need to be supplemented with projections related to wind gusts.

APPENDIX 5: LIST OF ADAPTATION MEASURES

The following (non-exhaustive) examples of adaptation measures that have been implemented (or are being implemented) by electricity companies may be useful for brainstorming purposes. Most of the examples are derived from a recent CSA Group report, which in turn reflects workshop discussions with electricity sector stakeholders.[99]

Type of climate impact	Adaptation measure	Type of adaptation measure
Increasing temperatures and heat waves	BC Hydro is testing the benefits of dynamic thermal rating systems to operate electricity distribution equipment closer to its design limits, enabling its equipment to respond to observed weather conditions rather than predicted climatic conditions.[100]	• Modifying operations
Support structures for conductors: towers and poles	National Grid, an electricity distributor in the United Kingdom and United States, has raised the standard of flood protection for its substations from a 1:100-year to a 1:200-year or 1:1,000-year flood, depending on the cost-benefit analysis and societal risk identified for each substation. For certain substations, design criteria were also revised to avoid locating new substations in flood zones, to ensure elevations of at least 24 inches above 100-year flood levels, consider relocating substations out of flood zone areas during major upgrade projects, and to elevate critical equipment. The company will rebuild and elevate parts of prioritized substations by 2022. While these infrastructure updates are taking place, National Grid has adopted emergency plans to use a mobile flood defense system, which can be deployed on short notice. It has also designated and trained certain employees to act as community liaisons in times of emergency.[101]	• Asset strengthening • Modifying designs • Changes to organization and staffing • Communication strategy
	Following the 2013 flood in Calgary, ENMAX made plans to install smart meters in flood-prone areas, which would allow it to remotely control specific neighbourhood and customer service connections and to ensure optimal use of utility resources.[102]	• Asset strengthening
	Con Edison and Siemens worked together to install fully submersible and flood-proof equipment in lower Manhattan.[103]	• Asset strengthening
	New standards seek to avoid locating new substations in flood zones, ensuring elevations of >24 inches above 100-year flood levels and relocating them out of flood zone areas during major upgrade projects.[104, 105]	• Modifying designs and standards
	One Canadian company put together a business case "showing that the higher cost of stainless-steel submersible transformers was worth the investment. They are more resistant to corrosion as we are seeing our vaults flood more often. This is now our standard."[106]	• Asset replacement

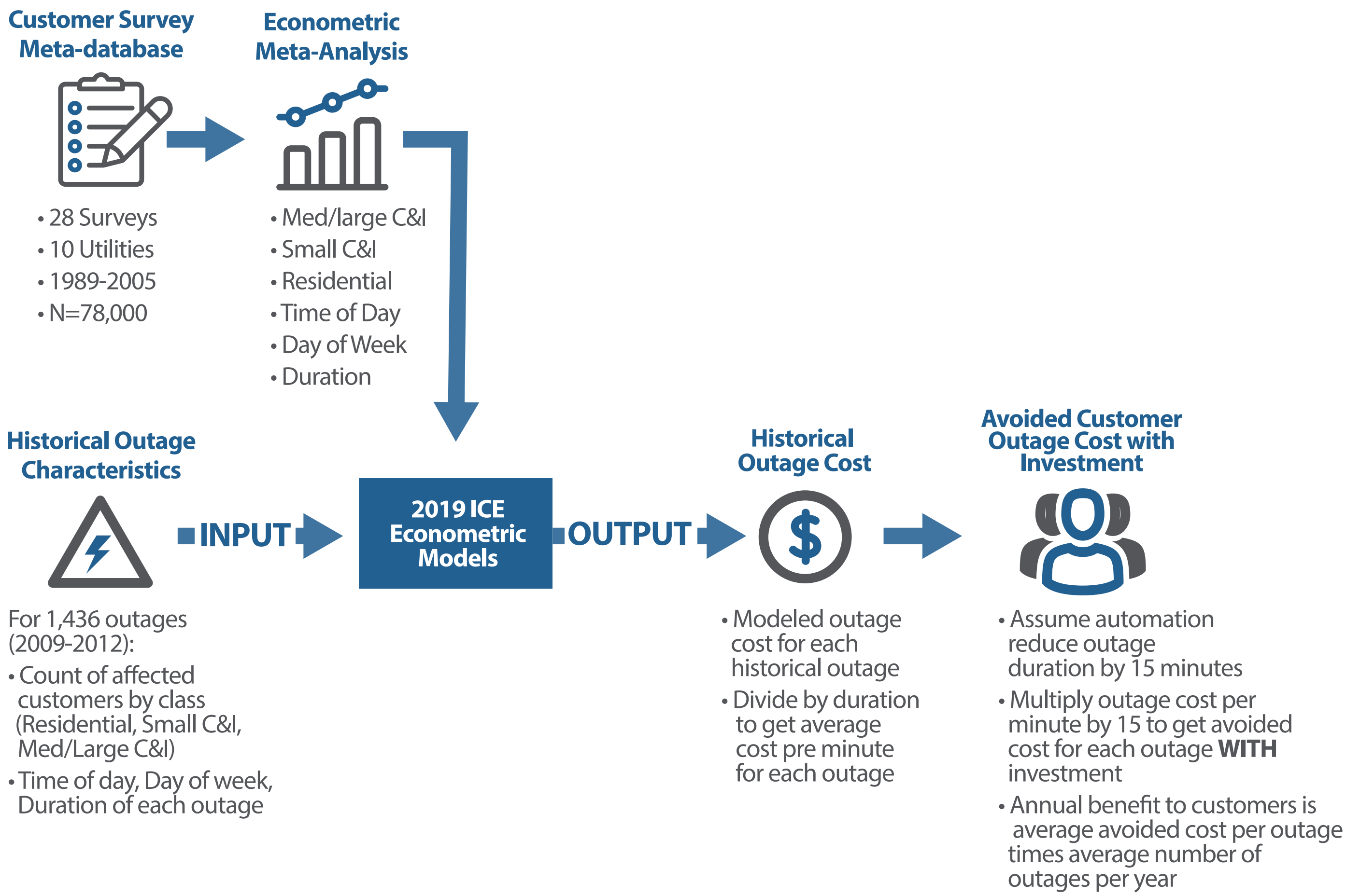
Type of climate impact	Adaptation measure	Type of adaptation measure
Sea level rise and storm surges	Con Edison has taken great strides to manage and adapt to coastal flood risks through retrofits, the design of new equipment and operational planning. Since 2007, the company has been replacing transformers in flood-prone regions with new ones that are submersible in salt water and factoring flood levels into the design of new substations. Con Edison has also adopted a Coastal Storm Plan and has tasked its Emergency Management Team and Incident Command Center with coordinating emergency planning and response.[107]	• Asset strengthening/ replacement • Modifying designs/ operations • Communication strategy
Hurricanes and high winds	Following Hurricanes Katrina and Rita in 2005, Entergy, an electric power producer and retail distributer based in the southern US, undertook an exercise to enhance the standards for its transmission and distribution systems. First, the company conducted an assessment of its infrastructure in the coastal areas. Then, it developed a hardening plan for its assets. Specific adaptation strategies were developed using historic storm tracking and wind speed data to predict potential damages and were prioritized based on their cost effectiveness. Some of the selected measures included using more durable materials within 20 miles of coast and along evacuation routes, increased wind design speeds, and elevation of substations.[108]	
	Following Hurricane Sandy, Con Edison—one of the world's largest energy companies, servicing 10 million customers in New York City and Westchester County—made plans to spend $1 billion in 2016 on adaptation and improvement strategies for its transmission and distribution system. The plans included a variety of adaption measures that range in required investment and expected benefits, including flood-proofing equipment in low-lying areas, undergrounding power lines, and building higher flood walls around substations. In Canada, gas distributors responded to the hurricane by initiating a review of mutual aid agreements via the Canadian Gas Association that are designed for utility companies to agree to assist each other in case of a disaster.[109]	• Asset strengthening • Changes in organization and staffing
Ice, wind and snow	The 1998 ice storm in eastern Canada prompted Hydro-Québec to review design standards for high-voltage lines and update its construction standards. To address high winds and icy conditions, the utility adopted measures such as using sturdier pylons and structures and strengthening and anchoring transmission poles. With new designs, conductors fall under heavy load conditions as opposed to poles.[110] Hydro-Québec also uses more stringent ice-loading standards than those required by the CE Code.[111]	• Modifying designs and standards • Asset strengthening
	Smart connectors release the system when ice loads become too heavy. These are also used when the line makes contact with a tree, allowing the line to come to the ground de-energized.[112]	• Asset strengthening/ replacement
	Hydro One updated design criteria and ice-loading requirements for equipment after a recent ice storm.[113]	• Modifying designs and standards
	Some utilities have switched to steel or fibreglass cross arms to address the ice accretion on towers with wooden arms.[114]	• Asset replacement

Type of climate impact	Adaptation measure	Type of adaptation measure
Ice, wind and snow	Manitoba Hydro uses ice-visioning systems that include a weather-hardened video camera integrated into the top of a pole. When ice forms, the systems can detect it. Manitoba Hydro also includes small compact weather stations on some poles, which are very low maintenance. Manitoba Hydro's ice-melting technology works in coordination with its ice-visioning systems. When ice buildup is detected, the company uses high- and low-voltage switching whereby the source station places voltage (12 kV or 25 kV) to melt ice. If ice cannot be melted, Manitoba Hydro will undergo "ice rolling" instead—the physical removal of ice by placing rollers on lines and dragging the rollers across lines by ground vehicles. [115]	• Asset strengthening
	Manitoba Hydro uses different pole and connector designs in "high-ice areas." Some designs allow suspension indicators to move such that they can handle more movement and galloping. Stronger bolts are used for through-bolts. [116]	• Modifying designs and standards
	Hydro-Québec uses "controlled-failure" techniques, where cable lines are designed to break upon ice buildup to stop poles from collapsing.[117]	• Modifying designs and standards
Permafrost	Increase building on-grade insulation, use different anchors, and allow for innovative designs. Additional insulation on all building sites could help reduce impacts from permafrost degradation. Helical piles (whereby one screws the pile into permafrost, then attaches the utility pole) are also effective.[118]	• Asset strengthening
	Minimizing the clearing of vegetation from rights-of-way in permafrost areas can help to ensure that the ground maintains the insulative properties of the covering.[119]	• Modifying operations
	Manitoba Hydro installs "frost boxes" below underground service entrances that include extra cable to allow for shifting of the building or frost heave.[120]	• Asset strengthening
	Develop standards to address foundations supported by heat exchangers, moderating the effects of permafrost degradation on existing buildings and managing changing snow loads and community drainage.[121]	• Modifying designs and standards
	ATCO has switched from a bolted connection for ground wiring to a wedge-type (squeeze-on) compression connection, which is a power-actuated wedge that shoots itself between the rod and the wire.[122]	• Asset strengthening

Type of climate impact	Adaptation measure	Type of adaptation measure
Wildfires	NRC has developed a "code-ready" national guide for wildland urban interface fire design and indicated that the associated fire code change request has been received. At least three provinces have stated they will adopt the technical guide as law.[123]	• Modifying designs and standards
	Manitoba Hydro has fire-guarded support structures such as radial feeder lines by putting a culvert filled with rock around the base of each wood pole to act as a thermal barrier against the wood.[124]	• Asset strengthening
	Employ improved/proactive vegetation management practices, such as implementing greater minimum clearances for vegetation, changes to tree-trimming standards, forest thinning, reducing buildup of hazardous fuels near key power lines, and reducing potential ignition points (e.g., through prescribed burning).[125]	• Modifying operations

APPENDIX 6: BUSINESS CASE TOOLS AND RESOURCES

Central Maine Power ICE Calculator: Avoided customer outage cost estimation methodology[126]



Cost curve

The City of Melbourne, Australia, has developed a robust cost curve exploring the cost effectiveness of various adaptation measures. The curve includes an analysis of one hundred current and planned actions that either reduce risk or raise resilience to climate change, and can be explored in its various aspects here.[127]

Sensitivity/robustness

The Food and Agriculture Organization (FAO) has a briefing note discussing cost-benefit analysis (CBA) for climate change adaptation.[128 129] Although the note is focused on the agriculture sector, its discussion of CBA of adaptation options has relevance for other sectors, including electricity. The FAO argues that while sensitivity analysis remains a useful feature of CBA, the way in which it is done for climate adaptation analysis is "significantly different" than "'traditional' sensitivity analysis," as it cannot work with "expected values."[130] As the note explains, "a fundamental issue in conducting CBA of adaptation options is the treatment of uncertainty."[131] Such an analysis, it goes on to say, must consider "future climate projections. Long-term adaptation investments … require assigning probability distributions to different climate change scenarios" to analyze "the sensitivity of the results."[132]

APPENDIX 7: METRICS AND REPORTING

Risks that may be material for reporting and disclosure:[133]

Risks	Organizational impacts	Financial impacts
Physical		
• Changing weather patterns • Water availability and quality	• Asset damage • Health and safety • Operational disruptions • Transportation interruptions • Restriction of licences availability, and use	• Asset writeoffs • Capital expenditures • Increased costs • Reduced revenues
Regulatory		
• Current/changing regulations (including those associated with greenhouse gas emissions)	• Compliance • Impact on market demand • Restriction of licences availability, and use • Market restrictions	• Increased costs • Capital expenditures • Reduced revenues • Asset valuations • Early retirement or writeoffs
Reputational		
• Employees' and investors' attitudes • Regulatory violations	• Reduced availability of capital • Litigation/penalties • Reduced demand for goods/services	• Asset writeoffs • Increased costs • Reduced revenues
Business model		
• Changes in demands for products/services • Renewable energy • Energy-efficient products	• Lower demand • Higher costs for transition	• Reduced revenues • Increased costs • Higher cost of capital/limited access to capital • Asset writeoffs

GLOSSARY OF KEY TERMS

The following are some key terms relevant to the discussion in this Guide.[134]

Adaptation Plan: The eight steps in this Guide provide a process for developing, documenting, and improving an adaptation Plan, from the defining of objectives through to review and continual improvement. In the context of this Guide, a Plan (in upper case) refers to the overarching Plan as defined, developed, and improved through this process. To avoid confusion between the overarching Plan (or program) and those plans designed to mitigate risk, the Guide refers to the latter as implementing actions. A company may also have implementing actions ("plans") and/or programs of various kinds that may support the development and implementation of actions within the Plan.

Baseline: A baseline period is needed to define the observed climate, with which climate change information is usually combined to create a climate scenario. When using climate model results for scenario construction, the baseline also serves as the reference period from which the modelled future change in climate is calculated.[135]

Canadian Standards Association (CSA, or CSA Group): The Canadian Standards Association is accredited by the Standards Council of Canada as a standards development organization. It is also accredited as a certification body. CSA is a non-profit membership association serving industry, government, consumers, and other interested parties in Canada and the global marketplace. The Canadian Securities Administrators (below) also uses the CSA acronym.

Canadian Securities Administrators (CSA): Securities regulators from each of the ten provinces and three territories in Canada have teamed up to form the Canadian Securities Administrators (CSA). The CSA "protects Canadian investors from unfair, improper, or fraudulent practices and fosters fair and efficient capital markets."[136] The Canadian Standards Association (above) also uses the CSA acronym.

Climate: Climate in a narrow sense is usually defined as the "average weather," or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is thirty years, as defined by the World Meteorological Organization (WMO). These relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

Climate change: Climate change is a pattern of change affecting global or regional climate, as measured by data such as average temperature and rainfall, or an alteration in frequency, intensity, and duration of extreme weather conditions. These variations may be caused by both natural processes and human activity. Global warming is one aspect of climate change.

Climate change adaptation: Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, in order to moderate harm or exploit beneficial opportunities. Various types of adaptation can be distinguished, including, for example, anticipatory and reactive adaptation. Construction of barriers to protect against flooding is an example of adaptation.

Climate change mitigation: Mitigation in the climate change context refers to actions to abate or reduce anthropogenic emissions (interventions to reduce the sources or enhance the sinks of greenhouse gases) in the hope of limiting the extent and potential impacts of climate change.

Climate impacts: Climate impacts are consequences of climate change on natural and human systems. Depending on the extent of adaptation undertaken, one can distinguish between inherent risks and residual risks from climate impacts. Inherent risks refer to all risks given a projected climate impact, without considering adaptation. Residual risks are the risks from climate change impacts that would occur after adaptation.

Climate model: A climate model is a numerical representation of the climate system based on the physical, chemical, and biological properties of its components and their interactions and feedback processes, and accounting for all or some of its known properties. The climate system can be represented by models of varying complexity—that is, for any one component or combination of components, a hierarchy of models can be identified, differing in such aspects as the number of spatial dimensions; the extent to which physical, chemical, or biological processes are explicitly represented; or the level at which empirical parameterizations are involved. There is an evolution underway toward more complex models with active chemistry and biology. Climate models are applied as a research tool to study and simulate the climate, but also for operational purposes, including monthly, seasonal, and multi-year climate predictions.

Company: For the purpose of this Guide, unless the context suggests otherwise, a company refers to a Canadian Electricity Association member organization that is aiming to develop or improve (as the case may be) a climate change adaptation Plan.

Customer Average Interruption Duration Index (CAIDI): CAIDI is the weighted average length of an interruption for customers affected during a specified time period. The formula to determine this average is:

$$\text{CAIDI} = \frac{\text{sum of customer minutes off for all sustained interruptions}}{\text{total \# of customers affected by the sustained interruptions}}$$

The unit of CAIDI is minutes. A relatively high value for this metric is typically related to a few common factors, such as scheduled service interruptions that resolve temporary faults in the system, power supply insufficiency, distribution system equipment outages (due to damage, extreme weather, faulty equipment, etc.), and outages due to non-payment of the utilities service. CAIDI, in conjunction with SAIDI and SAIFI, among other metrics, is used to measure the reliability of a utility company's power system.[137]

Enterprise risk: An enterprise risk is an uncertain event or condition (a probability or threat) that could adversely impact a company's ability to achieve its core objectives.

Enterprise risk management (ERM): ERM includes the methods and processes used by companies to manage risks and seize opportunities related to the achievement of their objectives. It provides a framework for risk management, which typically involves identifying particular events or circumstances relevant to the company's objectives (risks and opportunities), assessing them in terms of likelihood and magnitude of impact, and determining a response strategy and monitoring process. By identifying and proactively addressing risks and opportunities, business enterprises protect and create value for their stakeholders, including owners, employees, customers, regulators, and society overall. ERM is evolving to address the needs of various stakeholders, who want to understand the broad spectrum of risks facing complex companies to ensure they are appropriately managed. Regulators and debt-rating agencies have increased their scrutiny on the risk management processes of companies. The point of enterprise risk management is not to create more bureaucracy, but to facilitate discussion on what the really big risks are.[138]

Extreme value analysis (EVA): EVA is a statistical tool primarily used to deal with low-probability (infrequent), high-impact events. Often applied to analyses of flooding and climate.

Extreme weather: Extreme weather is rare within its statistical reference distribution at a particular place, and the characteristics of what is considered extreme weather will therefore vary from place to place. It may include unexpected, unusual, unpredictable, severe, or unseasonal weather. Definitions of "rare" vary, but an extreme weather event would normally be as rare as or rarer than the tenth or ninetieth percentile.

Forced outage: A forced outage refers to the unavailability of a facility that is not anticipated as part of regular maintenance—a hardware failure in the generation, transmission, or distribution system that results in interruption of service. Forced outages usually occur due to unexpected component failure or systemic problems such as downed lines or lightning-induced overloads. These outages may or may not affect an end-use customer depending on where they occur.[139]

Guide: This document, entitled "Climate Change and Extreme Weather: A Practical Guide to Adaptation Planning for Electricity Companies in Canada," is expressed in shorthand throughout as the Guide.

Implementing actions: Implementing actions are those activities (plans) that organizations put in place to mitigate risks associated with climate change. The mitigating actions support the achievement of the overall objective as defined in the Plan. The aggregate of the implementing actions forms the risk control(s).

Invasive species: An invasive species is a species that is non-native (or alien) to the ecosystem under consideration and whose introduction causes or is likely to cause economic or environmental harm or harm to human health. Invasive species can be plants, animals, and other organisms (e.g., microbes).[140]

Intergovernmental Panel on Climate Change (IPCC): The IPCC is a scientific body established by the United Nations Environment Program and the World Meteorological Organization. It reviews and assesses the most recent scientific, technical, and socio-economic work relevant to climate change, but does not carry out its own research.

International Organization for Standardization (ISO): The ISO is the largest standards development organization in the world, with members representing more than 145 countries worldwide. The Standards Council of Canada (SCC) is the Canadian member body at ISO.

Key performance indicator (KPI): A KPI is a measurable value that demonstrates how effectively a company is achieving key objectives.

Local climate models (LCMs): LCMs refer to high-resolution, small-grid-size models that provide greater detail than regional or global models. The grid size is often in the order of 1 km2. This degree of resolution is typically used when there are significant localized influences on weather (e.g., lake effects or topography), or when the climate/weather parameter of interest operates on a local scale (e.g., thunderstorm cells and other extreme weather events) or tends to display more variability in space (e.g., precipitation).

NERC reliability standards: NERC is the commonly used acronym for North American Electric Reliability Corporation. NERC reliability standards define the reliability requirements for planning and operating the North American bulk power system and are developed using a results-based approach that focuses on performance, risk management, and entity capabilities.[141]

Net present value (NPV): NPV is the difference between present value of cash inflows and outflows at a required rate of return and a specified period of time.

Pacific Climate Impacts Consortium (PCIC): PCIC "is a regional climate service centre at the University of Victoria that conducts quantitative studies on the impacts of climate change and climate variability in the Pacific and Yukon region. Results from this work provide regional climate stakeholders with the information they need to develop plans for reducing the risks associated with climate variability and change. In this way, PCIC plays an important bridging function between climate research and the practical application of that knowledge by decision makers."[142] PCIC is also the "primary source of climate model data" used by the Climate Atlas of Canada website.[143]

Plan: For the definition of a "Plan" (in upper case, as defined in this Guide), see Adaptation Plan as defined above. Actions to mitigate risk are often referred to as plans—however, to avoid confusion, the Guide refers to them as implementing actions.

Plan-do-check-act (PDCA) cycle: The PCDA cycle is an interactive four-stage approach for continually improving processes, products, or services, and for resolving problems. The concept was developed by management consultant Dr. William Edwards Deming in the 1950s and involves systematically testing possible solutions, assessing the results, and implementing the ones that are shown to work.[144]

Real options analysis: Real options analysis allows for evaluation of capital investment strategies by taking into consideration the strategic decision-making process.

Regional climate models (RCMs): RCMs refer to "medium" resolution models that provide more detail than global models but less than local models. The grid size is often in the order of 10 km2 (10–50 km). Such models are less costly to run than local models, but may not adequately account for localized influences such as topography or the proximity of water bodies. They may not adequately capture extreme weather events that tend to operate on a more localized scale.

Resilience: Organizational resilience is the ability of a company to anticipate, prepare for, respond to, and adapt to incremental change and sudden disruptions in order to survive and prosper.[145]

Return period: Return period is an estimate of the likelihood of an event to occur. It shows the average recurrence interval over an extended period of time. For example, a 100-year event may occur once or more often in a 100-year period, or not at all. Return periods can be calculated by taking into account such variables as sea level, wind speed, maximum and minimum temperature, precipitation, and snow depth.

Spatial resolution: Spatial resolution refers to how large grid cells are in a model—the larger the cells, the lower the resolution. Coarse Global Climate Models (GCMs) typically have grid cells that are about 100x100 km. Higher-resolution models will have more detailed, smaller grids. The higher the resolution, the more specific climate information a model can produce for a particular region—but this comes with the trade-off of taking longer to run (more costly) because the model has more calculations to make. The scale should be aligned with the variability of the parameter, the presence of localized significant influences (topography and proximity or water bodies, etc.), as well as need for precise information.

Subsector: In this context of this Guide, the three subsectors of the electricity sector are distribution, generation, and transmission.

System Average Interruption Duration Index (SAIDI): SAIDI is defined as the average duration of interruptions for customers served during a specified time period. Although similar to CAIDI (see above), the average number of customers served is used instead of number of customers affected. The formula used to determine SAIDI is:

$$\text{SAIDI} = \frac{\text{sum of customer-minutes off for all interruptions total}}{\text{\# of customers served}}$$

The unit of SAIDI is minutes.[146] A relatively high value for this metric is typically related to a few common factors, such as scheduled service interruptions that resolve temporary faults in the system, power supply insufficiency, distribution system equipment outages (due to damage, extreme weather, faulty equipment, etc.), and outages due to non-payment of the company's service. SAIDI, in conjunction with CAIDI and SAIFI, among other metrics, is used to measure the reliability of a company's power system.[147]

System Average Interruption Frequency Index (SAIFI): SAIFI describes the average number of times that a customer's power is interrupted during a specified time period. "SAIFI-momentary (< one minute)" is calculated using the number of customers affected by momentary interruptions. "SAIFI-sustained" is calculated using the number of customers affected by sustained interruptions.

$$\text{SAIFI-sustained} = \frac{\text{total \# of customers affected by sustained interruptions}}{\text{average \# of customers served}}$$

$$\text{SAIFI-momentary} = \frac{\text{total \# of customers affected by momentary interruptions}}{\text{average \# of customers served}}$$

The units for SAIFI are "interruptions per customer." A relatively high value for this metric is typically related to a few common factors, such as scheduled service interruptions that resolve temporary faults in the system, power supply insufficiency, distribution system equipment outages (due to damage, extreme weather, faulty equipment, etc.), and outages due to non- payment of the company's service. SAIFI, in conjunction with CAIDI and SAIDI, among other metrics, is used to measure the reliability of a company's power system.[148]

Temporal resolution: Temporal resolution refers to the size of time steps used in models (i.e., how closely together in time calculations are made). Extreme weather events are often short lived, and so they may require smaller time steps than other parameters (such as temperature) that typically change more gradually.

Top management: Top management refers to the senior officers and/or executives of a company who direct and control the company at the highest level. Of particular relevance to this Guide, they have overall accountability and authority for managing risks and opportunities in the company, as well as the power to delegate authority and provide resources.

Uncertainty: An expression of the degree to which a value (e.g., the future state of the climate system) is unknown. Uncertainty can result from lack of information or from disagreement about what is known or even knowable.

Value of lost load (VOLL): VOLL is a quantitative estimate of indirect costs to customers from climate change impacts. It represents "the value that customers place on reliable electricity service" and is also known as "the Customer Damage Function (CDF) or the Value of Service Reliability (VOS)."[149]

Vector: An organism, such as an insect, that transmits a pathogen from one host to another.

Verification Process: A companion document, Verification Process for Reporting Progress in Adaptation Planning for Electricity Companies in Canada, is expressed in shorthand throughout as the Verification Process. The Verification Process provides a series of yes-or-no questions accompanied by explanatory discussions. Companies may use the Verification Process both to clarify expectations for adaptation planning and to assess the progress of their Plans.

Vulnerability: Vulnerability measures the degree to which a system, organization, or company is susceptible to or unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system, organization, or company is exposed; its sensitivity; and its adaptive capacity.

Weather: Weather is the (short-term) state of the atmosphere with regard to temperature, cloudiness, rainfall, wind, and other meteorological conditions. It is not the same as climate, which is the average weather over a much longer period *(see climate definition above)*.

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