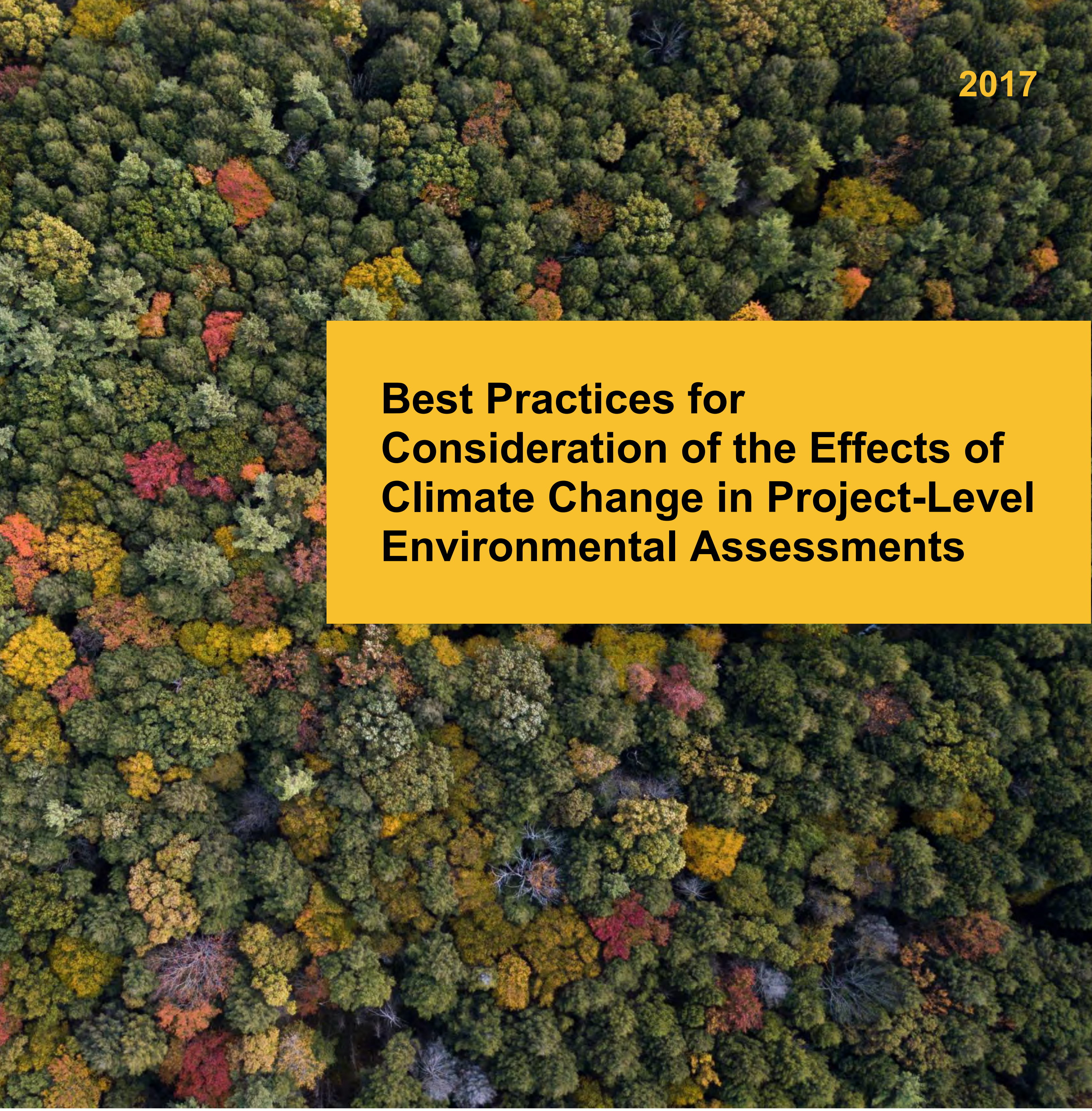

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Best Practices for Consideration of the Effects of Climate Change in Project-Level Environmental Assessments

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Best Practices for Consideration of the Effects of Climate Change in Project-Level Environmental Assessments

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Contents

Executive Summary

Climate change will have major implications for many proposed projects that require environmental assessments (EAs). This will include the effects of climate change both on the project and on the environmental impacts of the project. The Best Practices described in this report state how the effects of climate change can and should be addressed in EAs, to ensure that the public and decision-makers are provided the information needed to understand those implications and how to address them during project planning.

The Best Practices (BPs) are set out in 11 separate statements, which are summarized in the figure below and described in detail in the report.

Overview of Best Practices	
Scoping	**BP 1**. Identify environmental and project components affected by climate change (Section 2.1)
	BP 2. Identify level of detail for assessing effects (preliminary assessment) (Section 2.1)
	BP 3. Examine effects of climate change on need or justification for project (Section 2.1)
Assessing Effects	**BP 4**. Adjust future baselines for climate change (Section 2.2.1)
	BP 5. Assess effects of project (Section 2.2.2)
	BP 6. Assess effects of climate on project (Section 2.2.2)
Mitigating Effects (Adaptation)	**BP 7**. Assess options to reduce (mitigate) project effects (Section 2.3)
	BP 8. Assess options to reduce (mitigate) effects on project (Section 2.3)
Methodologies and Uncertainties	**BP 9**. Explain selection of methods used (Section 2.4)
	BP 10. Describe uncertainties and degree of confidence in the results (Section 2.4)
Follow-up	**BP 11**. Provide monitoring and management plan (Section 2.5)

These Best Practices generally follow the stages of an EA, from “scoping” to “assessing effects”, then “mitigating effects”, and lastly “follow-up”. There are also important Best Practices addressing “methodologies and uncertainties”. The following are the detailed statements of the 11 Best Practices:

Best Practice 1: The EA should explicitly identify environmental and project components that could be affected by future changes in climate/weather parameters for each phase of the project.

Best Practice 2: The EA should set out and explain, based on a preliminary vulnerability assessment, the level of detail and the general approach to be used in the EA for further assessing each climate change-related effect in each phase of the project:

a) detailed assessments should be done for those environmental and project components that may be highly affected by or vulnerable to changing climate and weather conditions;
b) less detailed assessments should be done for environmental and project components that may be moderately affected by or vulnerable to changing climate and weather conditions; and
c) no further consideration need be given to those environmental and project components that are considered largely resilient to changing climate and weather conditions.

Best Practice 3: The EA should examine whether the need or justification for the project could be substantially altered as a result of the effects of climate change, and any implications for project alternatives.

Best Practice 4: For each environmental component that could be moderately-to-highly affected by climate change in each phase of the project (see BP 2), the EA should project the future baseline condition of the component as it may be affected by climate change. Each estimate should be accompanied by a characterization of uncertainty and level of confidence in the estimate (see BP 10).

Best Practice 5: For each *project effect* requiring further climate-change analysis (see BP 2), the EA should assess the effect relative to the redefined baseline condition with climate change (see BP 4). Each estimate should be accompanied by a characterization of uncertainty and level of confidence in the estimate (see BP 10).

Best Practice 6: For each vulnerable *project component* requiring further climate-change analysis (see BP 2), the EA should assess how climate change and its impacts may affect the project component, and the potential consequences of these effects for related environmental components. Each estimate should be accompanied by a characterization of uncertainty and level of confidence in the estimate (see BP 10).

Best Practice 7: For each *project effect* assessed to be worsened by climate change (see BP 5), the EA should explicitly identify, evaluate and select feasible options for modifying the project to reduce the effect. This should include an estimate of the degree to which each adaptation option would reduce the effect. Each estimate should be accompanied by a characterization of uncertainty and level of confidence in the estimate (see BP 10).

Best Practice 8: For each *project component* assessed to be vulnerable to climate change (see BP 6), the EA should explicitly identify, evaluate and select feasible options for modifying the project to reduce its vulnerability to current and future climate conditions and their effects. This should include an estimate of the degree to which each adaptation option would reduce the vulnerability of the project, and reduce related risks to environmental components. Each estimate should be accompanied by a characterization of uncertainty and level of confidence in the estimate (see BP 10).

Best Practice 9: For each estimate and decision based on climate change (see BP 4-BP 8), the EA should provide an explanation and justification for the methodology that was used to consider future climate conditions, including the choice of models and methods, the choice of specific datasets, and adoption of key assumptions. Credible expertise and the latest, most credible scientific information and climate projections should be used.

Best Practice 10: For each estimate based on climate change (see BP 4 – BP 8), the EA should describe the uncertainties and degree of confidence and belief in the estimate based on the uncertainties and degrees of confidence in the models, methods, data and key assumptions that were used, and how these uncertainties and degrees of confidence were determined. It should also explain how the uncertainties and degrees of confidence affected any conclusions and decisions, including the choice of adaptation measures. Greater attention should be given to more significant effects.

Best Practice 11: The EA should include a monitoring and management plan that describes the measures that will be carried out to monitor, evaluate, manage (including adaptive management strategies) and communicate each of the following:

a) how climate change is affecting the baseline environmental conditions (see BP 4);
b) project effects considering climate change (see BP 5);
c) effects of climate change on the project (see BP 6); and
d) the effectiveness of adaptation measures implemented to address climate change (see BP 7 and BP 8), and the potential for contingency measures to address ineffective measures.

1.0 Introduction

The impacts of climate change have become increasingly evident. Changes in *average* climate conditions are impacting natural and manmade systems, and significant increases in the frequency and intensity of certain *severe* weather events (e.g., heavy rainfall) are creating hazards (e.g., riverine flooding) in various regions of the world (IPCC, 2012b; IPCC, 2014). Climate scientists predict that many current climate risks will be exacerbated in the future as climate change accelerates, with significant consequences for infrastructure, communities, industries and ecosystems (Lemmen et al., 2008; IPCC, 2013), and that many components of the environment, such as plant and animal communities, could become increasingly vulnerable to the effects of development and exhibit shifting baseline conditions over time (Nantel et al., 2014).

Climate change will have major implications for many projects that require environmental assessments (EAs) (Rodgers et al., 2014; Warren and Lemmen, 2014). Risks posed by climate change with respect to projects are generally three-fold. First, climate-related events such as heat waves and flooding, as well as more gradual changes in average climate, can directly affect the condition, performance, and longevity of project sites and infrastructure. Second, increases in the frequency and intensity of severe weather events as well as changes in average climate conditions can alter the impact of a project on the surrounding environment. Such may be the case with increased levels of runoff and the deposition of contaminants as the result of more frequent high intensity rainfall events. Third, climate change can increase the sensitivity of the environment to the effects of a project, as would be the case with longer or more intense droughts making aquatic ecosystems more vulnerable to the effects of water withdrawals.

Many jurisdictions around the world require proponents of physical projects to characterize and address the potential effects of these projects on the environment, and of the environment on the project through EA and similar processes[1]. Local climate conditions have long been considered as part of project planning processes; however, addressing the effects of climate change and the eventual need for project-related adaptation is a more recent focus (ClimAdapt, 2003; FPTC, 2003; CARICOM, 2004). The focus in this report is on the consideration of the effects of climate change on the project and the effects of climate change on the project's impacts on the environment.

Also important, but not addressed in detail here, are the effects of the project *on* climate change through greenhouse gas (GHG) emissions. As with the effects *of* climate change, guidance and practice around consideration of GHG emissions in EA is evolving. For example, there is a trend towards greater scope of emissions to be considered (i.e. beyond the project boundary), and

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[1] Although these best practices were developed for use in environmental assessment processes, they are also applicable in other project planning processes under other names such as impact assessment (IA) and predictive effects assessments.

that significance will be determined by contextualizing the project emissions within climate mitigation targets in short and long term, and alignment with need for transition to lower carbon economies, rather than simply calculating a project's emissions as a fraction of a nation's or global total emissions. Sources such as CEQ (2016), Doelle (2016), Garbett (2016), Gibson et al. (2016), New York Department of Environmental Conservation (2009), Williams and Nisbet (2016), and Woolsey (2012) elaborate on these issues.

While EAs should be a key means for mainstreaming the consideration of climate change effects into project planning and design, various reviews of Canadian EAs have indicated significant room for improvement (Byer et al., 2004, 2009, 2011; Rodgers et al., 2014; Williams and Nisbet, 2016), as have studies in the U.S. (Woolsey, 2012; GAO, 2015; Goodman and Rowan, 2013) and UK (IEMA, 2015; Hands and Hudson, 2016), among other jurisdictions.

Byer et al. (2011) identified some consideration of climate change in almost all of the 15 Canadian project EAs they reviewed[2] – a marked improvement over findings in the earlier Byer et al. report (2004). However, they also noted that many proponents tended to dismiss the potential for serious project or environmental effects and/or discount the potential for identifying and committing to reasonable risk mitigation (climate change adaptation) measures. Rodgers et al. (2014), in their review of 6 Canadian mining EAs completed between 2004 and 2012, have similar findings, while also identifying the need for: more systematic and better risk-informed consideration of climate change across all main facets of project EAs; more rigor and transparency in the validation of climate change models when subsets are chosen for the derivation of scenarios; and, more generally, clearer rationales for the choice of approaches and conclusions drawn through analyses of climate change-related uncertainties.

Both Byer et al. (2011) and Rodgers et al. (2014) found proponents tend to characterize climate change as having little effect on project design or operations either because "the impacts of climate change will occur after the lifespan of the project" and/or because "there is too much uncertainty in predicting climate change to incorporate it adequately into the project's design and conception" (Byer et al., 2011). Yet, there tends to be little information or analysis in the EAs to support such assertions and, furthermore, in certain cases, separate climate analyses, either for similar proposed projects or recent vulnerability assessments of existing assets in the same region, have been shown to contain contrary results (Rodgers et al., 2014).

In recognition of the gap that exists between Best Practice and typical practice for the consideration of climate change in EAs, various efforts have been made to develop related guidance in Canada (Charron, 2014; PIEVC, 2016), the U.K. (IEMA, 2015), the European Union (EC, 2013), the U.S. (CEQ, 2016; Wentz, 2015, 2016), and trans-nationally (Byer et al., 2012). This report synthesizes the best and emerging practices described in this growing number of guidelines and uncertainty in planning and decision-making more generally. Although many of the sources of information are Canadian, sources from other countries and international

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[2] The 15 EAs reviewed were for hydroelectricity, pipeline, nuclear, wind power, and mining projects between 2000 and 2009.

agencies were also significantly used, and therefore the proposed Best Practices should be applicable to EAs in all jurisdictions.

What is a "Best Practice"?

The Best Practices described in the report explain how climate change can be integrated in the EA process to ensure that the public and decision-makers are provided the information needed to understand the effects of climate change on the project and on the project's impacts on the environment, and how to address them during project planning. They are what practitioners should be striving to do, and not necessarily the best that practitioners are currently doing. As such, these Best Practices should be considered aspirational, i.e. the ideal to strive for, rather than the best that are currently achieved in practice. It is also important to note that certain Best Practices are currently beyond the legal requirements of various jurisdictions. However those legal requirements are likely to evolve, quite possibly towards these Best Practices. In addition, various stakeholders may request or expect these practices, even if not required under the legislation. Ultimately, proponents, EA practitioners and regulators will need to identify and apply those practices that are appropriate and feasible under the circumstances.

The Best Practices (BPs) are set out in 11 separate statements, which are summarized in Figure 1 and discussed in detail in Section 2.

Overview of Best Practices	
Scoping	**BP 1.** Identify environmental and project components affected by climate change (Section 2.1)
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Follow-up	**BP 11.** Provide monitoring and management plan (Section 2.5)

Figure 1: Overview of Best Practices (BPs).

These Best Practices generally follow the stages of an EA, from “scoping” to “assessing effects”, then “mitigating effects”, and lastly “follow-up”. There are also important Best Practices addressing “methodologies and uncertainties”. Finally, there is no Best Practice related to determining the significance of the effects of climate change, since this should be the same as judging the significance of any effect with or without climate change.

After the statement of each Best Practice, or group of Best Practices, explanations are provided, followed by further discussion and the identification of key challenges and opportunities. As the Best Practices are described and explained in Section 2.0, several terms are used that need to be clarified. The report generally uses the term “effects” rather than “impacts”, but as in EA and impact assessment (IA) practice, these are meant to be the same. Also, those effects on the environment are intended to include the effects on both natural and human systems. Secondly, we use the term “adaptation” to refer to methods to reduce adverse effects, which is generally referred to as “mitigation” in EA and IA practice. Lastly, we use the term “environmental component” to refer to any aspect of the environment, such as a stream, fish or people that is of concern, which is similar to what is often referred to as a valued ecosystem component (VEC). Similarly, “project component” refers to any physical part or operation and maintenance activity of the project during its full life cycle of construction, operation, closure and post-closure periods.

2.0 Statements and Explanations of Best Practices

This section provides statements and explanations of Best Practices for addressing the effects of climate change on the environment and on the project, and for adapting the project to climate change. It follows the steps shown in Figure 1.

2.1 Scoping

The Best Practices for scoping would generally be done as part of the EA, and governments could require these practices when setting EA requirements, such as the terms of reference.

Best Practice 1: The EA should explicitly identify environmental and project components that could be affected by future changes in climate/weather parameters for each phase of the project.

Best Practice 2: The EA should set out and explain, based on a preliminary vulnerability assessment, the level of detail and the general approach to be used in the EA for further assessing each climate change-related effect in each phase of the project:

a) detailed assessments should be done for those environmental and project components that may be highly affected by or vulnerable to changing climate and weather conditions;
b) less detailed assessments should be done for environmental and project components that may be moderately affected by or vulnerable to changing climate and weather conditions; and
c) no further consideration need be given to those environmental and project components that are considered largely resilient to changing climate and weather conditions.

Best Practice 3: The EA should examine whether the need or justification for the project could be substantially altered as a result of the effects of climate change, and any implications for project alternatives.

Explanation

This scoping should assume a reasonable, credible *range* of values for the climate/weather parameters to which the environmental and project components are sensitive over all project phases, and be based on an explicit preliminary climate change vulnerability assessment to identify, for each phase of the project:

a) the environmental and project components that *would not* be substantially affected by or vulnerable to climate change, and can therefore be excluded from further climate change and adaptation-related analyses; and
b) the environmental and project components that *could be* moderately-to-highly affected by or vulnerable to climate change, and therefore can be considered as priorities for further climate change analysis.

Arriving at a “reasonable, credible range of values for the climate/weather parameters” (as indicated above) requires adopting a defensible set of scientific and analytical methods and assumptions, as well as appropriate use of expert opinion, community knowledge and Indigenous Knowledge, as discussed in Section 2.4 on Methodologies and Uncertainties.

Assessing environmental and project components for probable levels of climate change vulnerability will require a combination of bottom-up (or “vulnerability threshold first”) and top-down (or “climate model first”) approaches. In general, top-down climate change vulnerability assessments start with, and are driven by, climate and climate change models. They are often more time and resource intensive than bottom-up assessments, and are best applied when guided by climatological expertise. Top-down approaches are especially important when scoping a range of climate impacts and variables for a region or more complex system. Bottom-up vulnerability assessments typically consider smaller and more localized issues and often focus more on current and short-term time scales, with vulnerability to *current* climate variability often serving as a starting point for understanding future vulnerability. Particular emphasis is placed on the identification of key thresholds, or climate parameter values which, if exceeded, may result in the state of an environmental or project component degrading more rapidly or in especially problematic ways. Once the sensitivity of each environmental or project component has been established for weather and climate-related variables of concern, the assessment must consider the potential for change in these parameters. It is at this point that information from climate model ensembles and trends analyses (the “top-down” component) is required.

Since preliminary assessments are, by design, a precursor to more rigorous assessment later on, analyses supporting this step of the process may be based, to the extent possible, on pre-existing information and time-efficient methods. However, in order to justify the *exclusion* of one or more environmental or project components from further climate change-related consideration, a defensible rationale must be provided, including descriptions of the information, analytical methods, and key assumptions used (see Section 2.4).

In certain cases, the effects of climate change may be initially unclear or highly uncertain. For these, a precautionary approach would suggest that additional assessment be required. When time horizons of interest (including all project phases) are short (i.e. within a decade), assessments of vulnerability to *current* weather and climate conditions, and recent trends, will likely be sufficient.

Preliminary assessments should consider climate change projections for time periods corresponding to each main phase of the proposed project and which include the credible worst case or greatest impact levels of the relevant climate variables. “Credible worst case” may be defined as a projected change that, although highly unlikely, *could* happen and should therefore be considered. Since projections of future climate conditions will vary based on the specific model used, as well as on assumptions related to future levels of GHG emissions coming from human economic activities (i.e. GHG scenarios), it is important to always use a group or ensemble of models as well as a high, medium and low emissions scenario. For more detailed guidance in this regard see Charron (2014).

For each project phase, the EA should list and pair the environmental and project components with the climate parameters and thresholds of potential consequence. Using the list, the EA should identify those pairs for which the environmental or project components could be moderately-to-highly impacted as a result of the credible worst projected change in the specified climate parameter.

In addition to addressing how climate change may affect the environmental and project components, climate change may also affect the context in which the project is being planned. For example, there may be:

a) changes in requirements for the services of the project. For example, communities for which a new road access is planned may need to relocate as the result of sea level rise; or
b) changes in the availability or reliability of a natural resource required for the project. For example, the minimum stream flows needed for a run-of-river hydro project may not be met due to reductions in precipitation.

These possibilities should be examined to determine if they affect the need for and viability of the project, together with alternative ways of achieving the purpose of the project.

Discussion and Basis in Literature

Recent guidance (CEQ, 2016; Wentz, 2015, 2016; IEMA, 2015; Rodgers et al., 2014; Hands and Hudson, 2016) emphasizes the importance of *identifying and communicating early on* in the EA process the weather and climate conditions that could, under climate change, substantially affect the project, its environment, or both. A main shared focus in this regard, across most recent guidance documents and literature-based critiques (Byer et al., 2012; Rodgers et al., 2014; EC, 2013; IEMA, 2015; Wentz, 2015; CEQ, 2016), is the importance of ensuring effective communication about this issue between the project proponents and EA stakeholders. Of particular interest is the potential high value of local knowledge – especially of historical climate-related events and their effects – for the climate change-related aspects of any EA. Best Practice examples of climate change vulnerability and risk assessments more generally have also emphasized the importance of understanding the local (“bottom-up”) particularities of climate conditions and their effects (Black et al., 2014; Moser, 2011; IPCC, 2013; PIEVC, 2016), and there are good Canadian examples of studies that have adopted this practice (e.g., AECOM and RSI, 2015; Perrin et al., 2015).

Across the guidelines and literature, and in some practice, two main *communications-related mechanisms* stand out for consideration by parties interested in systematically identifying, communicating, and ultimately vetting and prioritizing among climate change effects for further study. The first noted mechanism is a ledger providing explicit summaries of climate-environment, and climate-project interactions for which climate change assessment will be conducted. The second noted mechanism is use of an EA “climate change coordinator” (IEMA, 2015). The mandate of this resource would be to ensure that all potentially important climate change effects are identified and communicated, and that there is consistency in access, and in the interpretation and use of climate change information across different portions of the EA study team. In their in-depth review of six recent Canadian mining EAs, Rodgers et al. (2014) identified *within single EAs problematic disparities across topic areas* in relation to the sourcing, quality, and interpretation and use of climate change information. Appointment of a climate change coordinator could help solve this type of problem, and help identify the best knowledge and sources of locally relevant climate information (IEMA, 2015).

With respect to the structuring of early steps in EA and climate change analyses, a number of key principles stand out in the literature. First, though a core principle of EA more generally (Gibson et al., 2012), most recent climate change and EA guidelines (re)emphasize the importance of *proportionality* with respect to the consideration of climate change effects in particular; a tiered approach, based on well-reasoned exclusions of some, and retention of other climate parameters and effects for further analysis is broadly endorsed as an approach (e.g., Wentz, 2015; IEMA, 2015; CEQ, 2016). Second, adoption of climate change projections or assumptions *by plan or project phase* is common practice in climate change vulnerability and risk assessment more generally (Willows and Connell, 2003; PIEVC, 2016) and is likewise advocated by the most recent climate change and EA guidance documents (IEMA, 2015; CEQ, 2016; Wentz, 2016). Third, the combined use of “bottom-up” and “top-down” techniques is broadly recognized in the literature as important for defensibly identifying and assessing the effects of climate change (IPCC, 2012b; IPCC, 2013), as well as for building the support required among stakeholders for the effective implementation and maintenance of eventual adaptation measures (e.g., Moser and Ekstrom, 2010).

Noteworthy Challenges & Opportunities

Challenge 1: Access to adequate information, studies, and qualified professionals. Among the most commonly mentioned challenges to the consideration of climate change in EA (e.g., Agrawala et al., 2010; Byer et al., 2004, 2011; Rodgers et al., 2014; Wentz, 2015) and in project and environmental risk assessment more generally (e.g., NRTEE, 2009, 2011; Moser and Ekstrom, 2010; PIEVC, 2016; Eyzaguirre and Warren, 2014) is the availability of and access to climate information and studies for the locations and in the formats required for climate change-related analyses. Along these lines, new EA and climate change guidelines (e.g., CEQ, 2016; IEMA, 2015) identify as important resources for practitioners existing: global, national, and regional climate change studies; regional and/or sector-specific climate change impact and vulnerability assessments; and regionally and sectorally relevant EAs. A related issue is the potential lack of experienced professionals with strong understanding of climate and climate change science and its use in assessments and decision-making (Eyzaguirre and Warren, 2014; Moser and Ekstrom, 2010).

Related Opportunities: There is an increasingly rich assortment of information on regional and sector-specific climate change impacts and vulnerabilities. For example, in Canada, EA practitioners may be directed to:

- Federal Government-led climate change impact and vulnerability assessments by: major region (e.g., Lemmen et al., 2008), sector (e.g., NRTEE, 2011; Warren and Lemmen, 2014), and management issue (e.g., Johnston, 2009; Boulanger and Lorente, 2016; Lemmen et al., 2016);

- Provincial and territorially-led studies by management issue (e.g., Goulding, 2011; Bowman and Sadowski, 2012; GNWT, 2014); and
- On-line compendia of climate change impacts, vulnerability, and adaptation information (e.g., the National Compendium of Water Adaptation Knowledge [http://climateconnections.ca/water-and-climate/national-compendium-of-water-knowledge/] and, the Canadian Climate Change Adaptation Community of Practice [www.climateontario.ca/p_ccac.php]).

Related Opportunities: New opportunities for training, and even professional certification, in practices related to the understanding and consideration of climate change information in assessments are beginning to emerge.

Challenge 2: Trustworthiness and comparability of methods underlying existing climate information. Another routinely identified barrier to the scoping and implementation of climate change-related studies is a persisting lack of confidence in, and comparability of, climate information for practitioners (Lemmen et al., 2008; Ezyaguirre and Warren, 2014; Agarwala, 2010).

Related Opportunities: As noted earlier, government-led or supported assessments can help synthesize results from across a myriad of independent studies and thereby improve confidence in, access to, and context for, the results. In addition to this role, to improve comparability of results across climate change studies and to help ensure appropriately rigorous scientific and technical approaches in Canada, national codes and standards development organizations have begun to develop technical guidance documents for a range of climate and climate risk analytical methodologies, as further discussed in Section 2.4.

2.2 Assessing Climate Change Effects

2.2.1 The Changing Baseline Environment

Best Practice 4: For each environmental component that could be moderately-to-highly affected by climate change in each phase of the project (see BP 2), the EA should project the future baseline condition of the component as it may be affected by climate change. Each estimate should be accompanied by a characterization of uncertainty and level of confidence in the estimate (see BP 10).

Explanation

The impacts of a project, such as the effect of a quarry on groundwater levels, the effects of a housing project on a nearby wetland, or the effects of a dam on downstream fisheries, are based on a comparison of the conditions of these environmental components (groundwater, wetland, fisheries) with and without the project. In Figure 2, this comparison is illustrated by the difference between the two solid lines, shown by the arrow on the left, with the horizontal axis allowing for change over time. However, any changes in climatic conditions can also cause changes in the conditions of these environmental components. For example, climatic changes may cause a reduction in groundwater levels, wetland functions, and fisheries. The future environmental condition with climate change, and without the project, is represented by the lower dashed line, the "climate change-adjusted" baseline. The upper dashed line represents the status of the environmental component if the project proceeds and climate change *also* occurs, i.e. the effects of the project on the environmental component given climate change. The difference between the two dashed lines, shown by the second arrow, represents the effect of the project at any particular time with climate change. As shown by the two arrows, the difference between the effects considering climate change may be quite different (higher or lower) from the effects without considering climate change.

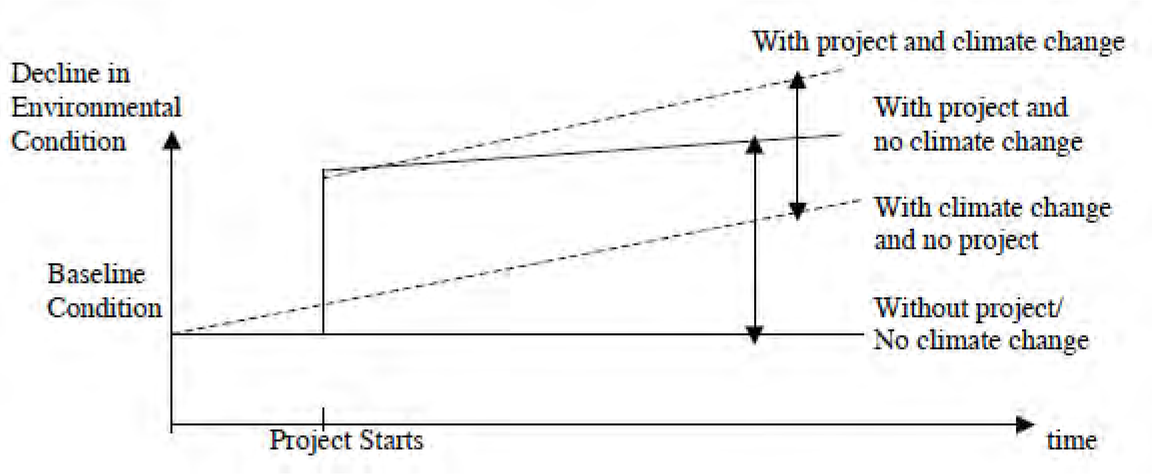

Figure 2: Effect of the project on the environment over time with and without climate change (from Byer et al., 2009).

Projecting future baseline conditions will, in many cases, require information on, assumptions about, and/or the modeling of biophysical parameters and systems beyond the initial environmental component and climate parameter pairing(s). For example, to project summertime low flow levels in fish-bearing streams, it may be necessary to acquire or derive information relating not only to the amount, forms and patterns of precipitation within a watershed, but also to the influences of, for example, vegetation and geomorphology as well; thus, site-level water balance or watershed-level hydrological information and modeling could be required. Depending on the environmental component and climate change-related effects of concern, requirements for biophysical data, information and/or models will vary, as will the challenges of re-parameterizing models to reflect climate change. Selection and sourcing of data, analytical methods, and tools should be rationalized in accordance with Section 2.4.

In many cases, it may be necessary to assess environmental change processes at a variety of scales in order to project the effects of climate change on local baseline conditions. Changes in macro-level ecosystem dynamics and characteristics, as already evidenced by, for example, shifts in certain northern eco-zone boundaries can be expected to affect local environmental conditions over time.

Since establishing new baselines can be highly resource and time consuming, the concept of proportionality (as already mentioned) is an important consideration here; i.e. the prioritization of environmental components for climate change-adjusted baselines should be based on best available knowledge of the potential seriousness of climate change and project effects on the environmental component, and hence the potential importance of adjusting the baseline (Wentz, 2016; Rodgers et al., 2014; Byer et al., 2012). Appendix B also provides further background on methods for establishing future baselines.

2.2.2 Effects of the Project on the Environment and Effects of Climate Change on the Project

Best Practice 5: For each *project effect* requiring further climate-change analysis (see BP 2), the EA should assess the effect relative to the redefined baseline condition with climate change (see BP 4). Each estimate should be accompanied by a characterization of uncertainty and level of confidence in the estimate (see BP 10).

Best Practice 6: For each vulnerable *project component* requiring further climate-change analysis (see BP 2), the EA should assess how climate change and its impacts may affect the project component, and the potential consequences of these effects for related environmental components. Each estimate should be accompanied by a characterization of uncertainty and level of confidence in the estimate (see BP 10).

Explanation

In-depth analyses of project effects and component vulnerability and related consequences will in many cases require information on, assumptions about, and the modeling of a range of biophysical parameters and systems. For example, to project the likelihood of fish habitat loss associated with tailing pond leakage triggered by rainfall extremes under climate change, it may be necessary to acquire or derive information relating not only to future environmental component (e.g., arctic char) baseline conditions and extreme precipitation patterns, but also, in this case, soil infiltration rates, runoff patterns and flood gate (project component) performance.

Depending on the environmental components and project effects of concern, requirements for biophysical data, information and models will vary, as will the challenges of re-parameterizing these models to reflect climate change. Selection and sourcing of data, analytical methods, and tools should be made in accordance with Best Practices identified in Section 2.4 on Methodologies and Uncertainties.

Since assessing project effects and vulnerabilities can require significant resources and time, it is important to prioritize the environmental components for the assessment of project effects, and project components for the assessment of climate change vulnerability, as was discussed in Section 2.2.1.

Discussion and Basis in Literature

Most early guidance on the consideration of climate change in EA (e.g., FPTC, 2003; ClimAdapt, 2003; NSE, 2011a, 2011b) left unspoken the need to develop “evolving” or “climate change-adjusted” baselines for environmental components. The absence of such guidance likely helps explain why few Canadian EAs have adopted methodical approaches to prioritizing among environmental components for the establishment of climate change-adjusted baselines, or carried out and conducted further analyses based on newly defined baselines (Byer et al., 2004, 2011; Rodgers et al., 2014), opting instead to use *current* baseline conditions (e.g., hydrological regimes, fish population densities) and only addressing the effects of climate change on baseline conditions, if at all, in a qualitative sense.

Meanwhile, recent guidelines and documents (e.g., EC, 2013; Wentz, 2015; IEMA, 2015; CEQ, 2016; Hands and Hudson, 2016; Byer et al., 2012) suggest the importance of methodically scoping and, as possible, using quantitative approaches to *establish climate change-adjusted baselines* for priority environmental components. The number of new, climate change-adjusted baselines for each prioritized environmental component will be a function of the duration of the project and each of its phases. Recent guidelines suggest that for projects of longer duration, with, e.g., development and closure activities separated by multiple decades, new climate change-adjusted baselines should be provided for each main project phase and/or time period (IEMA, 2015; Wentz, 2015; CEQ, 2016). Since certain phases of the project may affect some climate-sensitive environmental components but not others, those environmental components for which future baselines are adjusted may in some cases differ by project phase (Wentz, 2016).

These more recent guidelines and documents also suggest the importance of methodically scoping and, as possible, using quantitative approaches to assess *project effects* on each of the prioritized environmental components, considering climate change-adjusted baselines. Because it would be redundant of existing, authoritative sources to address here the general topic of project impact assessment, we do not delve into specific methods, but note that: (1) the general set of methods used in relation to the adjustment of baseline conditions could in many cases find application in the assessment of project impacts / effects as well; and, (2) uncertainties associated with climate change-adjusted baselines, and climate change impacts (e.g., extreme events) more generally, will also propagate through the project impact assessment. Methods for addressing these uncertainties are discussed in Section 2.4.

Similarly, these documents identify the importance of methodically scoping and, as possible, using quantitative approaches to *assess the effects of climate change on priority project components*. There has been considerable progress in the area of climate change and infrastructure vulnerability and risk assessment in Canada (Andrey et al., 2014) and abroad (e.g., DOT, 2014), including the development and testing of assessment protocols and guidelines with respect to infrastructure generally (e.g., PIEVC, 2016) and specific categories of infrastructure in particular (e.g., DOT, 2012).

Noteworthy Challenges & Opportunities

The main challenges and opportunities identified under Section 2.1 generally apply equally here. There are also three other noteworthy challenges, however, and related opportunities.

Challenge 1: Climate change data tailored for detailed assessments. A key concern raised in the literature is the mismatch between the climate data and information available and what is perceived as necessary for conducting detailed assessments. Calls for site-specific, detailed and short-term climate projections to inform assessments and planning processes have been widespread (CCA Community of Practice, 2011; Kovacs, 2011; McLeman et al., 2011). A related concern is the density and effectiveness of weather and climate monitoring networks (Steenhof and Sparling, 2011), critical for understanding historical conditions and vulnerabilities and for validating and downscaling climate projections.

<u>Related Opportunities</u>: Various initiatives are underway to help meet the tailored climate information requirements of climate change vulnerability and risk assessments. For example, in Canada, a new federal organization, the Canadian Centre for Climate Services, was recently established to work with other, *regional* climate services providers, as well as institutions like the national standards system, to augment the supply and ensure the quality of climate information products across Canada.

Challenge 2: Assessing uncertainties and confidence in estimates. There is an increasingly rich literature on approaches for assessing climate change-related uncertainties (e.g., Byer et al., 2004, 2007, 2009; CCSP, 2009; IPCC, 2013) and uncertainty in general (e.g., Edwards et al., 2007), with recognition of the significant potential challenges that can arise, whether with respect to historical and projected data scarcity (e.g., New et al., 2007; Moser, 2009), gaps in understanding of system dynamics (CCSP, 2009), or the resource intensity of certain analytical requirements (Byer et al., 2004, 2007; CCSP, 2009).

<u>Related Opportunities</u>: With respect to the assessment of uncertainties, various specialized resources have been developed (Byer et al., 2004, 2007, 2011; Columbo and Byer, 2012; CCSP, 2009). This is addressed further in Section 2.4.

Challenge 3: Communicating results to stakeholders and decision-makers. Despite progress in building the knowledge base to support climate change adaptation, significant challenges remain in conveying complex scientific and technical information to a range of groups (Eyzaguirre and Warren, 2014). Various factors contribute to this challenge, including inherent difficulties among decision-makers and technical experts in interpreting and using uncertainty information in rational ways (Kahneman, 2013), and the propensity of science outreach activities to be “one-way flows of information” (NRTEE, 2012).

<u>Related Opportunities</u>: With respect to the communication of scientific information, including uncertainties, to stakeholders and decision-makers, various specialized resources have been developed (Byer et al., 2004, 2009; CCSP, 2009), which is addressed further in Section 2.4.

2.3 Adaptation[3] to Reduce Effects of the Project on the Environment and Effects of Climate Change on the Project

Best Practice 7: For each *project effect* assessed to be worsened by climate change (see BP 5), the EA should explicitly identify, evaluate and select feasible options for modifying the project to reduce the effect. This should include an estimate of the degree to which each adaptation option would reduce the effect. Each estimate should be accompanied by a characterization of uncertainty and level of confidence in the estimate (see BP 10).

Best Practice 8: For each *project component* assessed to be vulnerable to climate change (see BP 6), the EA should explicitly identify, evaluate and select feasible options for modifying the project to reduce its vulnerability to current and future climate conditions and their effects. This should include an estimate of the degree to which each adaptation option would reduce the vulnerability of the project, and reduce related risks to environmental components. Each estimate should be accompanied by a characterization of uncertainty and level of confidence in the estimate (see BP 10).

Explanation

Adaptation options are ways the project design and/or operation can be modified now and in the future to adapt to or adjust for a changing climate in order to reduce effects. Various approaches should be considered, for example:

- *building robustness* into the design of project components to increase their resilience to extreme events caused by climate change; for example, increasing the capacity of a dam's emergency spillway to accommodate more intense storms;
- *design and/or operational measures* to accommodate a different climate average; for example, increasing the capacity of a storage pond to handle an increase in average precipitation, or designing access roads for non-frozen soils rather than for permafrost; and
- *adaptive management* that provides for future flexibility including design or operational modifications, such as staged additions or process modifications that can be implemented as we see how future climate change unfolds; for example, designing a storage pond to allow for a future increase in its capacity if necessary. Adaptive management is a key strategy to deal with the uncertainties in how and when future climate change will occur.

These are further explained in the next Discussion and Basis in Literature section.

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[3] The IPCC (2012a) defines "adaptation" as "the process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects".

For each effect of the project potentially worsened by climate change, technically and economically feasible adaptation measures should be identified. Measures that may initially appear to be too expensive should not be discarded too quickly since they may, in fact, be less expensive than the liabilities and costs that could occur under climate change if the project is not modified. The advantages and disadvantages of the feasible adaptation measures should then be estimated quantitatively or, if not possible, qualitatively; this should include their costs, their performance in reducing the climate change-adjusted effects, the degree of confidence in this presumed level of performance, related uncertainties, and eventual consequences if the adaptation proves to be ineffective.

The feasible adaptation measures should then be evaluated on the basis of their advantages and disadvantages in order to determine which options should be implemented. Various decision-making methods can be used for this, including stakeholder consultations, application of the precautionary principle and low regrets criteria (see below), and use of decision-analytic approaches.

The choice of adaptation measures should be informed by, among other things, the degree of uncertainty associated with each anticipated climate change impact requiring consideration. For example, when climate change projections are highly uncertain and the potential consequences of being wrong are high, it is particularly important to adopt flexible or “low regrets” adaptation actions (e.g., good emergency management planning, overdesign of high risk components) that would be at least reasonably effective and offer resilience over a broad range of future climates. Such an approach is consistent with the “precautionary principle” that is enshrined in laws and policies in many jurisdictions. Maladaptation can result from, among other factors, over-reliance on too few climate models, misplaced confidence in the capabilities of climate models with respect to a particular location or climate variable, and failures to adjust or bias-correct raw climate change model outputs. In such cases, one must balance the risks of being precise but potentially wrong (i.e. “precisely wrong”) with the risks of being “*generally* right” but less precise.

In practice, there is no single recommended approach for incorporating and mainstreaming climate change into adaptation actions, especially since approaches will be highly dependent upon the anticipated life of a project, the risks associated with its components, and the amount of risk the regulator, proponent, and other stakeholders are willing to accept. In some cases, where the planned life of a project is relatively short (i.e. operations lasting a decade or so), it may be sufficient to ensure good adaptation to currently observed climate trends and variability. For longer timeframes and higher risk components, it is essential to develop adaptation options that integrate scenarios of future climate conditions into the project.

Discussion and Basis in Literature

Recent studies of climate change and EA in Canada (Byer et al., 2004, 2011; Ford et al., 2011; Rodgers et al., 2014) and elsewhere (Agrawala et al., 2010; Loechel et al., 2013; Hands and Hudson, 2016) have identified a lack of commitment to and detail regarding potential adaptations (mitigation measures) as one of the major shortfalls in addressing climate change in EAs. Canadian studies (Rodgers et al., 2014; Byer el al., 2004, 2011) have reported as most prominent among all proposed strategies the “wait and see approach”. To be effective, adaptive management-based approaches, discussed further below, require formalized plans comprising, e.g., monitoring programs, indicators, and agreed upon trigger points for adaptive action, among other elements (Allen and Stankey, 2009), as discussed in Section 2.5.

Meanwhile, in most identified instances of planned adaptation (e.g., new design features), studies have generally found little if any analysis of the expected performance (i.e. risk reduction potential) of proposed measures (Rodgers et al., 2014; Hands and Hudson, 2016). Hands and Hudson (2016) further note a general lack of consideration for, and commitment to, the monitoring and reporting on adaptation performance over time.

The most recent IPCC Assessment Report (IPCC, 2014) concluded that “iterative risk management” is a useful framework for decision-making in “complex situations characterized by large potential consequences, persistent uncertainties, long timeframes, potential for learning, and multiple climatic and non-climatic influences changing over time”. The IPCC authors concluded that monitoring and learning would remain important components of effective adaptation and that a first step towards adaptation to future climate change consists of measures to reduce vulnerability and exposure to present climate variability (i.e. low regrets adaptation options). The 2012 IPCC special report on extremes provided guidance on when such low regrets adaptation options should be considered (IPCC, 2012b). The ISO 31000 risk management framework also requires monitoring and review of risks on a continuous basis.

Figure 3 provides a useful organizing framework for adaptation options to reduce (mitigate) the effects of climate change on projects and projects on the environment.

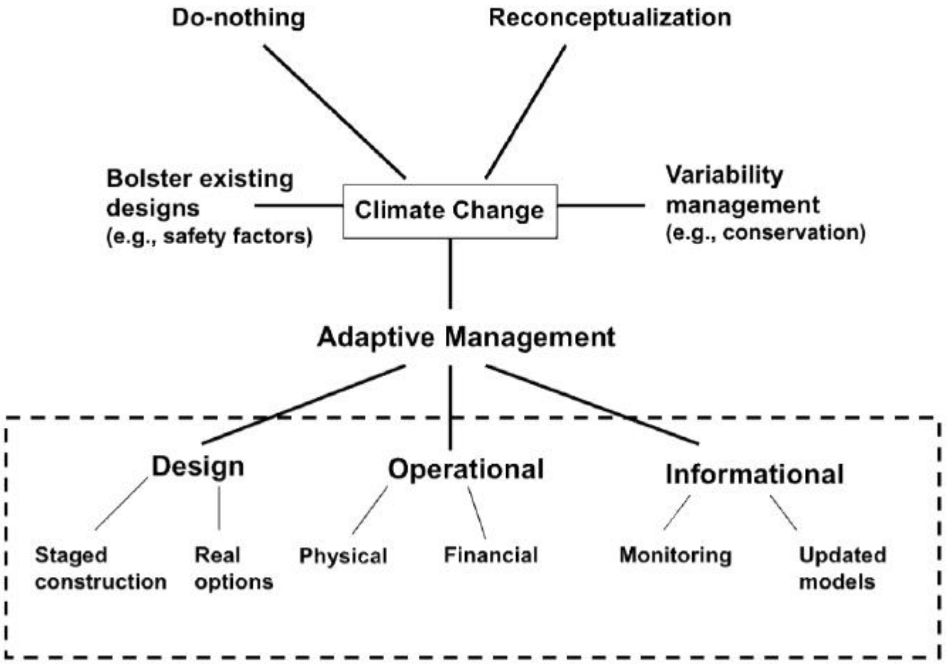


Figure 3: Options for reducing climate change and project effects, a conceptual model (from Byer et al., 2011).

In this framework, the “do-nothing” approach refers to project design that is not influenced by climate change considerations. While not an adaptation method, it is always one potential course of action and would tend to be motivated by a complete inability to reasonably characterize potentially consequential climate change scenarios or, e.g., strong evidence that substantial and/or relevant climate change effects will not occur within the lifetime of the project. Meanwhile, the idea of “bolstering existing designs” is akin to applying an “adaptation safety factor”. In engineering, it is routine to design for larger than normal loads through the application of “safety factors”, a practice that helps protect against system failure, especially when uncertainty is not easy to characterize or quantify.

The “variability management” approach addresses the fact that climate change is expected to increase variability in certain climate parameters by using design and/or operational measures to increase the capacity for the project to accommodate the increased variability. For example, more frequent prolonged heat waves are likely to cause future increases in the variability of electric power demands, and adding extra peak generating capacity into an electricity project could satisfy this. The “project reconceptualization” option entails reconceiving the way in which a project is planned, built and/or operated, possibly using novel or unusual approaches. An example of reconceptualization would be to use architectural approaches like green roofs instead of electrical air conditioning in order to provide cooler temperatures in buildings.

Finally, “adaptive management”, a “wait and see approach” of dealing with the uncertainties about climate change, has been commonly applied in the natural resources sector and is intended as a structured approach to “learning by doing” (Lee, 1999). The European Climate Adaptation Platform (2015) describes adaptive management as an approach that “can be modified to achieve better performance as one learns more about the issues at hand and how the future is unfolding…[such that] learning, experimenting and evaluation…are actively planned for in decision-making”. Figure 3 and Byer et al. (2011) and Columbo and Byer (2012) usefully categorize adaptive management into a range of different subcomponents, each of which can be used individually or in combination: *informational flexibility*, including proactive monitoring and any resultant updating of measured or modeled system performance; *operational flexibility*, including physical changes in operations (based on monitoring information) or financial instruments to insure against the potential for loss; and, *designed flexibility*, based on explicit design decisions up front that allow for the later addition of capacity or features to a project as the need arises.

Noteworthy Challenges & Opportunities

Challenge 1: Committing to adaptation given the uncertainties. In the climate change and EA literature, there is significant reporting of reluctance on the part of project proponents to commit to adaptation (effects mitigation) options that cost money up front in order to address uncertain effects in the future (Agrawala et al., 2010; Byer et al., 2011; Rodgers et al., 2014; Hands and Hudson, 2016).

Related Opportunities: There are opportunities for stricter requirements for the consideration of adaptation options and justification for decisions. More consideration can be given to “low regrets” adaptation actions that can be reasonably effective and offer resilience over a broad range of future climates, as addressed in more detail by Auld (2008), Hallegate (2009) and Wilby and Dessai (2010). There are also opportunities to use existing methods developed for decision-making under uncertainties to support well-reasoned and transparent adaptation decisions in the context of EAs, as described by Byer et al. (2011) and Colombo and Byer (2012).

Challenge 2: Formalizing adaptive management. Another key challenge with adaptive management is that (as noted above) “to be effective, it requires formalized plans comprising, e.g., monitoring programs, indicators, and agreed upon trigger points for adaptive action, among other elements”. The challenge is to ensure that the monitoring takes place and is acted upon according to a plan. This and related opportunities are also discussed in Section 2.5.

2.4 Methodologies and Uncertainties

Best Practice 9: For each estimate and decision based on climate change (see BP 4 – BP 8), the EA should provide an explanation and justification for the methodology that was used to consider future climate conditions, including the choice of models and methods, the choice of specific datasets, and adoption of key assumptions. Credible expertise and the latest, most credible scientific information and climate projections should be used.

Best Practice 10: For each estimate based on climate change (see BP 4 – BP 8), the EA should describe the uncertainties and degree of confidence and belief in the estimate based on the uncertainties and degrees of confidence in the models, methods, data and key assumptions that were used, and how these uncertainties and degrees of confidence were determined. It should also explain how the uncertainties and degrees of confidence affected any conclusions and decisions, including the choice of adaptation measures. Greater attention should be given to more significant effects.

Explanation

Each estimate of environmental condition or effects in the EA is necessarily based on assumptions about the future climate and on imperfect or uncertain data, models and methods. For example, climate/weather data problems can stem from: lack of climate or impacts data; inadequate or improper measurement instruments and methods; subjective judgments used to establish the data; and inherent randomness. Uncertainties in climate change model scenarios can arise from a variety of sources including: uncertainties in initial climate conditions input to the models, imperfect understandings of atmospheric processes, and climate gridding and interpolation methodologies. Similar uncertainties will exist in relation to modeled changes in other biophysical parameters (e.g., depth of permafrost thaw) and the environmental conditions themselves (e.g., stream flow, fish populations).

It is therefore important to explain the basis for each of the estimates presented in the EA and assess the degree of uncertainty and level of confidence attached to each of them. This will typically involve some degree of subjective judgments of confidence, which should conform to accepted practice in expert elicitation and be uniformly applied. Attention should also be paid to the potential influence of alternative adaptation options on levels of uncertainty and confidence associated with each of the estimated effects. Of particular concern when estimating climate effects on the project are a shortage of information or evidence on sensitivities of project components to weather and climate, and a lack of information on the frequency of certain extreme events (e.g., severe thunderstorms in remote locations).

The following interrelated types of information, as described in Byer et al. (2004, 2009), should be provided with respect to the choice of data, models and methods, adoption of key assumptions and resulting estimates:

- For each set of *data* used, the following should be documented: (i) the data source(s); ii) periods of record and any other information available on monitoring programs, including instruments used and siting; (iii) whether the data are primary or modified (secondary or extrapolated) data; (iv) whether the data are based on an established protocol, theory, or school of thought; and, (v) qualified expert critique of the validity, strengths and weaknesses of the data.
- For each *model* and *method* used, the following should be identified: (i) the source(s); (ii) the degree to which it is an accurate representation of reality (e.g., results of the validation of climate change models in hindcast mode); (iii) whether the model is based on an established underlying theory or school of thought; (iv) whether the model has undergone peer review; and (v) degree of acceptance of the model by the overall scientific community.
- For each key *assumption* made, the following should be stated: (i) the degree to which the assumption is known to be an accurate representation of reality; and (ii) the degree of acceptance of the assumption by the scientific community.
- For each set of resulting estimates, the following should be stated: (i) whether the estimates have been independently reviewed; and (ii) the degree of acceptability by the reviewers.
- Based on this, a summary statement of the level of *overall confidence* in the results of each study should be provided.

With regard to data, a range of credible climate information types and sources should be consulted, including:

- Synthesized information or existing studies on changes in regional climate and related biophysical conditions, including but not limited to climate change-related reports produced and/or vetted by governments, climate information service providers, and the Intergovernmental Panel on Climate Change (IPCC).
- Information on historical natural hazards-induced impacts in the region linked to weather and climate.
- Previous EAs on similar types of projects.
- Local experience, proponent/academic studies and Traditional Ecological Knowledge.

If the above information cannot support defensible conclusions, then other information should be sought or derived. Otherwise, given the potential risks from the changing climate, adaptation responses will need to incorporate significantly larger safety margins, more enhanced monitoring, flexible designs and operational programs, and other precautionary measures.

Where empirical data are of generally poor quality or lacking, or climate models perform especially poorly in reproducing past measured conditions, expert opinion and local or Traditional Ecological Knowledge may play a larger role. In all cases, clear and defensible protocols for the incorporation of local and Traditional Ecological Knowledge, and expert opinion (elicitation processes) should be used and reported on.

The resulting estimates should be presented in a way that is relevant and readily understandable to stakeholders and decision-makers so that they can judge their reliability. Where there is *quantitative* information, the following types of summary should be presented, where possible: (i) mean values and variances or spreads on the estimates; (ii) confidence intervals of the estimates; (iii) ranges of the estimated values noting possible extreme values in particular; and (iv) full probability distributions of the estimated impacts. Some examples are:

- “30% of model simulations indicate that future temperatures would cause the soil to remain as permafrost, and the other 70% indicate that there would no longer be permafrost”.
- “While the effluent of the project is not expected to increase the stream temperature above the level to support cold water fish, there is some likelihood, conservatively estimated to be 1 to 5%, that future temperatures and stream flows would result in the loss of these fish species”.
- “While capacity of the water storage facility has been designed to withstand future storm events, there is a conservatively estimated 5% probability that future climate would cause a catastrophic failure over the course of the project’s operation, resulting in the loss of fish downstream”.

Where the estimates and uncertainties are measured *qualitatively*, they can only be described and presented with considerably less precision, and the following types of summary descriptions should be provided: (i) description of the central tendency of the baseline condition, together with any possible variation away from the central tendency, such as “the soil would most likely remain as permafrost, though there is a moderate likelihood that it would no longer remain as such”; and (ii) ranges of the estimate, such as “low to medium”. Furthermore, when imprecise, qualitative terms and descriptors (such as “low”, “high”, or “significant”) are used, the basis underlying their particular application and the meaning of the term needs to be clearly explained.

Discussion and Basis in Literature

Recent studies of EAs in Canada and abroad have generally identified considerable room for improvement in the identification, description and justification of climate change information sources and analytical methods used. Motivated in part by the rapidly evolving state of climate change science, related analytical methods, and decision-support solutions, guidelines on the consideration of climate change in EA (IEMA, 2015; Wentz, 2016) and other assessment processes (EC, 2013; Charron, 2014; PIEVC, 2016) all now emphasize the importance of analysts clearly rationalizing their choices of climate and climate change information sources and methods. As part of this process, it is also important to spell out potential deficiencies in the information, such as brief (and therefore not necessarily representative) or otherwise incomplete or poor quality datasets.

There is an increasingly strong body of literature and guidance (e.g., CSA, 2010, 2011, 2014; Charron, 2014; PIEVC, 2016) that can help support practitioners in their decisions related to accessing, choosing, interpreting, and using climate change information, and related analytical methods. Some of these guidelines also note that the assistance of qualified climate professionals will be required for certain types of analyses or interpretations.

In order to use climate change information to estimate changes in baseline conditions, project effects, or the effect of future climate on the project, decisions need to be made with respect to methods for the analysis of related uncertainties. A range of methods can be used including sensitivity analyses, scenario-based analyses, probabilistic analyses and combinations of thereof, as discussed by Byer et al. (2004, 2007, 2009). In choosing among these techniques, a clear rationale should be provided for their choice. A key factor in the choice of methods is the measurability of the required data; whether the values the method require are well defined and quantifiable, or are ill defined and only qualitatively measurable (CCSP, 2009; Byer et al., 2004, 2009). In addition, the level of difficulty in using a method may play a major role in whether it is selected; for example, methods that require significant use of resources (i.e. expertise, time, data, cost) should not be used to study less important effects (Byer et al., 2004, 2007, 2009; IEMA, 2015). Furthermore, methods requiring significant modeling effort require a clearly developed level of understanding about the relationships between climate change and the effect (i.e., the existence of well-developed analytical models).

Sensitivity analysis can be a good first-step in most analyses, since they can be applied in virtually all cases as an analytical “screening device”. If the effect being assessed is of relatively minor importance in the EA, then additional analysis would not be required. Also, given its wide applicability, sensitivity analysis can provide the *only* choice when the other methods cannot be used.

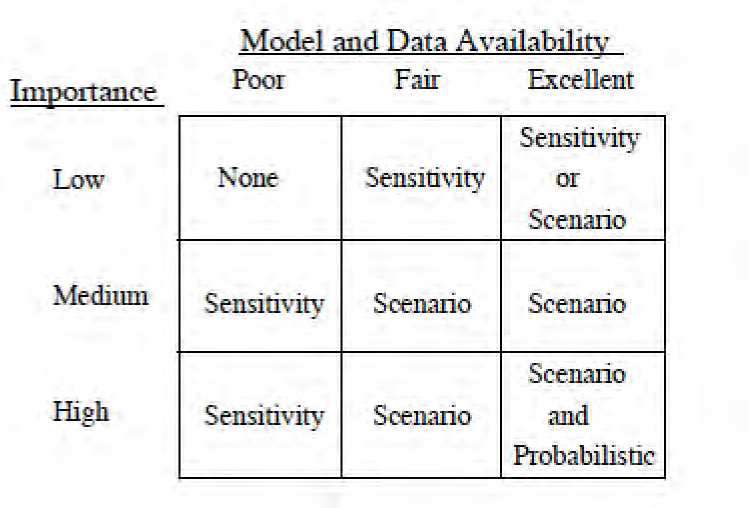
Scenario analyses can require more extensive computational efforts, better-developed models, and a better quality of quantitative data than sensitivity analyses (Edwards et al., 2007; Hallegate, 2009; Byer et al., 2004, 2007). *Scenario analysis* can be the most appropriate choice when the quality of the model and quantitative data availability is reasonably substantial, and when the effects being studied are of more than minor importance to the EA. This will often be the case for effects directly linked to climate change variables, considering the development of climate change scenarios that has already been done.

Probabilistic methods require the existence of both well-developed models and well-defined, quantitative data (New et al., 2007; Byer et al., 2004, 2007). They also require technical expertise and effort on the part of the user. To justify these needs, the effect being studied needs to be of high importance. Also, if an effect can only be measured qualitatively or cannot be defined probabilistically, then probabilistic methods are not an option.

In summary, two main factors influence the choice of analytical approach with respect to the consideration of uncertainty (Byer et al., 2004, 2007):

i) the importance to the project of the specific impact being studied and the importance of the information resulting from the analysis; and
ii) the quality of the models that are available to study the impact and the quality of the quantitative data that are available for use in the models.

Based on this, one possible framework for selecting the most appropriate method is shown in Figure 4.



	Model and Data Availability		
Importance	Poor	Fair	Excellent
Low	None	Sensitivity	Sensitivity or Scenario
Medium	Sensitivity	Scenario	Scenario
High	Sensitivity	Scenario	Scenario and Probabilistic

Figure 4: Alternatives for uncertainty analysis based on the importance of the effect being assessed and level of model and data availability (from Byer et al., 2004).

Finally, in order to effectively evaluate *adaptation options*, EA practitioners require means for considering uncertainty in performance outcomes (as discussed above). As already noted, recent reviews of EAs and their consideration of climate change identified few clear, well-structured analyses of the anticipated performance of eventual adaptation actions (Byer et al., 2011; Rodgers et al., 2014; Hands and Hudson, 2016).

In addition, there is a need to use this information to decide which adaptation option, if any, is to be chosen. Standard methods used to evaluate design or management alternatives, like cost-benefit analysis and multi-attribute analysis, do not typically address uncertainties in any meaningful way. Considering that uncertainty is a defining characteristic of climate change, they may be of limited use for the evaluation of adaptation options in EA and climate change process (Byer et al., 2011; Colombo and Byer, 2012). Instead, and absent use of probabilistic models, classical decision models under uncertainties can be applied. Byer et al. (2011) and Colombo and Byer (2012) provide descriptions and useful examples of how to pair climate and environmental change scenarios with alternative project design and adaptation options with decision criteria to support well-reasoned and transparent decision-making. An alternative, less technical approach to these various methods is for the proponent and stakeholders to engage in a structure discussion to try to arrive at acceptable decisions for adapting to climate change.

Noteworthy Challenges & Opportunities

Challenge 1: Communicating results to stakeholders and decision-makers. As discussed above (Section 2.2, Challenge 3), communicating degrees of belief and uncertainty in the impacts climate change to decision-makers and stakeholders – who will have a range of backgrounds and levels of knowledge – is a substantial challenge.

Related Opportunities: See the opportunities under Section 2.2, Challenge 3.

Challenge 2: Availability of good methods, models and data, and expertise to use them. See Challenge 1 in Section 2.1, and Challenge 1 in Section 2.2.

Related Opportunities: See the opportunities identified under Section 2.1, Challenge 1, and Section 2.2, Challenge 1.

2.5 Follow-up and Adaptive Management to Reduce Effects

Best Practice 11: The EA should include a monitoring and management plan that describes the measures that will be carried out to monitor, evaluate, manage (including adaptive management strategies) and communicate each of the following:

a) how climate change is affecting the baseline environmental conditions (see BP 4);
b) project effects considering climate change (see BP 5);
c) effects of climate change on the project (see BP 6); and
d) the effectiveness of adaptation measures implemented to address climate change (see BP 7 and BP 8), and the potential for contingency measures to address ineffective measures.

Explanation

Due to the nature and uncertainties of climate change, there are issues related specifically to climate change for inclusion in the design of follow-up programs. These include:

- Identification of climate thresholds at which corrective or adaptive management actions need to be taken. Thresholds need to remain below levels that exceed the resilience of project components or the acceptable levels of environmental impacts or performance, and that allow time for actions to be taken.
- Collection and evaluation of data for key climate/weather parameters over the lifetime of the project in order to anticipate whether further mitigation or adaptation actions are needed.
- Review and updating of vulnerability assessments of critical project components with

respect to changing climate.
- Design of contingency and emergency management plans to address unanticipated problems or events due to climate change.

Discussion and Basis in Literature

Follow-up programs for EAs are needed for a variety of reasons. As set out by the Canadian Government (CEAA, 2011), follow-up programs are used to:

- “verify predictions of environmental effects identified in the EA;
- determine the effectiveness of mitigation measures in order to modify or implement new measures where required;
- support the implementation of adaptive management measures to address previously unanticipated adverse environmental effects;
- provide information on environmental effects and mitigation that can be used to improve and/or support future EAs including cumulative environmental effects assessments; and
- support environmental management systems used to manage the environmental effects of projects.”

What distinguishes adaptive management from “muddling through” is its purposefulness (Lee, 1999); agreed-upon performance objectives are required and are meant to serve as a basis against which results can be measured and lessons learned and responded to (Stankey et al., 2005).

Recent guidelines on the consideration of climate change in EA (EC, 2013; IEMA, 2015; Wentz, 2015; CEQ, 2016) all recognize that climate change has *“upped the ante*” with respect to the design, maintenance and effective use of formalized project and environmental monitoring plans. Meanwhile, progress in this direction still requires considerable encouragement and support (e.g., Rodgers et al., 2014; Hands and Hudson, 2016).

Noteworthy Challenges & Opportunities

Challenge 1: Ensuring monitoring and follow-up. The key challenge here is ensuring that monitoring and follow-up actions take place. Once an EA has been approved and the project is completed, there is little incentive for the proponent to take these steps, and regulators are understaffed to check.

Related Opportunities: There are opportunities for stricter requirements for and enforcement of monitoring and action plans, and stronger commitment of resources for future adaptation.

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Appendix B: Further Explanation Related to Development of Climate Change-Adjusted Baselines

Specific methods for developing climate change-adjusted baselines can be highly particular to the environmental components in question and are not therefore comprehensively reviewed here. For example, estimations of changing permafrost baseline conditions as a result of climate change can require a range of information on underlying features or conditions, as well as analytical methods which may or may not be relevant for the assessment of other baseline conditions, such as flow levels in rivers or phenological changes among plant species (Mignan, 2012; Kappes et al., 2012). It is nonetheless possible and worthwhile to note a range of more general categories of approaches that find mention in the literature on EA and climate change (e.g., IEMA, 2015; Wentz, 2015; CEQ, 2016) and climate change and vulnerability and risk assessment more generally (Nelitz et al., 2013) with respect to the projection of climate change-adjusted baselines.

- **Existing studies**. First, as noted in the literature (e.g., CEQ, 2016), given the amount of scientific activity now focused on the study of climatic and other related environmental change, EA proponents may in some cases be able to draw information on future-adjusted baselines directly from existing studies. An important caveat is that users ensure the appropriateness of fit of the information they access, including the quality of data and methodologies used in its development (CEQ, 2016).
- **Climate analogues**. Recent EA-related guidance (e.g., IEMA, 2015) and practice (e.g., Gleason et al., 2011; Bowman and Sadowski, 2012) suggest use of climate analogues as one potential approach to establishing climate change-adjusted baselines. Studies focused on correlating species ranges, abundances and health with climate conditions are also referred to as “bioclimate envelope” analyses. They have been used to estimate the broad-scale effects of climate change on biodiversity in Europe (Harrison et al., 2006; Bertzky et al., 2010), and on fish habitats and species distribution across the continental U.S. (Eaton and Scheller, 1996; O’Neal, 2002).
- **Ecological indicators**. Biophysically-based indicators, or indicator sets, can help estimate the potential for, or specific threshold values at which shifts in environmental condition or baseline conditions may occur (e.g., Large et al., 2015, Nelitz et al., 2013).
- **Dynamic systems models**. Dynamic systems models use sophisticated functional relationships to explicitly represent linkages between system drivers (including climate variables, such air temperature and precipitation) and, e.g., hydrological, species and habitat responses. Various applications to climate change are available in the literature, typically developed for distinct needs unique to the particular regions of application (e.g., Battin et al., 2007; Rieman et al., 2007).
- **Expert-derived scenarios**. In some instances, expert elicitation could play an important role in describing potential future scenarios of changed environmental baseline conditions under climate change.

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