Model Code of Practice:

Principles of Climate Change Adaptation for Engineers

Prepared by:

WFEO Committee on Engineering and the Environment

December 2015

1 Foreward

This Model Code of Practice provides further amplification and explanation to engineers and national engineering organizations to interpret and implement principles of climate change adaptation at a practical level. It is intended for practicing engineers who are members of one or more of the national organizations who are members of the World Federation of Engineering Organizations (WFEO). The Model Code of Practice has been prepared as a complement to the WFEO Model Code of Ethics for Engineers and the Model Code of Practice for Sustainable Development and Environmental Stewardship.

The Model Code of Practice supports the WFEO vision of the global engineering profession supporting the achievement of the United Nations Sustainable Development Goals.

The Model Code of Practice reflects the use of engineers' judgement by the use of the 'Should, May, Shall' terminology.[1]

The word *should* is used to indicate that among several possibilities, one is recommended as particularly suitable without necessarily mentioning or excluding others; or that a certain course of action is preferred but not necessarily required; or that (in the negative form) a certain course of action is disapproved of but not prohibited (*should* equals *is recommended that*). The word *may* is used to indicate a course of action permissible within the limits of the guide (*may* equals *is permitted*).

Governing bodies for engineers who wish to adopt a version of the Model Code of Practice in whole or in part are advised to consider substituting the word *shall* for the word *should* to indicate requirements that must be followed (*shall* equals *is required to*) to effectively implement in their jurisdiction.

Governing bodies for engineers who wish to reference or recommend, instead of adopting, the Model Code of Practice in whole or in part, are advised to communicate that the Model Code of Practice are voluntary i.e. it is not binding on their organization or its individual engineers unless they wish to make it so.

National bodies who register but do not necessarily govern engineers may wish to adopt or endorse this Model Code of Practice voluntarily as a best or preferred practice to assist their members.

2 Acknowledgments

This Model Code of Practice was developed by the WFEO Standing Technical Committee on Engineering and the Environment. It was approved by the WFEO General Assembly in December 2015 for distribution to national and international members and placement on the WFEO website (www.wfeo.org)

[1] The 'Should, May, Shall' terminology has been generalized from **National Guideline on Environment and Sustainability**, Engineers Canada (2006). http://www.engineerscanada.ca/e/pu_guidelines.cfm

The primary source document for this publication is from Engineers Canada entitled "Principles of Climate Change Adaptation for Professional Engineers", published in October 2014. (http://www.engineerscanada.ca/sites/default/files/01_national_guideline_climate_change_adaptation.pdf).

3 Summary

The climate is changing. Historical climatic design data is becoming less representative of the future climate. Many future climate risks may be significantly under-estimated. Engineers cannot assume that the future will be similar to the past. Historical climate trends cannot be simply projected into the future as a basis for engineering planning, design, operations and maintenance of infrastructure.

The World Federation of Engineering Organizations and its national and international members are committed to raising awareness about the potential impacts of the changing climate as these relate to engineering of existing and future civil infrastructure and buildings. Engineers are encouraged to keep themselves informed about the changing climate, and consider potential impacts on their professional activities.

The Model Code of Practice is provided as guidance to engineers to consider the implications of climate change in their professional practice and that they create a clear record of the outcomes of those considerations. It consists of nine principles that constitute the scope of professional practice for engineers to initiate climate change adaptation actions, particularly for civil infrastructure and buildings. The principles are summarized into three categories:

1. Professional judgment
2. Integrating Climate Information
3. Practice guidance

Professional Judgment

Model Code Principle # 1: Integrate Adaptation into Practice

Model Code Principle #2: Review Adequacy of Current Standards

Model Code Principle # 3: Exercise Professional Judgement

Integrating Climate Information

Model Code Principle # 4: Interpret Climate Information

Model Code Principle # 5: Work with Specialists and Stakeholders

Model Code Principle # 6: Use Effective Language

Practice Guidance

Model Code Principle # 7: Plan for Service Life

Model Code Principle # 8: Use Risk Assessment for Uncertainty

Model Code Principle # 9: Monitor Legal Liabilities

The principles described in the Model Code of Practice support sound professional judgment for this element of engineering practice. Adapting to climate change presents beneficial opportunities to save money and protect public health and safety.

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4 Introduction

4.1 Background

The primary duty of engineers is to hold paramount the safety, health and welfare of the public and the protection of the environment and promote health and safety within the workplace.

The current state of scientific knowledge indicates that the climate is changing and will continue to change. Furthermore, evidence suggests that climate change has led to changes in climate extremes such as heat waves, record high temperatures and, in many regions, heavy precipitation in the past half century (Intergovernmental Panel on Climate Change). The IPCC in its report Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation (2012) notes that climate extremes, or even a series of non-extreme events, in combination with social vulnerabilities and exposure to risks can produce climate-related disasters.[2]

Changing climate conditions, particularly weather patterns that deviate from historical climate ranges, may adversely affect the integrity of the design, operation, and management of engineered systems. It is vital, therefore, for engineers to consider how those systems might appropriately anticipate the impact of changing climate conditions. In some cases, changing climate conditions result in impacts that pose un-accounted for risks.

It is incumbent upon the engineering profession to continue to advance means and practices to address the impacts of climate change within engineering works. Engineers in practice can contribute to this goal in two ways. First, engineers who design public facilities and infrastructure, and those who retain them, should recognize the need to accommodate the changing climate at the local level so as to protect the public health and safety. Second, engineers should contribute their expertise in furthering the level of awareness of this issue and communicating the risks and impacts arising from more intense and severe weather events. Scientific literature indicates significant departures from historical climate averages occurring globally, and engineering design should account for an expanded range of climate in the operating environments intended for their designs.

Engineers have a wide diversity of occupations and responsibilities. Many are involved in different types of economic and product development, which occur in a cost effective, socially and environmentally responsible manner. Engineers develop new projects and public infrastructure and keep existing facilities operating effectively. They explore resources and design economic and sustainable methods of developing these resources.

Engineers work as employees, employers, procurement and selection officers, researchers, academics, consultants, and in regulatory and managerial roles. They frequently work as a team where they are involved and must collaborate with other specialists in multi-disciplinary teams. An individual may or may not have control of, or be solely responsible for, a particular project. Regardless of the nature of their contributions, professional engineers should always pay heed to the public health and safety aspects of the project.

[2] IPCC Press Release. http://ipcc-wg2.gov/SREX/images/uploads/IPCC_Press_Release_SREX.pdf

Engineers are expected to exercise professional judgment and due diligence in the execution of their work. That expectation includes practicing in accordance with the code of ethics of the association in which they are licensed, provincial and federal laws, restricting practice to areas of personal expertise and practicing in accordance with established standards.

Engineers may or may not be directly managed by other engineers. Regardless, engineers should be encouraged and supported in making decisions that appropriately accommodate changing climate conditions, even if data pertaining to these changes is sparse. Management and other team members also have a societal responsibility for the design, construction, operation and managing of safe engineered systems that may be impacted by climate change.

Legislation and regulation in the field of climate change adaptation is sparse. In the absence of such regulation, engineers need guidance on climate change in their professional work. This Model Code of Practice is intended to fill this gap.

4.2 Limitations

While engineers should advise their clients or employers regarding matters related to climate change adaptation that may impact the professional activities for which they are responsible, they are generally not in a position to ensure that the appropriate action is taken.

Engineers are not expected to assume responsibility for considering the implications of climate change adaptation in engineered systems beyond their scope of authority. For example, an engineer is not responsible for implementing solutions that address climate change adaptation since the engineer's scope of authority generally limits him or her from doing so. The scope of authority is provided by the client or the employer of the engineer.

While the engineer presents the alternatives and rationale for implementing solutions that address climate change adaptation, the decision on the form of such solutions remains with the client or employer. Nevertheless, in keeping with their professional obligations an engineer can and should appropriately communicate the risks associated with ignoring recommendations related to climate change adaption to their employer or client. Such communications should be clearly documented in the appropriate files.

4.3 Scope

The Model Code of Practice is strictly advisory in nature and is solely intended to assist engineers to balance competing interests. This document, through amplification and commentary of each of the nine principles, summarizes how an engineer should strive to influence the practice of engineering in a manner that anticipates the effects of a changing climate on engineered systems. The application of this guideline will always be a matter of professional judgment. Application of the guideline may require engineers to balance competing interests, an essential element of the practice of engineering.

4.4 Purpose

The Model Code of Practice is intended to inform, to provide guidance, and to encourage engineers and consulting engineering firms that provide infrastructure planning, design and construction services to be pro-active in managing the impacts of a changing climate on engineered systems. The document also provides a basis for understanding and accepting definitions for key terms and concepts applied in assessing climate-induced risks.

The Model Code of Practice offers a considered interpretation of the responsibilities of professional engineers to adapt to a changing climate.

4.5 Definitions

This guideline uses a number of terms that may not be used in an engineer's day-to-day practice. These are defined in **Appendix A.**

As this document evolves, new definitions will be added as necessary.

5 Engineers and Climate Change Adaptation

In 2001, the national members of WFEO agreed to an international code of ethics[3] :

> ***To hold paramount the safety, health and welfare of the public including people with activity limitations, and the protection of both the natural and the built environments in accordance with the Principles of Sustainable Development***

Furthermore:

> ***Be aware of and make clients and employers aware of societal and environmental consequences of actions or projects and endeavor to interpret engineering issues to the public in an objective and truthful manner***

These expectations provide engineers with a foundation for a method of addressing or discharging their professional responsibilities. That is, engineers must be mindful of the public health and safety aspects of their professional activities and are also bound to disclose issues that could compromise the integrity of their professional work.

How does this play out in real professional practice?

Professionals can only be accountable for establishing that their work addresses concerns that could ***reasonably*** be identified given the state of knowledge at the time they executed the work. But what does reasonable mean in this context? In engineering practice we define ***reasonable*** in terms of the standard of care. In this context, the expectation is that engineers should behave in a way that draws on the composite of the entire professional community's opinion of how a typical member should behave in the same circumstances.

It is notable that this standard does not require that the engineer be an expert. Rather, it is based on how a typical engineer, with a normal level of professional experience and training, would discharge their responsibilities. In engineering practice, when the engineer identifies areas of practice that are outside of the scope of their training and expertise, they are required to seek input and advice from other qualified professionals who do have that expertise.

Climate change imposes a new and evolving pressure on the practice of engineering.

This understanding is generally accepted within a broader societal context resulting in the layperson's belief that the climate is changing. This guideline outlines principles for adjusting normal engineering practice to mitigate such risks.

The word ***reasonable*** is used throughout this document. This language is used in the context of the above commentary. The guidelines offer a series of objectives for professional engineers to incorporate in their practice so as to reflect the understanding that the climate is changing and that historical

[3] World Federation of Engineering Organizations, **The Model Code of Ethics**, adopted in 2001

weather and climate information traditionally used by the professional may require adjustment. Such adjustments would account for the changing climate, based on scientifically defensible methods and projections that are documented as part of the engineering process. This document provides guidance on how to ***reasonably*** address the concern given the current level of understanding of the issue.

6 Model Code of Practice Principles

The principles that comprise the Model Code of Practice are divided into three categories. Within each category there are three principles that engineers should apply within their professional practice.

The nine principles constitute the professional practice required to initiate climate change adaptation actions.

Each principle is described in three parts:

- A description of the principle;
- An amplification of the principle; and
- Suggested implementing actions that address the guideline principle.
  - Examples of actions for engineers to address these concerns.
  - Engineers may identify additional actions or may decide that only a subset of the suggested actions is necessary or appropriate.

Professional Judgment

Principle # 1: Integrate Adaptation into Practice

Principle # 2: Review Adequacy of Current Standards

Principle # 3: Exercise Professional Judgement

Integrating Climate Information

Principle # 4: Interpret Climate Information

Principle # 5: Work with Specialists and Stakeholders

Principle # 6: Use Effective Language

Practice Guidance

Principle # 7: Plan for Service Life

Principle # 8 Use Risk Assessment for Uncertainty

Principle # 9: Monitor Legal Liabilities

6.1 **Principle # 1**: Integrate Adaptation into Practice

All engineers are responsible and need to be engaged

Engineers should integrate an understanding of changing climate and weather into the normal day-to-day design, operation, maintenance, planning and procurement activities for which they are professionally responsible. These activities constitute the scope of engineering work.

6.1.1 Amplification

Engineers participate in many facets of a country's economy. Instituting meaningful change into professional practice requires recognition of this reality. Simply changing professional expectations in one element of the design, supply, construction, operation chain, will be difficult and ineffective. Ultimately, professionals can only institute adaptation measures when there is a broader acceptance that these actions are required.

To this end, engineers engaged in each sector of the economy should integrate climate change adaptation considerations into their professional works. It is unreasonable to place this entire obligation on the much smaller group of professionals that work specifically in design functions. Without support from the rest of the profession, these practitioners may not be able to gain approval for adaptation measures that exceed codes, standards or professional guidelines; especially if those changes result in higher overall project costs.

Understanding the potential of adverse impacts from climate change is especially relevant for those engineers that are in significant decision-making positions. These individuals establish the environment within which other professionals must function. They should establish organizational objectives that incorporate the recognition that climate change may demand professional practice that may exceed codes, standards and professional guidelines. Accepting this, the policy environment would furthermore be amenable to reasonable increases in project costs that address climate adaptation objectives. By establishing this environment, the decision-maker enables their subordinates and contractors to take reasonable actions to address climate change in their professional works.

Similarly, those professionals that work in procurement positions, setting project specifications and reviewing competitive proposals should include requesting consideration of current and future climate impacts on their projects. Achieving sustainable infrastructure that will last its whole service life without major damage or disruption will lower life cycle costs.

Foregoing consideration of climate change impacts in project scope may not lead to life cycle cost avoidance. The costs of future damage and disruption of service may far outweigh the incremental costs of anticipating climate change. Engineers engaged in, and advising others involved in infrastructure specification and procurement should recommend including climate considerations. Engineers in management positions or advising management should recommend the provision of sufficient financial resources or proposal evaluation incentives to support the integration of climate considerations.

Finally, those engineers in maintenance and operation functions see the impact of extreme weather events as well as creeping climate change on a daily basis. They should not only operate systems for which they are responsible sustainably, but also, should clearly identify the impacts to which they are responding to other professionals and managers/owners. The other professionals may have the capacity to incorporate appropriate changes in policies and procedures as well as their professional works, codes, standards and guidelines to reduce the impacts in the longer term.

Engineers rely on the work of other engineers and other professionals to support their work. It is critical that the profession, as a whole, create an environment where climate change adaptation is not only an accepted part of daily practice, but also, a guiding principle of professional practice. Individual engineers should make reasonable efforts to incorporate adaptation into their personal professional practice through continuing professional development and experience.

6.1.2 Implementing Actions

The following actions can help engineers integrate the consideration of, and adaptation to climate into their scope of practice. This will vary widely across disciplines and the nature of the engineering works or task being performed. Not all engineers will need the same level of integration into their practice; however, virtually all engineers engaged in direct and indirect work associated with all types of physical infrastructure should be aware of the climate change issue and always consider, if and how their work could be affected by current and future climate.

For designers, the need to incorporate climate change considerations into the work can be realized through the following actions:

1. Listing the climate change predictions and potential impacts for the area where your project is located;
2. Discussing the aspects of the project the engineer believes could be impacted;
3. Detailing what has been done in the design to mitigate those impacts; and
4. Detailing what additional/revised O&M and inspection procedures are recommended within the design-life of your project.

All engineering disciplines should use professional judgment to modify the above noted actions to address the specific job or circumstance.

The following additional actions are suggested as good practices. Not all of these may be appropriate to the situation at hand nor is the list complete. The engineer is encouraged to give thought to and implement other actions in addition to those listed here. Any successful practices or improvements should be reported to their national body and the World Federation of Engineering Organizations. These will be incorporated into the next edition of this model code of practice.

- Maintain a record of actions undertaken within daily practice that facilitate addressing climate change issues
- As appropriate, pursue education and training on climate change and meteorology to provide a scientific grounding on the subject matter that form a basis for climate change adaptation actions
- If an engineer is responsible for specifying engineering work, the specification should explicitly include consideration of climate
    - Consider the long term sustainability of the infrastructure
    - In procurement, allow margins to accommodate climate adaptation measures
    - In management, be receptive to recommendations that address climate risk

- Review operations, maintenance and management procedures and practices to accommodate future climate risks
- Consider using approaches that balance economic, environment and social considerations in recommending and implementing adaptation measures.
- Explicitly identify the requirement for identifying climate adaptation measures in contracted engineering work and reward proposals that include such recommendations.
- In defining environmental impact assessment terms and conditions, include climate change implications of the proposed project.

6.2 **Principle # 2**: Review Adequacy of Current Standards

Review applicable codes and standards and advise stakeholders on potential revisions or updates

Engineers should review the local design standards used within their professional practice. These standards should reasonably represent the current and anticipated climate that the engineered system will experience over its useful operating life.

6.2.1 Amplification

Given the potential impact of changing climate on engineering works, it may no longer be appropriate for professionals to simply rely on the veracity of codes, standards and professional guidelines that include embedded climate assumptions. In the course of their professional practice they may make changes to their professional practice that would be generally applicable to professional practice in their discipline. In this case, the professional should actively work towards the adoption of those changes in codes, standards and professional guidelines, as appropriate. Engineers must adhere, as a minimum, to published codes and standards, even when evidence may suggest that designing below a code or standard is possible.

The professional should routinely review and challenge the tools that they use in their practice. This is an outcome of ***Principle # 1***, but the focus of this principle is broader than the assessment of an individual project or work conducted by the professional. Knowledge gained through ongoing review of the professional's tools should be shared and ultimately universally represented in the tools of their professional discipline. Once a professional has identified a deficiency in a code, standard or professional guideline, they should promptly share their findings within their professional community. This will reduce the risk that the deficiency they have identified will creep into other professionals' work leading to threats to public health and safety.

The obligation to review professional tools also covers those used by professionals on a daily basis, such as procedures, codes of practice, rules of thumb, etc. These tools should be evaluated within the context of each situation to which the professional applies the tool and on a routine basis. As the professional identifies even small modifications to their tools, they should document the changes and share them within the group of professionals who would normally use the tools. For example, do historical return periods in available flood statistics accurately reflect recent trends in flooding? In many cases, a 1 in 100 year event derived from an older historical record may not reflect conditions where flooding is more frequent in recent years.

6.2.2 Implementing Actions

The following are suggested actions engineers should undertake to aid in their use of current codes and standards that include climate parameters. This includes advising other engineers and codes and standards governing bodies when a code or standard with embedded climate parameters warrants review of possible change based on evidence from practice.

Not all of these actions may be appropriate to the situation at hand nor is the list complete. Engineers are encouraged to develop their own successful strategies and experiences. Notifying their national body and the WFEO will enable the model code of practice to be updated to reflect most current and best practices.

- As a minimum, apply the most up to date revision of relevant practice guidelines, codes and standards, as a baseline from which climate change adaptation measures are applied.
- Create a file of adjustments made to codes, standards and assumptions to accommodate changing climate. As appropriate, communicate adjustments:
    - Within the department, division or organization;
    - To the employers and clients;
    - To professional societies, associations or groups; and
    - To standards organizations and regulators who developed the codes and standards.

6.3 **Principle # 3**: Exercise Professional Judgment

Evaluate and document the impact of climate on engineering works

A reasonable standard of professional judgment should be applied in order that changing climate conditions are considered within their professional practice.

6.3.1 Amplification

Engineers are held to a higher standard of reasonable care than the average layperson. By virtue of the professional's training and experience, they are expected to apply a high level of expertise to issues that affect their professional practice. Engineers are expected to be aware of the limitations of their professional scope and access other qualified professionals to augment those areas where they may not be fully qualified to express professional judgment. Through extensive media coverage, the average layperson is cognizant of the climate change issue and its potential for disruptive and serious impacts. Similarly, the average engineer should also be sensitive to the potential for changing climate conditions and appropriately apply these sensitivities to their professional practice. Given the level of public awareness of the climate change issue, a professional cannot make the argument that they were unaware that climate change could potentially affect their professional work.

This model code of practice should not be interpreted to mean that an engineer should become an expert on weather and climate issues. Rather, the expectation is that engineers should, as part of their normal practice, determine where climate information is embedded in codes, standards and assumptions and evaluate how the information is applied in their professional work. Where climate information is embedded in their professional work, they should challenge the information to assess if changing climate conditions might affect the information leading to a wider spectrum of operating environments that could lead to unanticipated outcomes from their engineering work. As a best practice, the engineer should document that they have undertaken this analysis and the outcomes. As part of this documentation, the engineer should outline their rationale for:

- Not making adjustments to climate information embedded in their work;
- Changes that they may have made; and
- Any other factor that may have been considered including, but not limited to, the results of their consultations with outside experts on the climate change issues affecting their work.

The overall intent of this principle is that engineers should consider the implications of climate change on their professional practice and that they create a clear record of the outcomes of those considerations.

6.3.2 Implementing Actions

The following actions are suggested to aid professional judgment. Not all may be appropriate to the situation at hand nor is the list complete. As engineering practice in climate change adaptation evolves, the nature and range of examples to help guide future practice will no doubt increase and will be reflected in future updates to this model code of practice.

- Develop a checklist of climate parameters with potential to impact performance of design.
- In the process of design, operation, procurement, management and maintenance activities, confirm applicability of climate information that may be embedded in codes, standards and assumptions.
- In engineering working papers, spreadsheets and other documents note that the review has been completed and prepare an accompanying memo to file that the review was completed. Outline where:
    - No changes have been made to climate information embedded in the work;
    - Changes have been made and the rationale for making them;
    - Any other factor that may have been considered including, but not limited to, the results of consultations with outside experts on the climate change issues affecting the work; and
    - The date of the review.
- The engineer responsible for engineering activity should sign the accompanying memo.

6.4 **Element # 4**: Interpret Climate Information

Consult with climate scientists and specialists

Engineers should work with climate and meteorological specialists/experts in order that interpretations of climatic and weather considerations used in professional practice reasonably reflect the most current scientific consensus regarding the climate and/or weather information.

6.4.1 Amplification

Many engineers do not have the extensive training or experience in managing and assessing climate and weather information necessary to be considered expert in the field. Historically, the professions have been consumers of such information, relying on government agencies and other authorities to package information into the formats used within their professional practice.

Assessing climate information can be a very subtle and technically demanding activity requiring a significant level of professional expertise. On the other hand, climate and weather specialists may not have a detailed understanding of the nature of the professional engineer's area of practice and may find it difficult, without guidance, to provide climate and weather information that is meaningful within the professional's area of practice.

These groups should work together to identify and develop the sorts of data that address the professional engineer's technical requirements. Engineers should secure the technical expertise and support provided by climate scientists and experts.

Climate and weather information often may contain embedded uncertainties or sensitivities. Climate experts are aware of these issues and can help the professional engineer come to grips with the overall quality of the information they are being provided. Furthermore, the engineer could apply climate and weather information in ways that are completely inappropriate based on the methodological limitations of the processes used to develop that information. The engineer should work with climate and weather specialists to gain a fulsome understanding of the strengths and limitations of the information they are using. Armed with this understanding, the engineer will be better equipped to incorporate appropriate measures within their own work to accommodate the quality of the information they are using.

Key to understanding future climate conditions is a fundamental knowledge of historical and current climate conditions and how these have evolved.

While consulting with weather and climate specialists, it is important to develop a firm understanding of historic weather information to develop a baseline. Engaging a specialist is even more important with respect to climate change information. Climate change projections are based on very sophisticated modeling and analysis derived from socioeconomic and greenhouse gas emission forecasts. A large number of models are used in developing climate projections and the models all have different strengths and weaknesses. Due to the inherent uncertainty associated with modeling, current practice is to apply an ensemble approach where more than one model is used to establish the boundaries of projected climate change. Furthermore, the underlying emission forecasts and socioeconomic assumptions are often not stated when presenting climate change projection information.

While these factors introduce some uncertainty into climate projections, the uncertainty can be managed through appropriate data treatment and climate scenario development. These practices are typically outside of the experience of the professional engineer. It is therefore important that engineers consult with climate experts in order to understand the overall integrity and limitations of the information they are planning to use and can incorporate appropriate measures from their own professional discipline to accommodate these factors within their professional work.

The OURANOS Consortium on Regional Climatology and Adaptation located in Montréal, Quebec, Canada has published a guidebook on climate scenarios and the use of climate information to guide adaptation research and decisions[4] . Published in September 2014, the guide is a resource for climate change adaptation decision-making and research. The following is an excerpt from the Executive Summary (reproduced with permission):

"*This guide is a tool for decision-makers to familiarize themselves with future climate information. It is aimed at all actors involved in climate change adaptation, from those in the early stages of climate change awareness to those involved in implementing adaptation measures.*

The guide consists of three main sections. The first categorizes climate information based on its use and on its level of complexity. The second section presents a catalogue of different ways in which climate information can be presented to decision-makers, such as planners, engineers, resource managers, and government. Finally, a third section outlines key climate modeling concepts that support a good understanding of climate information in general.

This document is not detailed enough to inform users on how to prepare different types of climate information, nor is it intended as a critical analysis of how the information is produced. Rather, it highlights the importance of working in collaboration with climate service providers to obtain climate information. The guide allows users to engage more easily with climate service providers and to become more critical of the information that is provided to them. It should be recognized that, at this point in time, the number of climate service providers is low relative to the demand for climate information.

Using this guide will allow engineers to become more familiar with climate information products and hence better evaluate what climate information best suits their needs."

Key important messages emerging from the guide include:

- Climate information at different levels of complexity can be valuable, depending on the type of decision being made
- More detailed information is not always necessary to inform better decisions
- Climate information can be tailored into formats that best match the level of expertise of the decision-makers
- Decisions should be based on a range of plausible futures; a single best climate scenario does not exist

It is important to understand the limitations of the climate information used. Engineers are cautioned that whatever climate information or methodologies used in their professional work should be considered scientifically defensible by the climate specialists they consult.

[4] Charron, I. (2014). A Guidebook on Climate Scenarios: Using Climate Information to Guide Adaptation Research and Decisions. Ouranos, 86 p.
ISBN (Print) : 978-2-923292-14-4
ISBN (PDF) : 978-2-923292-16-8
Copies of this guidebook can be downloaded from http://www.ouranos.ca/

6.4.2 Implementing Actions

The following are some suggested actions to aid engineers in interpreting and assessing climate information. Not all of these may be appropriate to the situation at hand nor is the list complete.

- List climate information needs in terms of parameters that are listed in codes, standards, guidelines and "rules of thumb" as well as other information that is not formally codified within codes, standards, etc. but are nonetheless relevant to the professional work.
    - Develop the current climate profile based on analysis of historical weather data
    - Estimate the changes in frequency and value of extreme values of relevant climate parameters based on scientifically defensible methods of future climate projections over the service life of the engineered system
    - Engage climate scientists and climate experts as appropriate to derive current and future extreme values and frequencies of relevant climate parameters

For this climate information seek the advice from climate scientists and climate experts to define the:

- Associated uncertainties with the information;
- Assumptions made;
- Data sources; and
- Relative differences between current climate data derived from measured metrological data and projected climate information based on modeling.
- Scientific validity of the methods and data used to derive current and future climate parameter values and frequencies

- Assess the criticality of the impact of the climate assumptions on the overall engineering design and function of the system.
- Determine if the assumptions and factors have undergone recent review/update in light of climate change.
- Review the assumptions and factors with climate experts to assess the applicability of the assumptions and factors over the anticipated service life of the design.
- Based on professional judgment, add appropriate safety factors or margins to plans and designs to accommodate anticipated future climate conditions in relation to the current climate conditions and where applicable and available, the climate design parameters used in the original design.

6.5 **Principle # 5**: Work with Specialists and Stakeholders

Work with multi-disciplinary and multi-stakeholder teams

Engineers should work with others, including those that are not engineers, in order to have a full understanding of the implications of changing climate and weather on the engineered systems for which they are responsible.

6.5.1 Amplification

Engineers normally work in multi-disciplinary teams. However, it is quite common for engineers to define those teams with respect to disciplines within engineering. To address climate change, the definition of multi-disciplinary teams should be expanded to include a much broader spectrum of players. The need for climate specialists is outlined in ***Principle # 4***. However, the impacts of climate change can be far reaching and outside of the scope of an engineer's normal practice. To accommodate this reality, the professional should structure project teams in order that, as a minimum, the team possesses:

- Fundamental understanding of risk and risk assessment processes;
- Directly relevant engineering knowledge of the system;
- Climatic and meteorological expertise/knowledge relevant to the region;
- Expertise in natural sciences such as hydrology, geology, forestry, biology and other specialized sciences;
- Hands-on operation and maintenance experience with the system or similar systems;
- Hands-on management knowledge with the system or similar systems;
- Local knowledge and history, especially regarding the nature of previous climatic events, their overall impact in the region and approaches used to address concerns, arising; and
- High awareness of levels of process or design "minimum acceptable performance" for the community and stakeholders reliant on the design.

Additionally, the professional should also consider adding skills for the team in:

- Natural sciences (geologists, hydrologists, agronomists, etc.) as appropriate to the geographic location and climatic region in which the engineering work is located;
- Social impact analysis (social scientists and policy specialists);
- Environmental impact analysis;
- Economic impact analysis;
- Political decision makers;
- Insurance specialists;
- Environmental practitioners'
- Community stakeholders;
- Emergency planning and response specialists; and
- Others stakeholders as appropriate. This may include members of the public or at the political level e.g. city councilor.

Practitioners may possess more than one of the requisite skill sets. Thus, teams may comprise a smaller number of individuals than the skills list may suggest. Engineers should evaluate the skills represented on their teams in order to have the right balance of skill and experience represented to reasonably anticipate climate change and incorporate reasonable adaptive measures into the project.

Where professionals do not have the skills outlined above, they should consult with other qualified professionals to augment the team's expertise, as they would normally do when they encounter issues outside of their professional scope of practice.

6.5.2 Implementing Actions

The following actions can help engineers secure the requisite range of skills and expertise that are needed to identify potential climate risks and impacts as well as develop acceptable adaptation solutions. Not all of these may be needed or appropriate as skill set needs depend on the situation at hand and the stakeholders that need to be involved.

The engineer is encouraged to give thought to and implement other actions or engage other stakeholders and expertise not listed in this guideline. These should be reported to their national body and the WFEO. These will be incorporated into the next edition of this model code of practice.

- During the formation of multi-disciplinary teams, review the overall service life and operability requirements of the engineered system in order to have the entire range of skills necessary to assess climate implications of the work are covered

  In working papers and files maintain a written record of the team membership and skill sets and training of each member of the multi-disciplinary team relative to the project/assignment.

6.6 **Element # 6**: Use Effective Language

Communicate effectively

Engineers should communicate about climate change adaptation issues and recommendations using simple, unambiguous, language.

6.6.1 Amplification

Engineers possess unique technical knowledge and skills necessary to plan and implement effective adaptation to changing climate conditions. However, engineers can only implement those adaptive measures when decision-makers approve these actions. Sometimes, decisions are politically motived and arguments based on pure logic and cost analysis may not be persuasive.

In most circumstances, the engineer cannot implement adaptive measures independently. This places a demand on the engineer to communicate effectively with the decision-maker about climate change adaptation issues and the associated risks. As part of this communication, the engineer should clearly communicate the costs and benefits of recommended actions and how those actions mitigate the identified risks. It is important that the engineer clearly articulate the economic benefits of the adaptation measure and the potential costs of not adapting to the identified risks.

The complexities and uncertainties inherent in the engineer's work should not cloud the necessity for action. Assessing climate change impacts demands a significant level of professional judgment that can be perceived to be subjective. However, professional judgment is a level of competence and knowledge of technical standards obtained through many years of training and professional practice guided by practitioners with many more years of professional practice in a specific area of professional practice. Thus the judgment applied by professionals on climate change should be based on a solid foundation of technical expertise and experience.

It is not unusual for expert practitioners to communicate using language embedded with technical terms. Even more perplexing, professionals may use common language with nuanced or very different meanings than the average person. The layperson may not know the meaning of the language being used by the professional and may not fully appreciate the full message the professional is attempting to convey. In addition, they may not know that they do not fully understand and may interpret the professional's language incorrectly resulting in inappropriate responses.

This is a very subtle problem. For their part, engineers may not realize that they have been misunderstood until the decision-maker takes decisions that do not seem to address the concerns the professional was attempting to convey.

Given the critical importance of these issues, the engineer should take all reasonable measures to be correctly understood. They should alter their language so that an average layperson can understand the magnitude of the risks. In addition, the professional should understand how they may be using common language in different ways than the average layperson. This is a situation where the professional cannot afford to simply sound knowledgeable, but rather should focus on communicating their knowledge and ensuring that they are appropriately understood.

When decision-makers have a fulsome understanding of the issues they are facing, they are much better equipped to place the climate change adaptation concerns in the broader context of the entire range of issues that the decision-maker is managing. With this context, they are better placed to advance appropriate, well rounded, decisions on climate change adaptation matters.

The need for communicating in clear and effective language also includes the professional's interactions with the general public. The professional may sometimes be required to communicate to the public such as during public consultation on behalf of a client or in representing their client or employer with media. In these circumstances, the professional should strive to clearly communicate the issue using language easily understood by the layperson. The public can influence decision makers to take either appropriate or inappropriate actions in response to climate change adaptation recommendations. The professional should strive for an accurate, if not comprehensive, understanding of the issues and recommended adaptive measures by the general public.

Finally, the professional may find that they have identified and communicated climate risks and adaptive measures to non-receptive decision makers. The decision maker may opt to reject or, even worse, simply ignore the professional's recommendations. In this situation the professional must assess the potential long-term implications of the decision maker's actions and decide if they are obliged, in the interest of public health and safety, to communicate their concerns more broadly. This situation is not unique to climate change, and the profession has a long history in managing such issues. The Code of Ethics holds the duty to the public welfare paramount in these situations, and the professional may be required to first advance the issue within their own organizations and then finally outside with regulators and other responsible external agencies.

Registering bodies may provide guidance and advice to engineers who suspect that they are in such a situation. For climate change adaptation the question is a bit less certain as the case law on these matters is evolving. However, it is essential for professionals to recognize that their professional obligations regarding climate change risks may not be satisfied simply by proposing actions to decision makers.

6.6.2 Implementing Action

The following actions can help engineers review communication of climate risks, costs and adaptation actions to decision-makers and the public as necessary. Not all of these may be needed or appropriate for the situation.

The engineer is encouraged to give thought to and implement other actions that result in improved and effective communication or climate risk, impacts and adaptation actions. These should be reported to their registering body and WFEO. These will be incorporated into the next edition of this model code of practice.

- Review each piece of professional writing with an eye to the intended audience for the piece.
    - In aid of clearly communicating the primary message of the piece, revise, edit and adjust the language used in the piece applying common language and expressions more likely to be understood by the audience.
    - As necessary, discuss suitable language with the intended audience and come to an agreement regarding the definition of terms used in the writing.
    - In situations where common language may not suffice, include sufficient background information and definitional material to promote the audience's understanding.
- Where the professional does not have the skills or expertise to simplify the writing, consult with or engage suitably qualified communications professionals in revising the piece for more general, broader, understanding.
- Consider hiring a communications consultant to redraft the language to convince the necessary decision-making audience(s)
- Assume that each piece of writing may be misunderstood and challenge the writing from different perspectives to identify areas where simplification or greater amplification may be necessary.
- Work with other members of the multi-disciplinary team and stakeholders engaged in the work for appropriate communication to different target audiences and stakeholders that will inform, or trigger evidence based decision-making with regards to climate change adaptation

6.7 **Principle # 7**: Plan for Service Life

Consider the entire service life of the engineering work

Engineers should give reasonable consideration to the impact of changing weather and climate conditions over the entire service life of an engineered system.

6.7.1 Amplification

Climate change is a long-term issue. Climate models project changes in climate parameters twenty, forty, even one hundred years into the future. The uncertainty in climate projections increases as the time horizon for those projections is extended farther into the future. Engineers develop and operate works that must be resilient to changing climate conditions over similar periods. Stable climate conditions observed in the past or even today may not be sustained throughout the entire service life of a project.

Engineers may find this a daunting task. Many large infrastructure systems are designed for an extended service life. If climate conditions change over that service life, it can be difficult to adapt the engineered system to the new environment without wholesale changes to the system. However, the engineer is not being asked to make perfect decisions that correctly anticipate all future events. They are being asked, based on professional judgment, to make ***appropriate*** decisions within the context of current scientific, economic and social constraints.

The refurbishment of infrastructure allows for checkpoints throughout the service life of a system. If there are no refurbishment opportunities, then the evaluation of climate change in the initial design becomes more critical, as the system will have to stand for a very long time without any routine opportunities to adjust. Even in these cases, many climate risks can be addressed through enhancements in operations, maintenance and management procedures and practices.

There are two facets to this issue. First, while it is difficult to anticipate climate change impacts forty or one hundred years hence, professionals should nonetheless contemplate the possible impacts of such change. Second, while projects may last for extended periods, they are normally subject to periodic refurbishment and upgrading that will afford the professional opportunities to incorporate appropriate adaptive measures at a number of points over the life of the project.

Engineers should capitalize on refurbishment opportunities to review, revise and adapt during the life of a project. Replacement in kind may not be the appropriate professional response for refurbishing a system. The engineer should evaluate the possibility that climate change may have contributed to the observed wear and tear on the project and upgrade the system appropriately. Furthermore, the professional should consider not only the useful life of the project, but also the useful life of the refurbishment activities with respect to climate change impacts. Even if the system elements being refurbished are not presently seeing the impact of climate change, it is possible that they will experience those impacts before the next refurbishment is planned. The engineer should contemplate those impacts in refurbishment planning in the same way that professionals would consider these factors for a new project.

In some ways, anticipating climate change on a refurbishment plan is simpler than it would be for the entire life of a project. The climate change projections are on a shorter time horizon and therefore have much less uncertainty associated with them. This provides the engineer with much greater confidence to recommend appropriate adaptive responses.

Extending the service life of an infrastructure system may sometimes be viewed as an adaptation strategy. It deals with infrastructure deficit issues by deferring the need to spend capital dollars on new infrastructure to a later date. It also defers decisions on building new structure into a timeframe where data may be more certain. Engineers can support this strategy by instituting monitoring and measurement programs to secure climate data to define evolving climate conditions. This climate information is less uncertain.

Refurbishment timeframes are typically shorter than the service life of the entire engineered system. Under these conditions, the engineer may be able to access sufficient climate data that can address the issue that is somewhat less detailed than a full climate projection. This can save costs and time.

Similarly, engineers in operations, maintenance and planning functions should seek to allocate (or are allocated) appropriate resources to allow other professionals the scope to incorporate appropriate adaptive measures into their engineered works. Where the engineer does not have direct authority to allocate resources, they should advocate decision-makers to delegate them sufficient authority to do so.

Projects that do not include consideration of climate in their scope may seem to be less costly for initial procurement. However, projects with no scope for incorporating climate risk are likely to incur much higher costs associated with renewing non-resilient designs over the life of the system. It is a question of allocating more resources now along with good operations and maintenance practices to reduce or avoid substantially higher costs of repair and replacement at some unexpected time later in the service life.

6.7.2 Implementing Actions

The following actions can help engineers anticipate the impacts of changing climate by considering actions that address the service life of the infrastructure asset. Not all of these may be appropriate to the situation at hand nor is the list complete. The engineer is encouraged to give thought to and implement other actions that better manage identified risks of the service life. Any new practices or improvements should be reported to their national body and WFEO. These will be incorporated into the next edition of this model code of practice.

- During the design phase of a project, maintain a record of any reviews of climate and/or meteorological assessment conducted during the design of the engineered system
    - Identify any adjustments made to the design based on climate considerations
    - Identify the basis for any adjustments made to the design based on climate considerations
    - Identify the economic impact of changes made to design based on climate considerations
    - Identify how the adjustments address the full service life cycle of the engineered system

- During refurbishment planning and design, maintain a record of any reviews of climate and/or meteorological assessment conducted during the design/plan of the refurbishment
    - Identify any adjustments made to the refurbishment design/plan based on climate considerations
    - Identify the basis for any adjustments made to the refurbishment design/plan based on climate considerations
    - Identify the economic impact of changes made to the refurbishment design/plan based on climate considerations
    - Identify how the adjustments address the full service life cycle of the refurbishment design/plan
- Ask the climate specialist to recommend a range of alternative methodologies for projecting climate information over the shorter timeframes used for refurbishment service cycles.
- Develop, institute, review and/or revise operations and maintenance policies, standards, and procedures to permit the infrastructure asset to function at the capacity it was designed to perform, including ability to respond to loadings imposed by future changes in climate.
- Good practices can extend service life beyond the design life, which means replacement or rehabilitation can be delayed, allowing re-allocation of human and financial resources to other priorities
- Review and modify training and competency policies and standards to enable operations and maintenance personnel to enhance operations and maintenance practices as well as emergency preparedness and response

6.8 Principle # 8: Apply Risk Management Principles for Uncertainty

Use risk management to address uncertainties

Engineers should maintain a reasonable level of professional competence in risk assessment strategies to assess the impact of changing climate on engineered systems where the engineer has professional responsibility. Where the engineer does not have a sufficient level of this expertise, their activities should be reviewed by professionals that do have such expertise.

6.8.1 Amplification

Assessing climate change impacts on professional work is, by its nature, a risk assessment process. In this work, professionals project the future climate and assign measures of the likelihood of those projected futures and the seriousness of the impacts of those changes on systems for which they are responsible. This is the very definition of risk assessment. The engineer will find further guidance on risk management approaches in a publication from Engineers Canada[5]

International standards on risk management are published by the International Standards Organization (ISO) in its 31000 series[6] as follows:

[5] Engineers Canada **National Guideline – Risk Management** (2013), https://www.engineerscanada.ca/sites/default/files/Risk-Management.pdf

[6] http://www.iso.org/iso/home/standards/iso31000.htm

1. ISO 31000:2009, Risk management – Principles and Guidelines provides principles, framework and a process for managing risk. It can be used by any organization regardless of its size, activity or sector.

2. ISO/IEC 31010:2009, Risk management – Risk assessment techniques focuses on risk assessment. ISO/IEC 31010:2009 focuses on risk assessment concepts, processes and the selection of risk assessment techniques.

3. ISO Guide 73:2009, Risk management - Vocabulary complements ISO 31000 by providing a collection of terms and definitions relating to the management of risk.

With this understanding, and in order to address potential climate change impacts, the engineer should develop a comprehensive understanding of risk assessment techniques or consult, as appropriate, with professionals who do have those skills.

Engineers Canada, recognizing this reality, developed a tool that Canada's professional engineers may use to aid in these assessments[7]. The PIEVC Engineering Protocol (the Protocol) guides professionals through the risk assessment process from project concept through to an evaluation of adaptation options in a manner that weighs social, environmental and economic factors. The Protocol is one of a number of tools and methodologies that have been developed to help professionals assess the impact of climate change through risk assessment. Not every engineer may be conversant with risk methodologies. In such cases, the engineer is urged to consult with those that do have risk assessment expertise and be guided through a robust evaluation of their professional work.

When considering the application of risk assessment methodologies in managing the impacts of a changing climate on engineered systems, professional engineers must follow relevant federal and/or provincial/territorial legislation regulating how such assessments are carried out.

The focus of this principle is the application of standard risk assessment techniques to the question of climate change. The engineering profession has developed a body of work that can support this activity (http://www.pievc.ca). It is up to the engineer to access and apply that knowledge.

6.8.2 Implementing Actions

Engineers can apply climate risk management principles and practices to plan and implement adaptations to their work to accommodate the impacts of current and future climate.

[7] Engineers Canada, **PIEVC Engineering Protocol for Infrastructure Vulnerability Assessment and Adaptation to a Changing Climate**, Version 10, March 2013 (www.engineerscanada.ca)

Not all of these actions may be appropriate to the situation at hand nor is the list complete. The engineer is encouraged to give thought to and implement other actions that better manage identified risks. Any new practices or improvements should be reported to their national body and WFEO. These will be incorporated into the next edition of this model code of practice.

- First, develop competence in risk assessment
    - Establish awareness and knowledge of the range and applicability of risk assessment tools, including international standards such as ISO 31000
    - Where appropriate, pursue professional development and training in risk assessment tools and approaches relevant to professional practice
- Where the engineer does not have sufficient expertise in risk assessment, seek guidance from qualified professional practitioners that have such expertise
- As appropriate retain the services of professional practitioners with risk assessment expertise to advise and/or assist in the review of climate risks
- Consider building risk assessment into all stages of the process – design, operation, maintenance, planning, procurement, management, etc.
    - Different tools will be applicable in different stages and the engineer should apprise themselves of the risk assessment approaches that are appropriate at each stage of a project or engineering task.
    - Consult with the broad range of stakeholders/users of the engineered system to assess their overall risk tolerance levels for the system.

Comment*: Establishing risk tolerance is very important because it establishes the stakeholder/owner willingness to trade-off between accepting a certain level of risk with the cost and complexity to mitigate or reduce risks through additional engineering and construction with a higher safety factor. Assessing different options with stakeholders to address the economic, environmental and social trade-offs is recommended. This will achieve buy-in of all parties to the final engineering solution.*

Comment: Establishing risk tolerance is very important because it establishes the stakeholder/owner willingness to trade-off between accepting a certain level of risk with the cost and complexity to mitigate or reduce risks through additional engineering and construction with a higher safety factor. Assessing different options with stakeholders that address the economic, environmental and social trade-offs is recommended. This will achieve buy-in of all parties to the final engineering solution.

6.9 Principle # 9: Monitor Legal Liabilities

Be aware of potential legal liability

Engineers should be aware of any legal liability associated with reliance on historic climatic and weather information within their professional practice.

6.9.1 Amplification

Case law is presently evolving on this issue.

Engineers operate under both a professional and social license. The social license is equally as important. The engineer should address the issues that concern the stakeholders under whose social license they are allowed to practice. In this case, if climate change is deemed to be a broad social concern, the profession neglects that issue at its peril. If engineers don't address this, they will be held accountable to a broader social group and ultimately may be sidelined as other professionals take up the task.

Engineers have always been held responsible for the effects of their works on public health and safety. With increasing understanding of the scope and impact of climate change, professionals may be held accountable for anticipating the impacts of climate change on their professional work.

Reliance on codes, standards and professional guidelines that fail to reflect an understanding of the impact of climate change may not be sufficient to mitigate potential liability related to managing those impacts on professional work. This is especially the case where there is an evolving understanding that historic climate information may not be reflective of future climatic conditions. With this understanding, it may be difficult for an engineer to argue that an average professional in their discipline would not have known that climate change might impact the work. The standard of reasonable care is evolving with society's increased awareness and understanding of potential climate change impacts, resulting in a corresponding evolution in the professional's obligation to evaluate those potential impacts and address them in their professional work.

Engineers have a much more detailed understanding of the codes, standards and guidelines that govern their professional practice than would a layperson. In this regard, the professional is much better placed to evaluate the implications of potential climate change impacts on climate, weather information and assumptions embedded in their professional tools. Failure to consider these implications may be construed as professional negligence and could expose the professional engineer to professional sanctions and/or legal action. If the applicable standard of care reflects an understanding that a technical standard may be deficient it follows that merely adhering to this outdated standard could be considered to be a breach of a professional engineer's standard of care. Under certain circumstances, merely designing to meet minimum code requirements may still be deemed negligent if the circumstances and the applicable standard of care dictate a design solution that clearly exceeds code.

As this is an evolving issue, it is important for the engineer to remain apprised of decisions and case law in their country of work governing societal expectations of reasonable professional care and practice. As a matter of self-interest, if for no other reason, the engineer should periodically contact his/her national body or the appropriate government agency to determine if there have been any material changes in liability case law in this area, or if new or amended practice guidelines to mitigate this risk for engineers are under development. In so doing, they will develop an appreciation of what their profession and society demands from them and take appropriate action to respond to those demands within their own professional practice.

6.9.2 Implementing Actions

Engineers should take reasonable steps so that potential legal liability from their practice in general and to particular engineering work is understood. Actions that consider and/or adjust the engineering work to accommodate current and future climate should be documented.

Not all of these actions may be appropriate to the situation at hand nor is the list complete. The engineer is encouraged to review these and give thought to other actions that address the need to demonstrate due diligence of the issues at hand. Such documentation will help discharge professional responsibility for dealing with this aspect of practice.

- Consult on any applicable case law that may apply to the general scope or responsibilities as an engineer, including projects, engineering work or tasks that may be affected by climate considerations.
    - Professional associations where they exist in countries routinely report on disciplinary actions and will report on such cases as they arise
    - National members of WFEO or professional and technical associations may develop practice guidelines specific to the topic of climate or include reference to it in the context of more specific areas of practice.
- Maintain a record of actions undertaken to address climate change issues within daily practice as appropriate or as part of the documentation of a completed task or project
- Pursue enough additional professional training on climate change and meteorology to increase knowledge of climate science, measurement, data and definitions to enable review of climate analysis and advice provided by climate scientists and specialists.
- As appropriate, consult with climate and meteorological specialists to inform climate change adaptation measures
- In working papers and files, maintain written documentation of training and consultation on climate change and meteorology

7 Other Resources

In 2015, the American Society of Civil Engineers (ASCE) released a white paper providing considerable detail on adapting infrastructure and civil engineering practice to a changing climate[8]. The executive summary describes the purpose and scope of this document as follows:

”*The purpose of the white paper is to:*

- *foster understanding and transparency of analytical methods necessary to update and describe climate, including possible changes in the frequency and intensity of weather and extreme events and for planning and engineering design of the built and natural environments*
- *identify (and evaluate) methods to assess impacts and vulnerabilities caused by changing climate conditions on the built and natural environments*

[8] “Adapting Infrastructure and Civil Engineering Practice to a Changing Climate
Committee on Adaptation to a Changing Climate” Edited by J. Rolf Olsen, Ph.D., Published by American Society of Civil Engineers (2015) (with permission of ASCE), http://ascelibrary.org/doi/pdfplus/10.1061/9780784479193

- *promote communication of best practices in civil engineering practice for addressing uncertainties associated with changing development and conditions at the project scale, including climate, weather, extreme environments and the nature and extent of the built and natural environments*"

It consists of the following sections:

- Section 2: "Review of climate science for engineering practice," provides an overview of the current knowledge of climate and weather science, as well as its limitations and relevance, to engineering practice.
- Section 3: "Incorporating climate science into engineering practice," presents the challenges of incorporating climate change and weather science into engineering practice.
- Section 4: "Civil engineering sectors," reviews the impacts of climate change on specific sectors, including codes and standards that might be affected, and includes recommendations for action.
- Section 5: "Research, Development and Demonstration needs," proposes research and other activities to advance civil engineering practices and standards to effectively address climate change impacts.
- Section 6, "Summary, Conclusions and Recommendations," concludes the white paper with a discussion on near-term decision making and recommendations for research, development and implementation of improved practices".

Engineers active in planning and implementing adaptation actions are encouraged to consult this paper for the background science of climate and to gain further understanding of the issues facing engineers and what can be done to address them.

Appendix A – Definitions

The Model Code of Practice uses the following terms and definitions.

Act	The applicable engineering act that has legal standing in a jurisdiction. Some acts in Canada include "geoscientists" or "geologists and geophysicists."
Adaptation to climate change	An adjustment in natural or human systems in response to actual or expected climatic changes, which moderates harm or exploits beneficial opportunities.
Acquiescence	To accept or comply passively, without question or objection.
Adverse effect	Impairment of, or damage to, the environment, human health or safety or property.
Climate	Climate is the statistics of weather events over a long period of time. The term weather is used to describe discrete events in place and time.
Climate change	Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forces, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.[9]
Climate information	In this document "climate information" means data and projections and any other form of climate factor/assumption/etc. In other literature this may sometimes be called climate factors or parameters.
Climate scientist	Those individuals engaged in the development of, or execution of, scientific climate projections based on one or more climate models.
Climate specialist	Any individual compiling, analyzing and/or interpreting meteorological and/or climatological data, producing or interpreting weather forecasts or any other individual that may interpret climate information. The expressions "meteorologist" or "weather forecaster" refer to those individuals that provide climate information based on measured data. In this document, use of the phrase climate specialist is inclusive of all those individuals.
Climate risk mitigation	Actions taken to reduce the level of risk associated with changing

[9] Intergovernmental Panel on Climate Change (IPCC), 2007: Summary for Policymakers. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, J.P. Palutikof, P.J. van der Linden and C.E. Hanson, Eds., Cambridge University Press, Cambridge, UK, 7-22.

	climatic conditions. These can include changes in system designs, or other procedural, operational or management adaptations to reduce impacts from identified risks.
Cost-benefit analysis	An economic analysis method that seeks to express the costs of an activity, in comparison to the benefits, using common units, to aid decision-making. The analysis would normally include capital, operating, maintenance, and decommissioning, social and environmental costs.
Cumulative effects	Individual effects that are incremental, additive or synergistic such that they must be considered collectively and over time, in order for a true measure of the total effect and associated environmental costs of an activity to be assessed.
Due diligence	The reasonable care that a person exercises under the circumstances to avoid harm to other persons, property and the environment. In professional practice, engineers must document the steps that they have undertaken to demonstrate due diligence.
Engineered system	Any civil infrastructure including buildings or engineering work that interacts with or may be affected by climate.
Engineering adaptation	A process of engineering decision-making in response to any kind of vulnerability or socio-political consideration.
Engineering vulnerability	The difference between an engineered system's capacity and the loads that the system is expected to see
Environmental effects	Outcomes arising from a technological activity that cause changes to the environment. Any change that project may cause in the environment, including but not limited to: • Health and socioeconomic conditions • Physical and cultural heritage • Current use of lands and resources • Or any change to the project that may be caused by the environment.
Liability	Legal responsibility to another or to society, which is enforceable by civil remedy or criminal penalty.
Life-cycle assessment	Assessing the environmental, social or economic effects of a chemical, product, development or activity from its inception, implementation and operation through to termination or decommissioning. It is the assessment of a system throughout the term of its entire service life.
Mitigation	Within the context of this model guideline, mitigation refers to technological change and changes in activities that reduce greenhouse gas emissions, thereby reducing the anthropogenic emissions causing climate change.
Professional engineer	The protected title given to a person licensed to engage in the practice of engineering under the applicable engineering act in a Canadian province or territory. Canadian professional engineers

	use the designation “P.Eng.”, or in Quebec “Eng.” or “Ing.” In the United States the designation is P.E. and in Europe through FEANI the designation is EurEng. Other countries may use other forms of designation to identify engineers.
Professional judgment	A level of competence and knowledge of technical standards obtained through many years of training and professional practice guided by practitioners with many more years of professional practice in a specific area of engineering practice. Typically, it takes four years of university, five years of practice under the guidance of licensed professionals and then many more years of professional practice as a licensed professional before the profession would deem an individual fully qualified to express independent professional judgment.
Quality of life	The factors related to the state of health and well-being of an individual or a community.
Resiliency	The ability of a system to withstand stress, adapt and recover from a crisis or disaster and move on. Resiliency is the societal benefit of collective efforts to build collective capacity and the ability to withstand stress including that caused by a changing climate.
Societal values	The attitudes, beliefs, perceptions and expectations generally held in common in a society at a particular time.
Socio-economic effects	The effects of a development, product or activity, on the economy and social structure of affected communities. Socio-economic effects may include issues such as: employment, housing and social needs, medical services, recreational facilities, transportation and municipal infrastructure and financial benefits to local residents and businesses.
Stakeholder	A person or organization that is directly involved with, or affected by, a development, product, or activity or has an interest in it.
Sustainability	Ability to meet the needs of the present without compromising the ability of future generations to meet their own needs, through the balanced application of integrated planning and the combination of environmental, social, and economic decision-making processes.
Vulnerability	The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate, including climate variability and extremes or any other natural events or man-made activity.
Weather	Specific events that occur within a set of meteorological data. The term weather is used to describe discrete events in place and time. Unique pieces of data that contribute to an overall statistical synopsis.