Monitoring and Evaluation for a Resilient Electricity Sector

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Executive Summary

Climate change poses significant physical and financial risks for the Canadian electricity sector, and electricity utilities are working to reduce these risks by undertaking adaptive actions like storm hardening of existing assets, improved vegetation management, and risk informed decision-making regarding future investments. Adaptation monitoring and evaluation is essential to understand the effectiveness and appropriateness of these actions in light of organizational goals and targets on adaptation. Furthermore, as climate risk disclosure rules expand to include adaptation, utilities are looking to incorporate best practices for adaptation monitoring and evaluation in both internal assessment and external reporting procedures.

The purpose of this report is to frame the role of adaptation monitoring and evaluation in building the resilience of the Canadian electricity sector to climate change impacts, and synthesize the current state of practice on adaptation monitoring and evaluation among governments and electricity utilities. Building on the conceptual framework of Price-Kelly et al. (Price-Kelly et al. 2015), it examines four dimensions of adaptation monitoring and evaluation: context, content, operationalization, and communication.

Following a desktop review approach, the report finds that national monitoring and evaluation frameworks are in varying stages of maturity. While national monitoring and evaluation is almost always tied to the adoption of an adaptation plan or strategy, countries use a variety of approaches and indicators to operationalize these frameworks. Among Canadian electricity utilities, adaptation monitoring and evaluation is still in early stages and is commonly integrated into existing procedures for sustainability and ESG reporting. Some companies have also developed internal assessment and reporting frameworks to inform corporate decision-making. While existing practices build on guidance provided by entities like the Task Force on Climate-Related Financial Disclosures (now folded into the International Sustainability Standards Board) and the Sustainability Accounting Standards Board, significant ambiguity remains around tracking and reporting on the financial implications of adaptation-relevant decisions,

connecting performance outcomes with adaptation investments, and standardization of scenario analysis and performance metrics in public reporting. While most adaptation monitoring and evaluation is currently oriented around public reporting and accountability, further work also remains to identify opportunities for integrating learning into internal decision-making processes.

The report concludes with four proposed research directions: 1) Conduct a comprehensive study on the state of adaptation planning in the Canadian electricity sector. 2) Examine how monitoring and evaluation frameworks can meet multiple objectives while minimizing administrative burdens. 3) Advance multi-dimensional approaches to assessing adaptation actions and outcomes. 4) Identify opportunities for monitoring and evaluation to contribute to organizational learning on adaptation.

Glossary of acronyms

CAIDI	Customer Average Interruption Duration Index
CDP	Climate Disclosure Project
CKAIDI	Circuit Average Interruption Duration Index
CKAIFI	Circuit Average Interruption Frequency Index
EMS	Environmental Management Systems
EPCARR	Expert Panel on Climate Adaptation and Resilience Results
ESG	Environmental, Sustainability, and Governance
GRI	Global Reporting Initiative
IPCC	Intergovernmental Panel on Climate Change
ISO	International Standards Organization
ISSB	International Sustainability Standards Board
M&E	Monitoring and evaluation
NAS	National Adaptation Strategy
OPG	Ontario Power Generation
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SASB	Sustainability Accounting Standards Board
TCFD	Task Force on Climate-Related Financial Disclosures

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1. Introduction

Over the past decade, adaptation has emerged as a core pillar in climate policy alongside emissions mitigation (Lesnikowski et al. 2017). The Government of Canada released its first National Adaptation Strategy in 2023, while Canadian provinces, territories, and municipalities have been engaged in adaptation planning at varying levels of advancement since the mid-2000s. Stress and damage to critical infrastructure is one of the most significant climate change risks facing Canada (Ness et al. 2021). Protection of critical infrastructure is thus a major focus of these policies, for example through strengthened technical standards, risk-informed decision-making, and prioritization of strategic investment in vulnerable communities (Government of Canada 2023).

The purpose of this report is to frame the role of adaptation monitoring and evaluation (M&E) in building the resilience of the Canadian electricity sector to climate change impacts. Adaptation monitoring and evaluation refers to formalized frameworks for: 1) tracking progress on the implementation of adaptation actions, and 2) assessing the outcomes and impacts of adaptation responses. Robust adaptation M&E helps us understand the effectiveness and appropriateness of adaptation, for example whether adaptation priorities reflect key risks and are keeping pace with changing climatic conditions. Adaptation M&E also provides an evidence base for examining whether changes in resilience or vulnerability outcomes are attributable to adaptation responses. While performance assessment and evaluation are integral components of managing operations and planning capital investments in the electricity sector, adaptation M&E is an entrypoint for assessing changes in vulnerability to climate change impacts over the long-term.

The report proceeds as follows. First, it briefly describes key climate change-related risks for the Canadian electricity sector and the evolving adaptation policy landscape in Canada. Then it describes the characteristics of a climate resilient electricity sector and identifies the contributions that adaptation M&E makes to achieving desired outcomes. The third section of the report details the characteristics ("building blocks") of adaptation M&E, including the context, content, operationalization, and communication of M&E. Fourth the report surveys emerging practices in adaptation M&E across key countries and within the electricity sector

itself. The report conclusions with proposed directions for future work on adaptation M&E in the electricity sector.

1.1 Climate change impacts on the Canadian electricity sector

Canada faces a wide range of climate change impacts, including extreme temperatures, storms, drought, wildfires, permafrost melt, changes in streamflows, and sea level rise (Bush and Lemmen 2019). These impacts will affect every dimension of the Canadian electricity sector, including electricity supply, transmission, and demand (Navius Research 2020). Existing electricity infrastructure is largely built to design standards for historic climatic conditions, which has implications for operations, service reliability, asset maintenance, and event recovery costs (Canadian Electricity Association 2020). Potential impacts on electricity utilities are costly and wide ranging, including damage and reduced system reliability due to extreme weather events, changes in power generation capacity due to changes in climate variability and extreme weather conditions, and increased energy demand for cooling during the summer months (Lemmen et al. 2021). The indirect costs of these impacts are even higher, including for example economic costs of business closures, missed wages, and disruptions or closures of social institutions like schools and health care facilities (Sawyer et al. 2020). Updating codes and standards, like the Canadian Electrical Code, is a key priority in the National Adaptation Strategy, and an ongoing focus of the Canadian Standards Association and National Research Council.

The electricity sector also faces the potential for cascading impacts like drought-induced reductions in hydrological capacity that coincide with periods of extreme heat that increase energy demand for mechanical cooling (McMahan and Gerlak 2020). These impacts imply significant financial risks to electricity utilities from climate change-induced damage, including exposure to damage claims for disaster events related to corporate assets (e.g. wildfires), failure to meet commitments for electricity provision or costs, uninsured losses from damage to critical infrastructure, or high deductibles for assets covered by insurance (Hydro One 2022c). Furthermore, as Canada embarks on ambitious plans for electrification that require a doubling or tripling of clean power generation, it is essential for the net-zero transition to ensure that the electricity system remains financially stable, reliable, safe, and affordable. The challenge for

the electricity sector is thus to develop adaptation approaches that address key risks and vulnerabilities across the whole process of electricity generation, transmission, distribution, and consumption.

1.2 State of climate change adaptation policy for the Canadian electricity sector

The Canadian adaptation policy landscape has evolved rapidly over the past five years. In 2023 the Government of Canada finalized its first National Adaptation Strategy (NAS)[1], which responds to national priorities identified in national climate change assessments and the Pan-Canadian Framework on Climate Change. Among the targets identified in the strategy, the NAS commits that "By 2027, 80% of highly exposed businesses include adaptation to climate change in plans and strategies in order to strengthen their competitiveness" (Government of Canada 2023). Sectors identified as high risk include the energy sector, among others. In British Columbia, the Climate Change Accountability Act now requires public sector organizations to report on steps being taken around emissions reduction and climate risk (Government of British 2022). These target and regulatory changes bely a broader shift underway in Canada towards adoption of strategic adaptation plans and assessment frameworks by governments and public organizations like crown corporations. Several electricity companies have developed climate or adaptation plans (e.g. Hydro Québec, Ontario Power Generation, Nova Scotia Power, and BC Hydro), or guiding documents on risk assessment (Manitoba Hydro). A number of other companies reference sustainability or resilience in their strategic plans, but as yet have no formal plans related to climate change adaptation.

In parallel we have seen the emergence of new reporting and disclosure requirements for critical sectors. For example, the Task Force on Climate-Related Financial Disclosures (TCFD) was created after the signing of the Paris Agreement to scale up and improve climate risk disclosures in the private sector. In 2023 these responsibilities were subsumed under the International Sustainability Standards Board (ISSB), with the aim of developing harmonized international standards for climate disclosure. The International Standards Organization (ISO) has also developed several protocols to assist organizations with adaptation planning efforts

[1] The National Adaptation Strategy was initially released in 2022 and finalized in 2023.

(e.g. ISO 14001 and 14090/14091/14092), although they do not provide standalone guidance for adaptation M&E or assessment. Electricity Canada urges all electricity providers to develop adaptation plans and has created a general guide to assist with their development (Canadian Electricity Association 2020). Their recommendations include the creation of M&E frameworks, and a few proposed metrics for tracking plan implementation and evaluating the results of adaptation actions. Despite this, however, there are few examples of adaptation M&E frameworks in development by electricity companies in Canada (see section 4.2).

2. What is a climate resilient energy sector?

Adaptation is an ongoing "process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities" (IPCC 2022). The aims of adaptation are frequently articulated around the need to reduce vulnerability, build adaptive capacity, and achieve resilience in the face of climate change-induced risks. In common practice, resilience and vulnerability are commonly framed as inverse conditions, where vulnerability is the likelihood to experience harm from climate change-related hazards (IPCC 2022) and resilience is the ability to cope with extreme events or short or long-term stressors, while maintaining a system's ability to function at an (close to) optimal state (IPCC 2022). Within the climate change scholarship, however, there is a wide-ranging debate about the relationship between these terms. Vulnerability research, for example, points to the limits of addressing only proximate causes of climate risk and overlooking root causes of vulnerability, such as outdated land use planning frameworks or energy poverty (Ford et al. 2018).

The concept of resilience is more frequently referenced in climate action planning for critical infrastructure systems such as electricity. The 2016 Hydropower Status Report from the International Hydropower Association, for example, describes climate resilience as: i) the ability to recover from an external stressor or event; ii) the capacity to achieve desired outcomes in an environment characterized by deep uncertainty; and iii) the capacity of a system or asset to withstand and adjust to climate change impacts (Ray et al. 2018). The International Energy Agency adds that "climate resilient energy systems support the clean energy transition by

addressing adverse impacts of climate change on renewable energy, promoting sustainable development by ensuring reliable energy services, boosting energy security through coping with climate-driven disruptions, and reducing risks from climate disasters".[2] The literature defines a number of qualities in resilient energy systems, which Ahmadi et al. (2021) distill into four key characteristics: *anticipation* of disruptive events, *absorption* of disruptive events, *capacity to self-organize and adapt* to perturbations, and *recovery capacity* to contain losses in a timely manner. Notably, their analysis of energy system metrics for measuring resilience finds that existing indices generally measure only one or two of these attributes, and that indicators for anticipation and adaptive capacity are notably lacking, as are indicators that account for social resilience, like access to electricity, electricity pricing, and energy poverty (Ahmadi, Saboohi, and Vakili 2021). Reliability measures like System Average Interruption Duration Index (SAIDI) and System Average Interruption Frequency Index (SAIFI) are metrics that electricity companies use to track system (non-)failures, and are summarized in annual performance reports. As discussed in Section 4.2 below, these metrics are commonly referenced in relation to climate change-related risks in corporate climate change reporting.

A major challenge with existing resilience indicators, however, is that they tend to assume historic and stationary climatic states. Climate change, however, entails changes in variability and extremes over multi-decadal time horizons. Resilience may therefore assume different meanings at different temporal scales. For example, minimizing damage and hastening recovery from extreme weather events may be a critical short-term goal, but resilience over the long-term (e.g. at end of century) entails slower moving changes in average conditions. Long-term climate change adaptation planning thus raises questions about whether existing systems (or specific components of those systems) will be fit-for-purpose in a changing climate (Kates, Travis, and Wilbanks 2012). Incremental changes that are intended to increase system resiliency to short-term shocks could be made obsolete by longer-term environmental change, leading to ineffective or even maladaptive outcomes in the future (Juhola et al. 2016), along with increased economic costs and missed opportunities. This presents not only analytical

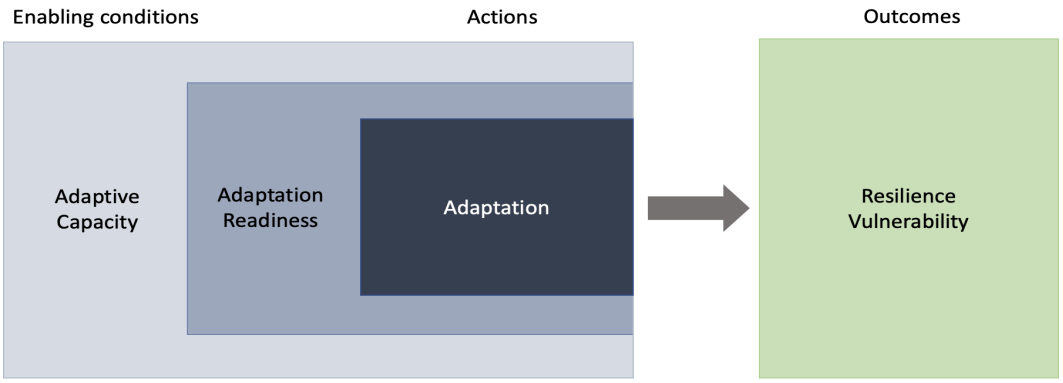
[2] IEA, Policy Preparedness for Climate Resilience. Available from: https://www.iea.org/reports/climate-resilience-policy-indicator/policy-preparedness-for-climate-resilience

challenges with respect to anticipating and preparing for future climatic risks, but also political and economic questions about how to value future risks.

2.1 Conceptual model underpinning this scoping report

The conceptual model that guides our discussion about adaptation in the electricity sector is summarized by Figure 1. It characterizes adaptation as a type of action that occurs within particular organizational contexts. These contexts shape decision-making processes and available adaptation options. Adaptive capacity refers to the "ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences" (IPCC 2022). The relationship between adaptive capacity and realized adaptation is thus assumed to be positive. The literature proposes a number of different analytical frameworks for measuring adaptive capacity, but generally they tend to emphasize elements like learning capacity, leadership, room for adaptive management, governance, and resources (Gupta et al. 2010). The relationship between adaptive capacity and observed (i.e. realized) adaptation is not inevitable however; adaptive capacity reflects the *potential* to undertake adaptation, but it cannot be assumed that adaptation action will inevitably follow from high adaptive capacity (Repetto 2008). Indeed, the climate change scholarship notes a wide range of barriers or constraints on adaptation action, such as lack of leadership and financing, limited coordination among actors, conflicting priorities among actors, or jurisdictional ambiguities (Biesbroek et al. 2013; Moser, Ekstrom, and Kasperson 2010).

Figure 1: Conceptual model



While adaptation research and practice pay particular attention to the need for improving adaptive capacity, it is essential to ensure that organizational structures and supports are in place to translate this capacity into planning, decision-making, and implementation. Adaptation readiness refers to conditions and measures that support the ability of organizations or other actors to adapt. Ford and King define readiness as "the extent to which human systems (e.g. nations, regions, businesses, communities etc.) are prepared to adapt, providing an indication or measure of the likelihood of adaptation taking place" (Ford and King 2015). They conceptualize readiness along six dimensions: i) political leadership on adaptation; ii) institutional organization for adaptation; iii) adaptation decision-making and stakeholder engagement; iv) availability of usable science to inform decision-making; v) funding for planning, implementation, and evaluation; and vi) public support for adaptation. Carriere and Lesnikowski propose a seventh dimension to adaptation readiness: vii) recognition of equity and justice dimensions to climate vulnerability and adaptation (Carriere and Lesnikowski In review). Ford and King's model assumes that high levels of adaptation readiness create enabling conditions for adaptation planning, implementation, and evaluation, and improve the likelihood of observing formal adaptation responses to climate change impacts.

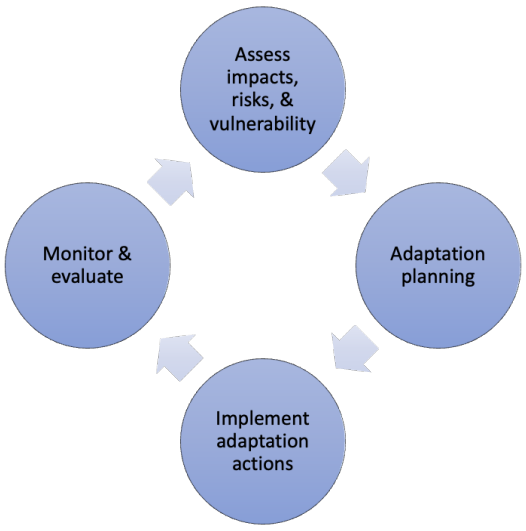
Planned adaptation refers to deliberative actions taken to reduce risks and seize opportunities associated with a changing climate. Adaptation can also emerge autonomously, for example through changes in household behaviors like the purchase of a generator to cope with storm-induced power outages or reallocation of power generation capabilities in electricity markets (Rübbelke and Vögele 2013). This report is concerned with how we assess progress on formal adaptation being implemented by electricity companies, however, and so focuses specifically on planned adaptation. Generally, planned adaptation aims to achieve outcomes associated with reduced vulnerability and/or enhanced resilience. The language of specific adaptation goals and targets reflects the conditions and priorities of different sectors and actors, and so here we are agnostic with respect to the outcomes that adaptation initiatives in the electricity sector aim to accomplish. We will return to the issue of adapting monitoring and evaluation systems to address different goals and targets in section 3.

It is important to note that other policies and actions can also contribute to building resilience (Dupuis and Biesbroek 2013), for example Quebec's Dam Safety Act, which requires development of water management plans, emergency response plans, and monitoring plans for all dams in the province and the design of dams to withstand large floods. The extent to which these kinds of policies and activities are incorporated into strategic planning for adaptation will vary depending on how actors frame their relationship to climate change.

2.2. Adaptation to climate change in the electricity sector

Adaptation processes are generally portrayed as a series of iterative steps leading from initial efforts to determine key risks and issues, identifying and selecting appropriate adaptation responses, implementation of those responses, and ongoing assessment of adaptation progress and effects (monitoring and evaluation). A simplified version of the adaptation cycle is captured in Figure 2. In some cases, actors undertake dedicated strategic planning processes to identify climate change impacts, adaptation opportunities, and action pathways. In other cases, actors mainstream a climate adaptation lens into existing frameworks like Environmental Management Systems.

Figure 2: The adaptation cycle



Adaptation planning commonly begins with the completion of an impact and vulnerability assessment that examines how current and future climate change under different emissions scenarios will impact exposure to key environmental hazards such as extreme temperatures or storms. These assessments frequently involve detailed technical analyses, for example on impacts to hydrological basins, wind speeds, or tidal dynamics. Early research in this space dates to the early 1990s, and Canadian electricity companies draw from a mix of internal expertise, government and university-supported research organizations like Ouranos and the Pacific Climate Impacts Consortium, and private consulting companies to conduct scenario modelling and climate change impact assessments. Sometimes this is accompanied by the creation of new tools for monitoring changes in environmental conditions or resources (Andrew and Sauquet 2017). Hotspot analysis is understudied but can identify places with particularly high vulnerability and help decision-makers prioritize how they target adaptation investments (Gu et al. 2022). Conversely, this type of analysis can help to identify areas with relatively less vulnerability that should be prioritized for new investment.

Adaptation options for the electricity sector are highly diverse and will reflect different circumstances like energy source, future growth and development patterns, business operations, sectoral structure, and infrastructure conditions. Some examples of adaptive actions from the scientific literature include: expanding energy storage capacity during periods of high production to meet demand during periods of low production (Taseska, Markovska, and Callaway 2012), for example hydro-electricity generation with pumped storage (Gu et al. 2022); diversification of energy portfolios to meet present and future demand (Taseska, Markovska, and Callaway 2012) and reduce conflict from different users of resources like water (Nobre et al. 2019); hardening infrastructure with tougher building standards (Almeida and Mostafavi 2016); and deploying digital smart grids to build self-restoration capacity, automate equipment monitoring, enhance storage technology, and support distributed generation (Balogun et al. 2020). Improvements in urban planning and design may also yield resilience gains for the electricity sector, for example by reducing energy demand with passive cooling standards in buildings and expansion of green infrastructure in urban spaces (Hintz et al. 2018). Criteria for selecting appropriate adaptation responses can include consideration for co-benefits for other

priorities or targets, no-regrets options that deliver benefits regardless of future climatic conditions (for example efficiency improves to reduce water demand), and incremental changes that improve business planning and operations at low-cost (for example during routine maintenance and retrofits) (Lemmen et al. 2021).

Table 1: Examples of adaptation actions in the Canadian electricity sector

2.3 What is adaptation M&E and how does it contribute to building resilience?

Adaptation M&E is a growing area of focus in the scientific literature (UNEP 2017; 2020). Spending on adaptation priorities is growing, and there are growing calls to determine whether these investments are effective, efficient, and equitable reducing risk and vulnerability and building resilience (Fisher 2023). The adoption of the Global Goal on Adaptation in the Paris Agreement pushed national monitoring and evaluation of adaptation progress higher on the global climate policy agenda (Lesnikowski et al. 2017). Strengthened national reporting requirements under the Paris Agreement necessitated that national governments devise more systematic approaches to assessing adaptation progress that can generate comparable information that can be integrated for the completion of the Global Stocktake, a 5-year review on country progress towards their commitments under the Paris Agreement. Balancing the need for comparable and scaling assessment approaches with the analytical challenges inherent to adaptation tracking is a core political and technical challenge for the UN Framework Convention on Climate Change. Nonetheless, very few countries have functioning, comprehensive adaptation M&E systems in place (Leiter 2021).

While there is a well-established scholarship on new frontiers in adaptation assessment, advancement lags for various analytical and practical reasons. Adaptation monitoring and evaluation presents a number of complex analytical challenges, including: i) shifting baselines associated with changes in the climate system that will simultaneously change hazard magnitude and frequency and play out over long time horizons; ii) attributing changes in vulnerability and resilience to specific (and generally new/additional) adaptation responses; iii) identifying avoided impacts, for example where the signs of adaptation success are the absence of a disruptive event; iv) predicting the outcomes of low likelihood but very high impact risks; v)

making sense of diverse perspectives on the nature of vulnerability, resilience, and adaptation; vi) identifying indicators (either quantitative or qualitative) that act as reasonable proxies for our notions of these concepts; and vii) capturing maladaptation, meaning unintended negative consequences of adaptation responses (Leiter 2021; Lesnikowski et al. 2017). Furthermore, adaptation tracking work highlights the absence of consensus on what adaptation success looks like (Dilling et al. 2019). Additionally, the emerging practice of adaptation M&E highlights the challenges of designing effective M&E systems when: i) adaptation goals and targets are vague; ii) responsibilities for adaptation are diffused across multiple levels of government and sectors; and iii) political/policy planning cycles differ from the timeframes needed to understand the effects of adaptation responses (Lesnikowski and Leiter 2022).

Early adaptation M&E work was strongly influenced by the international development sector, where climate finance was increasingly being directed to adaptation projects and programmes in low and middle-income countries. Frameworks like the Pilot Programme for Climate Resilience and the Tracking Adaptation and Monitoring Development Framework emerged from that work. These frameworks relied on various measurement techniques, including indicators, scorecards, and self-reporting mechanisms. Appendix C provides a sample list of indicators from existing adaptation M&E frameworks. The sheer number and diversity of metrics demonstrates the lack of universality in M&E systems. With respect to the electricity sector, the specific design of adaptation M&E frameworks should reflect the operational profile of electricity companies, for example their portfolio of assets, governance structure, and energy mix profile.

Importantly, the design of adaptation M&E frameworks influence how adaptation is governed. Knowledge production practices prioritize different types of information and allow participation of particular types of actors (Njuguna et al. 2023). The Report of the Expert Panel on Climate Adaptation Results and Resilience, for example, emphasizes the importance of integrating Indigenous Knowledge Systems with scientific data and analytical approaches with Canada's future adaptation M&E framework (EPCARR 2018). Adaptation accounting reveals specific problem framings and solution spaces that represent underlying values, assumptions, and visions for the future. The frameworks and metrics that organizations operationalize in

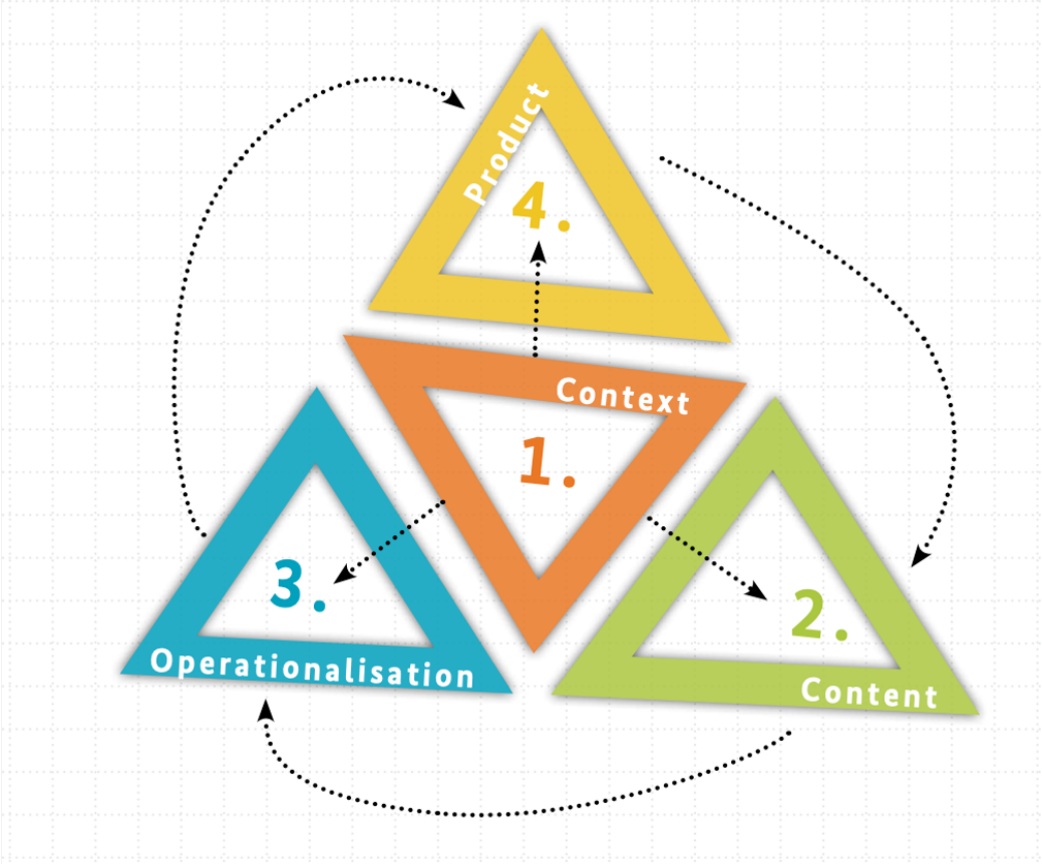
their M&E frameworks influence future decisions and actions. M&E frameworks become embedded in organizational goals and processes, and can serve different agendas (Fisher 2023). M&E design choices are therefore not only technical; they force decisions about what kind of knowledge and expertise is considered relevant and whose view(s) on adaptation success is legitimized. This means that underlying assumptions and perceptions about what adaptation means and what success entails need to be made explicit so that measurement frameworks are relevant, and the trade-offs and implications of design choices are clear (Fisher 2023).

3. The building blocks of adaptation monitoring & evaluation

Monitoring and evaluation systems provide two key functions. Monitoring captures whether organizations, governments, or other actors are on track towards reaching their adaptation goals, commonly by focusing on the implementation status of specific policies, programs, or other measures identified through the adaptation planning process. Evaluation captures whether adaptation actions are achieving desired outcomes identified in the planning process (for example: reduction in damage, improvements in service reliability, improving or maintaining energy affordability and accessibility).

There are a number of guidance documents published to assist actors in development adaptation monitoring and evaluation systems (see synthesis reports by the Global Commission on Adaptation and the Adaptation Committee of the UN Framework Convention on Climate Change for recent examples) (Adaptation Committee 2023; 2021; Leiter et al. 2019). This highlights how there is no singular model for how to conduct adaptation monitoring and evaluation, but we can draw from the work of Price-Kelly et al. (2015) to discern the general components of comprehensive M&E frameworks (Figure 3). The following section describes Price-Kelly's model, with relevant examples from the electricity sector. See Leiter and Lesnikowski (2022) for a similar analysis on adaptation M&E for Canada's National Adaptation Strategy.

Figure 3: The building blocks of adaptation monitoring and evaluation (from Price-Kelly et al., 2015)



3.1 Context: motivation, purpose, scope of M&E

The first component of adaptation monitoring and evaluation refers to the broad organizational or governance context for adaptation, including the motivation, purpose, and scope of M&E. Many adaptation strategies are **motivated** by government mandates to assess climate change-related risks and identify adaptations to address key risks and vulnerabilities. A recent global assessment of national adaptation M&E systems indicates that they are nearly always created following the adoption of a climate change adaptation strategy or plan (Leiter 2021), following the stages of the adaptation cycle illustrated in Figure 2 above. In other cases these mandates are embedded in legislation. In the province of British Columbia, for example, the Climate Change Accountability Act requires an annual report on progress under the government's climate change goals and targets, including a description of actions taken and future plans to

manage climate risks. The Act further requires public sector organizations to submit an annual climate change accountability report. The Climate Action Secretariat is currently developing a comprehensive monitoring and evaluation framework to assess implementation of the Province's Climate Preparedness and Adaptation Strategy. The Province is also currently updating its emergency management legislation to better prepare for climate change impacts (Government of British Columbia 2022).

The type of mandate is important to consider, as research suggests that weak mandates can slow or limit M&E development. Legislated mandates, for example, are generally seen to be stronger than mandates originating from executive orders or strategic plans (Leiter 2021). This is particularly significant because M&E systems are rarely finalized prior to the adoption of adaptation policies. In Canada, for example, the National Adaptation Strategy was adopted with a preliminary set of indicators to track adaptation progress and a statement that Canada's M&E "framework will be refined and improved on an ongoing basis to develop a better understanding of the state of resilience across the country" (Government of Canada 2023). Climate risk disclosure in the electricity sector is still voluntary in most jurisdictions, although it is anticipated to become mandatory soon (see section 4.2). Several international frameworks currently guide internal risk assessment, adaptation planning practice, and external disclosure, most notably the recommendations of the Task Force on Financial Disclosures, now moved to the International Sustainability Standards Board, the Sustainability Accounting Standards Board, and the International Organization for Standardization. See Appendix A for a comparison of these frameworks.

Robust adaptation M&E also requires clarity on the intended **purpose** of M&E. This may include building accountability to the public or shareholders for meeting stated goals or targets, tracking implementation of key policies or programs to ensure new investments or activities are meeting intended milestones, meeting legislative or disclosure requirements, or producing knowledge and learning to support improved policy or program design or decision-making processes. Ideally, adaptation M&E is designed to meet multiple purposes and supports transparency as well as iterative decision-making over the long-term.

Finally, M&E frameworks must specify the **scope** of analysis and data collection. This should be informed by both the motivation and purpose of the framework, as well as organizational characteristics. For example, in the electricity sector scoping may identify: i) what aspects of the electricity sector will be assessed (generation, transmission, storage, demand); and ii) what types of assets and operations are relevant.

3.2 Content: Approaches and indicators for M&E

The content of an M&E framework refers to its design and analytical operationalization. Various **approaches** to adaptation M&E are identified in previous reviews (Lesnikowski and Leiter 2022; Leiter et al. 2019), but broadly speaking existing approaches can be categorized as focusing on assessing outputs or outcomes of adaptation strategies, policies, programs, or projects (Ford et al. 2013). Output-based approaches focus on assessing processual dimensions of new projects or services, such as money spent on new initiatives, number of staff trained on identifying climate risks, or the share of assets that are updated to new engineering standards. For example, one performance indicator for critical infrastructure systems identified by the Government of Canada in its National Adaptation Strategy is the percentage of public and municipal organizations that factored climate change adaptation into decision-making processes for infrastructure (Government of Canada 2023). Outcome-based approaches focus on assessing the effects of those interventions on resilience building or vulnerability reduction. For example, outcomes of interest may be reductions in outages during extreme weather events or avoided costs associated with damage to key assets.

In reality, adaptation M&E frameworks are typically a hybrid of these two approaches, although Leiter (2021) notes that most national M&E frameworks tend to favour output-based analyses, particularly progress reports rather than evaluation reports. Developing M&E frameworks that deliver on multiple objectives like those discussed in Section 3.1, however, indeed requires a hybrid approach. This could include other types of outcome-oriented methodologies like cost-benefit analyses of the economic benefits derived from adaptation interventions, and cost-effectiveness analyses that examine economically efficient options for achieving set goals (Michaelowa and Stadelmann 2018). Berrang-Ford et al. proposed a hybrid

approach to assessing the sufficiency and appropriateness of adaptation measures against organizational goals and targets, as well as vulnerability and resilience outcomes (Berrang-Ford et al. 2019).

The methodological design of M&E frameworks likewise can incorporate both qualitative and quantitative dimensions. Progress reports on the implementation status of different actions tend to adopt a qualitative, narrative approach that summarizes key milestones and progress made under different action items. To-date, for example, nearly all adaptation progress reporting under provincial and territorial adaptation strategies focuses on monitoring policy implementation and thus adopts this style (Lesnikowski and Leiter 2022). The European Union developed a scorecard approach that uses 5 criteria and 13 indicators to assess adaptation progress among each of its member states. This approach was adapted in the 2020 UN Adaptation Gap report to assess global adaptation progress based on nationally determined contributions, national adaptation plans, and national communications (UNEP 2020). There is limited development to-date of evaluation frameworks that focus on (quantitatively) measuring changes in resilience and vulnerability outcomes. The United Kingdom's Third National Adaptation Programme, however, aims to develop more quantitative adaptation targets with the use of pathways scenarios, which would require a stronger focus on evaluation (see section 4.1 for more information on this example).

M&E commonly makes use of **indicators** (also referred to as metrics) to track changes over time. While climate vulnerability indices have long-made use of outcome indicators (e.g. ND-GAIN), adaptation M&E tends to rely heavily on output-oriented indicators, which experts warn can lead to misleading interpretations about how much adaptation is really occurring (Leiter and Pringle 2018). There are a vast number of potential indicators that can be useful in adaptation M&E. Appendix C provides examples of proposed indicators from selected adaptation M&E guidelines and synthesis reports. In 2014, for example, the International Institute for Sustainable Development compiled a repository of adaptation indicators in use across different adaptation M&E frameworks. The report identifies over 100 indicators pertaining to average climatic conditions, climate change impacts, adaptation actions, and adaptation results (Hammill et al. 2014). In 2018, the Expert Panel on Climate Adaptation and

Resilience Results convened by the Government of Canada narrowed down to a list of 54 sector-specific indicators that could be useful to assessing the Pan-Canadian Framework on Climate Change (EPCARR 2018). Though indicators are commonly presumed to be quantitative forms of data, they can also make use of qualitative data, for example expert judgments, theories of change, or score cards (Leiter et al. 2019). The sheer volume of indicators that encompass different features like climatic conditions, action planning, adoption of policies and measures, adaptive capacity, and vulnerability or resilience outcomes demonstrates both the range of potential indicators and the impossibility of determining a universal set of adaptation indicators.

Given these nuances, indicator selection should be informed by the stated purpose of the M&E framework (e.g. accountability, learning, or improved decision-making), the most relevant outputs and outcomes to established goals and targets, and practical limitations related to information availability, time, and resources (Price-Kelly et al. 2015). Guidelines on how to operationalize each indicator are essential to ensure transparency and consistency in measurement. Indicator factsheets on calculations and data sources are one common approach to doing this (EPCARR 2018).

It is therefore important to recognize that there is no one-size-fits-all group of indicators, and that indicator selection needs to reflect the M&E framework's context and design approach. One potential pathway forward for the electricity sector is to focus on connecting adaptation planning and decision-making with existing indicators that are already standard practice in performance evaluation and risk assessment. Electricity Canada gives several examples of indicators that may be relevant for the electricity sector: 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); forced outages; damage costs from extreme weather and climate impacts; and customer satisfaction levels (Canadian Electricity Association 2020). The scientific literature on energy systems also proposes various measurements for measuring robustness, resilience, residence, and adaptability (for a thorough review see Ahmadi et al (2021)).

There are also notable limits to what indicators can convey. For example, they are unable to explain how or why changes in values occur, which is essential information to understand whether adaptation measures are effective or not and in turn to support evidence-based decision-making. Some countries like Norway have integrated qualitative forms of information collection like surveys, dialogues, and decision-maker networks to share knowledge and lessons learned about the results of adaptation responses (see section 4.1). A major challenge for developing more evaluative assessment frameworks is the vague nature of most adaptation policy goals. In the absence of clear targets rooted in comprehensive impact and vulnerability assessments, it is unclear what outcomes should be prioritized and how to benchmark changes in exposure, adaptive capacity, vulnerability, or resilience. This points to the importance of situating adaptation M&E in strategic adaptation decision-making processes, and developing M&E frameworks alongside the articulation of clear goals and targets and action plans. M&E frameworks that aim to improve policy learning, for example, should include information from how implementation processes unfold and the experienced effects of adaptation responses.

3.3 Operationalization: roles & responsibilities, organizational processes, data acquisition

Operationalization of the M&E framework refers to how organizations establish roles and procedures related to creation and implementation of an assessment approach. This includes assigning **roles and responsibilities** for data collection, analysis, and communication; **timelines and steps** for producing relevant information and deliverables; and **procedures for data collection, aggregation, and analysis**. Governmental adaptation M&E frameworks are often assigned to an environment department or dedicated office for leading climate change planning. Among electricity utilities, adaptation assessment is commonly integrated into governance procedures for ESG management and reporting like Environmental Management Systems. For example, at Hydro One climate change planning is under the direction of the Chief Safety Officer and integrated into the work of relevant committees, which meet quarterly to advance work on climate planning (Hydro One, 2021). In 2021 the company completed a climate change scenario analysis using global climate models that examined material and

financial impacts under high, medium, and low global warming scenarios. At Emera (Nova Scotia Power), the Enterprise Risk Management Committee oversees responsibility for climate risk analyses within its risk register (Emera 2022).

Utility companies are increasingly developing internal capacity for climate risk analysis and energy adaptation planning, including dedicated groups for managing climate change planning. Manitoba Hydro, for example, maintains a Climate Change Opportunities, Risks and Adaptation Working group to support scientific analysis on adaptation needs. Determining how much adaptation M&E will rely on existing capacities or require development of new capacities is an important step in creating an M&E framework. Potential trade-offs between resource efficiency and analytical capacity need to be identified and deliberated on. Providing adequate training and resources for departments or working groups tasked with implementing M&E is essential for improving feasibility and robustness of results. Digitization brings new opportunities for data collection and analysis in the context of adaptation M&E, but it is still largely unexplored in the research and practice realms and warrant further discussion (Balogun et al. 2020).

3.4 Communication: the format, timing, and frequency of M&E

Effective communication of findings from M&E assessments is essential for accountability, learning, and improved decision-making. M&E frameworks need to establish clear guidelines on the f**requency, timing, and format of deliverables**. Government M&E requirements typically center around the submission of annual progress reports to legislatures or ministerial offices (see Section 4.1). Electricity companies similarly submit annual corporate reports on sustainability and other matters, and we can see these reports are beginning to address matters related to climate change adaptation (see Section 4.2). M&E deliverables are commonly designed as narrative reports (Lesnikowski and Leiter, 2022), but we also see an increasing number of examples of digital dashboards to track changes in quantitative indicators (e.g. the IMF Climate Change Dashboard and Nova Scotia Power's Climate Commitment Tracking Tool).

Finally, **reporting intervals** should be frequent enough to feed up-to-date information into key decision-making moments, but avoid creating burdensome reporting requirements for companies and other actors. Aligning major milestones in reporting timelines with corporate planning cycles is one way to ensure that relevant information is being made available in an efficient and timely manner. Intermediate updates can be designed in a more targeted manner. For example, under Hydro One's Enterprise Risk Management process, quarterly updates on climate-related risks are delivered to the corporate Board and relevant committees. Detailed impact and vulnerability assessments are typically conducted on multi-year time frames (e.g. every 5 years).

4. Current practices in adaptation monitoring and evaluation

The following section describes the current state of practice on adaptation monitoring and evaluation in national adaptation planning and in the Canadian electricity sector. The former is indicative of how design principles for adaptation M&E are advancing more broadly in the realm of M&E practice, while the latter provides an overview of early efforts to integrate adaptation M&E within electricity companies more specifically. The country and company cases described below were selected based on two criteria: 1) evidence that adaptation M&E is already being implemented in some form, and 2) relevance to the Canadian context. In the case of the second criteria, we only reviewed national adaptation M&E systems from industrialized countries.

4.1 National-level adaptation monitoring and evaluation in industrialized countries

To identify whether there are existing adaptation M&E frameworks designed to assess progress towards resilience or vulnerability goals in the electricity sector, we conducted a database review of major international and overseas development organizations working in the energy and climate change sectors (International Renewable Energy Agency, Organization for Economic Cooperation and Development, Energy EU, GIZ, International Standards Organization, and the UN Framework Convention on Climate Change), as well as the US Department of

Energy. We identified guidance documents on adaptation assessment, as well as national adaptation strategies that include policy goals for the electricity sector (n = 46). Of the documents, 34 contained information specifically relevant to monitoring and evaluation. None of these guidance documents provided specific advice on the design of adaptation M&E systems for the electricity sector, however, and not all of the national adaptation strategies have accompanying M&E frameworks. We did identify 16 industrialized countries that have adopted national adaptation M&E frameworks for further review. This country list was validated with the findings from Leiter (2021), who conducts a global survey of existing national monitoring and evaluation systems but does not analyze the specific characteristics of those systems. In this section, we conduct an analysis of each of these national M&E frameworks based on the building blocks model from Price-Kelly et al., 2015 (see Appendix B). This allows us to compare existing M&E frameworks based on their context, content, operationalization, and communication strategy.

We find that national M&E frameworks are in varying stages of maturity. There are a number of overarching similarities across these frameworks, each also contains unique components. For example, the M&E frameworks we analyze are nearly all tied to the development of a national adaptation plan or strategy, with the notable exception of the United Kingdom where the mandate for adaptation M&E is found in the 2008 Climate Change Act. The use of indicators is also ubiquitous in the countries we analyzed. Nearly every country uses some combination of indicators to capture outputs, outcomes, and climatic variables. Some countries have developed entire indicator systems (e.g. Colombia, Germany), while others select indicators in relation to specific adaptation measures (e.g. France). In some cases, countries note that indicator systems are still under development (e.g. Norway). Several countries also make use of other types of data, including surveys (Colombia, Germany, Norway), interviews (Germany, Norway), stakeholder dialogues (Norway), and even Delphi surveys to validate findings from M&E reports (Norway). Few countries describe the development of change theories to understand and explain adaptation success or weakness (e.g. Germany, United Kingdom), despite recommendation to do so in best practice guides to monitoring and evaluation.

The operationalization of these frameworks tends to be relatively top-down, with environment ministries or climate change departments frequently tasked with the responsibility of implementing adaptation plans and assessing their progress. In some cases governments also collaborate with other stakeholders, like regional and local governments (Finland, Slovakia, Sweden) and civil society organizations (Germany, Norway). Reporting requirements frequently entail annual, biannual, or periodic report submission to legislative bodies or an executive office (e.g. Cabinet). Occasionally they also entail periodic climate risk assessments to generate data and information on changing climatic conditions and vulnerability outcomes (e.g. Finland, Germany, United Kingdom). In some cases it is unclear if countries are abiding by the reporting timelines set out in their adaptation plans, as public information on monitoring or evaluation reports was unavailable online.

The heterogeneity of these frameworks demonstrates that there is no one-size-fits all approach to adaptation M&E. In general we observe, however, that the proliferation of national adaptation strategies is being accompanied by efforts to develop formal ways of assessing progress towards key goals. The following subsections highlight the most relevant findings from our country review of adaptation M&E frameworks.

4.1.1 Belgium

Belgium has implemented a monitoring and evaluation framework for its National Adaptation Plan titled the Belgian National Adaptation Plan (Nationale Klimaatcommissie 2019). The scope of the plan and its M&E framework is multi-level, encompassing both a federal plan and regional plans for Brussels, Flanders, and Walloon. The M&E framework includes the evaluation of the impact of climate change on energy supply security and infrastructure, assessment of the socio-economic impacts of climate change in Belgium, evaluation of the integration of climate change impacts and adaptation needs into the future environment and health action plan, and promotion of transnational cooperation on adaptation. To measure progress and effectiveness, various output indicators are identified, including: the use of plan results by the scientific community, climate service providers, and policy makers; contributions to CORDEX (downscaled regional climate modelling); completion of an adaptation roadmap; creation of an

online platform for adaptation; participant numbers and satisfaction levels in symposiums; assessments of invasive species considering climate change; and the integration of climate-related projects in the future environment and health action plan.

Operationalization of M&E is carried out by the National Climate Commission, which is responsible for implementing and monitoring the National Climate Plan, collecting and exchanging data, and preparing reports. The Coordination Committee for International Environmental Policy plays a key role in coordinating Belgian international environmental policy. M&E deliverables include mid-term and final evaluations, spanning from the plan's original creation in 2010 to the set revision in 2023. Indicators have been tracked from 2017 to 2019 and beyond with continuous or recurring timelines. The previous National Adaptation Plan was approved in 2017, with a mid-term evaluation published in 2019 and the final evaluation completed in 2020.

4.1.2 Colombia

The monitoring and evaluation framework for Colombia's adaptation plan is found in the National Plan for Adaptation to Climate Change (PNACC). The plan and its M&E framework operate at national, regional, and sectoral levels. To monitor and evaluate the PNACC, Colombia identified a National System of Adaptation Indicators (Romero-Ruiz et al. 2016). This system is based on a review of more than 150 indicators, from which a group of 34 indicators was selected and grouped according to threat, exposure, sensitivity, adaptation capacity, and impact. These indicators cover seven categories: Biodiversity and Ecosystem Services, Water resources, Agricultural and Food Security, Infrastructure, Energy, Human Habitat, and Health. Additionally, Colombia has conducted an analysis of risk and vulnerability to climate change at the municipal level using 113 indicators that account for threat, sensitivity, and adaptation capacity. Operationalization of the PNACC's M&E is led by the Ministry of Environment and Sustainable Development of Colombia. The framework is implemented through surveys, periodic reporting, and analyses to assess the progress of adaptation measures and evaluate their effectiveness. The PNACC was published in 2016, but the required frequency of monitoring and evaluation activities is unclear in official documentation.

4.1.3 Finland

Finland's monitoring and evaluation framework is found within the Finnish National Climate Change Adaptation Plan 2022 (Mäkinen et al. 2020). The scope of the plan and its M&E framework encompass both national and regional levels. A list of proposed indicators to support monitoring were published in 2017, but they are as yet unformalized.

The operationalization of the M&E framework involved the establishment of a national monitoring group on climate change adaptation, which included key stakeholders from ministries, regional and municipal actors, and research institutes. This cross-sectoral group was appointed and coordinated by the Ministry of Agriculture and Forestry. Annual progress reports on the national adaptation plan are unavailable, although the plan was evaluated in 2022. The stated deliverables of the M&E framework also include national climate risk assessments, which contribute to assessment of changing climate risks and vulnerability.

4.1.4 France

France developed the French National Adaptation Plan for Climate Change (PNACC-1) in 2011 and the second French National Adaptation Plan for Climate Change (PNACC-2) in 2018 (Government of France 2011; 2018). The scope of the plans and their accompanying M&E frameworks are at the national level and cover aggregated sectors and thematic areas. The development of PNACC-2 was based on the recommendations of the assessment of the PNACC-1 from 2011-2015 and involved a national consultation process that engaged over 300 representatives from civil society, experts, and representatives of local authorities and ministries. This approach was participatory, relying on a consultation process and inter-ministerial collaboration, as well as quantitative, calculating the percentage of implementation of each sector's adaptation actions for the annual monitoring report.

The M&E framework for PNACC-2 defines at least one monitoring indicator for each adaptation action. The operationalization of the monitoring is entrusted to the specialized commission of the French National Council for Ecological Transition, which acts as a national adaptation monitoring committee. Annual monitoring reports are presented to and reviewed by key stakeholders through the National Committee for Ecological Transition.

4.1.5 Germany

Germany's national adaptation strategy, known as the German Adaptation Strategy (DAS), includes a monitoring and evaluation framework called the “Methodology for the evaluation of the German adaptation strategy” that is implemented at both the federal government and federal-state levels (Kind, Kaiser, and Gaus 2017). The framework aims to make several contributions. First, it generates knowledge about the DAS process and contributes to a better understanding of its implementation. Second, it ensures accountability by checking the implementation of planned measures. Third, it facilitates a learning process by identifying success factors and challenges, enabling continuous improvement. Lastly, it serves as a documentation of the achievement of objectives, providing legitimacy to the adaptation efforts.

Monitoring and evaluation of the DAS is based on a logic model that includes five central evaluation questions. A multi-method approach is employed to collect the necessary data and information, including document analysis, interviews, and the analysis of indicators. To validate the findings, a Delphi survey is conducted with key stakeholders involved in the adaptation policy process. There are several types of deliverables under Germany’s M&E system, including monitoring reports, progress reports, and vulnerability analyses. Monitoring reports describe observed consequences of climate change and current adaptation activities in Germany, utilizing a defined indicator system that was adopted by a working group on adaptation. Vulnerability analyses, carried out by the Vulnerability Network, examine risks from climate change, identify vulnerable regions and sections, and prioritize action needs for the federal government. Progress reports provide general updates of the DAS. Key indicators encompass various aspects of climate change impacts, including damage caused by heat exposure, water availability impacts from warming and drought, damage to buildings and infrastructure from heavy rain and flooding, damage to coastlines from rising sea levels and storm surges, and changes in species composition due to temperature rise.

The M&E framework was approved by an interministerial working group on adaptation, which comprises representatives from various ministries under the leadership of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The coordination of adaptation activities between the federal government and federal states is facilitated by the

Standing Committee for the Adaptation to Climate Change Impacts. The first evaluations took place in 2017 and 2018, with the initial evaluation report published in 2019. The evaluation of the DAS is conducted on a regular basis to ensure continuous monitoring and improvement.

4.1.6 Italy

Italy's National Adaptation Plan has a monitoring and evaluation framework that operates at the national level. The framework aims to ensure that the adaptation plan is comprehensive and aligns with Italy's national adaptation goals (Government of Italy 2023). It includes several output indicators, such as the issuance of Ministerial decrees and passing of acts and the number of plans and programs for which adaptation responses have been identified, as well as 27 climate indicators (Government of Italy 2022). Deliverables include a climate impacts analysis of current and future risks, and their expected impacts on sectors prioritized within the plan.

Operationalization of the M&E framework is connected with the Ministry of the Environment and Energy Security, and the Institute for Environmental Protection and Research, which supports the preparation of documentation related to the strategic environmental assessment and adaptation and mitigation strategies for climate change. The latest adaptation report was conducted in 2017, and public hearings on the adaptation were scheduled for early 2023.

4.1.7 Latvia

The Climate Change Adaptation Strategy of Latvia 2030 contains a monitoring and evaluation framework that is national in scope and focuses on assessing changing climatic conditions in Latvia (Government of Latvia 2019). This involves monitoring climate change through the summarization and analysis of meteorological parameters and climate indices. Additionally, Latvia maintains a climate change impact monitoring database, which includes selected climate change impact indicators and vulnerability calculations for different sectors. Under the framework Latvia aims to ensure public access to the database, create a database on disaster-

related losses associated with climate change, assess methods for monitoring coastal erosion, and establish a permanent monitoring approach.

Operationalization of monitoring and evaluation is led by an inter-ministerial working group and a working group of experts. The lead convener for these groups is the Ministry of Environmental Protection and Regional Development, which is also tasked with submitting mid-term and final reports on the plan's implementation to Cabinet. Reporting deliverables include mid-term and final reports, due by December 31, 2026 and December 31, 2031, respectively.

4.1.8 Norway

The Norwegian Climate Adaptation Programme was established in 2007 (GIZ 2014). The M&E approach taken under the programme is based on learning-by-doing, where climate change actions are implemented and lessons are integrated into subsequent policy and programme decisions. The purpose of this is to understand what is working in climate change adaptation and why, and to inform future policy decisions. Both formal (structured surveys, research) and informal (dialogues, network support) approaches to information collected are used to understand the results of adaptation actions. M&E activities include national vulnerability and adaptation assessments conducted every five to eight years. These are linked to global assessment cycles under the Intergovernmental Panel on Climate Change (IPCC). The assessments include adaptation activities and experiences at the subnational level. Indicators are used to a limited extent in the monitoring and evaluation framework, with a high-level indicator related to the national goal for climate change adaptation under development.

M&E is operationalized through an inter-ministerial group led by the Ministry of the Environment. An expert committee representing various sectors and levels of decision-making also prepared vulnerability and adaptation assessments. Vulnerability and adaptation assessments are conducted every five to eight years at the national levels, while specific results and lessons learned are captured in regular reports.

4.1.9 Portugal

Portugal's National Strategy for Adaptation to Climate Change spans six thematic areas in all sectors, including research and innovation, financing and implementation, international cooperation, communication and dissemination, adaptation in spatial planning, and adaptation in the management of water resources (Government of Portugal 2020). The strategy's accompanying monitoring and evaluation framework includes progress reports, and does not make explicit mention of any indicators or other metrics.

Operationalization is coordinated by the Agência Portuguesa do Ambiente. The reporting timeframe is biannual, with sectors relevant to each thematic area expected to submit details on adaptation implementation that outlines objectives and activities to be carried out within the strategy's timeline.

4.1.10 Sweden

Sweden's National Strategy for Climate Change Adaptation was adopted with a general model for guiding monitoring and evaluation, but without a final list of indicators for measuring progress under the strategy (Government of Sweden 2017). Operationalization of the strategy and it's M&E framework is multi-level, and involves 32 national authorities and 21 County Administrative Boards. The Swedish Meteorological and Hydrological Institute plays a significant role in coordinating and analyzing the climate change adaptation work carried out by relevant agencies. The aim of this multi-level approach is to build a more collaborative and integrative approach to adaptation. The timeline identified for monitoring and evaluation follows the strategy's policy cycle, with recommended updates occuring every five to seven years.

4.1.11 Spain

The monitoring and evaluation framework for Spain's adaptation plan can be found in its National Plan of Adaptation to Climate Change (PNACC) (Government of Spain 2020). Spain's monitoring and evaluation framework for the PNACC aims to be agile, versatile, and continuously updated. The framework includes synthesis reports on climate risks and

adaptation measures; sectoral progress reports are also prepared to analyze the status of specific areas of work within the PNACC. Additionally, monitoring reports are produced to gather information on the actions developed within the framework, including conclusions, challenges, and future perspectives. The framework uses a variety of indicators, including information related to costs and benefits for adaptation actions, and demographic information on adaptation beneficiaries (particularly with a gender lens).

Operationalization of the M&E framework is led by the Spanish Climate Change Office of the Ministry for the Ecological Transition and the Demographic Challenge. The office is responsible for organizing information, monitoring progress, and evaluating the effectiveness of the PNACC. Regular working forums, thematic seminars, and coordination groups are help to facilitate communication and collaboration among stakeholders. The reports produced within the framework provide detailed information on the progress, challenges, and future perspectives of the adaptation plan. The timing of the reports varies, with climate risk and adaptation reports published at least every five years. Two monitoring reports are proposed for the period of the new PNACC, with indicative publication dates of 2024 and 2029.

4.1.12 Slovenia

The monitoring and evaluation plan for Slovenia's Strategic Framework for Climate Change Adaptation includes climate risk and vulnerability assessment, as well as the assessment of risks and capabilities for disaster risk management (Government of Slovenia 2016). The plan states that it employs indicators to monitor Slovenia's vulnerability at the national and municipal levels, although these indicators are not explicitly described. Monitoring and evaluation is led by an inter-ministerial climate change adaptation working group, which produces biannual reports and regularly updates adaptation information and guidelines.

4.1.13 Slovakia

Slovakia's National Action Plan for the implementation of the Adaptation Strategy of Slovakia is national in scope but focuses on urban settlements (Government of Slovakia 2021). Local governments therefore play a role in implementing and guaranteeing the measures outlined in

the plan. Monitoring and evaluation under the plan includes detailed assessments of adaptation measures, with a particular focus on avoiding negative impacts on vulnerable populations. This may involve proposing new measures, policies, or changes to existing ones. Reporting on the implementation of actions for specific priorities and objectives is included in the framework. The plan incorporates various output indicators to measure progress, such as the number of new constructions, repairs/renovations, adoption/revision of legislation, and the development of new methodologies related to adaptation. Monitoring and evaluation for the plan are the responsibilities of the Ministry of Environment, which coordinates with an adaptation working group comprising representatives from line ministries, CSOs, academia, NGOs, and other stakeholders.

4.1.14 Switzerland

Switzerland's Adaptation to Climate Change in Switzerland Action Plan is federal in scope, but emphasizes the importance of collaboration and coordination among the Confederation, cantons, cities, and municipalities (Burkhardt et al. 2020). Selected climate indicators are used to assess the impact of climate change, including rising maximum temperatures and number of hot days, rising snow line and fewer days with fresh snow, drier summers, and more frequent and intense heavy precipitation. However, we were unable to identify the indicators for the monitoring and evaluation of the 75 adaptation actions identified in the plan.

The operationalization of M&E under the plan involves coordination among various federal agencies responsible for drafting and assessing the measures. Deliverables include performance audits, impact analysis, and a synthesis report on the pilot projects. Switzerland has adopted adaptation action plans for the periods 2014-2019 and 2020-2025. The results of the impact analysis were last summarized in a report in 2017 and submitted to the Federal Council. The frequency of monitoring and evaluation activities includes regular reviews to verify compliance with goals and principles. This includes five-yearly reporting of activities at the cantonal level, and biennial reporting on the implementation status of actions taken by federal agencies. In the future, the impact analysis will be conducted every three years.

4.1.15 United Kingdom

The monitoring and evaluation framework in the United Kingdom is now in its third iteration as part of the Third National Adaptation Programme (NAP3) (Government of the United Kingdom 2023). The M&E approach taken by the UK government involves a theory of change approach. This applies a causal logic to tracking interventions from action to impact, with the aim of understanding what works and why, and encouraging iterative learning. The government aims to develop a new set of indicators to evaluate the programme's success, including indicators related to infrastructure, regulations, training, infrastructure service disruptions, damages from flooding, instances of heat strokes, flooding and drought extent, and adverse impacts on ecosystems.

Operationalization of the framework involves the independent Committee on Climate Change and its Adaptation Sub-Committee, which prepares biennial progress reports to Parliament. The government has a statutory duty to respond to these reports based on the Climate Change Act. The format of reporting progress is through progress reports, and NAP3 explains the government's plans to adapt to climate change over the next five years, from 2023 to 2028. The frequency of reporting is every five years, aligning with the government's assessment of climate risks and opportunities and its commitment to managing climate risk effectively. The first progress report for NAP3 is expected in 2025, and the UK's approach to climate adaptation places it at the forefront of global efforts in this field.

Sectoral case study: Monitoring and evaluating the Dutch Delta Programme

The Dutch government operates the Delta Plan on Spatial Adaptation (or Delta Programme) to help achieve the goal of a climate-proof and water-resilient Netherlands by 2050. Under the Delta Programme, the national government along with provinces, municipalities, district water boards, Rijkswaterstaat (the executive branch of the Ministry of Infrastructure and Water Management) and various NGOs collaborate on three sub-programmes: Flood Risk Management, Freshwater Supply, and Spatial Adaptation. Each sub-programme includes both a Delta Decision and a Delta Plan. Delta Decisions typically comprise national frameworks or policies, with a special focus on vital and vulnerable functions which may be impacted by

flooding or extreme weather. The Delta Plans set out implementation measures for national policy as well as detailed implementation schedules. For example, the Delta Plan on Spatial Adaptation expedites and intensifies measures to combat waterlogging, heat stress, drought, and the impact of flooding. This includes: 1) Mapping out vulnerabilities; 2) Conducting risk dialogues and drawing up strategies; 3) Drawing up implementation agendas; 4) Capitalising on linkage opportunities; 5) Promotion and facilitation; 6) Regulating and embedding; and 7) Responding to disasters.

Monitoring and evaluation under the Delta Programme looks at progress towards the goals and actions determined in the Delta Plan on Spatial Adaptation, and acts as an entry point to revise and update adaptation measures. In recent years, the Delta Programme developed a monitoring and evaluation system called the 'Monitoring, Analysing, Acting' system. The framework is built on four key questions:

1. On schedule: are we implementing the measures within the time frame and budget agreed upon? The central point of focus here is tracking implementation progress on actions (i.e. outputs).
2. On track: are we on track with goals and measures, or do external developments constitute a reason for reconsiding goals or measures? The central point of focus here is attainment of the goals (outcome).
3. Integrated approach: are we implementing tasks in an integrated manner?
4. Participation: where appropriate, are governments, businesses, NGO's, and residents involved in adaptation decisions or implementation?

The Delta Programme reports on the implementation status of the Delta Decisions and Delta Plans in annual reports to the Parliamentary House of Representatives. These reports are submitted along with a position paper by the Association of Provincial Authorities. The reports can include proposals for policy adjustment or optimizations depending on the observation of new obstacles or developments. Evaluations of the content of the Delta Decisions and its strategies are conducted every six years. The first results of those evaluations were presented in 2021. Every twelve years, the Minister of Infrastructure and Water Management reports to the House of Representatives about the assessment of all primary flood defences.

In 2021, the Dutch Ministry of Infrastructure and Water Management commissioned the Climate-proof Together Platform, which is setup under the Delta Plan on Spatial Adaptation to monitor adaptation progress. This Platform is responsible for contacting 50 to 75% of the 45 Working Regions for telephone interviews, with the interview outcomes presented in the Delta Plan progress report. Prior to 2021, the Ministry of Infrastructure and Water Management requested that the Delta Plan Working Regions would fill out a monitoring questionnaire, which would be used to develop the progress report in past years.

4.2 Adaptation M&E in Canada's electricity sector

We conducted a desktop review on annual reporting by nine[3] Canadian electricity utilities to assess the current state of adaptation monitoring and evaluation across the sector. The companies were selected based on their demonstrated engagement with climate risk assessment and adaptation planning. The review was supplemented by discussions with staff from Hydro Québec, Ontario Power Generation, Manitoba Hydro, BC Hydro, and Nova Scotia Power to gain further insight into past and future adaptation priorities at those companies.

We find that Canadian electricity utilities are at varying stages of adaptation planning and implementation, but overall adaptation is in earlier stages relative to planning for net-zero targets and decarbonization. Eight of the nine companies report on the completion of climate change scenario analyses and risk assessments, indicating that research on climate change impacts on the electricity sector is advancing across Canada. Companies are in different stages of prioritizing among identified risks and setting adaptation goals and action plans for addressing them. Hydro Québec and Nova Scotia Power finalized dedicated adaptation plans in 2022 and 2021, respectively, which includes goals and associated actions for addressing key risks (Emera 2022; Hydro Quebec 2022). Maritime Electric and Hydro One are in the process of preparing adaptation plans (Hydro One 2022c; Maritime Electric 2023). Several other utilities, including Ontario Power Generation (OPG) and Manitoba Hydro, have released climate change

[3] Maritime Electric, Nova Scotia Power and its parent company Emera, New Brunswick Power, Hydro Québec, Ontario Power Generation, Hydro One, Manitoba Hydro, and BC Hydro.

plans that focus primarily on emissions reduction but include some attention to adaptation (Ontario Power Generation 2020; Manitoba Hydro 2020). Electricity companies all maintain Environmental Management Systems that act as overarching frameworks for conducting ongoing risk analysis that inform strategic planning and decision-making. Climate change-related risks are commonly linked to these systems in company reporting, but the extent to which these frameworks are being updated with emerging knowledge on climate change risks is unclear. To date, reporting on climate change risks and adaptation by electricity utilities occurs within annual public reports that companies release on services, finances, and ESG. These reports play a strong role in enforcing accountability for regulatory requirements on corporate finances, energy costs, and sustainability.

Several developments are motivating engagement with climate risks and adaptation issues. First is the accumulation of research on climate change coupled with past extreme weather events that highlights the salience of climate change impacts for the electricity sector. In Québec, for example, the 1996 flood at Saguenay Lac St Jean and 1998 ice storm pushed Hydro Québec to begin modelling hydrological impacts of climate change on energy supply and reliability, particularly in relation to extreme events. This research portfolio broadened over time to include issues like forest fires and changes to energy demand. A recent string of extreme weather events, like the 2017 and 2019 western Québec floods, triggered a push towards a more structured approach on adaptation within the company. Similarly, BC Hydro has a long-standing climate change research collaboration with the Pacific Climate Impacts Consortium at the University of Victoria, particularly around hydrological modelling of energy supply. More recently, extreme weather motivated an expanded focus on climate change impacts to energy transmission and distribution.

Second are legislative requirements for climate change-related reporting. In British Columbia, for example, the *Climate Change Accountability Act* requires government entities including crown corporations to submit annual progress reports on their work towards achieving provincial climate change targets, particularly with respect to net zero and decarbonization targets. In Nova Scotia, the *Electricity Plan Implementation Act* requires the Nova Scotia Utility and Review Board to establish performance standards for Nova Scotia

Power. Though not specifically designed for climate change reporting, these performance standards include relevant indicators on reliability and response to adverse weather conditions. Nova Scotia Power reports annually on these indicators in its Performance Standards Report (Nova Scotia Power 2023). Manitoba Hydro's 2023 Integrated Resource Plan states that "actions by governments at all levels – federal, provincial, and municipal – are already shaping the changing energy landscape. In Canada, the federal government is working on strategies to address climate change and transition to a cleaner economy…Provincial and local governments are also changing the energy landscape through their actions, including introducing measures to attract economic development" (Manitoba Hydro 2023a). As government action on climate policy progresses, it is possible that adaptation reporting requirements will become further institutionalized in regulations or policies. Hydro Quebec's 2022 Sustainability Report, for example, states: "Although the application of TCFD recommendations is currently on a voluntary basis, its prescribed practices could one day become part of international certification requirements" (Hydro Québec 2022). The Auditor General of New Brunswick recommends that "New Brunswick Power publish in its annual report consistent performance indicators connected to short-, medium- and long-term energy efficiency objectives and the New Brunswick Climate Change Action Plan" (New Brunswick Power 2023). New Brunswick's Climate Change Action Plan 2022-2027 includes goals and actions on adaptation, as well as mitigation.

Third, electricity companies are anticipating future requirements for financial disclosure of climate change-related risks (Manitoba Hydro 2023b). In the European Union, for example, the Corporate Sustainability Reporting Directive requires large EU companies as well as certain non-EU companies to disclose information on emissions, targets, energy use, material and financial climate risks, and transition plans (European Union 2022). The guidelines were prepared based on the recommendations of the Task Force on Climate-related Financial Disclosures and the Partnership for Carbon Accounting Financials (European Securities and Markets Authority 2023). The United Kingdom adopted similar disclosure rules in 2022 based on the International Sustainability Standards Board guidelines (Government of the United Kingdom 2022). In discussions with electricity sector companies for this report it was noted that the industry anticipates that the United States and Canada will soon follow suit.

The content of adaptation reporting focuses largely on implementation progress of specific actions and linking existing indicators with climate change-related risks. For example, OPG's 2022 ESG report identifies actions like "Development and issuance of an internal climate change strategy and roadmap of deliverables; Establishment of an internal climate change adaptation working group, with cross-functional business unit representation and senior leadership endorsement; Initiation of climate risk and vulnerability assessment for existing generation assets and for specific Nuclear and Renewable Generation projects…." (Ontario Power Generation 2023). Hydro Québec reports that 5% of actions identified in its 2022-2024 Adaptation Plan are complete, 74% are in progress, and 21% are commencing soon (Hydro Québec 2022). Actions include process-oriented measures like completion of risk and vulnerability assessments, adoption of strategy planning tools, or creation of working groups to guide adaptation work, as well as concrete measures like asset upgrades and replacements or adoption of new technologies for managing repairs or outages. Companies report on established key performance indicators for reliability, such as System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI), outages reported, Customer Average Interruption Duration Index (CAIDI), and the total value of new investments in infrastructure upgrades designed to improve the resilience of assets to extreme weather events (Nova Scotia Power 2023; Emera 2022; BC Hydro 2023; Manitoba Hydro 2023b). These are tracked in annual performance reporting, but it is unclear whether the targets for each metric have been revised in light of climate change scenario modeling or risk assessments.

We also observe that companies use various international frameworks to guide sustainability or climate change reporting, including the Sustainability Accounting Standards Board (SASB), Global Reporting Initiative (GRI), and TCFD frameworks, and ISO standards (see Appendix A for a comparison of these frameworks). Hydro One, for example, provides short performance reports according to the SASB indicator framework and GRI indicator framework (Hydro One 2022a; Hydro One 2022). It also provides descriptive responses based on the TCFD framework about governance and management structures to oversee adaptation work, major findings on climate risks and opportunities from completed climate change assessments, how adaptation is being integrated into strategic decision-making, and relevant metrics (including

emissions targets and trends, and reliability indicators like SAIDI and SAIFI) (Hydro One 2022a). Hydro Québec does the same in its annual sustainability report (Hydro One 2022c). All nine companies maintain Environmental Management Systems (EMS) based on ISO 14001 as overarching frameworks for conducting environmental risk analysis and managing environmental performance (Malteic et al., 2015; Rino and Salvador, 2017). Some companies, for example Maritime Electric and Nova Scotia Power, indicate that these climate risks are considered within these systems but further research is needed to substantiate exactly how climate risks and adaptation are being integrated into EMS, particularly in light of more recent ISO standards for adaptation (14090/14091/14092) (Nova Scotia Power 2023; Maritime Electric 2023).

Adaptation is commonly included within sustainability or ESG reports, although some companies like BC Hydro and Manitoba Hydro have produced individual climate change reports that summarize work happening on mitigation goals and adaptation (Manitoba 2020; BC Hydro 2022). Integrating adaptation into sustainability and ESG reporting has the advantage of building on regular annual corporate reporting to provide updates on the implementation of resilience-building measures and other key milestones like the adoption of climate change plans. These reports also provide an important accountability mechanism for boards, governments, and shareholders. The information contained in them, however, tends to be relatively limited in comparison to dedicated adaptation M&E reports like those emerging as part of national adaptation M&E systems. This indicates that the addition of cyclical reports dedicated to climate change planning would provide greater depth on how companies are responding to climate risks. Notably, BC Hydro now produces an annual climate change accountability report, in line with provincial requirements, although the report focuses principally on emissions reduction progress (BC Hydro 2022). Companies already completing annual disclosures through global platforms like CDP can integrate those deliverables into their general climate change and adaptation reporting system.

Adaptation reporting is still largely voluntary and disclosure guidelines from groups like TCFD allow for a wide range of interpretation with respect to both climate risk analysis and adaptation reporting. This creates several challenges, not least of which is comparability of

disclosure information between companies. Ensuring that companies are using similar methods to calculate financial risk, for example, is essential for benchmarking and making efficient investment decisions across the sector. Methodological standards for scenario analysis and modelling uncertainties is one area where disclosure guidelines need clarification and strengthening. Furthermore, disclosure rules do not adequately address key issues like interpretation and communication of uncertainties in accounting and financial reporting. This lack of standardization contributes to the perception that adaptation reporting is less robust than reporting on emissions changes or other conventional (and quantifiable) metrics, and can create reluctance to fully disclose the results of scenario and risk analysis.

Case study: Nova Scotia Power (Emera)

Nova Scotia Power serves over half a million customers in Nova Scotia, and provides 95% of Nova Scotia's power generation, transmission, and distribution services. It is a wholly owned subsidiary of Halifax-based Emera, an energy company with subsidiaries in Canada, the United States, and the Caribbean. As a parent company, Emera sets standards and policy for itself and its subsidiaries, including EMS requirements, review and reporting requirements, benchmarking, and auditing. As one of its operating companies, Nova Scotia Power is responsible for implementing environmental requirements (including the Emeria EMS framework) and complying with reporting rules.

Climate disclosure work in both companies initially focused on emissions reductions and net zero targets. Adaptation emerged as a strategic priority in both companies beginning around 2018. Emera now notes that climate adaptation is an environmental priority for its companies, alongside the low-carbon transition (Emera 2022). Early adaptation planning within both Emera and Nova Scotia Power was informed by recommendations from Electricity Canada's adaptation guide. Nova Scotia Power partnered with consulting companies Manifest Climate, Willis Towers Watson, and Mantle Development to develop data and information tools on climate variables, scenarios, and risks (Mantle Developments 2023). This provided a foundation for integrating climate change into existing asset management tools like risk matrices (Linares Fuster and Khosa 2022). Risk profiles for assets are continually updated by

reliability teams consisting of engineers, operations staff, planners, and environmental managers.

In 2021 Nova Scotia Power adopted a climate change adaptation plan and Emera adopted a Climate Adaptation Framework (see Figure 3). The framework focuses on integrating climate change impacts into Emera's Enterprise Risk Management framework, and was developed based on recommendations from Electricity Canada (Canadian Electricity Association 2020).[4] The framework is in place across all of Emera's operational companies, and guides risk assessment, identification of adaptation measures, and creation of formal Climate Adaptation Plans. Oversight of environmental management at the Emera corporate level is led by the Health, Safety and Environment and Risk and Sustainability committees, and executive leadership. Primarily responsibility for adaptation at Nova Scotia Power is housed within the asset management team, while the environmental performance and risk management team manages company-specific planning and reporting, and reports to Emera's senior leadership (Emera 2023).

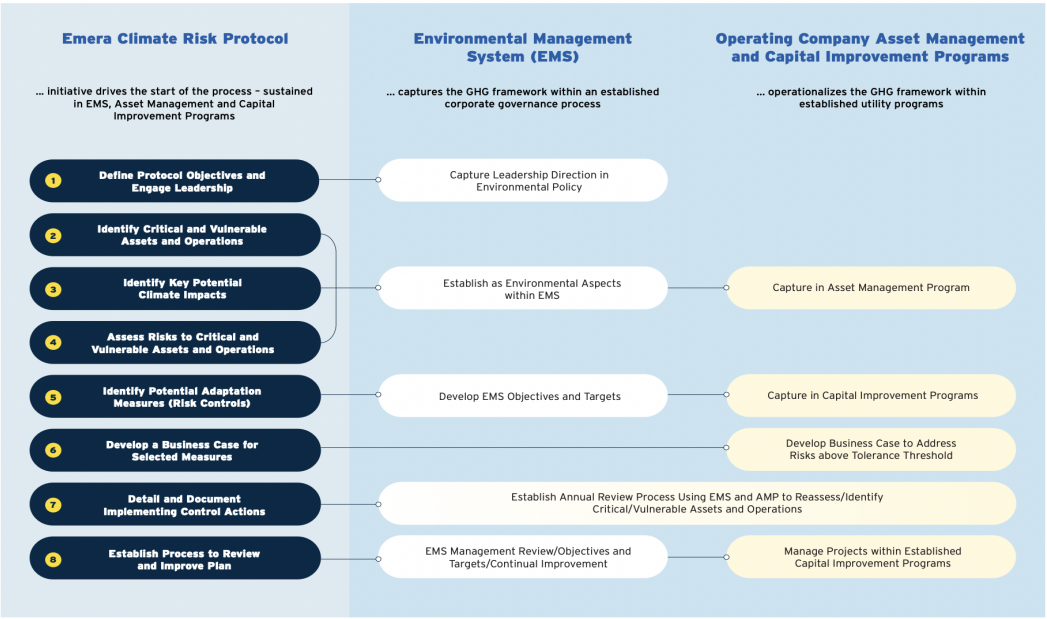
Emera and Nova Scotia Power voluntarily disclose information on climate risk and adaptation within annual reports. Reporting on progress under Emera's Climate Adaptation Framework is contained in its sustainability report. It includes information related to the GRI and SASB indicators, as well as the TCFD framework, including governance, strategy, risk management, and metrics and targets (Emera 2022). For example: *Governance* includes information about board oversight at Emera and its operating companies (including Nova Scotia Power), senior management, and Emera's EMS, which contains elements relevant to climate risk and adaptation. *Strategy* includes information on strategy infrastructure investments relevant to adaptation, like Nova Scotia Power's $110M investment in storm hardening and power system reliability, scenario analysis, and consultation approaches with groups like government, environmental groups, and First Nations. *Risk management* includes information on Emera's Enterprise Risk Management approach, which includes a risk heat map represented on a dashboard that is regularly reviewed and updated. Climate-related risks encompass changes in policy and law, technology, market changes, reputational impacts, physical impacts,

[4] Emera also has a Climate Transition Plan, which encompasses targets and actions related to emissions reduction.

and financial impacts. Each operating company, including Nova Scotia power, has its own risk register and heat map. *Metrics and targets:* Emera's internal Climate Commitment Tracking Tool includes a dashboard to track progress on emissions reductions and project status updates, however the dashboard does not currently track climate risk information or adaptation. In addition to annual sustainability reports, Emera submits an annual report to the Climate Disclosure Project (CDP), which principally addresses matters related to emissions reductions but also mentions work happening under the Climate Adaptation Framework (Emera 2023).

Nova Scotia Power completes an annual Performance Standards Report that provides data on reliability standards, adverse weather response, and customer service. Indicators comprise standard measures like SAIDI, SAIFI, Circuit Average Interruption Duration Index (CKAIDI), Circuit Average Interruption Frequency Index (CKAIFI), and reported outages (Nova Scotia Power 2023). Information from climate scenario analyses and risk assessment are also integrated into the Environmental Management System and budget planning processes (Nova Scotia Power 2023). Nova Scotia Power maintains internal targets and metrics related to climate risks and adaptation, but these are not disclosed in public reporting.

Figure 3: Emera's Climate Adaptation Framework (Emera 2022)



5. Proposed future research directions

1) **Conduct a comprehensive study on the state of adaptation planning in the Canadian electricity sector.**

This report frames the contributions of monitoring and evaluation to the adaptation process and summarizes the current landscape of M&E practice among governments and Canadian electricity companies. Advancing useful adaptation M&E requires strong strategic planning frameworks that give clarity on adaptation goals, targets, and pathways, including risk prioritization, identification of appropriate actions with accompanying timelines and resource allocations, and clear assignment of tasks, responsibilities, and accountability. Future work to progress more sector-specific recommendations for adaptation M&E would benefit from a complete evidence base on how adaptation is being institutionalized within Canadian electricity companies, including: common practices around climate change modelling and scenario analysis, company goals and targets and their associated actions, and organizational structures and decision-making processes around adaptation. This report relies on publicly available reports and informal discussions with staff responsible for adaptation work; future work could also include a systematic review of internal documents and formal interviews to develop a deeper information base.

2) **Examine how monitoring and evaluation frameworks can meet multiple objectives while minimizing administrative burdens.**

Two clear motivators for integrating adaptation into annual company reports emerged from this report (see section 4.2). First was the early recognition that physical impacts associated with climate change pose substantial risks to the core mission and financial stability of the electricity sector. Second was the global push to include climate risks in sustainability reporting and financial risk disclosure. In jurisdictions like the European Union this is now becoming legally formalized in corporate disclosure requirements. As Canadian governments advance work on climate change legislation and policy, it is likely that additional reporting requirements on climate risk will emerge at federal and provincial levels, as we see already in provinces like British Columbia. This report discusses how comprehensive M&E contributes to more than just

corporate accountability; its fundamental purpose is also to improve adaptation as an ongoing and long-term activity. Future research should examine how company-level adaptation M&E frameworks can meet emerging (and sometimes multiple) disclosure requirements, for example reporting requirements from securities regulators and governments, while also providing information and insights to improve internal decision-making processes and learning from successes and failures. A key challenge will be developing more nuanced and meaningful adaptation monitoring and evaluation that minimizes creation of additional administrative burdens.

3) **Advance multi-dimensional approaches to assessing adaptation actions and outcomes.**

Indicators are a useful tool to track implementation progress and changes in key outcomes of interest, but to understand the significance of changes in values and their relationship with one another indicators must be contextualized within explanatory frameworks that connect climate change impacts, adaptation actions, and observed changes in resilience or vulnerability outcomes. This implies a multi-dimensional approach to monitoring and evaluation that makes use of both quantitative and qualitative methods. Examples of potential information sources include experiences or perceptions of key stakeholders in the electricity sectors (including customers), cost-benefit analyses regarding climate change impacts and alternative adaptation measures, content analysis of media reporting on specific companies or the sector overall, and equity-informed analyses to understand whether adaptation measures are reaching those who are most heavily impacted by climate change impacts like service interruptions. Companies can also build on existing metrics (e.g. SAIDI/SAIFI) that track performance in core areas like reliability, and link these metrics with climate change-informed performance targets.

4) **Identify opportunities for monitoring and evaluation to contribute to organizational learning on adaptation.**

Public disclosure on climate risks and adaptation progress is an important goal for adaptation monitoring and evaluation, but M&E stands to make greater contributions towards improving decision-making if electricity companies also make organizational learning an explicit objective

for M&E. Future research should examine how companies can consistently integrate learning into adaptation M&E, and create spaces for fostering discussion within the electricity sector about weaving reflexivity into existing operations and procedures. Organizational exchanges or visits and case studies are some examples of how companies can facilitate peer-to-peer learning about what works for supporting learning and iterative adaptation.

References

Adaptation Committee. 2021. “Approaches to Reviewing the Overall Progress Made in Achieving the Global Goal on Adaptation.” Bonn, Germany: UNFCCC.

———. 2023. “Monitoring and Evaluation of Adaptation at the National and Subnational Levels.” Bonn, Germany: UNFCCC.

Ahmadi, Somayeh, Yadollah Saboohi, and Ali Vakili. 2021. “Frameworks, Quantitative Indicators, Characters, and Modeling Approaches to Analysis of Energy System Resilience: A Review.” *Renewable and Sustainable Energy Reviews* 144 (July): 110988. https://doi.org/10.1016/j.rser.2021.110988.

Almeida, Beatriz Azevedo de, and Ali Mostafavi. 2016. “Resilience of Infrastructure Systems to Sea-Level Rise in Coastal Areas: Impacts, Adaptation Measures, and Implementation Challenges.” *Sustainability (Switzerland)*. MDPI. https://doi.org/10.3390/su8111115.

Andrew, John T., and Eric Sauquet. 2017. “Climate Change Impacts and Water Management Adaptation in Two Mediterranean-Climate Watersheds: Learning from the Durance and Sacramento Rivers.”

Balogun, Abdul Lateef, Danny Marks, Richa Sharma, Himanshu Shekhar, Chiden Balmes, Dikman Maheng, Adnan Arshad, and Pourya Salehi. 2020. “Assessing the Potentials of Digitalization as a Tool for Climate Change Adaptation and Sustainable Development in Urban Centres.” *Sustainable Cities and Society* 53 (February). https://doi.org/10.1016/j.scs.2019.101888.

BC Hydro. 2023. “Powering a Sustainable B.C. Environmental, Social, and Governance Report.”

BC Hydro. 2022. “2021 Climate Change Accountability Report.”

Berrang-Ford, Lea, Robbert Biesbroek, James D. Ford, Alexandra Lesnikowski, Andrew Tanabe, Frances M. Wang, Chen Chen, et al. 2019. “Tracking Global Climate Change Adaptation among Governments.” *Nature Climate Change* 9: 440–49.

Biesbroek, Robbert, Judith Klostermann, Catrien J. A. M. Termeer, and Pavel Kabat. 2013. “On the Nature of Barriers to Climate Change Adaptation.” *Regional Environmental Change* 13 (5): 1119–29.

Burkhardt, Andrea, Josef Eberli, Christine Hofmann, Stephan Müller, Michael Reinhard, Hans Romang, Carlo Scapozza, et al. 2020. “Projektgruppe Des Interdepartementalen Ausschusses Klima (IDA Klima).” www.bundespublikationen.admin.ch.

Bush, E., and Donald S. Lemmen. 2019. “Canada’s Changing Climate Report.” Government of Canada.

Canadian Electricity Association. 2020. “Climate Change & Extreme Weather: A Guide to Adaptation Planning for Electricity Companies in Canada.” Canadian Electricity Association. https://www.electricity.ca/files/reports/english/CEA_ClimateAdaptationGuide_2020.pdf.

Carriere, Zacharie, and Alexandra Lesnikowski. In review. “Climate Change Adaptation Readiness and the Transformative Potential of Co-Operative Housing in Nova Scotia, Canada.” *Environmental Policy and Governance*.

Dilling, Lisa, Anjal Prakash, Zinta Zommers, Farid Ahmad, Nuvodita Singh, Sara de Wit, Johanna Nalau, Meaghan Daly, and Kerry Bowman. 2019. “Is Adaptation Success a Flawed

Concept?" *Nature Climate Change* 9 (8): 572–74. https://doi.org/10.1038/s41558-019-0539-0.
Dupuis, Johann, and Robbert Biesbroek. 2013. "Comparing Apples and Oranges: The Dependent Variable Problem in Comparing and Evaluating Climate Change Adaptation Policies." *Global Environmental Change* 23 (6): 1476–87.
Emera. 2023. "Emera Inc. - Climate Change 2023." Halifax.
Emera, Inc. 2022. "2022 Sustainability Report."
EPCARR. 2018. "Measuring Progress on Adaptation and Climate Resilience: Recommendations to the Government of Canada." Ottawa, ON: Ministry of Environment and Climate Change, Government of Canada.
European Securities and Markets Authority. 2023. "The Heat Is On: Disclosures of Climate-Related Matters in the Financial Statements." Paris.
European Union. 2022. "Directive (EU) No2022/2464 of the European Parliament and of the Council of Decemeber 2022." Brussels.
Fisher, Susannah. 2023. "Much Ado about Nothing? Why Adaptation Measurement Matters." *Climate and Development*, May, 1–7. https://doi.org/10.1080/17565529.2023.2204070.
Ford, James, Lea Berrang-ford, Alexandra Lesnikowski, Magda Barrera, and Jody Heymann. 2013. "How to Track Adaptation to Climate Change: A Typology of Approaches for National-Level Application." *Ecology and Society* 18 (3).
Ford, James, and Diana King. 2015. "A Framework for Examining Adaptation Readiness." *Mitigation and Adaptation Strategies for Global Change* 20: 505–26.
Ford, James, Tristan Pearce, Graham McDowell, Lea Berrang-ford, Jesse S. Sayles, and Ella Belfer. 2018. "Vulnerability and Its Discontents: The Past, Present, and Future of Climate Change Vulnerability Research." *Climatic Change* 151: 189–203. https://doi.org/10.1007/s10584-018-2304-1.
GIZ. 2014. "Norway: Learning by Doing for Measuring Progress in Adaptation." https://www.adaptationcommunity.net/download/me/giz2014-factsheet-norway.pdf.
Government of British, Columbia. 2022. "Climate Preparedness and Adaptation Strategy - Actions for 2022-2025."
Government of Canada. 2023. "Canada's National Adaptation Strategy - Building Resilient Communities and a Strong Economy." Gatineau.
Government of France. 2011. "Plan National d'adaptation de La France Aux Effets Du Changement Climatique." Ministère de l'Écologie, du Développement durable, des Transports et du Logement.
———. 2018. "Le Plan National D'Adaptation Au Changement Climatique."
Government of Italy. 2022. "Valutazione Ambientale Strategica Comunicazione Di Avvio Della Consultazione." Ministero Dell'Ambiente e della Sicurezza Energetica. https://va.mite.gov.it/it-IT.
———. 2023. "Piano Nazionale Di Adattamento Ai Cambiamenti Climatici." Ministero Dell'Ambiente e della Sicurezza Energetica.
Government of Latvia. 2019. "Latvian National Plan for Adaptation to Climate Change Until 2030." Ministry of Environmental Protection and Regional Development. https://likumi.lv/ta/id/306691-par-valdibas-ricibas-planu-deklaracijas-par-artura-krisjana-karina-vadita-ministru-.

Government of Portugal. 2020. “Estratégia Nacional de Adaptação Às Alterações Climáticas ENAAC.” Ministério do Ambiente, Ordenamento do Território e Energia.
Government of Slovakia. 2021. “Akčný Plán Pre Implementáciu Stratégie Adaptácie SR Na Zmenu Klímy.” Ministry of the Environment of the Slovak Republic (Ministerstvo životného prostredia Slovenskej Republiky. https://minzp.sk/files/oblasti/politika-zmeny-klimy/nus-sr-do-roku-2030-finalna-verzia.pdf.
Government of Slovenia. 2016. “Strategic Framework for Climate Change Adaptation.”
Government of Spain. 2020. “Plan Nacional de Adaptación al Cambio Climático 2021-2030.” Ministerio para la Transición Ecológica y el Reto Demográfico.
Government of Sweden. 2017. “National Strategy for Climate Change Adaptation.”
Government of the United Kingdom. 2022. “The Companies (Strategic Report) (Climate-Related Financial Disclosure) Regulations 2022.”
———. 2023. “The Third National Adaptation Programme (NAP3) and the Fourth Strategy for Climate Adaptation Reporting.” www.gov.uk/official-documents.
Gu, Weiyi, Wenfeng He, Hanshi Su, and Beibei Liu. 2022. “Prioritizing Climate Change Adaptation Needs for Hydropower Sector in China.” *Environmental Research Letters* 17 (3). https://doi.org/10.1088/1748-9326/ac4c1b.
Gupta, Joyeeta, Catrien J. A. M. Termeer, Judith Klostermann, Sander Meijerink, Margo van den Brink, Pieter Jong, Sibout Nooteboom, and Emmy Bergsma. 2010. “The Adaptive Capacity Wheel: A Method to Assess the Inherent Characteristics of Institutions to Enable the Adaptive Capacity of Society.” *Environmental Science and Policy* 13 (6): 459–71.
Hammill, Anne, Julie Dekens, Timo Leiter, Lena Klockemann, Eva Stock, and Anne Glaser. 2014. “Repository of Adaptation Indicators: Real Case Examples from National Monitoring and Evaluation Systems.” International Institute of Sustainable Development & GIZ.
Hintz, Marie Josefine, Christopher Luederitz, Daniel J. Lang, and Henrik von Wehrden. 2018. “Facing the Heat: A Systematic Literature Review Exploring the Transferability of Solutions to Cope with Urban Heat Waves.” *Urban Climate* 24 (June): 714–27. https://doi.org/10.1016/j.uclim.2017.08.011.
Hydro One. 2021. “Energizing Life for People & Communities - 2021 Sustainability Report.”
———. 2022a. “2022 SASB Table.” Toronto.
———. 2022b. “2022 Task Force on Climate-Related Financial Disclosures.” Toronto.
———. 2022c. “Enabling Ontario’s Clean Energy Future - 2022 Sustainability Report.” www.HydroOne.com.
———. 2022d. “GRI Context Index.” Toronto.
Hydro Quebec. 2022. “Climate Change Adaptation Plan 2022-2024.” Hydro Québec. https://www.hydroquebec.com/themes/plan-adaptation-changements-climatiques/pdf/pg-1037-2022g344a-pacc-v02a.pdf.
Hydro Québec. 2022. “Sustainability Report 2022.” Montréal.
IPCC. 2022. *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK and New York, NY, USA: Cambridge University Press.
Juhola, Sirkku, Erik Glaas, Bjorn-Ola Linner, and Tina-Simone Neset. 2016. “Redefining Maladaptation.” *Environmental Science and Policy* 55: 135–40.

Kates, R. W., W. R. Travis, and T. J. Wilbanks. 2012. “Transformational Adaptation When Incremental Adaptations to Climate Change Are Insufficient.” *Proceedings of the National Academy of Sciences* 109 (19): 7156–61. https://doi.org/10.1073/pnas.1115521109.

Kind, Christian, Theresa Kaiser, and Hansjörg Gaus. 2017. “Methodology for the Evaluation of the German Adaptation Strategy.” German Environment Agency. https://www.umweltbundesamt.de/sites/default/files/medien/1410/publikationen/methodology_for_the_evaluation_of_the_german_adaptation_strategy.pdf.

Leiter, Timo. 2021. “Do Governments Track the Implementation of National Climate Change Adaptation Plans? An Evidence-Based Global Stocktake of Monitoring and Evaluation Systems.” *Environmental Science & Policy* 125 (November): 179–88. https://doi.org/10.1016/j.envsci.2021.08.017.

Leiter, Timo, Anne Olhoff, Rima Al Azar, Vicki Barmby, Dennis Bours, Viviane Wei Chen Clement, Thomas William Dale, Craig Davies, and Heather Jacobs. 2019. “Adaptation Metrics - Current Landscape and Evolving Practices.” Global Commission on Adaptation.

Leiter, Timo, and Patrick Pringle. 2018. “Pitfalls and Potentoal of Measuring Climate Change Adaptation Through Adaptation Metrics.”

Lemmen, Donald S., Catherine Lafleur, James MacLellan, Denis Chabot, Nancy Shackell, Helen Gurney-Smith, Jackie King, et al. 2021. “Sector Impacts and Adaptation; Chapter 7 in Canada in a Changing Climate: National Issues Report.” Government of Canada. https://changingclimate.ca/site/assets/uploads/sites/3/2020/05/Chapter-7_Sectors-Impacts-and-Adaptation_Final_EN-1.pdf.

Lesnikowski, A., J. Ford, R. Biesbroek, L. Berrang-Ford, M. Maillet, M. Araos, and S. E. Austin. 2017. “What Does the Paris Agreement Mean for Adaptation?” *Climate Policy* 17 (7). https://doi.org/10.1080/14693062.2016.1248889.

Lesnikowski, Alexandra, James Ford, Lea Berrang-Ford, and Robbert Biesbroek. 2017. “Assessing Adaptation Progress at the Global Level: Conceptual and Methodological Issues.” In *Adaptation Gap Report 2017: Towards Global Assessment*, edited by Anne Olhoff. UNEP-DTU Partnership.

Lesnikowski, Alexandra, and Timo Leiter. 2022. “Assessing Progress on Climate Adaptation in Canada: Building Blocks and Best Practices for a Robust M&{E} System.” Canadian Climate Institute.

Linares Fuster, Álvaro, and Bob Khosa. 2022. “Increasing Power Utilit Resilience Through Climate Change Scenario Analysis.”

Mäkinen, Kirsi, Jaana Sorvali, Anna Lipsanen, and Mikael Hildén. 2020. “Implementation of Finland’s National Climate Change Adaptation Plan 2022-A Mid-Term Evaluation.”

Manitoba Hydro. 2020. “Manitoba Hydro’s Climate Change Report.” Manitoba Hydro. https://www.hydro.mb.ca/environment/pdf/climate_change_report_2020.pdf.

———. 2023a. “2023 Integrated Resource Plan.” Winnipeg.

———. 2023b. “Manitoba Hydro’s Environmental, Social, and Governance (ESG) Report.” Winnipeg.

Mantle Developments. 2023. “Nova Scotia Power Case Study: Increasing Power Utility Resilience Through Climate Change Scenario Analysis.” Toronto.

Maritime Electric. 2023. “Maritime Electric Sustainability 2023 Report.” Charlottetown.

McMahan, Ben, and Andrea K. Gerlak. 2020. “Climate Risk Assessment and Cascading Impacts: Risks and Opportunities for an Electrical Utility in the U.S. Southwest.” *Climate Risk Management* 29: 100240.

Michaelowa, Axel, and Martin Stadelmann. 2018. “Development of Universal Metrics for Adaptation Effectiveness.”

Moser, Susanne C., Julia A. Ekstrom, and Roger E. Kasperson. 2010. “A Framework to Diagnose Barriers to Climate Change Adaptation.” *Proceedings of the National Academy of Sciences of the United States of America* 107 (51): 22026–31. https://doi.org/10.1073/pnas.to.

Nationale Klimaatcommissie. 2019. “Mid-Term Evaluatie van Het Nationale Adaptatie Plan (2017-2018).” Government of Belgium.

Navius Research. 2020. “Impacts of Climate Change on Canada’s Electricity System.” Vancouver, BC: Navius Research.

Ness, Ryan, Dylan G. Clark, Julien Bourque, Dena Coffman, and Dale Beugin. 2021. “Under Water: The Costs of Climate Change for Canada’s Infrastructure.” Canadian Institute for Climate Choices.

New Brunswick Power. 2023. “Annual Report 2022/23.” Fredericton.

Njuguna, Lucy, Robbert Biesbroek, Todd A. Crane, Art Dewulf, and Peter Tamás. 2023. “Do Government Knowledge Production and Use Systems Matter for Global Climate Change Adaptation Tracking? Insights from Eastern Africa.” *Regional Environmental Change* 23 (3): 85. https://doi.org/10.1007/s10113-023-02077-4.

Nobre, Paulo, Enio Bueno Pereira, Francinete Francis Lacerda, Marcel Bursztyn, Eduardo Amaral Haddad, and Debora Ley. 2019. “Solar Smart Grid as a Path to Economic Inclusion and Adaptation to Climate Change in the Brazilian Semiarid Northeast.” *International Journal of Climate Change Strategies and Management* 11 (4): 499–517. https://doi.org/10.1108/IJCCSM-09-2018-0067.

Nova Scotia Power. 2023. “Nova Scotia Power 2022 Annual Performance Standards Report.” Halifax.

Ontario Power Generation. 2023. “Electrifying Life in One Generation - 2022 ESG Report.” Toronto.

Ontario Power Generation, Inc. 2020. “Building a Brighter Tomorrow - Our Climate Change Plan.”

Price-Kelly, Hayley, Anne Hammill, Julie Dekens, Timo Leiter, and Julia Olivier. 2015. “Developing National Adaptation Monitoring and Evaluation Systems: A Guidebook.”

Ray, Patrick A., Laura Bonzanigo, Sungwook Wi, Yi Chen E. Yang, Pravin Karki, Luis E. García, Diego J. Rodriguez, and Casey M. Brown. 2018. “Multidimensional Stress Test for Hydropower Investments Facing Climate, Geophysical and Financial Uncertainty.” *Global Environmental Change* 48 (January): 168–81. https://doi.org/10.1016/j.gloenvcha.2017.11.013.

Repetto, Robert. 2008. “The Climate Crisis and the Adaptation Myth.” *Forestry & Environmental Studies Publication Series 9*.

Romero-Ruiz, Milton, Natalia Hernandez, Oscar Ocampo, Camila Pacheco, Astrid Pulido, Adriana Sarmiento, Ximena Pajarito, et al. 2016. “Sistema Nacional de Indicadores de Adaptación al Cambio Climático (SIACC): Propuesta de Protocolos de Indicadores

Incluidos En El Sistema." Dirección de Cambio Climático, Ministerio de Ambiente y Desarrollo Sostenible de Colombia.
Rübbelke, Dirk, and Stefan Vögele. 2013. "Short-Term Distributional Consequences of Climate Change Impacts on the Power Sector: Who Gains and Who Loses?" *Climatic Change* 116 (2): 191–206. https://doi.org/10.1007/s10584-012-0498-1.
Sawyer, Dan, Ryan Ness, Dylan Clark, and Dale Beugin. 2020. "Tip of the Iceberg - Navigationg the Known and Unknown Costs of Climate Change for Canada." Ottawa, ON: Canadian Climate Institute. https://climatechoices.ca/wp-content/uploads/2020/12/Tip-of-the-Iceberg-_-CoCC_-Institute_-Full.pdf.
Taseska, Verica, Natasa Markovska, and John M. Callaway. 2012. "Evaluation of Climate Change Impacts on Energy Demand." *Energy* 48 (1): 88–95. https://doi.org/10.1016/j.energy.2012.06.053.
UNEP. 2017. "The Adaptation Gap Report: Towards Global Assessment." UN Environment.
———. 2020. *Adaptation Gap Report 2020*. United Nations Environment Programme.

Appendix A: Guidance frameworks related to adaptation monitoring and evaluation

A comparison of core frameworks guiding adaptation planning and M&E work in the electricity sector is available online from the following link:

Appendix A: Guidance frameworks related to adaptation monitoring and evaluation

Appendix B: Analysis of national monitoring and evaluation frameworks

More information on the analysis of national M&E frameworks described in section 4.1 are available online from the following link:

Appendix B: Analysis of national monitoring and evaluation frameworks.xlsx

Appendix C: Example indicators for adaptation monitoring and evaluation

Examples of different indicators used for adaptation M&E are available online from the following link:

Appendix C: Example indicators for adaptation monitoring and evaluation