3. WHAT ENGINEERS NEED TO KNOW ABOUT CLIMATE CHANGE AND ENERGY STORAGE

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Abstract. Climate change is increasingly apparent. Regional impacts of climate change are being observed. Those commonly cited include extended growing seasons; shifts of plant and animal ranges; earlier flowering of trees, emergence of insects and egg-laying in birds; and local temperature, humidity and wind-speed anomalies. Air temperatures in Alaska and western Canada have increased as much as 3–4 °C in the past 50 years. Engineers who design infrastructure for predicted future conditions face challenges due to these shifts in climate. Building codes already specify minimum health and safety requirements for some key climate variables such as heating and cooling design temperatures; heating and cooling degree days; rainfall and snow loads; and wind pressures. Predicted changes in these variables at specific locations are not usually available. Regional scenarios give a general trend but lack precision and verification. Eco-conscious clients and a concerned public are causing manufacturing and construction firms to adopt more environmentally sound engineering practices. Proactive members of every important industry are getting involved with education and research into new technologies and approaches to address design problems with sustainable solutions. The demand for "green" innovations in design is growing. Even with the mitigation measures underway to cut net emissions of greenhouse gases and so reduce climate change, current predictions see more frequent and more severe extreme weather events. As climate change continues, the prediction and mitigation of climate related hazards will ultimately require adaptation across the entire construction sector. Another response to climate change is the development of regulations and standards of professional practice designed to protect the environment while protecting the public and its infrastructure from increased weather hazards. Approaches to the prediction of weather trends, the reduction of human impacts on the climate, and the mitigation of the effects of changes beyond our control require integrated global efforts. Adaptation can keep up with the predicted shifts in conditions if it is begun well before it is forced by natural disasters. The predictions for most communities in Canada include more violent winter storms, high intensity rainfalls of short-duration,

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and extended heat waves with the accompanying increased risk of smog, wildfires, tree parasites, severe thunderstorms and tornadoes. Current structural design, farming, and forestry practices as well as water resource management, health standards, land use planning, power supply, and insurance policies were developed for the existing conditions. All these aspects of our society and infrastructure will have to change along with the climate. Water and energy conservation are of primary importance, followed by pragmatic and future-oriented reviews of standards, codes, regulations and other practices. The climate is changing at an unprecedented rate and in ways that are not yet fully understood, hence the difficulty and urgency of adaptation. This chapter focuses on the building industry.

Keywords: Adaptation; climate change; global warming; greenhouse effect; infrastructure; mitigation; thermal energy storage; weather hazard.

3.1. Introduction

Climate change is increasingly apparent. Regional impacts of climate change are being observed. Those commonly cited include extended growing seasons; shifts of plant and animal ranges; earlier flowering of trees, emergence of insects and egg-laying in birds; and local temperature, humidity and wind-speed anomalies. Air temperatures in Alaska and western Canada have increased as much as 3–4 °C in the past 50 years. According to the Third Assessment Report (TAR) of the Intergovernmental Panel on Climate Change (IPCC), the Earth's average surface temperature increased 0.6 ± 0.2 °C in the 20th century. This trend is expected to continue, with an increase of 1.4–5.8 °C by 2100. Even with "best case" mitigation efforts, some climate change cannot be avoided due to the inertia of the global climate system. Warming will vary by region and be accompanied by significant changes in precipitation patterns as well as changes in the frequency and intensity of some extreme events. Average global sea levels will rise between 9 and 88 cm by 2100. Fifty to seventy per cent of the world's population currently live in low-lying coastal areas.

Even with the mitigation measures underway to cut net emissions of greenhouse gases and so reduce climate change, current predictions see more frequent and more severe extreme weather events. As climate change continues, the prediction and mitigation of climate related hazards will ultimately require adaptation across the entire construction sector. Another response to climate change is the development of regulations and standards of professional practice designed to protect the environment while protecting the public and its infrastructure from increased weather hazards. Approaches to the prediction of weather trends, the reduction of human impacts on the climate, and the mitigation of the effects of changes beyond our control require integrated global efforts.

The adaptation reflects the need to prepare for and respond to the impacts of climate change, and the corresponding recognition that any future global climate change regime will need to address adaptation in a more prominent manner. Defining a new approach to addressing adaptation in a post-2012 regime will be challenging, in part because the international community is only beginning to understand how to effectively respond to the complex socio-economic and environmental impacts that will result from climate change. Adaptation to human-induced climate change is a new process for all countries and concrete experience in applying an integrated approach to adaptation is limited.

Increasing evidence of human contributions to climate change is coming to light. The market pressure of eco-conscious clients and a concerned public is causing manufacturing and construction firms to adopt more environmentally sound engineering practices as a result. Proactive members of every important industry are getting involved with education and research into new technologies and approaches to address design problems with sustainable solutions. The demand for "green" innovations in design is bound to grow with our awareness of our impacts on nature in an increasingly industrialized world.

Even with the preventive measures being developed to protect the environment, the current research and climate models show that we can expect global warming to accelerate causing more frequent and more severe extreme weather events. For professionals involved in construction, the designing of structures for predicted future conditions is a challenge but also an investment that pays off with reduced maintenance and retrofit costs. As climate change continues, the prediction and mitigation of climate related hazards will ultimately require adaptation across the entire construction sector.

Approaches to the prediction of weather trends, the reduction of human impacts on the climate, and the mitigation of the effects of changes beyond our control require integrated global efforts. The sharing of the latest studies, defined risks and new solutions through communication between different governments and various professional disciplines is essential to timely, economical progress. Adaptation can keep up with the predicted shifts in conditions if it is begun immediately and before it is forced by natural disasters.

The predictions for almost all communities in Canada include more violent winter storms, very high intensity rainfalls of short-duration, and extended heat waves with the accompanying increased risk of smog, wildfires, tree parasites, severe thunderstorms and tornadoes. Current structural design, farming, and forestry practices as well as water resource management, health standards, land use planning, power supply, and insurance policies were developed for the existing conditions. All these aspects of our society and infrastructure will have to change along with the climate.

Individuals, enterprises and policies related to planning and infrastructure development need to address climate change with strategies and measures that offset or reduce its effects. Diversified and integrated approaches involving all stakeholders improve adaptive capacities, reduce vulnerability to climate change, and reduce the costs associated with impacts. Successful adaptation is contingent on proper communication and collaboration, sufficient funding and technological capability.

3.2. Climate Change

The Earth has experienced many different climate regimes throughout geological history and will undoubtedly experience them in the future. Carbon dioxide levels have been much greater during past epochs and temperatures have been much higher. Climate change is a naturally occurring phenomenon at a geological time scale and more or less hospitable to varying life forms, including human beings. The pace of climate change is the danger for modern societies.

Key climate variables:

- Temperature.
- Precipitation and atmospheric moisture.
- Extent of land and sea ice and permafrost.
- Sea level.
- Snow cover.
- Patterns in atmospheric and oceanic circulation.
- Extreme weather and climate events.
- Climate variability.
- Habitat.

Potential impacts of the key climate variables:

- Increased average and peak temperatures.
- More varied and severe weather—greater storm related damage and insurance claims.
- Faster sea level rise (5 centuries of rise have already been experienced in Europe).
- Less pack ice in polar regions and permafrost.
- Decreased snow cover harms agricultural areas.

- Increased snow cover increases roof loads and increases building collapses.
- Changed agricultural zones.
- Habitat modification—pressure on fragile species, changed disease vectors.

A change in the net radiative energy available to the global Earth-atmosphere system is termed a "radiative forcing". Positive radiative forcings tend to have a warming effect while negative radiative forcings have a cooling effect. Greenhouse gases are positive; aerosols and volcanic eruptions have a negative effect. Greenhouse gases persist for decades while aerosols act over weeks.

According to the IPCC the global average surface temperature has increased by $0.6 \pm 0.2\,^{\circ}\mathrm{C}$ since the late 19th century. A causal relationship is suggested between increased greenhouse gas emissions and the observed temperature increase. Current CO_2 and CH_4 concentrations are higher than at any time during past 420,000 years, based on the Vostok Ice Core. Present N_2O concentration has not been exceeded during the past 1,000 years. Halocarbons are anthropogenic compounds and are potent GHG's in addition to their ODP. However, Montreal Protocol has been successful in curbing their emission.

The IPCC "Hockey Stick" model of temperature increase has been challenged as faulty (e.g., 15th century is warmer than 20th century if data is properly analyzed). Predicting future climate states is like predicting the weather—very difficult especially because of non-linearity. The argument that human activity is causing climate change is one of circumstantial evidence. The correlation between GHG's and change in temperature is not causation. What causes what? Use of General Circulation Models (GCM's) to predict future climate states and to postdict past climate states is the basis of predictions. GCM's are developing as the understanding of natural systems and level of computing power increases.

"The dominant issue in global warming, in my opinion, is sea level change and the question of how fast ice sheets can disintegrate. A large portion of the world's people live within a few meters of sea level, with trillions of dollar in infrastructure. The need to preserve global coastlines sets a low ceiling on the level of global warming that would constitute dangerous anthropogenic interference" [3].

The Planetary Energy Balance [3] of Incoming Solar (340 W/m^2) minus Reflected (101 W/m^2) minus Radiated (238 W/m^2) = 1 W/m^2. This excess energy warms the oceans and melts glaciers and ice sheets. The GHG component is 2 W/m^2. The amount of heat required to melt enough ice to raise sea level 1 m is about 12 Watt-years (averaged over the planet)—energy that could be accumulated in 12 years if the planet is out of balance by 1 W/m^2 per year.

Earth's climate has swung repeatedly between ice ages and warm interglacial periods. We are currently in the Holocene interglacial (12,000 yrs old), at the peak temperature. The previous interglacial period (Eemian) was warmer than the Holocene with a sea level 5–6 m higher. One additional W/m^2 of forcing, over and above that of today, will take global temperature approximately to the maximum level of the Eemian—thus providing a proxy estimate of sea level considered by Hansen to be the most critical metric of climate change impact.

Based on paleoclimate evidence, the highest prudent level of additional warming is not more than 1 °C. This means additional climate forcing should not exceed 1 W/m^2. Another way to work with climate scenarios is to examine changes in individual climate forcing agents. In the 1980s there was a growth rate of 0.5 W/m^2 per decade that declined in the 1990s to 0.3 W/m^2 supposedly due to a decline in CFCs. CO_2 is growing between 1.5 and 2 ppm per year although the CH_4 growth rate is down by 2/3 in the past 20 years.

The long-term reduction of CO_2 is a greater challenge, as energy use will continue to rise. Continued efficiency improvements are needed along with more renewable energy and new technologies that produce little or no CO_2 or that capture and sequester it. Study of the Earth's climate suggests that small forces maintained long enough can cause large climate change (nonlinear effects, 29th day). The positive aspect of this situation is that mitigation efforts can make a real difference in the rate and magnitude of climate change.

Climate change is happening. If current climate change is natural, then all we can do is try to adapt. If human activity is causing or contributing to climate change, then mitigation measures can make a difference.

3.3. Climate Change Implications for Engineers

Engineers involved with providing society's infrastructure requirements face new challenges and new opportunities due to shifts in climate occurring around the world today. Building codes already specify minimum health and safety requirements for some key climate variables such as heating and cooling design temperatures; heating and cooling degree days; rainfall and snow loads; and wind pressures. Predicted changes in these variables at specific locations are not usually available. Regional scenarios give a general trend but lack precision and verification. Eco-conscious clients and a concerned public are causing manufacturing and construction firms to adopt more environmentally sound engineering practices. Proactive members of every important industry are getting involved with education and research into new technologies and approaches to address design problems with sustainable solutions.

Every engineering discipline has specific climate change issues, preventive measures and adjustments to impacts. Some of these are summarized in

Appendix. For example, lighting accounts for roughly a third of the electricity demand in buildings. Many energy efficient lighting products and ballasts are available. Better lighting controls are also effective in reducing electricity use. New design standards will also be effective in creating better illumination while increasing energy efficiency.

Effective mitigation of and adaptation to the impacts of climate change require a common set of response priorities. Water and energy efficiency are of primary importance, followed by pragmatic and future-oriented reviews of standards, codes, regulations and other practices. Measures to assess risk and manage durability need to be developed and integrated into practice. Finally, emergency preparedness and response programs need to be further improved as extreme weather risks are becoming less predictable. The climate is changing at an unprecedented rate and in ways that are not yet fully understood, hence the difficulty and urgency of adaptation.

Another response to climate change is the development of regulations and standards of professional practice designed to protect the environment at the same time as protecting the public and its infrastructure from increased weather hazards. When these codes of conduct come into effect they force changes that must legally be implemented immediately. Although they usually represent the minimum required for due diligence, they may be more expensive to implement at the last minute than changes responsibly planned ahead based on predictions of future conditions.

Adaptation can keep up with the predicted shifts in conditions if it is begun immediately and before it is forced by natural disasters. The predictions for most communities in Canada include more violent winter storms, high intensity rainfalls of short-duration, and extended heat waves with the accompanying increased risk of smog, wildfires, tree parasites, severe thunderstorms and tornadoes. Current structural design, farming, and forestry practices as well as water resource management, health standards, land use planning, power supply, and insurance policies were developed for the existing conditions. All these aspects of our society and infrastructure will have to change along with the climate.

Energy is used in the construction, operation, maintenance and renewal of buildings. Energy efficient building technologies from construction through to deconstruction are under development. Some emerging and advanced technologies are listed on the Greentie web site [5]. Some of the technologies are listed below.

- Agriculture.
- Buildings.
- Coal combustion.
- Combined cycle.
- Combined heat & power.

- Combined renewable energy technologies.
- Electrical.
- Forestry & energy crops.
- Fuel cells.
- Gas cleaning systems.
- Geothermal energy.
- Heat recovery & storage.
- High temperature technologies.
- Hydroelectricity.
- Hydrogen.
- Industrial technologies.
- Industrial waste.
- Landfill gas.
- Lighting.
- Municipal waste.
- Nuclear technology.
- Ocean energy.
- Solar energy (heat).
- Solar power.

3.3.1. EMERGING AND ADVANCED TECHNOLOGIES [5]

Short descriptions of some building related technologies are given. Application of these technologies will make a significant contribution to mitigation efforts.

Buildings use about 30% of the total world's energy resources. Existing buildings can typically cut energy usage by 20% or more by intelligent energy management. New buildings can be built to cut energy usage by more than 50% and remain economical.

Renewable electricity technologies can supply energy to remote or off grid communities. They can also feed electricity into the grid. Technologies include photovoltaic, wind and low head hydro.

Fuel cells can be highly efficient in generating electricity on-site as well as providing waste heat. Building applications are in the demonstration phase and offer security of electricity supply.

Geothermal energy or ground source heat pumps extract energy from the earth for heating and cooling. Combined with energy storage this technology offers one of the more efficient means of supplying building energy requirements.

Hydrogen is emerging as a potential future energy medium with applications to all energy sectors. It is used to feed fuel cells. The major question is the source of the hydrogen and the energy required to produce it. Ultimately it is hoped to produce hydrogen from renewable energy sources.

Landfill gas is produced as a result of organic wastes decomposing in landfill sites. It can be recovered at an inexpensive cost of for direct use as a boiler fuel, converted into electricity with a microturbine or upgraded to a higher value fuel gas. This is a very effective mitigation technology since methane is 21 times as powerful as carbon dioxide as a greenhouse gas.

Lighting is one of the single largest end uses for electricity and thus greenhouse gases. Energy efficient design and products combined with intelligent controls can reduce electricity demands and cut cooling loads.

Solar thermal energy can also be used to economically provide heat for a variety of applications. Solar cooling technologies are also available. Through the use of climate-sensitive building design, solar energy can be used for space heating, natural daylighting and even ventilation.

3.4. Climate Change: Dealing with the "Inevitable"?[2]

Dealing with the inevitable is adapting or adjusting to the effects of climate change to reduce the consequences.

3.4.1. ASPECTS OF ADAPTATION

- Develop approach and practices for protecting and improving existing construction against effects of climate change.
- Develop approach and practices for design, operation and maintenance of buildings (such as additional cooling requirements in the summer and heating in the winter).
- Revise codes, such as flood plain mapping and climate data and return frequencies for hazard-prone areas, adjusting to new realities, i.e., 100-year floods become 500-year floods, higher snow and wind loads.
- Consider land use restriction on new construction, especially for floodplains, coastal shoreline, landslide prone areas.

Three-step approach for protecting existing buildings

- Screening—to set priority (ranking) for detailed evaluation needs (based on building's location, type and use of the building, building age, A/M/E systems, etc) .
- Evaluation—to determine a building's deficiency against effects of climate change.
- Retrofitting—improve a building's performance against effects of climate change.

Aspects of Mitigation

- Develop and adapt energy-saving technologies.
- Construction: material selection (minimum use of natural resources), design for disassembly, efficient and durable envelope, durability.
- O&M: clean renewable energy, energy efficient HVAC and lighting systems.
- Building renewal/deconstruction: waste management, deconstruction practice, effective and efficient recycling.

Environmental Goals for Energy Efficient Buildings

- Energy and resource efficiency.
- Water conservation.
- GHG reduction.
- Waste reduction.
- Recycling construction materials.
- Safety and health (Indoor Environmental Quality).
- Community sustainability.

The Passive Energy Saver

- Building materials—minimum use of natural resources.
- Building structure—durability, adaptability.
- Building envelope (walls, roofs, windows)—adequate insulation, air leakage prevention, durability, etc to minimize energy consumption during O&M of buildings, while maintaining interior environment healthy and comfortable for the occupants.
- Waste reduction at the design stage (design for disassembly) and the deconstruction stage.

The Active Energy Saver

- Clean and renewable electricity.
- Efficient heating, ventilating and air conditioning.
- Energy efficient lighting and office equipment.
- Ultra-low energy new buildings.
- Water conservation.

Building Materials: Use of Industrial By-Products

- Supplementary cementing materials.
- Producing 1 tonne of cement leads to 0.9 tonne of GHG emission.
- 2,200,000 tonnes of fly ash available, only 450,000 tonnes used.
- In Ontario, 40% of concrete produced, 20% of fly ash used (used by 60% contractors).
- Reduce use of natural resource and GHG emission.

Waste Reduction: Resource Recovery

- *Lumber:* mainly reused, re-graded by lumber grader.
- *Steel:* mostly recycled, not reused (no way of qualification for reuse—opportunity: can it be stamped at production or a re-grading standard for reuse?).
- *Concrete:* 50% of construction & demolition waste is concrete.
- Economic benefits and reuse versus recycling.

Performance Requirements for Buildings

- Health .
- Safety.
- Security.
- Energy efficiency.
- Sustainability.

3.5. Concluding Remarks

Climate Change is changing Engineering Practice. Already mitigation efforts have been applied to energy efficiency improvements in the building stock (see Chapter on Sustainable Buildings). Adaptation efforts are beginning. Many of these efforts will be carried out through national building codes as the design values for key climatic variables change. Proactive designs will also be necessary for predicted changes.

Thermal energy storage has obvious mitigation benefits. It is necessary when using renewable or natural energy. It can tap a vast quantity of waste and natural energy sources. It will be even more important during post-Kyoto mitigation efforts.

Although mitigation efforts may influence the timing and severity of climate change, adaptation efforts are also necessary. Climate change will lead to inevitable natural hazards, but need not necessarily lead to natural disasters.

Appendix: Impacts of Climate Change on Architectural and Engineering Practices

1. *Disciplines:* All
    - Climate Change Issue.
        - Global Warming and increased Climatic Variability due to Greenhouse Gas (GHG) Accumulation in the Atmosphere and Increased Radiation due to Ozone Depletion by Chlorofluorocarbons (CFC).

- Preventive Measures.
  - GHG and CFC Reduction Research.
  - Energy Conservation, Exceeding Minimum Code Requirements, & Development of New Sustainable Technologies.
  - Broadened Education (e.g., experience with Engineers Without Borders).
  - Interdisciplinary and International Consultation (as recommended in the "Climate Change Strategy and Technology Innovation Act"—USA).
  - Consideration of Indirect and Delayed Effects (such as those from GHGs and CFCs).
  - Seeking "Spill-Over" Technologies from other fields as Solutions or to Derive more immediate Benefits from Environmental Technologies.
  - Political Initiatives to promote all the above (e.g., Canada's $1 billion in Kyoto-compliance incentives and the "Clear Skies and Global Climate Change Initiatives" of USA).
- Adjustments to Impacts.
  - Knowledge Sharing, Consultation, and Research into Sustainable Climate Change Adaptations such as Water Conservation and Safer Structures, e.g., the Centre for Sustainable Infrastructure which studies:
    1. efficient motors & transformers (India and China).
    2. eco-homes for energy-efficient, affordable housing (South Africa).
    3. decentralized energy-efficient wastewater treatment (USA).
    4. storm water management and erosion control for transportation systems (USA).
    5. earth brick technology transfer for low-income house construction (South Africa).
    6. blended cements to reduce energy consumption (USA).
    7. transportation tech.to reduce GHC emissions (India).
    8. community transportation strategies for GHC reduction (Pennsylvania).
    9. conversion of refineries to unleaded fuel production (South Africa).
    10. International Network & Standard Method for Natural Disaster Investigation.
- Climate Change Issue.
  - Climate Change in general.
- Preventive Measures.
  - Participatory Approaches inclusive of all stakeholders—both before an activity is initiated and throughout (e.g., women in developing countries).

    - Long-Term Engagement.
    - Consideration of Multiple Scales—local, landscape, national, regional, and global.
    - Involvement of Other Disciplines in teams.
    - Appropriate Technology that is Adapted to the social, political, and cultural Context.
    - Engineering Systems that consider not only Supply Management but also Demand Management, e.g., we need to focus on using water and electricity efficiently as well as producing more
      1. designs that are Easily Maintained.
      2. designs that Consider the Technical Capacity of People who must Maintain them, and that have a Capacity-Building Component.
      3. Advancing Local Adaptation by Learning from the "Spatial Analogues" of Other Communities and Commercial Operations that have already Adapted Successfully and Economically to the Anticipated Climate
2. *Discipline:* Development of Standards
  - Climate Change Issue.
    - Climate Change in general.
  - Preventive Measures.
    - New & Stricter Environmental Standards based on UN Protocols: Kyoto (GHGs) & Montreal (ozone-depleting chemicals: CFCs, etc) (e.g., Canada's New Model Energy Code for Housing that reduces GHGs).
    - Guidelines for Sustainable.
    - Professional Practice (e.g., ASCE Policy Statement 418 "The Role of the Civil Engineer in Sustainable Development" & "The 12 principles of Green Engineering").
  - Adjustments to Impacts.
    - Standards for Durability including resistance to long-term effects and extreme weather impacts.
    - Revision of Safety and Fire Codes for buildings and other structures.
3. *Discipline:* Climatology/Meteorology
  - Climate Change Issue.
    - Climate Change in general.
  - Preventive Measures.
    - Continued Detailed Study of the Changing Situation.
    - Improved methods of Sharing Information.
  - Adjustments to Impacts.
    - Development of more powerful Predictive Tools (e.g., for thunderstorms, tornadoes & hailstorms, & ones that help prepare for the impacts of events like "Ice Storm'98").

    - Contribution to an International Network and a Standardized Methodology for the Investigation of Natural Disasters to Learn from Rare Severe Weather Events (like “Ice Storm’98”).

4. *Discipline:* Infrastructure Design
   - Climate Change Issue.
     - Climate Change in general.
   - Preventive Measures.
     - Accelerated Technology Development.
     - Immediate Implementation of Adaptive Measures.
     - Encouragement of Win–Win Actions.
     - Contingency Planning Assuming GHG Emissions Are Costly.
     - Experimentation with Land Use and Pricing to affect demand.
   - Adjustments to Impacts
     - Accelerated Technology Development.
     - Immediate Implementation of Adaptive Measures.
     - Seeking Win–Win Solutions.
5. *Discipline:* Civil Engineering
   - Climate Change Issues.
     - Global Warming and the accompanying increase in climatic extremes in a relatively short period of time and causing a disproportionate increase in disaster losses.
   - Preventive Measures.
     - Life Cycle Analysis of projects to develop Design and Construction processes that address Energy Efficiency and the Reduction of GHG Production.
     - Immediate Start to a Steady process of Adaptation while there is Still Time to do it Economically.
   - Adjustments to Impacts.
     - Civil Infrastructure made to withstand the best predictions of likely Extreme Weather Events and with adequate Durability for their exposure to Worsened Average Conditions (CAN/CSA S478 is the Canadian Standards Association’s “Guideline for Durability in Buildings”).
     - Emergency Service Procedures and Facilities undergoing ongoing modification, as extreme weather risks are too unpredictable to be fully contained (IDNDR’s research units for hazard mitigation and/or disaster preparedness are in place at the Université de Québec à Rimouski, the University of Manitoba, & the University of British Columbia).
6. *Discipline:* Geotechnical Engineering
   - Climate Change Issues.
     - Weakening of Foundations, Diminishing Slope Stability, Erosion & Landslides from Increased Rainfall.

- ◦ Reduced Bearing Capacity from Lowered Water Tables due to Increased Evaporation and/or Reduced Precipitation.
- ◦ Erosion of Coasts and Inland Shores by Rises in Water Levels, by Increased Waves due to Higher Winds, and by Floods (in combination with high tides in the case of Howe Sound, British Columbia).

- Preventive Measures.
  - Retaining Walls, Sea Walls, etc or carefully selected Planted Trees on slopes, shores and coasts for Soil Retention.
- Adjustments to Impacts.
  - Awareness of changed climate and Increased Vigilance of changed Hazards in Applying Existing Technologies to Mitigate New Risks.
- Climate Change Issue.
  - Weakening of Foundations by irreversible Permafrost Thaw due to Higher Average Temperatures in the North.
- Preventive Measures.
  - Protection Against Melting in the short term (one attempt in Alaska, painting highways white to reflect the sun's heat, failed because of the distracting glare).
- Adjustments to Impacts.
  - Monitoring of older structures.
  - Projecting areas of greatest threat.
  - Budgeting for the expensive changes.
  - Retrofitting or Rebuilding as needed.
  - Designing structures to Allow for the Thaw.

7. *Discipline:* Municipal Engineering
   - Climate Change Issues.
     - Altered Precipitation Patterns causing More Severe Storm Damage.
     - Worse Snowstorms with potentially Reduced total Snowfalls.
     - Rising or Falling Water Levels—even to the point of Flooding or Drought.
   - Preventive Measures.
     - Combined Municipal Water and Sewage Treatment Plants in the interest of Water Conservation and Reduction of Pollution of Natural Waterways.
     - Integrated Solutions that consider the water needs of all communities Sharing given Water Resources, leading to Improved Irrigation and Management of Wells (including the decommissioning of old wells to prevent contamination of the water table).
   - Adjustments to Impacts.
     - Reduced Need for Snow Removal.
     - Increased Need for Emergency Preparedness (in case of events like Ice Storm'98).

    - Contribution to an International Network and a Standardized Methodology for the Investigation of Natural Disasters to Learn from Rare Severe Weather Events (like "Ice Storm'98").
    - Improved Drainage.
    - Higher Capacity Sewers and Treatment Plants.
    - Separate Storm Sewers.
    - Protection of the Drinking Water Supply: this is the most pressing concern especially in developing island nations like Tuvalu in the Pacific but even in the Netherlands where Protection Against Sea Water Encroachment in the Water Supply is harder to ensure than Prevention of the Flooding of Land near or below sea level.
  - Climate Change Issues.
    - Global Warming from Vehicle-Generated Greenhouse Gases.
  - Preventive Measures.
    - Experimentation with New Solutions that Anticipate Future Conditions.
    - Reduction of Travel Demand by improved Street Layouts, creative Land Use solutions, & better Transit.
    - Increased Transit Use & Cycling through the use of Tolls for Motor Vehicles & improved Convenience of Bicycle and Transit Routes.
  - Climate Change Issues.
    - Increased Heat Waves and More Severe Precipitation Events due to Global Warming.
  - Preventive Measures.
    - Increased Parkland through zoning, and incentives for buildings to have "Green Roofs" with water retention and heat reflection.
  - Adjustments to Impacts.
    - Adaptation of better Emergency Preparedness Measures (e.g., to increased incidents of wildfires near residential areas, increased heat-related illnesses, & more severe summer and winter storms).

8. *Discipline:* Hydrotechnical Engineering
  - Climate Change Issues.
    - Increased Extreme Precipitation Events leading to Worse Flooding (e.g., China 1995 & Cadiz, Spain 1990s).
    - Raised or Lowered average Precipitation Rates (e.g., central prairies 1999).
    - Changes in Floodplains.
    - Lowered Water Levels from Evaporation (possibly affecting shipping, water supply & quality, & hydropower production in the Great Lakes—St. Lawrence system).
    - Droughts (e.g., Spain 1992, Portugal 2005).

  - Severe Snowstorms and Ice Storms (e.g., Eastern Canada & USA 1998).
  - Higher Waves due to Stronger Winds.
  - Accelerated Sea Level Rise due to Ice Cap and Glacier Melt.
- Preventive Measures.
  - Improved Predictive Tools both for Design Tolerances and the Management of the Impacts of Natural Disasters.
  - Hydrological Studies to predict Water Supply and Flood Protection Needs, and to Avoid exacerbating water problems with Poorly Conceived Solutions (e.g.: desertification in one area caused by channeling water to irrigate another—such as in Iran; or flooding worsened downstream in urban areas by dykes protecting farmland—like Poland's 1997 flood).
  - Waterway Designs that do not narrow, block or accelerate natural flows, causing erosion or silting of channels.
- Adjustments to Impacts.
  - Development of Reliable Predictions of water-related Threats.
  - Continued Research into Mitigation Measures against effects of Precipitation, Waves, Floods and the Sea Level's Rise (e.g., the North Sea drilling platforms that are designed by oil companies for a one-meter rise in sea level).
  - Identification and Protection of Coastlines most sensitive to Erosion (e.g., Charlottetown, P.E.I. & near Vancouver, B.C.).
  - Development of an International Network and a Standardized Methodology for the Investigation of Natural Disasters to Learn about the Impacts of Rare Severe Events (like the flood in Quebec in 1996).
  - Predictions of possible Advantages (such as a lengthened shipping season in the Great Lakes).

9. *Discipline:* Structural Engineering
   - Climate Change Issue.
     - Changes in Local Climatic Averages and in Frequency and Severity of Extreme Weather Events, mostly due to Global Warming.
   - Preventive Measures.
     - Exceeding the Current Minimum Requirements of Codes to Adapt to the Latest Understanding of Climate Change.
     - Reduced Life Cycle Impact of structures on the environment, especially by Choices of Materials (e.g., depending on local availability and forest management practices wood can be a versatile, sustainable alternative) and Construction Methods that Minimize the Production of GHGs:—Construction Waste Management including Recycling and Reuse.
     - Life Cycle Costing to Optimize Durability and Waste Reduction.

   - Consideration of Embodied Energy of Materials including processing and transportation.
- Adjustments to Impacts.
   - Exceeding the Current Minimum Requirements of Codes to Adapt to the Latest Understanding of Climate Change.
   - Selection from existing or innovative Construction Methods, Schedules and Designs to Adapt projects to the Latest Understanding of the Changing Risks due to Climate at each individual site (e.g., the passive damping system at the Taipei Financial Center).
   - Targeted Durability based on Life Cycle Analyses considering the best Predictions of Future Conditions (in terms of changed averages and new extremes).
   - Possible Longer Building Season with the warming trend (e.g., in Ontario and Quebec).
   - Monitoring of Structures during extreme weather (e.g., Ice Storm'98) to Fine-Tune Climate Design Data and Contribute to the International Investigation of Natural Disasters.
   - Developing broadly applicable Emergency Procedures and Facilities.

10. *Discipline:* Materials Engineering
   - Climate Change Issues.
      - Global Warming Caused by GHGs from Power Generation and Materials Processing.
   - Preventive Measures.
      - Improved Materials Processing and Recycling Techniques that Reduce Energy Consumption and GHG Production (e.g., reduction of Portland cement use by substitution of industrial waste products such as fly ash, which has several side-benefits).
11. *Discipline:* Mining Engineering
   - Climate Change Issues.
      - Indirect Climatic Effects of Deforestation and Pollution.
   - Preventive Measures.
      - Continued Efforts to Develop Practices to Protect the Environment such as Reforestation of old mine sites, Confinement of Tailings and Minimized Disruption and Contamination of Natural Streams.
   - Climate Change Issues.
      - Warming of the Climate Causing Permafrost Thaw and Reduced Winter Ice in Arctic Waters.
   - Adjustments to Impacts.
      - Opportunities for easier Mining and Oil Exploration in Permafrost Areas.
      - Reduced Need for Ice-Breakers in the Northwest Passage.

    - Adaptations to potentially Increased Risks of Landslides, Flooding and Erosion.

12. *Discipline:* Mechanical Engineering
    - Climate Change Issues.
        - Global Warming from GHGs.
        - Increased Need for Air Conditioning and Refrigeration resulting from the warming trend.
        - Ozone Depletion by CFCs and other chemicals, especially from AC and refrigeration systems.
    - Preventive Measures.
        - Improved Efficiency of Motors and Mechanical Systems to Reduce Energy Consumption and Harmful Emissions from the use of hydrocarbon-fuels (e.g., natural gas, biodiesel & hybrid engine vehicles; improved, popular mass transit; "Energuide-Award"-winning cars that are cheaper to run; Stirling engines or microturbines as auxiliary CHP—combined heat and power—generators running on natural gas or waste gases from landfills, pipeline gas-flaring locations and farms).
        - Adoption of Technologies that Do Not Contribute at all to Global Warming and Ozone Depletion, especially for Sustainable Electrical Power Generation (e.g., 100% renewable resources such as geothermal, wind, solar, wave & tidal power, & hydro-dams; or abundant, non-polluting energy sources like nuclear fission reactors, fuel cells and eventually fusion reactors), Transportation (e.g., fuel-cell vehicles, & alternative fuels such as biodiesel & coconut oil), & HVAC (e.g., passive solar heating/cooling, heat-driven absorption coolers & CHP).
    - Adjustments to Impacts.
        - Generators Powered by Waves, Tides or Wind to Harness the Impacts of Climate Change where the Effects have made such installations Feasible in New Locations.
13. *Discipline:* Refrigeration Engineering
    - Climate Change Issues.
        - Ozone Depletion by CFCs and other chemicals.
    - Preventive Measures.
        - Designing systems that use Ozone-Friendly Refrigerants.
    - Adjustments to Impacts.
        - Designing More Efficient Refrigeration systems.
14. *Discipline:* Industrial Design of aerosol cans, fire extinguishers and foam products
    - Climate Change Issues.
        - Ozone Depletion by CFCs and other chemicals.

- Preventive Measures.
  - Switching to Ozone-Friendly Compressible Gases and Propellants
  - Using Atomizers for Sprays.

15. *Discipline:* Environmental Engineering
  - Climate Change Issues.
    - Climate Change in general.
  - Preventive Measures.
    - Ongoing Studies of Environmental Impacts from Engineering Practices and the Provision of Infrastructure.
    - Rules or Laws of Professional Conduct that Protect the Environment from Causes of Climate Change (e.g., ASCE Policy Statement 418 "The Role of the Civil Engineer in Sustainable Development").
    - Guidance on Sustainable Practices (e.g., the 12 Principles of Green Engineering).
16. *Discipline:* Waste Management Engineering
  - Climate Change Issue.
    - Global Warming from GHGs.
  - Preventive Measures.
    - Development of Re-use, Recycling (e.g., redirected construction wastes) and Composting Programs to Reduce Landfill Loads.
    - Research into Improved Landfill Efficiency, Accelerated Waste Degradation (e.g., leachate recycling & bioreactor landfills), the Generation of Electricity from Landfill Gases (e.g., microturbines & Stirling engines), & "Mining" Landfills for Raw Materials.
17. *Discipline:* Chemical Engineering
  - Climate Change Issues.
    - Climate Change in general.
  - Preventive Measures.
    - Reduction of GHGs, CFCs and other climate-affecting Pollutants generated in the Delivery of Civil Infrastructure Projects and elsewhere.
    - Development of Alternate Fuels for Transportation, Electrical Power Generation and various Industrial Processes (e.g., biodiesel from renewable sources such as vegetable oils).
    - Engineering of Existing Fuels to make them Less Harmful.
18. *Discipline:* Natural Resource Management
  - Climate Change Issues.
    - Climate Change in general.
  - Preventive Measures.
    - Development of Integrated Systematic Engineering Approaches to Sustainable Resource Exploitation (e.g., life-cycle analysis, soft-systems analysis) in fields such as Mining, Forestry, and Agriculture,

especially using Geotechnical and Hydrotechnical Expertise and the latest Climate Information Systems (refer to the relevant areas for more details).
    - Exploitation of "Spill-Over" Technologies from other sectors (e.g., from mining or defence to agriculture or forestry).
    - Involvement in S&T at the International Decision-Making Level and at the Local Resource Management Level.
    - Focus on Technologies Adapted and Integrated into the Local Social, Political, and Cultural Contexts as well as meeting the Physical Constraints while not Relying on Prolonged Outside Involvement.
  - Adjustments to Impacts.
    - Case by Case Adapted Solutions, Taking Advantage of Knowledge Gained from Experience Worldwide shared through Information Technologies such as Databases and through Direct Consultation Between different Disciplines and Governments.
    - Adaptation of Some Traditional Practices to the changed climates and Abandonment of Others (such as slashing and burning).

19. *Discipline:* Agriculture
  - Climate Change Issues.
    - Climate Change and its Worse Effects such as Erosion and Desertification.
    - Increased Evaporation from the Warming Trend in North America possibly causing the Moisture Balance to Decrease 35% this century despite increased precipitation (during the same timeframe, GIS Studies and Computer Modeling of Global Warming show the Okanagan Valley's crop water demand could potentially increase by more than 35%).
    - Increased Risks of Pests, Diseases, and Wildfires in Canada, from the Hotter Climate.
  - Preventive Measures.
    - Development of Agriculture Techniques that have Less Impact on Ecosystems.
    - Capturing and Processing Livestock Methane (e.g., to generate electricity).
    - Exhausting Carbon Dioxide from Engines or Heating (or CHP) into Greenhouses to Reduce GHG Contribution and Help Plants Grow.
    - Elimination of Demand for the Slashing and Burning of Forests through Maintenance of Soil Fertility (e.g., through crop rotation, irrigation).
    - Reversal of some of the Effects of Deforestation by the Afforestation of Unused Farmland.

    - ◦ Containment of Desertification by Irrigation, Limiting Grazing, and Planting Grasses and Bushes that Hold the Soil.
  - Adjustments to Impacts.
    - ◦ Selection of Crops and Farming Methods Adapted to Altered Climates.
    - ◦ Adaptation of Traditional Methods and New Approaches to Water Conservation.
    - ◦ Farming Opportunities due to an Extended Agricultural Growing Season in Ontario and Quebec and perhaps Atlantic Canada (e.g., allowing the selection of alternative crops).
    - ◦ Possible Benefits from Improvements in Plants' Water Utilisation and Overall Yields for some crop types due to the Increase in Atmospheric CO_2 Concentrations.
    - ◦ Possible Agricultural Opportunities in the Mackenzie Basin and other previously Less-Developed Areas.

20. *Discipline:* Forest Management
  - Climate Change Issue.
    - ◦ Increased Heat Waves.
  - Preventive Measures.
    - ◦ Reforestation/Afforestation.
  - Adjustments to Impacts.
    - ◦ Emergency Preparedness Measures adapted to increased incidents of forest fires, insect infestations and the impacts of soil erosion.
    - ◦ Potentially Longer Growing Season.
    - ◦ Studies and Measures to Ensure Adequate Water Supplies to Forests.
21. *Discipline:* Building Engineering
  - Climate Change Issue.
    - ◦ Global Warming and Ozone Depletion.
  - Preventive Measures.
    - ◦ R&D and Investment in Energy-Efficient and Ozone-Friendly Building Technologies that also Save Money in the Life-Cycle Analysis and Predict the Trend of Environmental Standards (e.g., energy-smart buildings that use daylighting, other renewable energy resources, energy-efficient technologies and other sustainable features in new constructions, rehabilitations and retrofits).
    - ◦ CHP Generation with optional Grid-Independence.
  - Adjustments to Impacts.
    - ◦ Designing for Controlled Durability Adapted to the best Predictions of Future Weather Conditions.
22. *Discipline:* Illumination Engineering
  - Climate Change Issue.
    - ◦ Global Warming.

- Preventive Measures.
  - Higher-Efficiency Lighting that uses Less Power—reducing GHG emissions—and generates Less Heat—reducing cooling load (e.g., CMHC's publication of the first book on passive solar house designs for Canada; reduction of unneeded illumination in offices by the installation of individual lighting controls).
- Adjustments to Impacts.
  - Application of the latest illumination standard of the IESNA (www.iesna.org).
  - ANSI/IESNA-RP-04.

23. *Discipline:* HVAC (Heating, Ventilation and Air Conditioning) Technology
    - Climate Change Issues.
      - Global Warming, which is Increasing Weather Variability and Cooling Loads.
    - Preventive Measures.
      - Advanced Controls.
      - Innovative Duct Layouts.
      - Zoning of Modular Systems (e.g., individual environmental controls at each workstation).
    - Adjustments to Impacts.
      - HVAC Systems that can handle a Wide Range of Temperatures.
      - Increased Cooling Capacity.
      - Decreased Cooling Demand.
24. *Discipline:* Building Envelope Design
    - Climate Change Issues.
      - Global Warming and Weather Variability.
    - Preventive Measures.
      - Development of Durable & Healthful Building Enclosures that Reduce Energy Costs.
      - Building Envelope Research (e.g., at proposed centre at Oak Ridge National Laboratory, USA).
      - Long-Term Monitoring of untried building Products & Methods.
      - Consideration of the Embodied Energy of the Materials while Extending the Useful Life of Structures.
      - Providing for Change of Use at some later stage.
      - Research on Flexibility in Design, allowing Economical Rearrangement and Reuse of Components and Assemblies.
      - Increased Weather-Tightness for Fuel Economy.
    - Adjustments to Impacts.
      - Protection from the Humidity Trapped by Weather-Tightness (including threats to occupant health & building durability).

  - Designing for Extreme Climatic Events to Provide Safe Structures but Designing Components & Assemblies for Climatic Averages to Cope with their Gradual Deterioration.
  - Retention of the Economic Benefit of Lowered Energy Consumption by an accurate Life Cycle Analysis.
  - Consideration in LCA for Climate Change Effects on Humidity Control (i.e., sizing of heating and cooling systems made to handle extreme ranges of heat, cold and wind), Cladding Ventilation/ Dehumidification Measures, Weather-Dependent Attacks on Cladding (from Radiation, Moisture and Pollutants such as acid rain), Correct Materials Choices, & Periodic Maintenance.

25. *Discipline:* Real Property Management
    - Climate Change Issues.
      - Threats caused by Climate Change in general and Impacts of Infrastructure Design on the Environment.
    - Preventive Measures.
      - Life Cycle Analysis to help Lower Energy Consumption and Global Warming through Considerations for Embodied Energy and Waste Reduction.
      - Development of new and existing Risk Assessment Tools (e.g., Natural Hazards Electronic Map and Assessment Tools Information System—NHEMATIS), Risk Management Tools inclusive of all stakeholders in the process (e.g., CAN/CSA Q850-97 for risk management in Canada, CAN/CSA-Z763-96 specifically for environmental concerns) & Effective Risk Communication.
    - Adjustments to Impacts.
      - Life Cycle Costing to Reduce Economic Impact of Adaptation.
      - Risk Assessment, Management & Communication.
26. *Discipline:* Architecture
    - Climate Change Issue.
      - Global Warming.
    - Preventive Measures.
      - Priority on Environmental Protection as a Design Criterion.
      - Staying Informed as to the Latest Environmentally-Friendly Technologies to Make Responsible Choices (e.g., “green roofing”, natural & recycled cladding, high-efficiency lighting, photoluminescent emergency lighting, natural ventilation, individualized controls for lighting and HVAC systems in office spaces, passive solar heating, daylighting windows and floor-plans: the CMHC has published the first book on passive solar house designs for Canada, and the American DOE promotes “Zero Energy Homes”).

- Adjustments to Impacts.
  - Continued Suiting of the Design to the Environment, as always, but with an Awareness now of How that Environment is Changing.

27. *Discipline:* Information Technology
    - Climate Change Issue.
      - Climate Change in general.
    - Preventive Measures.
      - Continued Development of Computerized Modeling (e.g., to be able to include tornadoes, thunderstorms, hailstorms, & iceberg migration).
      - Monitoring and Measuring Technologies using the latest in Satellite-Based Remote Sensing (e.g., NASA's EOSDIS).
      - Geomatics, and High-Speed Communications to Gather, Process (e.g., by Distributed computing) and Disseminate (e.g., via the WFEO's virtual engineering library & the iiSBE web site) useful Climate Information Globally (especially including developing countries, thanks in part to the Clean Energy Initiative of the World Summit on Sustainable Development) to assist with Risk Analysis, Design (e.g., of the Confederation Bridge over ice-covered waters), Emergency Preparedness and Post-Disaster Studies.
28. *Discipline:* Port Authorities
    - Climate Change Issue.
      - Higher Sea Levels and More Severe Storms due to Global Warming.
    - Adjustments to Impacts.
      - Retrofit of Seaports to Allow for Higher Water Levels and Worse Storms.
29. *Discipline:* Shipping Regulation
    - Climate Change Issue.
      - Shortened Period of Ice Cover, Thinner Ice, and Higher Sea Levels.
    - Adjustments to Impacts.
      - Possible Longer Shipping Season in the Great Lakes, the St. Laurence Seaway, and the Northwest Passage.
30. *Discipline:* Shipping Regulation and Coast Guards
    - Climate Change Issue.
      - Worse and More Frequent Storms.
    - Adjustments to Impacts.
      - The development of more reliable Weather Advisory Systems.
31. *Discipline:* Fishing Quota Regulation
    - Climate Change Issue.
      - Warmer Waters and Longer Summers.
    - Adjustments to Impacts.
      - Possible Higher Sustainable Fishing Quotas.

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