The Importance of Building Physics to Life Cycle Assessment

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24 October, Building Physics Seminar, Tampere, Finland

Overview / Yhteenveto

- **Lecture overview**
- Life Cycle (Environmental) Assessment (LCA)
- Durability, longevity and climate change
- Approaches to assessing durability of building assemblies
- Global activities focused on the:
  rakennusmateriaalien ja komponenttien kestävyys
- Conclusions and Invitation
- Bonus - Issues as relate to the "**kestävyys**" of ETICS

PART 1 — LIFE CYCLE ASSESSMENT (LCA)

Life Cycle (Environmental) Assessment

Life Cycle of constructed assets

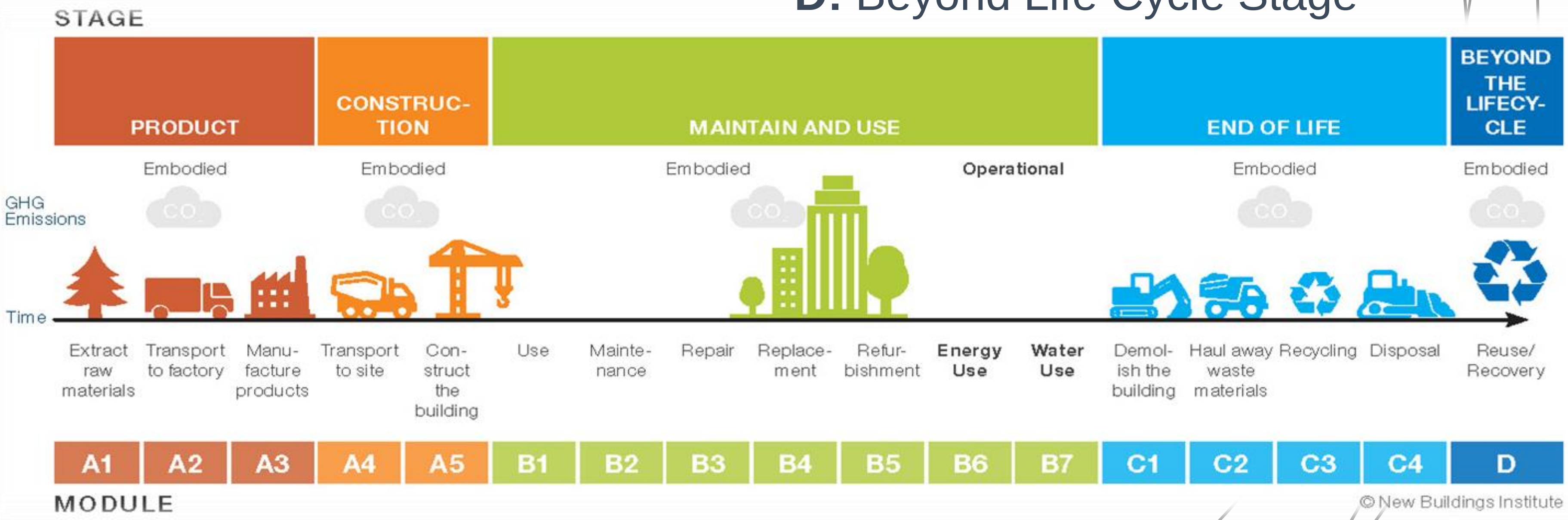
A1-A3: Product Stage

A4-A5: Construction Stage

B1-B7: Maintenance & Use Stage

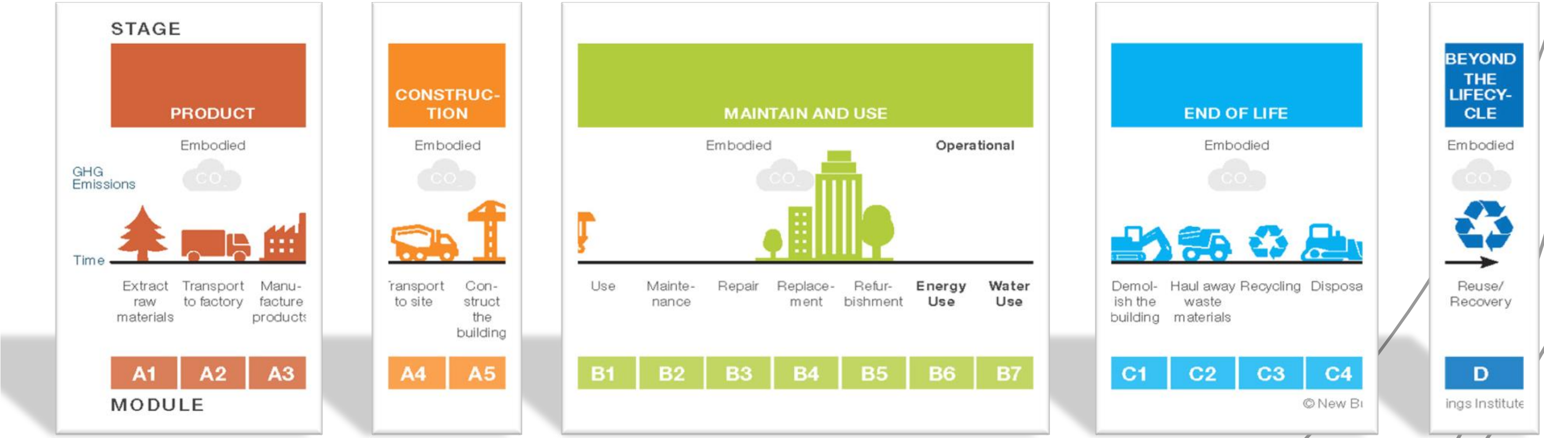
C1-C4: End of Life Stage

D: Beyond Life Cycle Stage



Life Cycle Assessment (LCA)

- Construction emissions over Life Cycle of constructed asset can be categorized by life cycle modules **A-D**
- LCA is a method of measuring potential environmental impact of a process, product, project…..
- LCA helps practitioners make environmentally focused design choices



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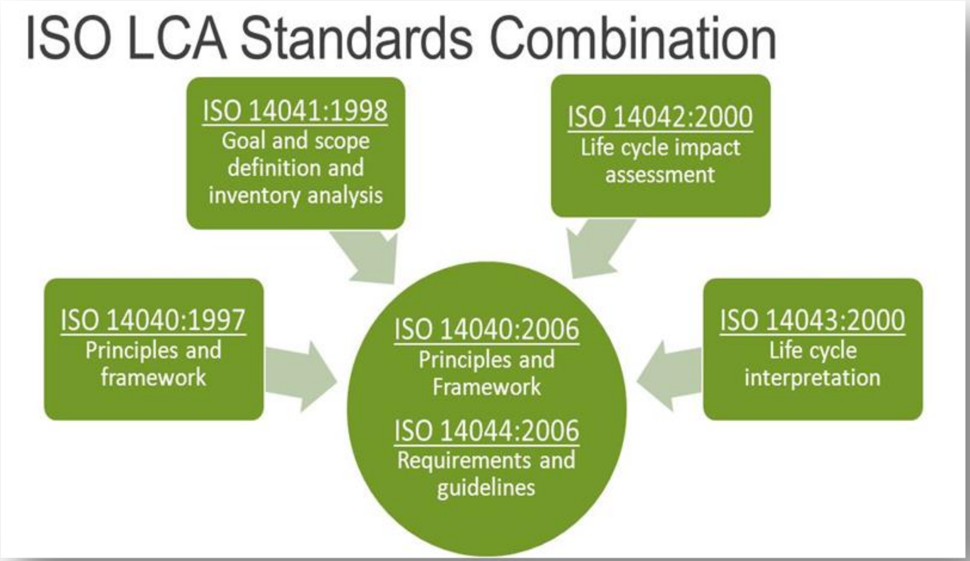


Life Cycle Assessment (LCA)

- Global Warming Potential (kgCO_2eq) to end of life stage
- Values of impacts arising from GWP over required (design) service life of constructed asset must be taken into account
- A prolonged service life reduces intensity the GWP impact
- Conversely – a shortened life increases intensity the GWP impact

Global Warming Potential for each life cycle stage

Indicator	Unit	Product (A1-3)	Construction process (A4-5)	Use stage (B1-7)	End of life (C1-4)	Benefits and loads beyond the system boundary (D)
(1) GWP - fossil	kg CO_2 eq					
(2) GWP - biogenic	kg CO_2 eq					
GWP – GHGs (1+2)	kg CO_2 eq					
(3) GWP – land use and land use change	kg CO_2 eq					
GWP – overall (1+2+3)	kg CO_2 eq					

Notes:
Impacts referred to the use of 1 m^2 of useful internal floor per year for a default reference study period of 50 years[1].

PART 2 — DURABILITY, LONGEVITY AND CLIMATE CHANGE

Durability, longevity and climate change

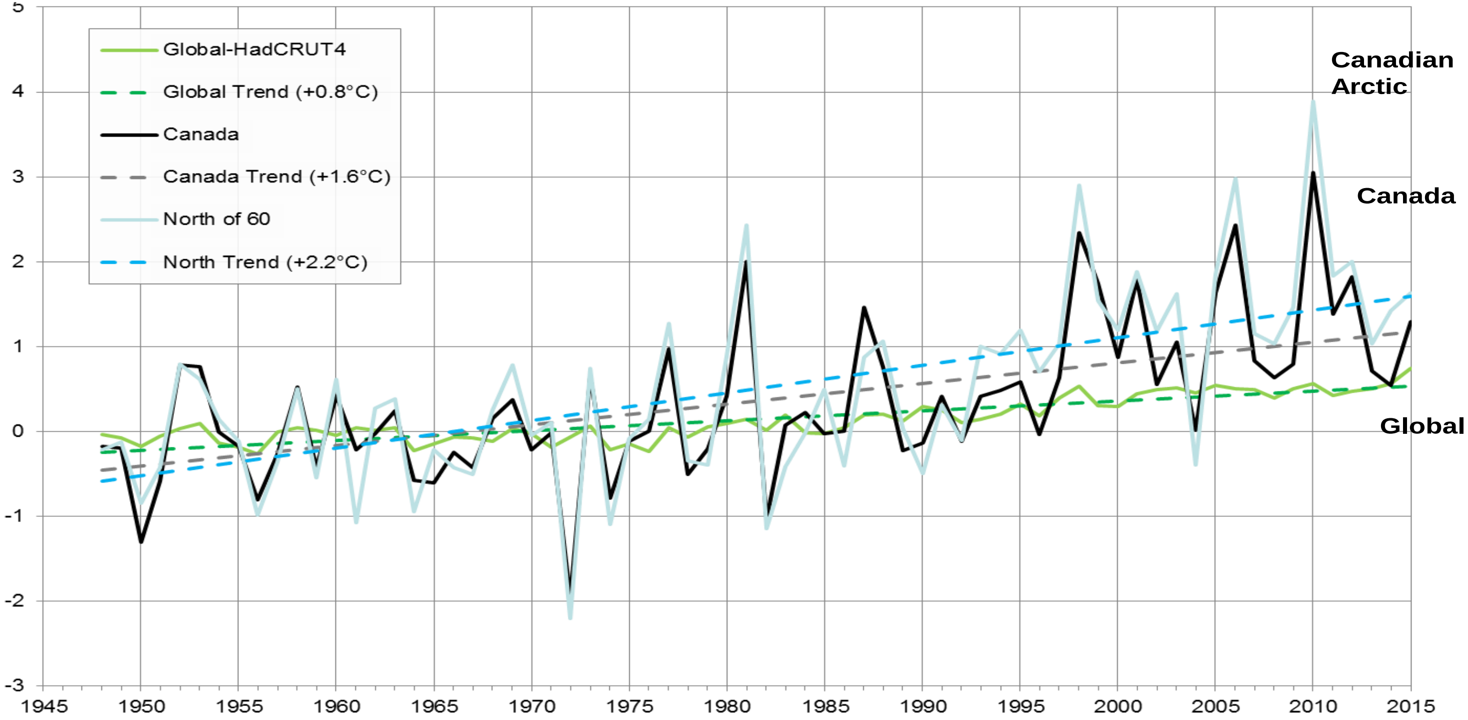
Durability in the context of LCA

- The durability and, in turn, the longevity of a constructed asset, necessarily affects the intensity in GWP and in turn, the **Life Cycle Impact Assessment**
- Estimating the service life of *new* constructed assets or the *retrofit* of existing assets, is of importance in determining the carbon (**LCIA**) impact of such assets
- This is all the more important given a changing climate

Climate change in Canada

- Annual average surface air temperature over Canada's landmass has warmed by 1.5°C: twice global rate (since 1948)
- Parts of the North have warmed by 2.2°C
- Total annual precipitation in Canada has increased over 1948–2012
- Strong regional variability in climate change
- Increase of frequency and severity of extreme weather events — including floods, heat waves, droughts, extreme winds, fires
- Sea level rise increases risk of storm-surge flooding

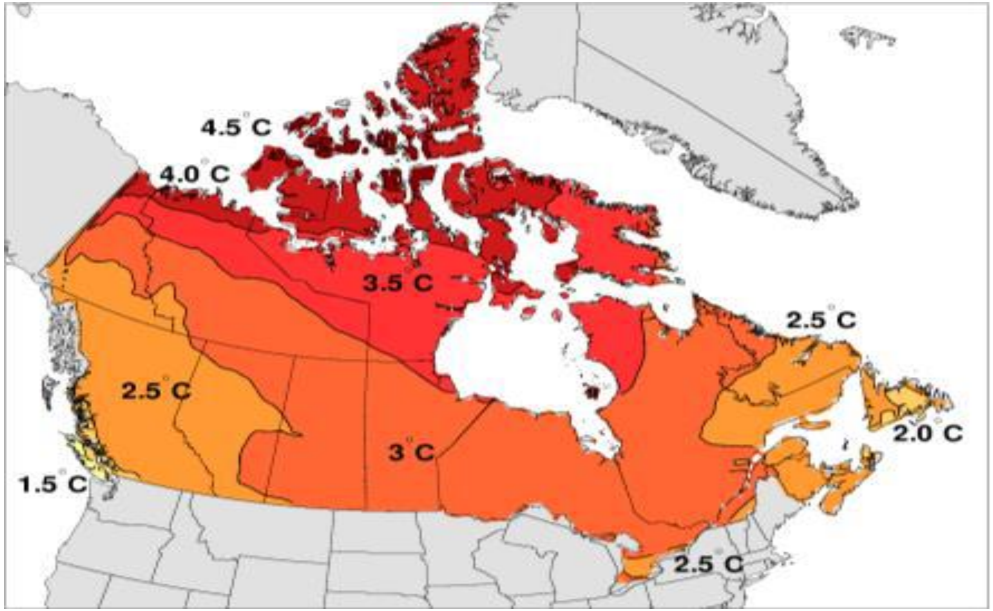
Canada's changing climate



Observed Changes in Annual Temperature in Canada and Globe

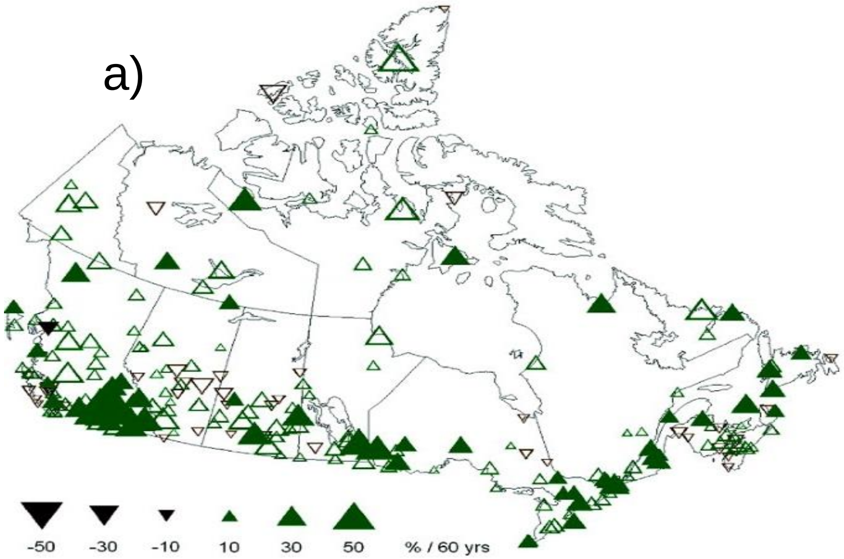
(Shepherd & Zhang 2016)

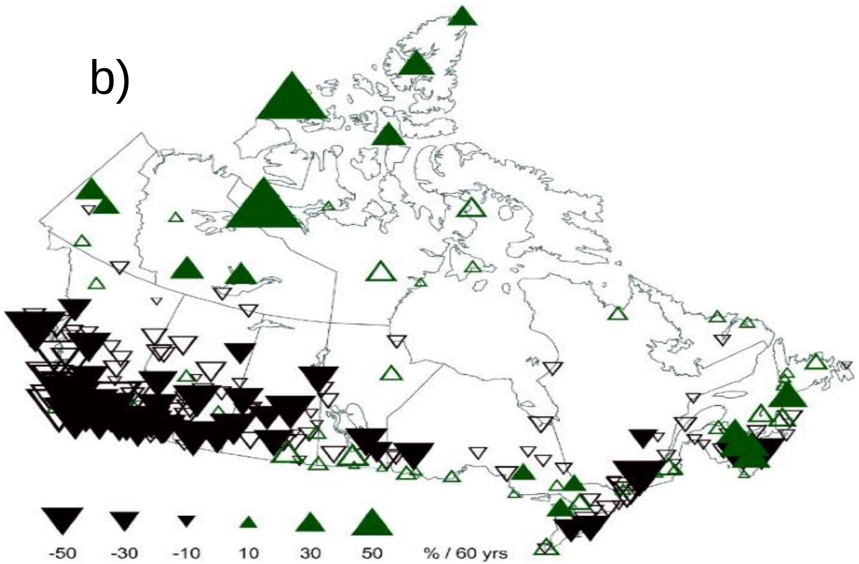
Canada's changing climate



Projected increase in annual average temperature by 2070
(Ouranos 2015)

Canada's changing climate





Observed Annual Precipitation Trends: 1950–2009 a) Rainfall; b) Snowfall

(From Mekis & Vincent, 2011)

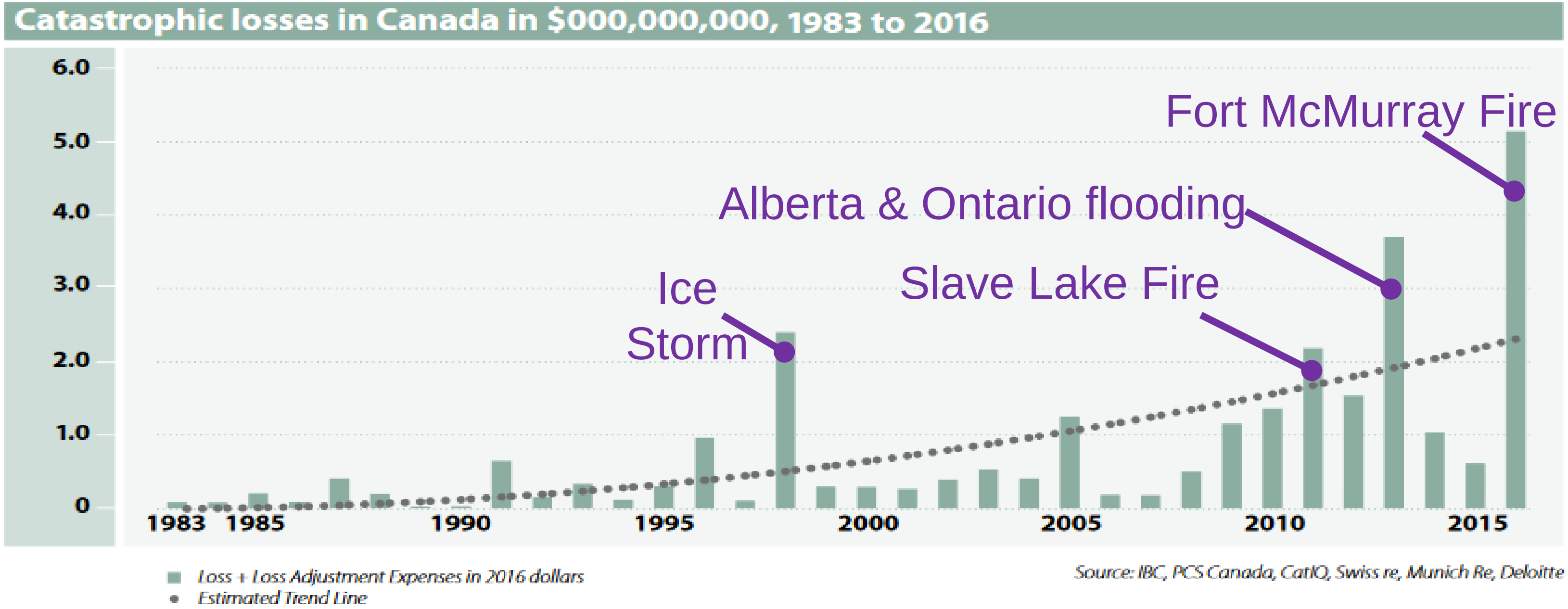
Canada’s changing climate

Climate change can lead to:

- Increased load and reduced resistance of Infrastructure
- Higher stresses on, and increased risk of failure of infrastructure assets ➡ Shorter service life of Infrastructure
- Increased risk of loss of life, injuries, illnesses due to Infrastructure failures
- Increase potential liability issues with existing codes and standards (unreliable climatic data)

Cost of extreme weather events

Insured Losses



Source: IBC Fact Book 2017

Climate change and impacts on buildings

Anthropogenic climate drivers:
GHG emissions

Climate change

Changes in mean & variability:
- Temperature
- Precipitation
- Humidity
- Solar radiation
- Wind conditions

Natural climate determinants:
Terrestrial, solar planetary, orbital

Environmental effects

Gradual climate change
- Means
- Frequency
- Geography

Extreme weather events
- Frequency
- Severity (intensity, duration)
- Geography

Coastal sea level rise
- Storm surges

Impacts on buildings, land & coastal systems

Thermal effects

Convective (wind) and precipitation effects

Environmental degradation
- Urban fabric
- Land & coastal systems

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Impacts on buildings, land & coastal systems

Thermal effects

Shift in energy use
- Decrease heating
- Increase cooling

Shift in thermal conditions
- Risk of overheating
- Passive no longer effective / Passive out of range

HVAC capacity mismatch
- Heating / cooling peak loads
- Energy use inefficiencies

Climate change and impacts on buildings

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Impacts on buildings

Convective (wind) and precipitation effects

Increased wind
- Peak loads
- Change in frequency

Increased precipitation
- Increase in frequency, intensity and duration

Flooding building:
- Structure / systems / infill / contents

Environmental degradation
- Urban fabric
- Land & coastal systems

PART 4 — APPROACHES TO ASSESSING DURABILITY OF BUILDING ASSEMBLIES

Approaches to assessing durability

Assessing durability of building assemblies

- Pertinent standards:
  - **ISO** 15686-1:2011 **Service life planning**
  - **ISO** 13823 **– General principles on the design of structures for durability**
  - **BS** 7543:2015 **Guide to durability of buildings and building elements, products and components**
  - **NZBC** B2 COMPLIANCE **– Durability**
  - **CSA** S478:19 **– Durability of Buildings**

Climate resilient buildings – durability

Adaptation — Approach to design & retrofit

- **Require methodical approach to assess resilience and long-term performance of building (envelope)**

- **Use of standard approach –**
    - **CSA** S478-19 Durability in Buildings – **references these documents:**

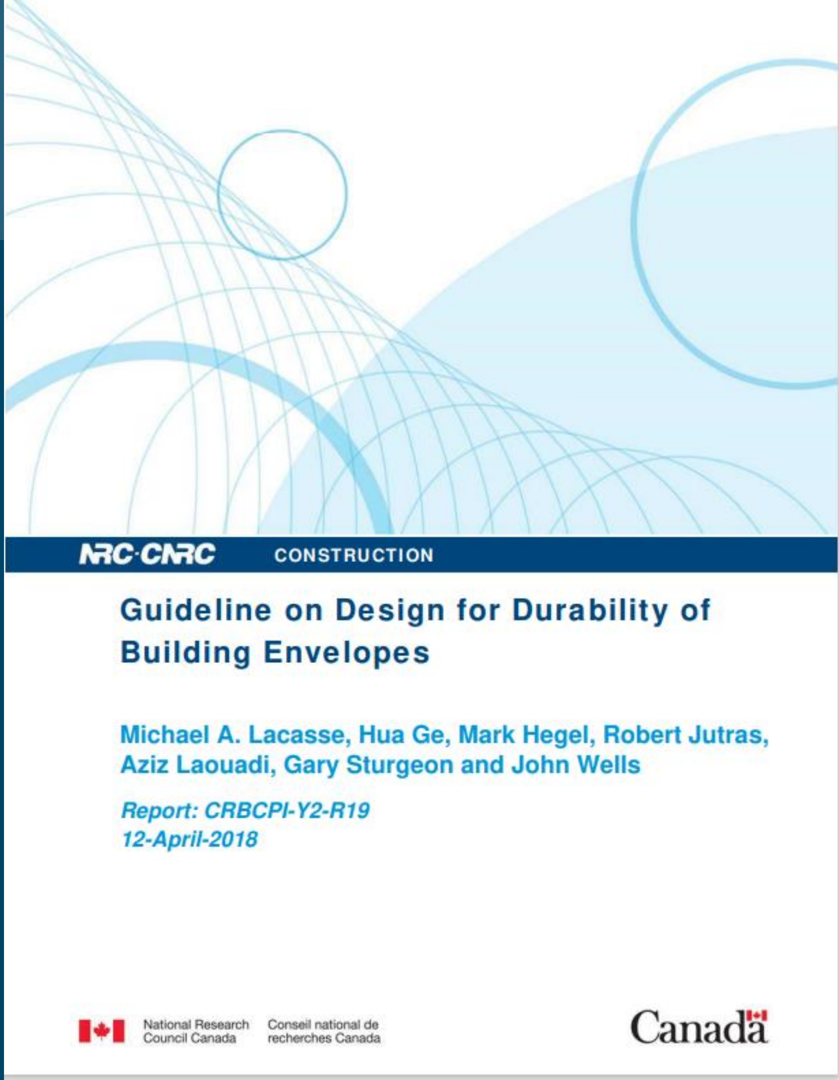
        ➔ **ISO** 15686-1:2011 **Service life planning - Part 1: General principles & framework**

        ➔ **Guideline on the Design of Durability of Building Envelopes**

Guideline on design for durability of building envelopes

NRC-CRC, Technical Report, CRBCPI-Y2-R19

- **Based on: ISO 13823**
  General principles on the design of structures for durability
- **CSA S478-19 § 7 Predicted service life of building elements**
  - Use of hygrothermal simulation models for modelling degradation processes
  - Building Physics ➡ hygrothermal simulation models


NRC·CNRC CONSTRUCTION

Guideline on Design for Durability of Building Envelopes

Michael A. Lacasse, Hua Ge, Mark Hegel, Robert Jutras, Aziz Laouadi, Gary Sturgeon and John Wells

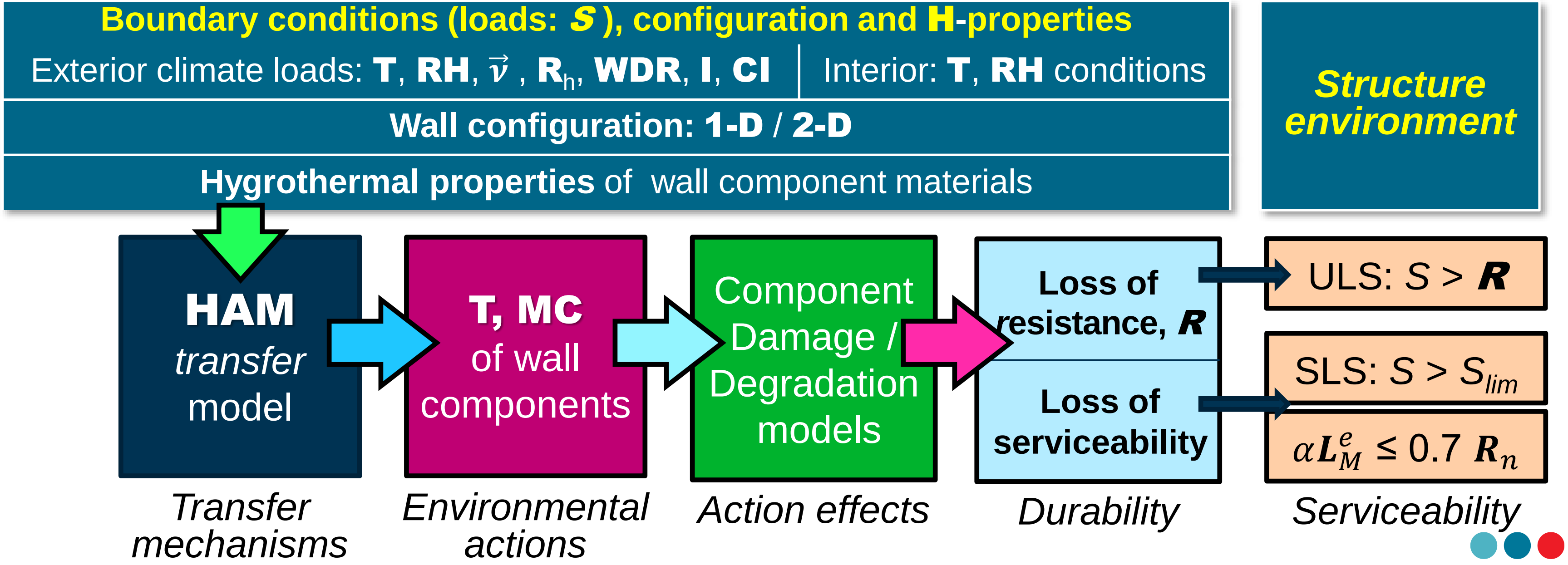
Report: CRBCPI-Y2-R19
12-April-2018

National Research Council Canada
Conseil national de recherches Canada

Canada

Climate resilient buildings – Design & Retrofit

- Use of ➔ Guideline on the Design of Durability of Building Envelopes
- Guide on use of precepts of **Building Physics** ➔ hygrothermal simulation models ➔ provides results from which to estimate durability of building



Climate resilient buildings – approach

Use ➔ Guideline on the Design of Durability of Building Envelopes

Develop reference (baseline) moisture performance of various wall assembly (WA) types for several different locations across Canada 1

➔

Undertake H-simulations of WAs using:
- Historical climate loads & assess reference moisture performance*
- Future projected climate loads & assess moisture performance for all warming scenarios

2

➔

Compare reference moisture performance to that of the moisture performance of WAs subjected to future projected climate loads 3

*moisture performance as indicated by values of:
mould index of building products | **wood** decay index | **masonry** freeze-thaw index | **metal** corrosion index

Climate resilient buildings – approach

Use of ➔ Guideline on the Design of Durability of Building Envelopes

Compare reference moisture performance, as based on historical climate loads, to that of the moisture performance of WAs subjected to future projected climate loads

➔

Mitigate significant changes in performance by adaptation of building design to resist future climate loads

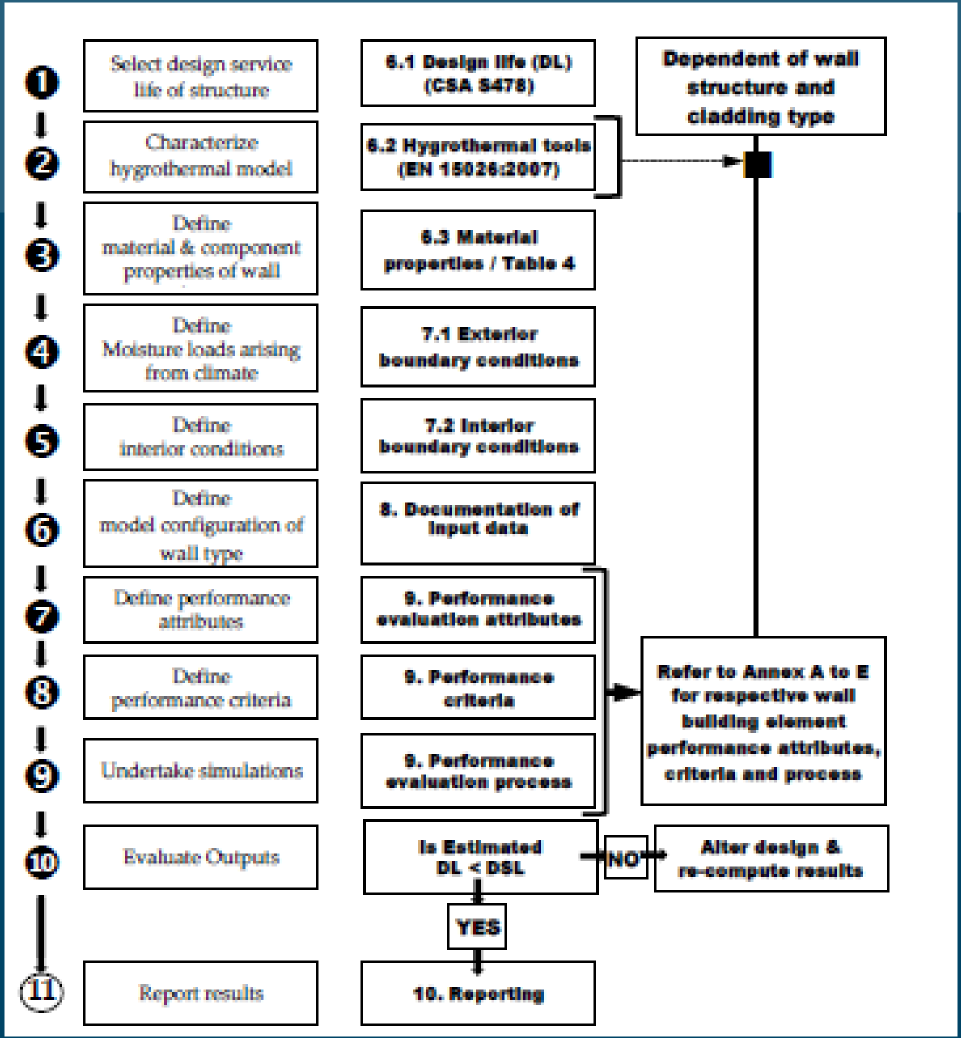
3

*moisture performance as indicated by values of:
mould index of building products | **wood** decay index | **masonry** freeze-thaw index | **metal** corrosion index

Guideline on design for durability of building envelopes

Lacasse et al. (2018),
NRC-CRC, Technical Report, CRBCPI-Y2-R19

Summary of procedure for completing a durability evaluation



Climate resilient buildings –

Adaptation — Approach to design & retrofit

- **Use of ➔Guideline on the Design of Durability of Building Envelopes**

Design for durability of building envelope systems or components	**ISO 13823:2008** **ISO 15686−1:2011**
Boundary conditions to which envelope subjected on exterior as well as interior of assembly	**ANSI/ASHRAE 160−2009** **ISO 15927−3 / ISO 15927−4**
Ensure material properties input to **H**-model consistent with requirements to calculate non-steady-state **HAM** transfer	**DIN EN 15026:2007-07** **ASTM E3054/E3054M−16**
Undertaking hygrothermal simulations	**DIN EN 15026:2007−07** **ASTM E3054M−16** **ANSI/ASHRAE 160−2009**

Climate resilient buildings –

Adaptation — Approach to design & retrofit

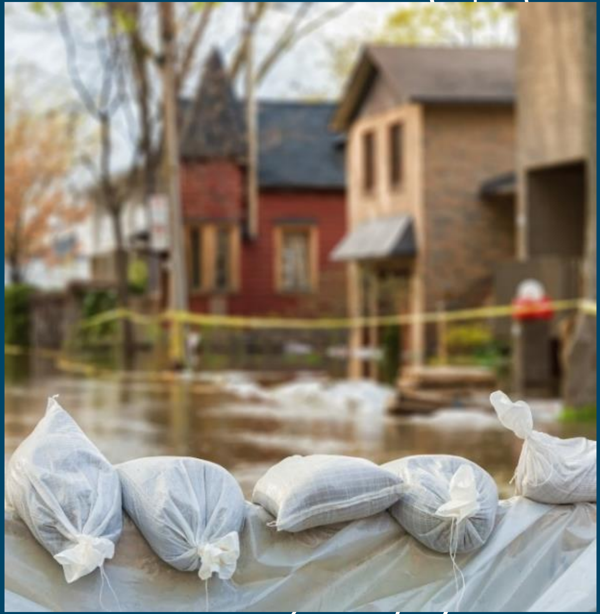
- **Use of ➔ Guideline on the Design of Durability of Building Envelopes**
- Helps ensure uniformity of input to a defined **H-**model
- Provides consistent means to assess response of building elements on basis of results from simulation and relating response to accepted performance criteria
- Affords a reproducible and demonstrable means of verifying designs for durability of building materials, components and wall assemblies

NRC Climate Resilience Research Initiatives

Ongoing partnership with Infrastructure Canada to integrate climate-resilience into guidance, codes and standards

Climate Resilient Buildings and Core Public Infrastructure Research Initiative (2016-2021)

Climate Resilient Built Environment Research Initiative (2021-2026)



Priority areas

Climatic Load Design Data

Existing & New **Buildings**
- All Occupancies

Existing & New **Infrastructure**
- Bridges
- Roads
- Water and Wastewater
- Transit

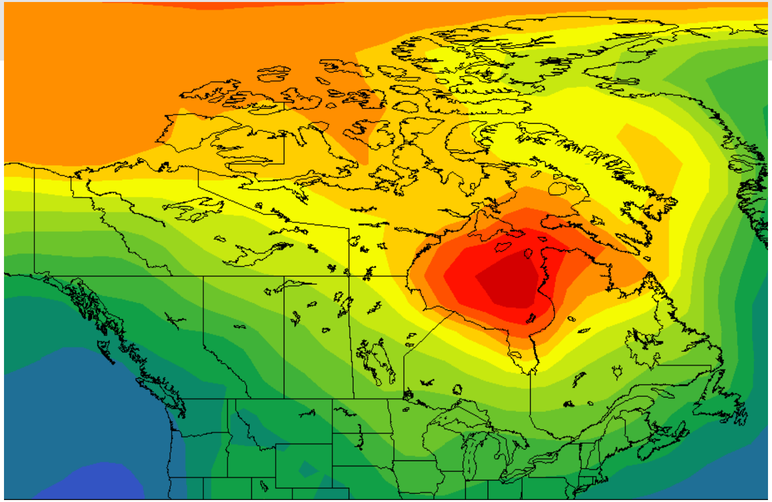
Decision Support **Tools**
- Risk Assessment and Asset Management
- Life Cycle Environmental Analysis

Building climatic data and loads

Updated historic data - Limited provisions ready for 2020 / All data & structural load provisions ready for 2025

Climate extremes: temperature, precipitation, wind & flood

Accounting for uncertainties in climate models & scenarios and in performance of buildings & CPI



Sample map of winter temperature change - ECCC

Key Deliverables

- Development of revised historical climatic data for Canada’s National Building Code (NBC), for **design of buildings** and approach for implementation
- Development of climatic data for extreme events
- Projected future climate data for several warming scenarios

PART 5 — GLOBAL ACTIVITIES FOCUSED ON:
rakennusmateriaalien ja komponenttien **kestävyys**

Global activities focused on:
rakennusmateriaalien ja komponenttien kestävyys

International Council
for Research and Innovation
in Building and Construction

CIB W080
Prediction of Service life of building materials and components

CIB W086
Building Pathology

Global activities focused on:
rakennusmateriaalien ja komponenttien kestävyys

← ISO/TC 59

ISO/TC 59/SC 14

Design life

About

Secretariat: BSI

Committee Manager: Mr Tom Stack

Chairperson (until end 2025): Michael Lacasse

ISO Technical Programme Manager [TPM]: Dr Anna Caterina Rossi
ISO Editorial Manager [EM]: Mrs Yvonne Chen

Creation date: 1997

ISO 15686-1

Buildings and constructed assets /
Service life planning /
Part 1: Concepts, Principles and terminology

CONCLUSIONS & INVITATION

Conclusions and Invitation

- Approach to design and retrofit of climate resilient buildings requires methodical approach to assess resilience and long-term performance of building envelope
  - **Guideline on the Design of Durability of Building Envelopes**
  - **Based on durability assessment standards (ISO 13823 / CSA S478)**
- Guideline on use of precepts of **Building Physics,** as provided in hygrothermal simulation models, affords results from which to estimate service life (longevity/durability) of building envelope elements
- **Estimating the service life of *new* constructed assets or the *retrofit* of existing assets, is of importance in determining the Life Cycle Impact Assessment of such assets**
- The durability and, in turn, the longevity (service life) of a constructed asset, necessarily affects the intensity in GWP and in turn, the LCIA

Invitation

To the:

17TH International Conference on the
Durability of Building Materials & Components
(rakennusmateriaalien ja komponenttien kestävyys)

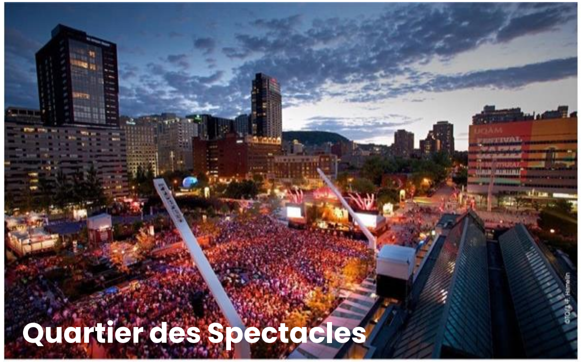
In Montreal, Canada, July **2026**

HOSTS – **HOST ORGANIZATIONS**

National Research Council Canada,
primary National agency of the Government of Canada dedicated to science, technology research & development.

Concordia University,
top-ranked university in Canada founded within the last 50 years and among the most innovative in its approach to experiential learning and cross-functional research.

MONTREAL'S ATTRACTIONS



See you in MONTREAL in 2026 for 17DBMC!

THANK YOU

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Climate resilient buildings – durability

Durability and climate change: implications for service life prediction and the maintainability of buildings

Lacasse, Michael A.; Gaur, Abhishek; Moore, Travis V.,
Buildings, Vol.: 10(3), Publication date: 2020-03-12

Guideline on design for durability of building envelopes

Lacasse, Michael A.; Ge, Hua; Hegel, Mark; Jutras, Robert; Laouadi, Aziz; Sturgeon, Gary; Wells, John
Technical Report, No. NRCC-CONST-56270E, National Research Council of Canada. Construction, Publication date: 2018-04-12, 35 p, DOI:https://doi.org/10.4224/23003983

Approach for assessing the climate resilience of buildings to the effects of hygrothermal loads

Lacasse, M. A.; Defo, M.; Gaur, A.; Moore, T.; Sahyoun, S.
Technical Report, No. NRCC-CONST-56269E, National Research Council of Canada. Construction, Publication date: 2018-06-30, 44 p, DOI:https://doi.org/10.4224/23003982