EBC

Energy in Buildings and Communities Programme

# Next Generation Building Energy Codes

## Sixth EBC Building Energy Codes Working Group Symposium

### 18 November 2024, Melbourne, Australia

# Welcome and Introduction

**Stanford Harrison**
BECWG Co-chair
Director, Commercial Buildings Policy
Department of Climate Change, Energy, the Environment and Water
Australia

We acknowledge the Traditional Owners of Country throughout Australia and recognise their continuing connection to land, waters and culture.
We pay our respects to their elders past and present.

# Welcome to Melbourne

International Energy Agency (IEA)
Energy in Building and Communities (EBC)
Technical Collaboration Programme (TCP)

Australia is hosting for first time since 2016

Thank you to international delegates and operating agents who have traveled from afar and those joining us virtually

## Important events and meetings happening this week:

IEA EBC:

- Building Energy Codes Working Group (BECWG) Symposium
- Annex 89 Workshop
- Executive Committee Meeting
- Impact Masterclass

Partner Events:

- Decarbonising the Building Industry (DBI) Conference
- Building Energy Performance Summit

# Building Energy Codes Working Group

EBC

Energy in Buildings and Communities Programme

Building energy codes are an effective policy tool for improving the energy efficiency of buildings.

The BECWG is a collaborative international effort between governments.

# Agenda:

**13:30 – 18:00 AEDT (02:30 – 07:00 UTC/GMT)**

- Welcome
- Meeting goals and overview of BECWG accomplishments and planned activities
- BECWG work plan for the next two years and sign ups
- Discussion of work plan and country contributions
- Session 1: Energy and Climate Resilience
- Session 2: Embodied Carbon in Building Energy Codes
- Closing

# House keeping

Exits & restrooms

**For those online:**
Please mute microphones

This meeting is being recorded

Photographer attending session

# Meeting goals and overview of BECWG accomplishments and activities

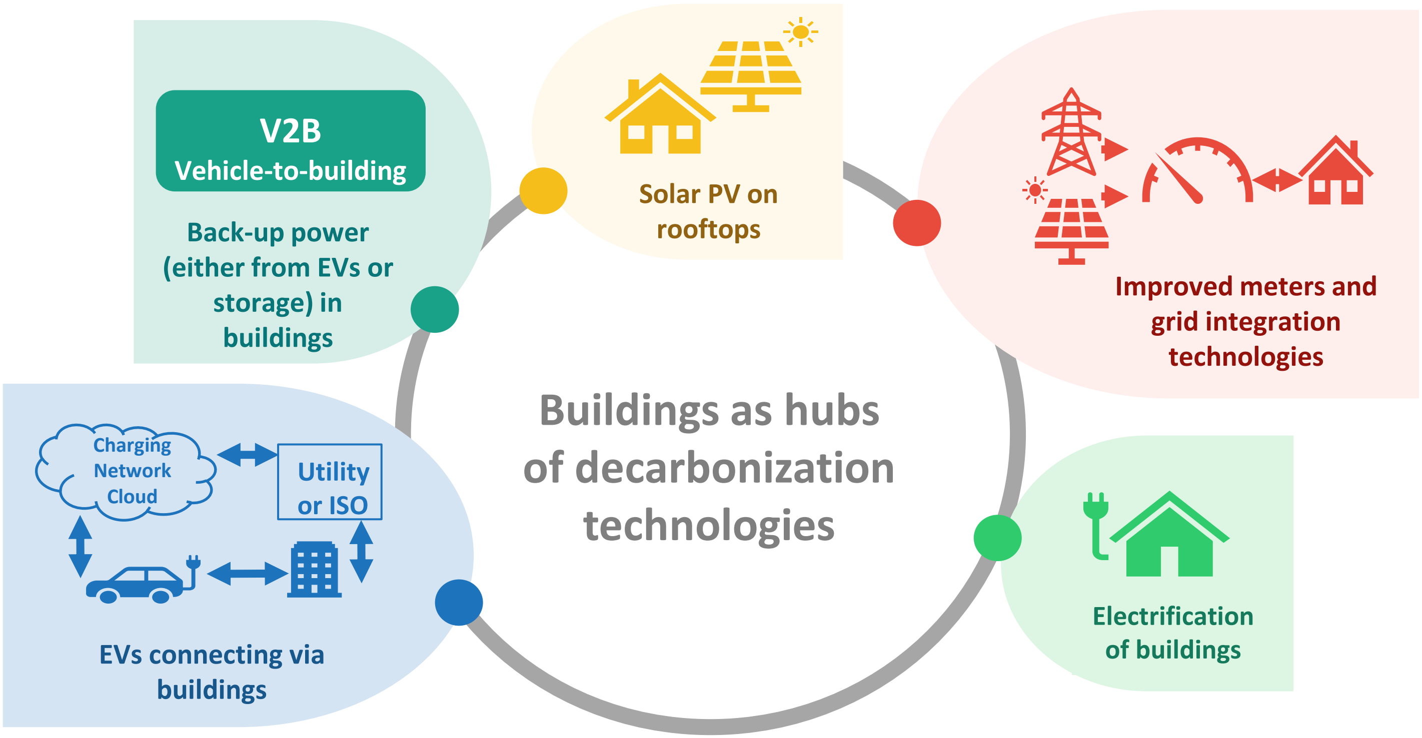
Meli Stylianou
Natural Resources Canada
BECWG Co-Chair

Energy in Buildings and Communities Programme

# Symposium Objectives

Energy in Buildings and Communities Programme

1. Learn from countries' experiences and perspectives on building energy codes, particularly next-generation building energy codes and related issues
2. Develop key research questions and next steps for collaboration on building energy codes



# Symposium Agenda

EBC

Energy in Buildings and Communities Programme

| Introduction | | |
|---|---|---|
| **Moderator: Meredydd Evans** | | |
| **13:30 – 13:35** | Welcome and introduction | Stanford Harrison |
| **13:35 – 13:45** | Meeting goals and overview of BECWG accomplishments and planned activities | Meli Stylianou |
| **13:45 – 13:55** | BECWG work plan for the next two years and sign-ups | Meredydd Evans |
| **13:55 – 14:20** | Discussion of workplan and country contributions | |

# Symposium Agenda cont.

Energy in Buildings and Communities Programme

| Session I. Energy and Climate Resilience | | |
|---|---|---|
| **Moderator: Meredydd Evans** | | |
| **14:20 – 14:35** | Resilience to overheating: metrics and challenges in codes | Aeric Siu |
| **14:35 – 14:50** | Impact assessment of climate resilient energy codes | Ellen Franconi |
| **14:50 – 15:05** | Case-study from the UK on code resilience | Paul Ruyssevelt |
| **15:05 – 15:20** | Discussion on new technologies for improving climate resilience in buildings | Mat Santamouris |
| **15:20 – 15:50** | Panel Discussion | |
| **15:50 – 16:10** | Break | |

# Symposium Agenda cont.

Energy in Buildings and Communities Programme

| Session II. Embodied Carbon in Building Energy Codes | | |
|---|---|---|
| **Moderator: Carlos Flores** | | |
| ***16:10 – 16:25*** | Global Vision and Perspectives from Australia | Stanford Harrison & Suzanne Lavender |
| ***16:25 – 16:40*** | Global status of embodied carbon in codes | Adam Hinge |
| ***16:40 – 16:55*** | Case-study on Denmark | Maria Balouktsi |
| ***16:55 – 17:10*** | Embodied carbon data and whole lifecycle carbon requirements in building codes | Thomas Lützkendorf & Greg Foliente |
| ***17:10 – 17:40*** | Panel Discussion | |

# Symposium Agenda cont.

EBC
Energy in Buildings and Communities Programme

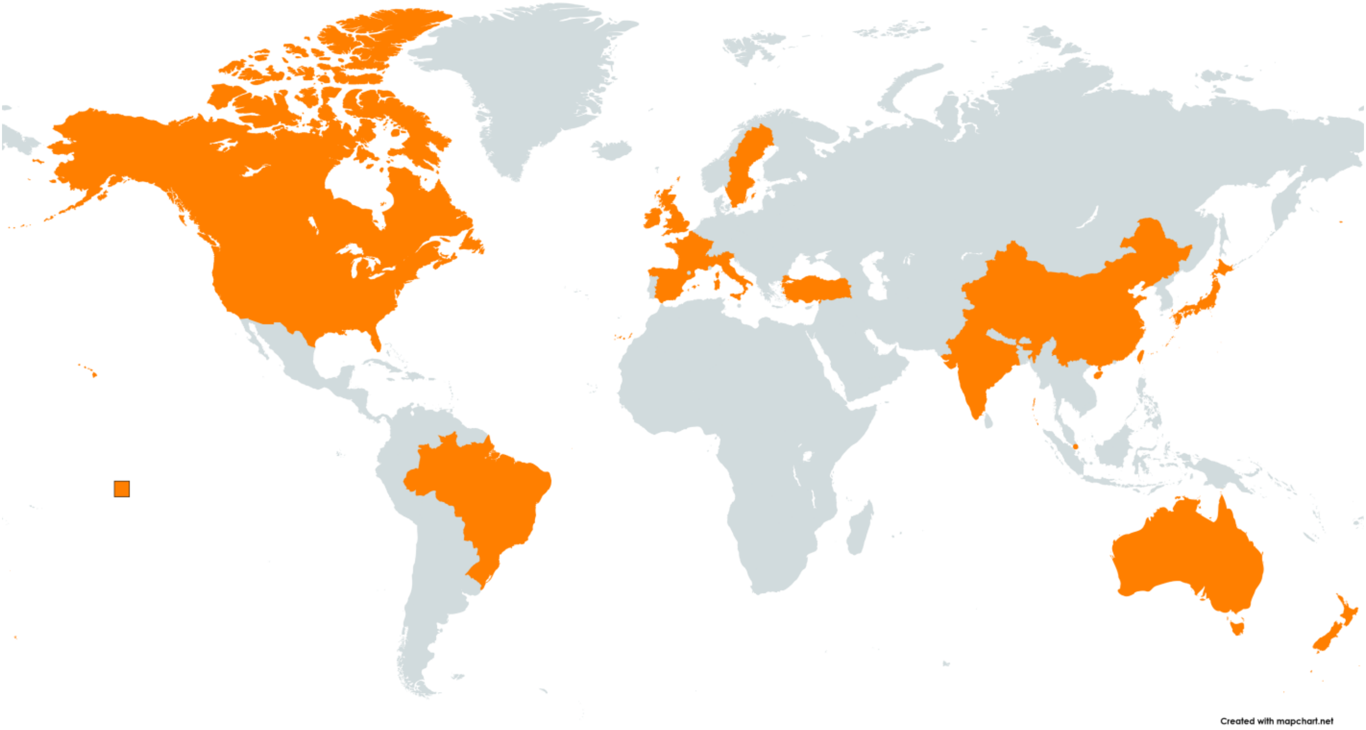
| Closing | | |
|---|---|---|
| ***17:40 – 17:50*** | Key research questions and next steps for collaboration | Meredydd Evans |
| ***17:50 – 18:00*** | Concluding remarks | Stanford Harrison |

# IEA EBC Building Energy Codes Working Group

EBC
Energy in Buildings and Communities Programme

**Types of exchange:**

- ✓ Research/analysis on innovative code practices
- ✓ Webinars on latest code developments
- ✓ Quarterly newsletters highlighting BECWG activities and emerging research
- ✓ Outreach/dialog to disseminate findings and encourage improvements and innovation in practices
- ✓ Free and open access




**18 member countries. 75 Working Group members/delegates and ~123 regular participants (webinars, newsletters)**

https://www.iea-ebc.org/working-group/building-energy-codes


13

# BECWG Activities in 2023-24

Energy in Buildings and Communities Programme

**Outreach and Engagement**:

- Webinars:
  - A Universal Method of Comparing Building Energy Codes (Joint with IEA Secretariat)
  - Flexible Codes for Hot Climates (with ASHRAE)
- Presentation at Behavior, Energy, and Climate Change Conference on virtual inspections research, *November 2023*
- Buildings and Climate Global Forum, Paris, *March 2024*
- Newsletter

behavior, energy & climate change

**BECWG NEWS**

EBC Building Energy Codes Working Group E-Newsletter

**April 2024**

# BECWG Activities in 2023-24

EBC

Energy in Buildings and Communities Programme

## Publications:

- *New technology integration in building energy codes* (Japan, January 2024)
- Planning around 4 additional publications (2025-26 Workplan)

International Energy Agency

**Survey on New Technology Integration in Building Energy Codes**

**Energy in Buildings and Communities Technology Collaboration Programme**

**November 2023**

1. *Global Impacts of Building Energy Codes in Meeting 1.5 °C* (United States)
2. *Resilience to Overheating: Global Experience in Building Energy Codes* (Canada)
3. *Whole Lifecycle Carbon: Embodied Carbon in Standards* (Australia)
4. *Streamlined, collaborative approach for flexible building code development and implementation planning in emerging economies* (ASHRAE)

# BECWG work plan for the next two years and sign-ups

Meredydd Evans

Pacific Northwest National Laboratory

BECWG Operating Agent

Energy in Buildings and Communities Programme

# 2025-26 BECWG Workplan

EBC
Energy in Buildings and Communities Programme

- **Publications** (info on following slides)
- **Webinars**
  - Potential Webinar Topics for 2025:
    - Resilience and overheating
    - Embodied carbon
    - Impact of codes globally and the options for enhancing code coverage
- **Annual Symposiums**
- **Periodic newsletters**

# 2025-26 BECWG Workplan

EBC

Energy in Buildings and Communities Programme

## Confirmed Papers:

1. Global Impacts of Building Energy Codes in Meeting 1.5 °C *(United States-led, expected late 2024 or early 2025)*
2. Resilience to Overheating: Global Experience in Building Energy Codes *(Canadian-led, planned for early 2025)*
3. Whole Lifecycle Carbon: Embodied Carbon in Standards *(Australian-led, planned for mid 2025)*
4. Streamlined, collaborative approach for flexible building code development and implementation planning in emerging economies *(ASHRAE-led, planned for 2025)*

# 2025-26 BECWG Workplan:
# Looking for country sign-ups

Energy in Buildings and Communities Programme

**Topics under consideration:**

- Climate resilience in building energy codes: connections and challenges
- Building Performance Standards
- Building electrification in codes
- Building energy code compliance: technologies and techniques
- Analysis of the impacts of national support efforts for code adoption and implementation

EBC

Energy in Buildings and
Communities Programme

# Discussion: Workplan and country contributions

# Session I.

# Energy and Climate Resilience

EBC

Energy in Buildings and Communities Programme

Natural Resources Canada | Ressources naturelles Canada

Canada

EBC

Energy in Buildings and Communities Programme

# Resilience to Overheating: Metrics and Challenges in Codes

Aeric Siu

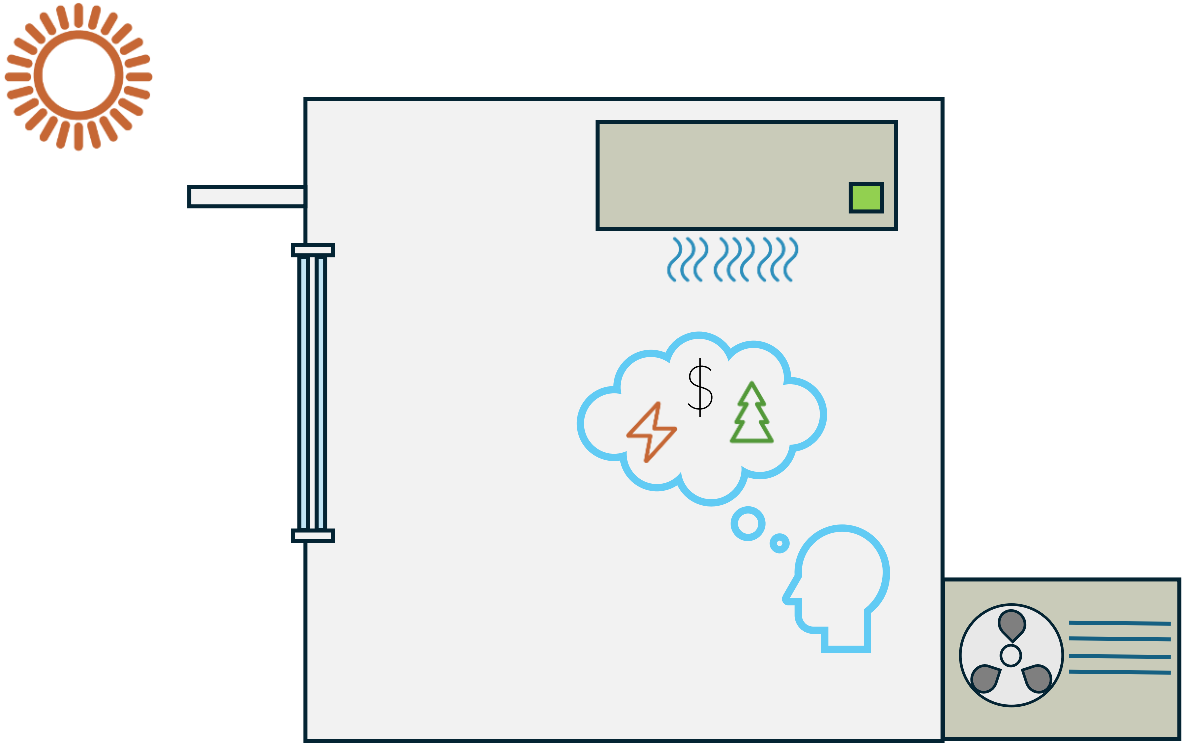
Research Affiliate (PhD Student) - Natural Resources Canada, Housing and Buildings Team

# Agenda

- Background
- Global Overview
- Overheating Concepts
- Metrics
- Thresholds
- Exposure
- 26 $^{o}$C Threshold
- Challenges

# Background - Challenges of Thermal Resilience to Overheating (OH) (I)

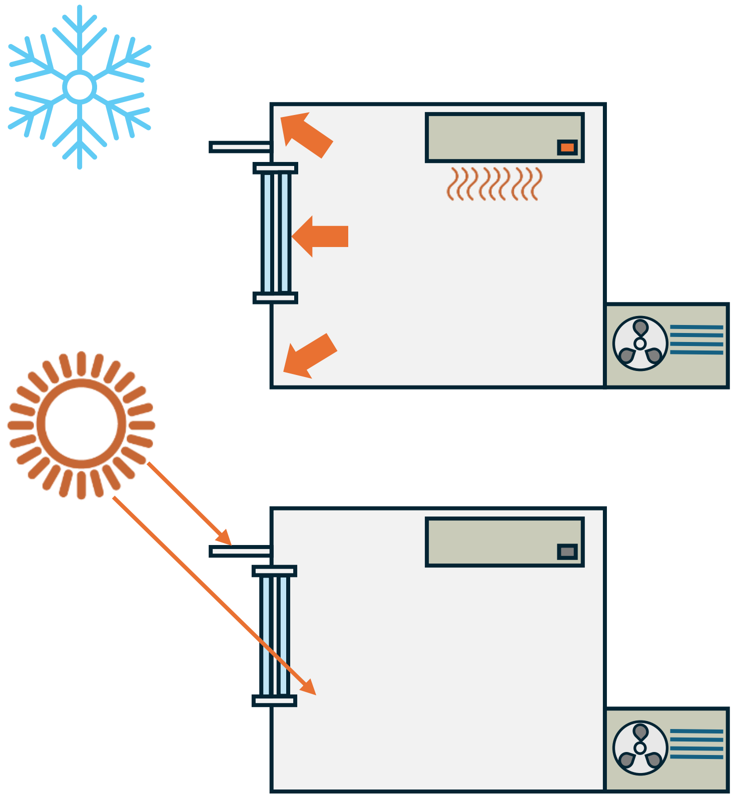
- Leverage/balance both **passive** and **active** measures
  - **Passive cooling** first approach can reduce cooling load (preferred in European Countries) [1], but passive measures alone may not be sufficient in future climate [2]
  - **Active cooling** is an effective health measure, but requires power & refrigerant to operate which can affect mitigation efforts; there are also affordability and social equity considerations



[1] Mohamed Hamdy, et al. The impact of climate change on the overheating risk in dwellings—a Dutch case study. Building and Environment, 122:307–323,9 2017.
[2] UK House of Commons Environmental Audit Committee. Heat resilience and sustainable cooling fifth report of session 2023-24 report, with an appendix, together with formal minutes relating to the report, 2024.

# Background - Challenges of Thermal Resilience to Overheating (OH) (II)

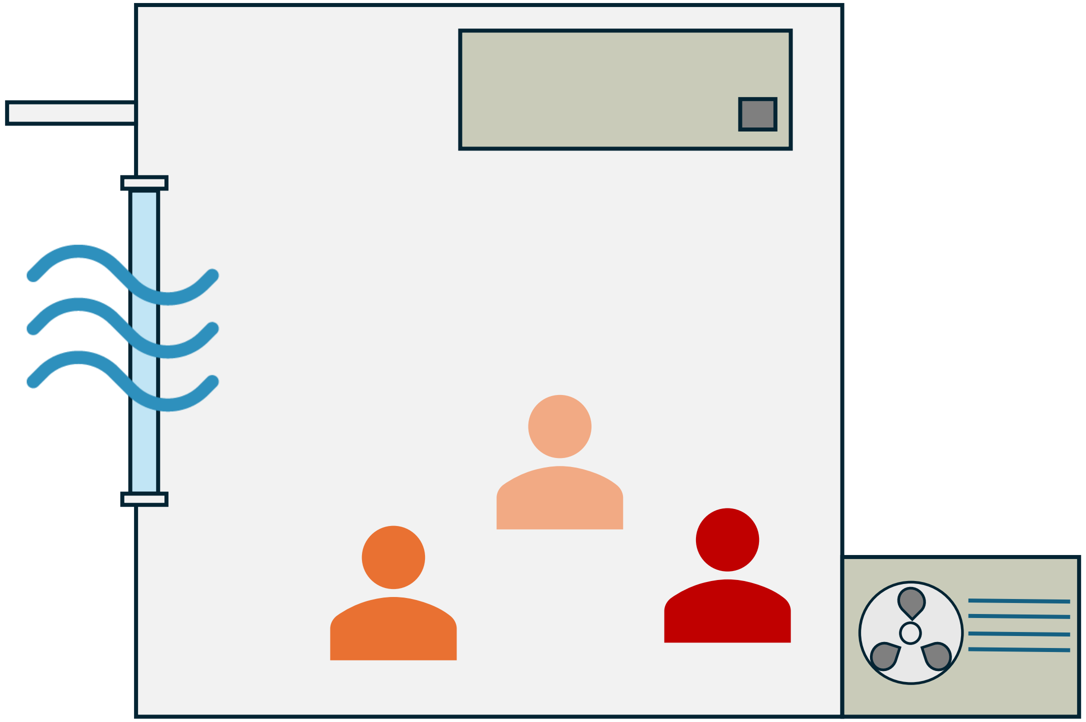
- Need to consider both cooling season (summer) and heating season(winter)
    - High performance envelopes (well insulated) are beneficial for heating season(winter), but can trap heat in cooling season(summer) when operating without adequate ventilation [3]
    - Fixed shading is beneficial for reducing overheating in the summer, but limits solar heat gain in the winter [3]



[3] William O'Brien and Isis Bennet. Simulation-based evaluation of high-rise residential building thermal resilience. ASHRAE Transactions, 122:455–468, 2016.

# Background - Challenges of Thermal Resilience to Overheating (OH) (III)

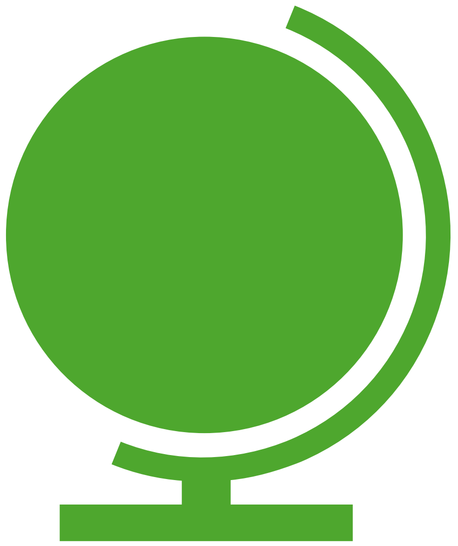
- Occupant considerations (adaptation)
  - Occupants' tolerance to heat may differ [4]
  - Occupants' role/ability in managing natural ventilation(operable windows) could be critical [3]



[3] William O'Brien and Isis Bennet. Simulation-based evaluation of high-rise residential building thermal resilience. ASHRAE Transactions, 122:455–468, 2016.
[4] Robert D. Meade, et al. Effects of daylong exposure to in-door overheating on thermal and cardiovascular strain in older adults: A randomized crossover trial. Environmental Health Perspectives, 132, 2 2024.

# Global Overview of OH in Building Code (I)

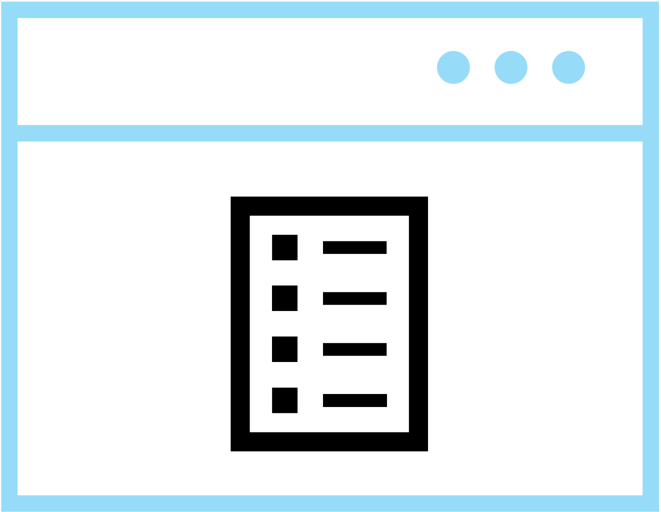
- IEA EBC Annex 80 conducted a review on overheating evaluation strategies in different European National Building Codes (mostly focused on thermal comfort) [5]
  - **Variety** of calculation methods and criteria were found
  - Study focus is on **thermal comfort**, most countries stated a thermal threshold based on operative temperature/air temperature
  - Most (15 out of 26) countries surveyed, the responses on criteria for thermal comfort and overheating evaluation are the same/similar, only some indicated overheating criteria different from comfort
  - Some of the respondents mentioned exposure limits (typically degree hour or % of occupied time limits)



[5] Shady Attia, et al. Overheating calculation methods, criteria, and indicators in European regulation for residential buildings. Energy and Buildings, 292:113170, 2023.

# Global Overview of OH in Building Code (II)

- We surveyed researchers from other countries
  - Canada - national building code does not have direct requirements on overheating thresholds
  - United States – overheating not in model energy code (IECC-R, ASHRAE 90.1)
  - Australia – overheating requirements not explicitly included
  - Argentina, Turkey – overheating currently not considered in national building code
- Survey of building code stakeholders by the Global Resiliency Dialogue [6]
  - Building codes are limited in adapting to climate change (new buildings, major renovation, not existing buildings; consideration of community/urban planning)
  - Potential competing priorities
  - Need to establish performance targets and acceptable of levels of risk



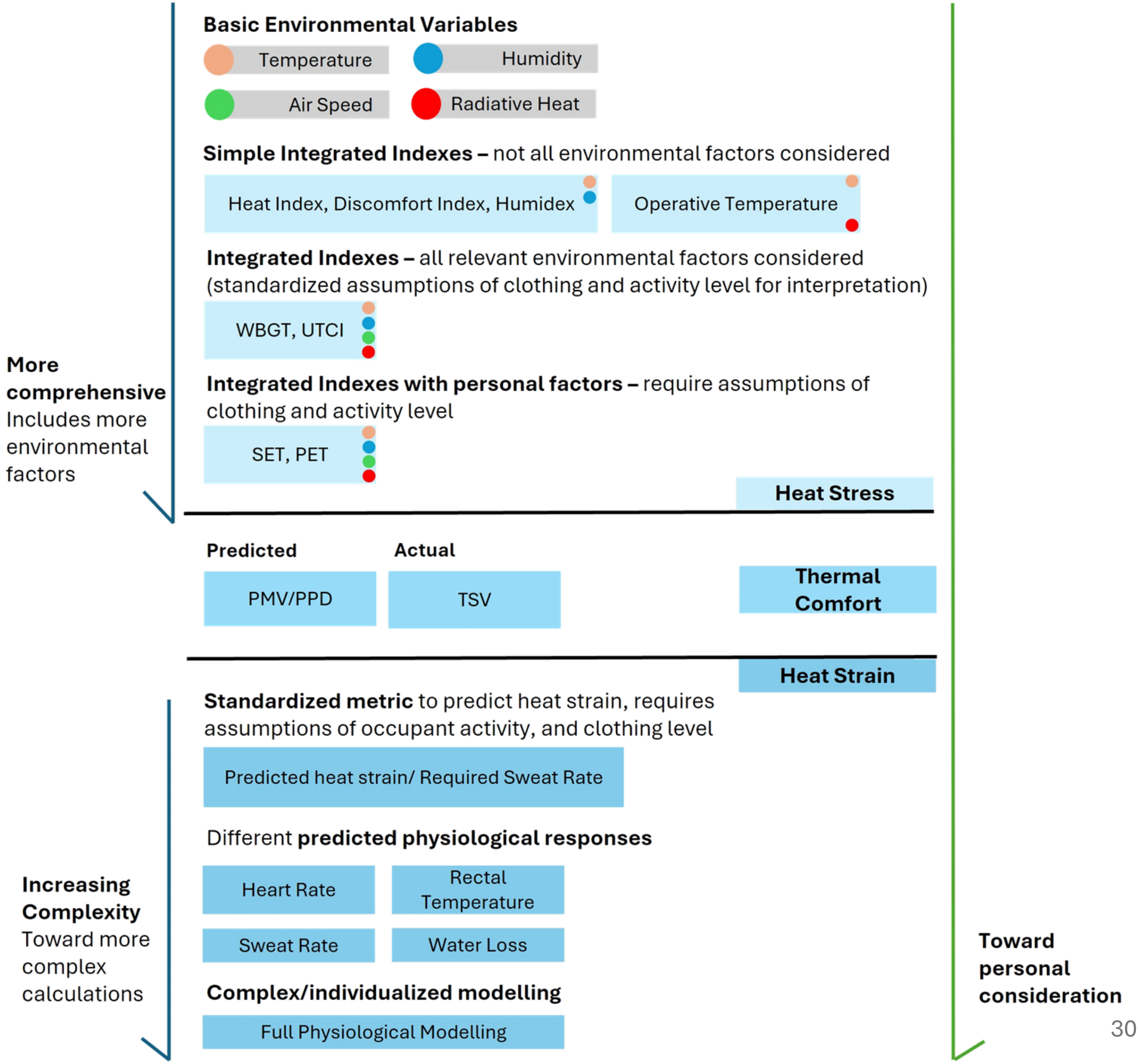
[6] The Global Resilience Dialogue. Delivering climate responsive resilient building codes and standards: Findings from the global resiliency dialogue survey of building code stakeholders in Canada, Australia, New Zealand and the United States, 11 2021

# Overheating Concepts

| Concepts | Description | Factors |
|---|---|---|
| Heat Stress | **Measure/indicator of heat load**<br>the level of heat we experience in the environment with consideration of our clothing and activities | • Environmental<br>• Personal (Activity, Clothing etc.) |
| Thermal Comfort | **Indicator of thermal sensation/ satisfaction**<br>how people feel/ perceive the thermal condition | • Environmental<br>• Personal (Activity, Clothing etc.)<br>• Preference<br>• Sensation<br>• Thermal history |
| Heat Strain | **Measure/indicator of direct phycological responses**<br>Our bodies' physiological reaction to heat stress | • Environmental<br>• Personal (Activity, Clothing etc.)<br>• Physiological conditions (health, acclimatization, age, body composition etc.) |

# Metrics

- Different metrics for different purposes and varying levels of comprehensiveness
- More comprehensive metrics generally require more assumptions
- When selecting metrics, need to balance comprehensiveness of metrics with practicality of application
- Health professionals generally prefer simpler metrics (considering application by public)
- Consider using multiple metrics for analysis



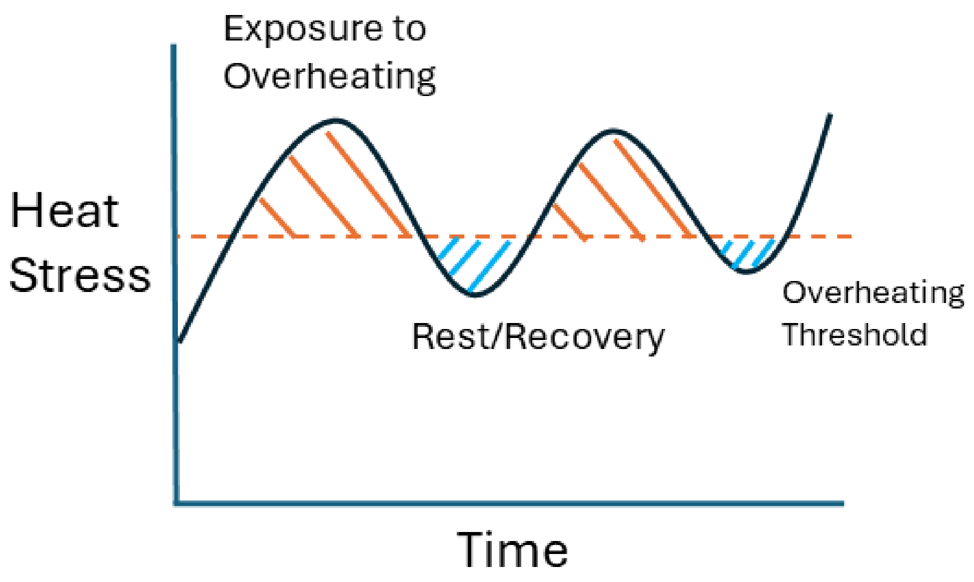
# Thresholds Overview

| Method for Threshold Determination | Strengths and Limitations | Examples |
|---|---|---|
| Climate Chamber Experiments with Physiological Measurements | [+] Direct evidence<br>[+] Control over variables<br>[-] Expensive<br>[-] Limited sample size<br>[-] Ethical Considerations | (Habitability) Meade et al. [4]<br>(Comfort) Zhang et al. [7] |
| Study of Mortality/ Morbidity Data | [+] Leverage existing data<br>[+] Relatively inexpensive<br>[-] Limited availability of quality datasets<br>[-] Often lack insight on indoor conditions | (Habitability) Mora et al. [8]<br>(Habitability) LEED Passive Survivability [9,10] |
| Field Studies | [+] Allows large sample size<br>[-] Limited control over variables<br>[-] Often rely on surveys to gather insight on occupant comfort/ perceived strain<br>[-] Time Consuming | (Comfort) ASHRAE Thermal Comfort Database II [11] |
| Heat Balance | [+] Relatively inexpensive<br>[+/-] Leverages existing knowledge of physiology<br>[-] Generally requires assumptions about person and activity<br>[-] Needs validation with experimental data | (Habitability) Sherwood and Huber [12] |

[4] Robert D. Meade, et al.. Effects of daylong exposure to indoor overheating on thermal and cardiovascular strain in older adults: A randomized crossover trial. Environmental Health Perspectives, 132, 2 2024.
[7] Y. Zhang, H. Chen, J. Wang, and Q. Meng. Thermal comfort of people in the hot and humid area of China-impacts of season, climate, and thermal history. Indoor air, 26:820–830, 10 2016.
[8] Camilo Mora ,et al. Global risk of deadly heat. Nature climate change, 7(7):501–506, 2017.
[9] Big Ladder Software. Resilience metrics. https://bigladdersoftware.com/epx/docs/9-4/engineering-reference/resilience-metrics.html
[10] Alex Wilson. Putting "thermal resilience" in the LEED pilot credits to the test, 1 2016. https://www.resilientdesign.org/putting-thermal-resilience-in-the-leed-pilot-credits-to-the-test/
[11] Veronika F. Ličina, et al. Development of the ASHRAE global thermal comfort database ii. Building and Environment, 142:502–512, 2018.
[12] Steven C Sherwood and Matthew Huber. An adaptability limit to climate change due to heat stress. Proceedings of the National Academy of Sciences, 107(21):9552–9555, 2010.

# Exposure

- Prolonged (multi-day) exposure to heat can lead to heat related mortality even at relatively low average air temperatures [13]
- Time and level of heat stress are important when considering exposure
- Can be considered with time integrated metrics – such as degree hour, hours of exceedance etc. [14]




[13] Glen P. Kenny, et al. Towards establishing evidence-based guidelines on maximum in-door temperatures during hot weather in temperate continental climates. Temperature, 6:11–36, 1 2019.
[14] R. Rahif, D. Amaripadath, and S. Attia. Review on time-integrated over-heating evaluation methods for residential buildings in temperate climates of Europe. Energy and Buildings, 252:111463, 2021.

# 26 °C Threshold

- **Participants:** older adults with no prior health conditions
- **Goal:** Develop threshold to reduce cardiovascular strain
- **Method:** Participants exposed to controlled environment in climate chamber with physiological monitoring
- **Outcome:** 26 °C dry-bulb temperature(at 45% RH) is a limit determined to not induce strain even under prolonged exposure (8 hours)
- **Limitations:** Participants are local and healthy; multiday scenario; humidity, air flow and radiant heat load should be considered in future studies
- 26 °C limit is used by City of Toronto and Vancouver in overheating bylaws. Also recommended by NHS in England for providing cooling space to high-risk groups in care, nursing and residential homes. [15]

Randomized Controlled Trial > Environ Health Perspect. 2024 Feb;132(2):27003.
doi: 10.1289/EHP13159. Epub 2024 Feb 8.

**Effects of Daylong Exposure to Indoor Overheating on Thermal and Cardiovascular Strain in Older Adults: A Randomized Crossover Trial**

Robert D Meade [1, 2], Ashley P Akerman [1], Sean R Notley [1], Nathalie V Kirby [1], Ronald J Sigal [1, 3, 4, 5, 6], Glen P Kenny [1, 6]

Affiliations — collapse

**Affiliations**

1. Human and Environmental Physiology Research Unit, School of Human Kinetics, University of Ottawa, Ottawa, Ontario, Canada.
2. Harvard T.H. Chan School of Public Health, Harvard University, Boston, Massachusetts, USA.
3. Department of Medicine, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada.
4. Department of Cardiac Sciences, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada.
5. Department of Community Health Sciences, Cumming School of Medicine, University of Calgary, Calgary, Alberta, Canada.
6. Clinical Epidemiology Program, Ottawa Hospital Research Institute, Ottawa, Ontario, Canada.

PMID: 38329752 PMCID: PMC10852046 DOI: 10.1289/EHP13159

Meade et al. [4]

[4] Robert D. Meade, et al.. Effects of daylong exposure to indoor overheating on thermal and cardiovascular strain in older adults: A randomized crossover trial. Environmental Health Perspectives, 132, 2 2024.
[15] Dame Sally C. Davies. heatwave - Plan for England, 2011https://assets.publishing.service.gov.uk/media/5a7c83bde5274a559005a655/dh_127235.pdf

# Challenges with Incorporating OH Requirements in Building Code

- Metric selection
  - comprehensive or simple
- Threshold selection
  - method for threshold determination
- Exposure consideration
  - requires more research
- Balancing modelling requirements and practical implementation
  - hourly/sub-hourly simulation
  - zonal analysis
- Prescriptive requirements
  - limit solar heat gain
  - openings for natural ventilation
- Limits on scope of building code
  - leverage other policy mechanisms
  - reference IEA EBC Annex 80 policy recommendations [16]

[16] Peter Holzer. International energy agency resilient cooling of buildings – policy recommendations (annex 80), 5 2024. https://www.building-research.at/1020357/b7288c/

PNNL-SA-205799

# Impact Assessment of Climate Resilient Building Energy Codes

Ellen Franconi, Ph.D.

Pacific Northwest National Laboratory


Image of Mexico Beach, Florida home following Hurricane Michael

Resilience is defined as the ability to prepare for, absorb, recover from and more successfully adapt to adverse events.

Energy in Buildings and Communities Programme

# Tri-Lab project focused on quantifying the impact of increased efficiency on thermal resilience

What:
- A collaborative PNNL, NREL, and LBNL project guided by a technical advisory group and the U.S. DOE Building Energy Codes Program

Purpose:
- Expand energy efficiency cost effectiveness assessment to include resilience considerations.
- Develop a standardized methodology to quantify impacts using metrics

Application:
- Use metrics in a decision matrix
- Monetize metrics and include in net present value calculations

PNNL-32737, Rev. 1

Pacific Northwest NATIONAL LABORATORY
NREL NATIONAL RENEWABLE ENERGY LABORATORY
BERKELEY LAB

## Enhancing Resilience in Buildings Through Energy Efficiency

July 2023

*Pacific Northwest National Laboratory*
Ellen Franconi, Luke Troup, Mark Weimar, Yunyang Ye, Chitra Nambiar, and Jeremy Lerond

*National Renewable Energy Laboratory*
Eliza Hotchkiss, Jordan Cox, Sean Ericson, Eric Wilson, Philip White, Conor Dennehy, Jordan Burns, Jeff Maguire, and Robin Burton

*Lawrence Berkeley National Laboratory*
Tianzhen Hong, Linqian Sheng, and Kaiyu Sun

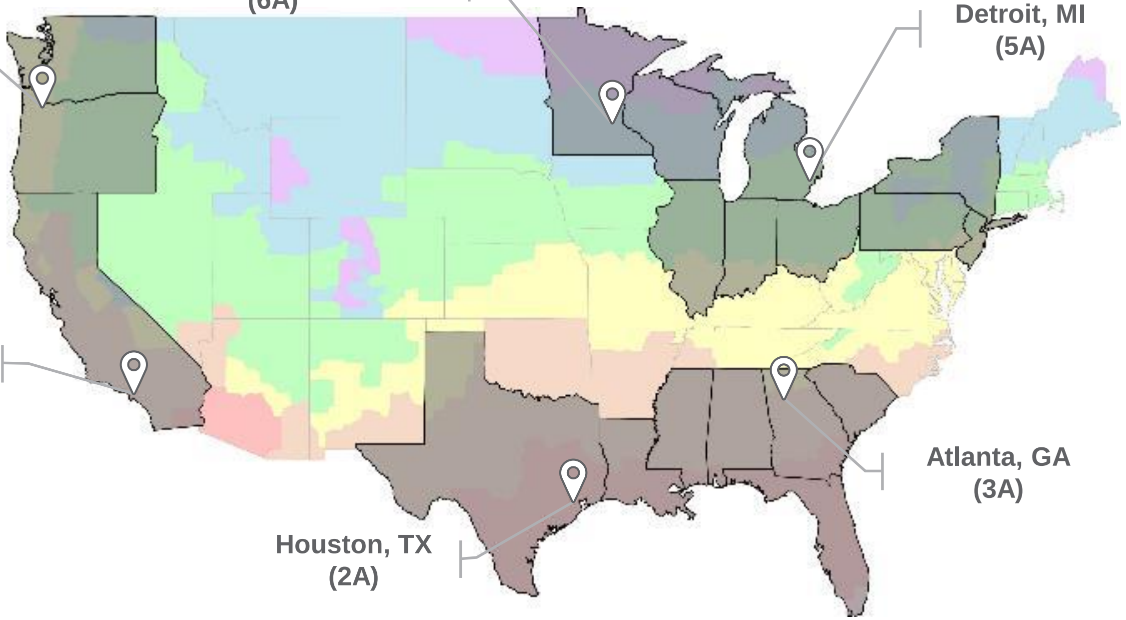
*Department of Energy*
Michael Reiner, Christopher Perry, and Jeremy Williams

U.S. DEPARTMENT OF ENERGY

Final report is available at https://www.energycodes.gov/energy-resilience

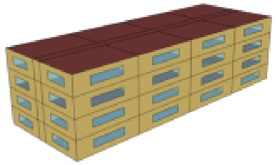
# Tri-Lab Study - Quantifying impacts of efficiency on passive survivability

**Focus:** Investigate how adopting current energy code or stretch codes benefits resilience
**Analysis Scope:** 2 residential building types, 3 efficiency conditions, 6 U.S. locations




Extreme Cold & Heat Events

Multi-Family

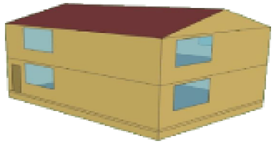


New & Existing

**Baseline Condition**
Historic Code/Existing Stock

**Current Code**
ASHRAE 90.1-2019 & IECC-R 2021

**Beyond Code**
Informed by 2021 Passive House



Single-Family

## Metrics & Valuation

**Thermal Resilience:** Thermal comfort and the ability to shelter in place
**Mortality:** Attributable to heat and cold
**Investment:** Efficiency investment costs, efficiency and resilience benefits, net present value

# Tri-Lab Study - Quantifying impacts of efficiency on resilience Analysis components and workflow

### Hazard Risk Analysis

- Historical extreme temperature event identification and representation
- Severe weather - power outage data review

**Characterization of risk** →

### Exposure Analysis

- Baseline and efficiency packages
- Extreme temperature weather data files
- Building energy simulation models and analysis

**Indoor conditions related to health and well being** →

### Vulnerability Assessment

- Indoor temperature livability indicators
- Population excess mortality fragility curves
- Property damage

**Occupant and asset damage** →

### Mitigation Valuation

- Monetization of damages
- Mitigation measure costs
- Annualized impacts
- Net present value analysis

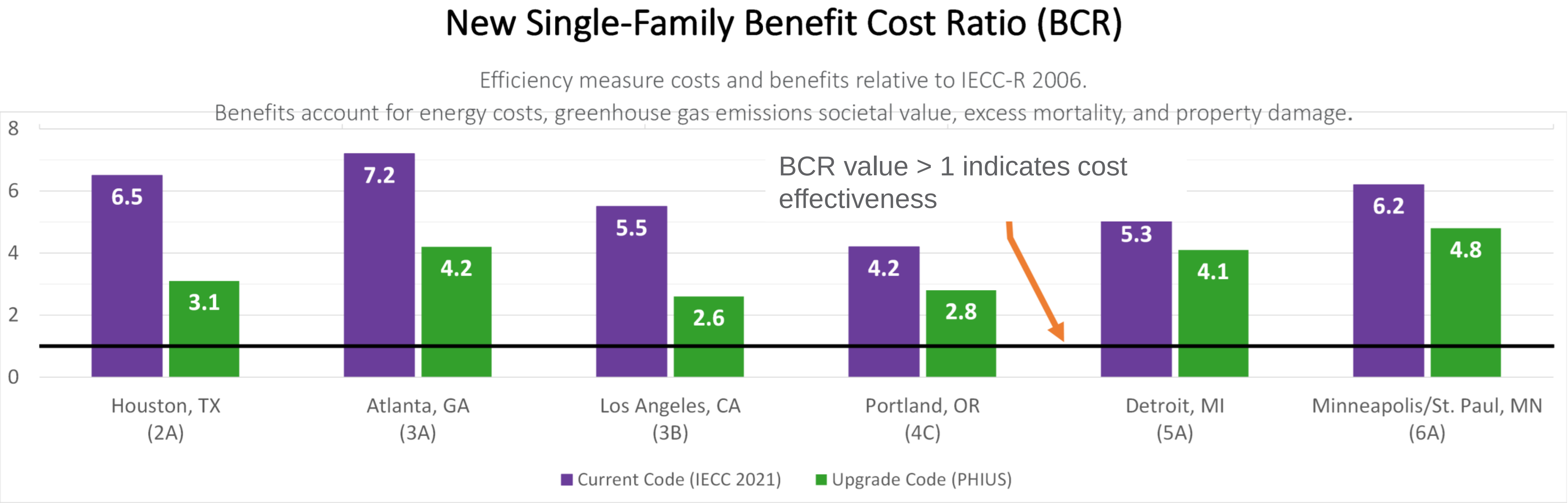
**Investment value**

# Use resilience metrics to assess and compare mitigation impacts

| **Thermal resilience metrics indicating occupant exposure** | |
|---|---|
| Standard Effective Temperature (SET) | Indoor conditions measurement that considers of temperature and relative humidity |
| **SET Degree Hours** | Cumulative hourly SET degrees that fall outside of a specified threshold (54°F and 86°) |
| **Days of Safety** | The time elapsed over a seven-day period when the SET Degree Hours does not exceed a value of 216. |
| **Occupant damage metrics** | |
| **Excess deaths** | Deaths attributed to extreme heat or cold |
| **Economic metrics (for annualized net present value calculation)** | |
| Measure investment costs | First costs for installation of measure package |
| Measure annual energy cost savings | Evaluated based on a typical weather year |
| Societal value of emissions reduction | Associated with annual energy use savings |
| **Losses associated with excess deaths** | Based on $10 million per excess death |
| Losses associated with property damage | Based on FEMA national risk data base values |
| Benefit cost ratio | Based on **annual coincident risk of extreme temperature events** and above economic values |

# Example Benefit Cost Ratio Results

What is the return on building efficiency investment with **annual energy cost saving, societal value of reduced CO2e emissions, and annualized excess deaths?**



# Methodology Robustness Assessment

| Category | Component | Robustness |
|---|---|---|
| **1. Hazard Risk Identification** | Develop weather data files representative of extreme temperature events | |
| | Develop coincident probability risk factors to annualize event losses and benefits | |
| **2. Exposure Analysis** | Assess relative impact of efficiency measures on habitability | |
| | Determine indoor habitability conditions exceeding thresholds | |
| **3. Vulnerability Assessment** | Evaluate occupant exposure effect on mortality, health, and well-being | |
| | Evaluate property exposure effect on active building state and systems | FUTURE |
| **4. Mitigation Valuation** | Quantify the monetary value of resilience | |
| | Inform resilience planning efforts | |

Pacific Northwest NATIONAL LABORATORY

# Use resilience metrics to prioritize actions

How can resilience metrics be used to inform investment decision-making?

## Example decision matrix

| Existing SF Building in Houston extreme heat event | Value | | Assigned Weights | Normalized Values | |
|---|---|---|---|---|---|
| | Current Code | Beyond Code | | Current Code | Beyond Code |
| Reduction in SET Degree Hours | 581 | 600 | 10% | 0.97 | 1.00 |
| Days of habitability | 7 | 7 | 10% | 1.00 | 1.00 |
| Lives saved per year | 62 | 93 | 15% | 0.67 | 1.00 |
| Energy affordability | 25 | 30 | 20% | 0.83 | 1.00 |
| Annual energy savings (kWh/ft2/year) | 3.1 | 4.1 | 10% | 0.76 | 1.00 |
| Societal cost savings GHG emissions ($/ft2 year) | 0.6 | 0.8 | 15% | 0.75 | 1.00 |
| Efficiency improvement cost ($/ft2/year) | 0.63 | 0.77 | 20% | 1.00 | 0.82 |
| Weighted Normalized Total | | | 100% | 0.85 | 0.94 |

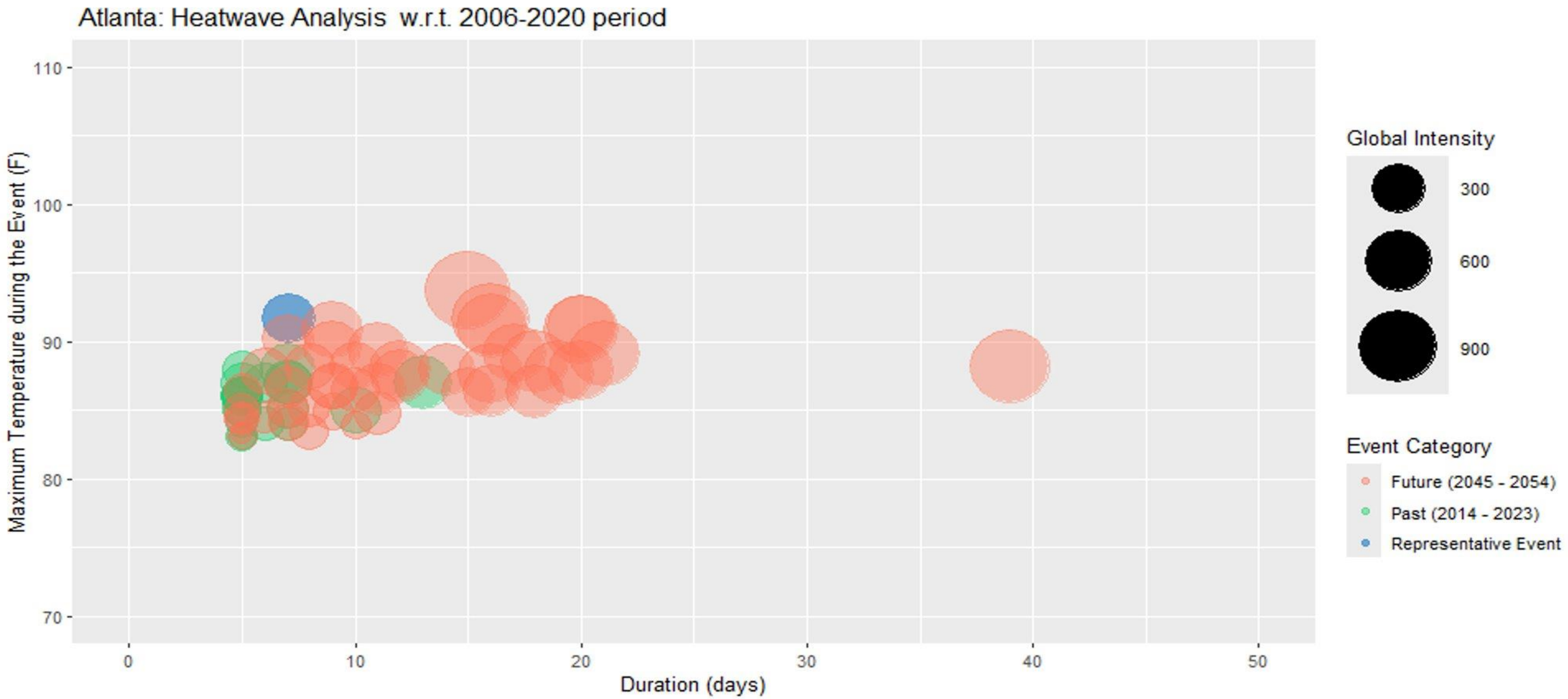
Pacific Northwest NATIONAL LABORATORY

# Climate resilient energy code (CRE) development and adoption

**How can the Tri-Lab methods support the development of CRE code and encourage its adoption?**

- Assess extreme event risk and damage potential
- Evaluate the relative impact of resilience mitigation measures
- Demonstrate the added value of CRE code provisions

# Assess extreme event risk
## Compare historical and future relative intensity




- Ouzeau method applied to identify events using historical and future scenario RCP8.5 projected temperatures
- Event duration anticipated to increase on average from 6.3 days to 11.9 days
- A standard set of representative event weather data files are needed for code development and other applications

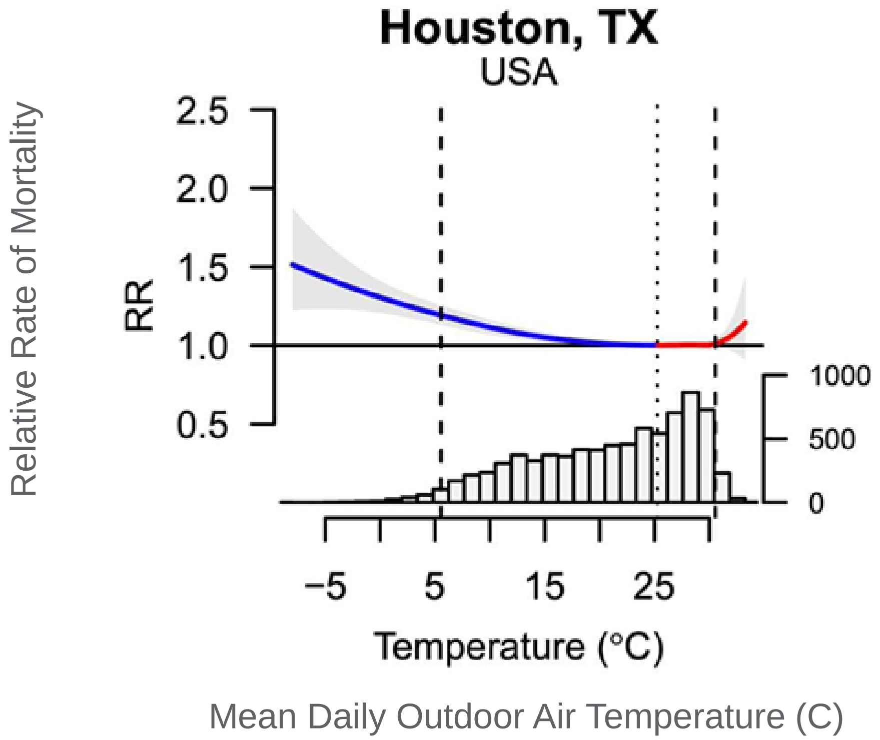
# Estimate occupant damage and monetary loss

How does extreme heat and cold impact mortality rate? Monetary losses?

Gasparrini et al. have published relative rate of mortality curves as a function of outdoor temperature for over 130 U.S. and 320 global locations.

Tri-lab study applied the curves to estimate the effect of more comfortable indoor temperatures on mortality

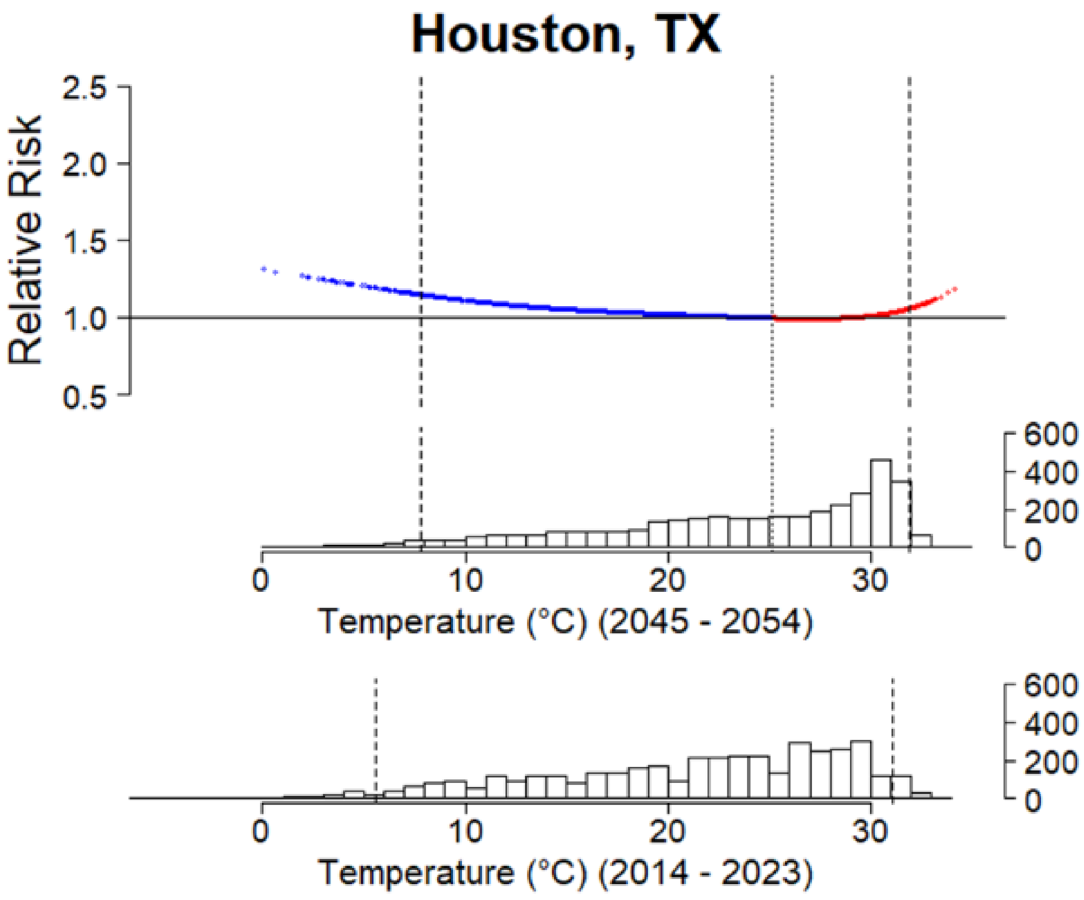
*Annual loss = Annual hazard risk probability * Lives loss during extreme event * $10 million per life*

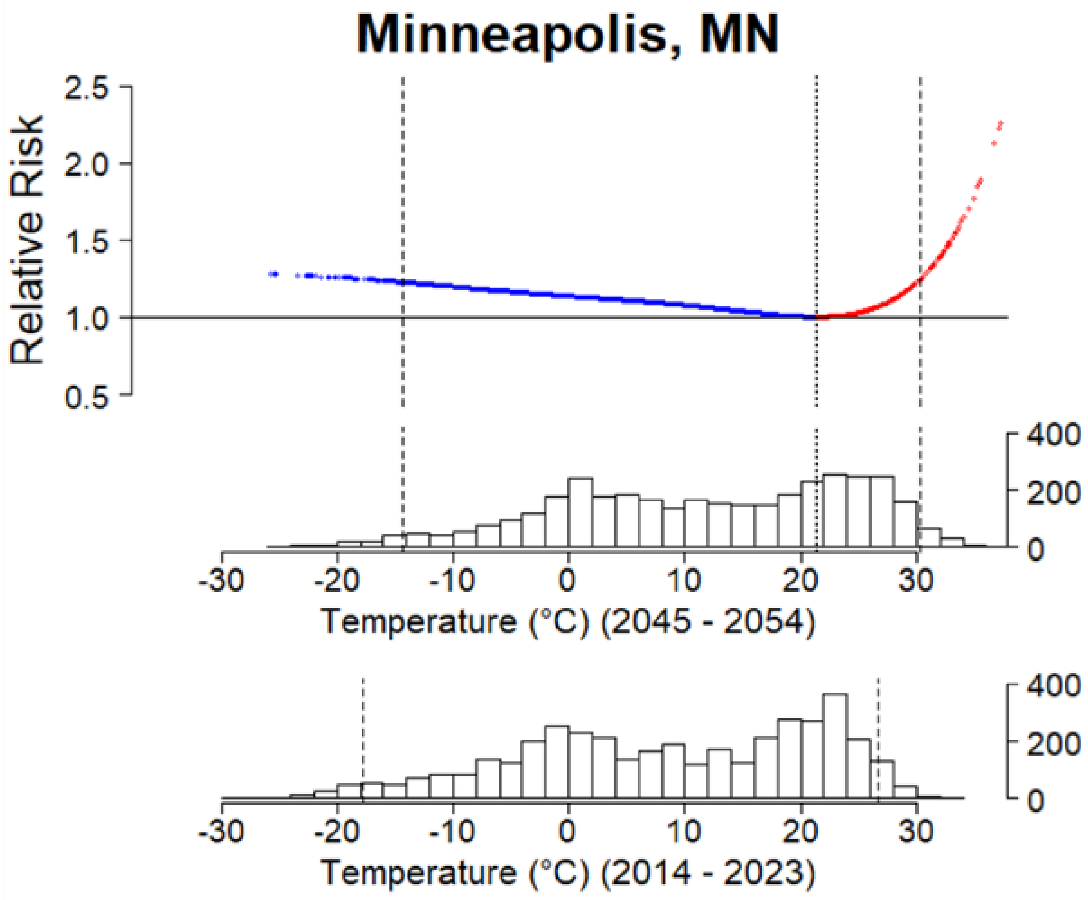



Notes: Vertical dashed lines indicate the temperature at 2.5th percentile and 97.5th percentile. The vertical dotted line indicates the temperature at which the relative rate of death is one or the temperature at which deaths are not attributed to severe temperatures

# Occupant damage and monetization

How might future weather affect occupant damage?

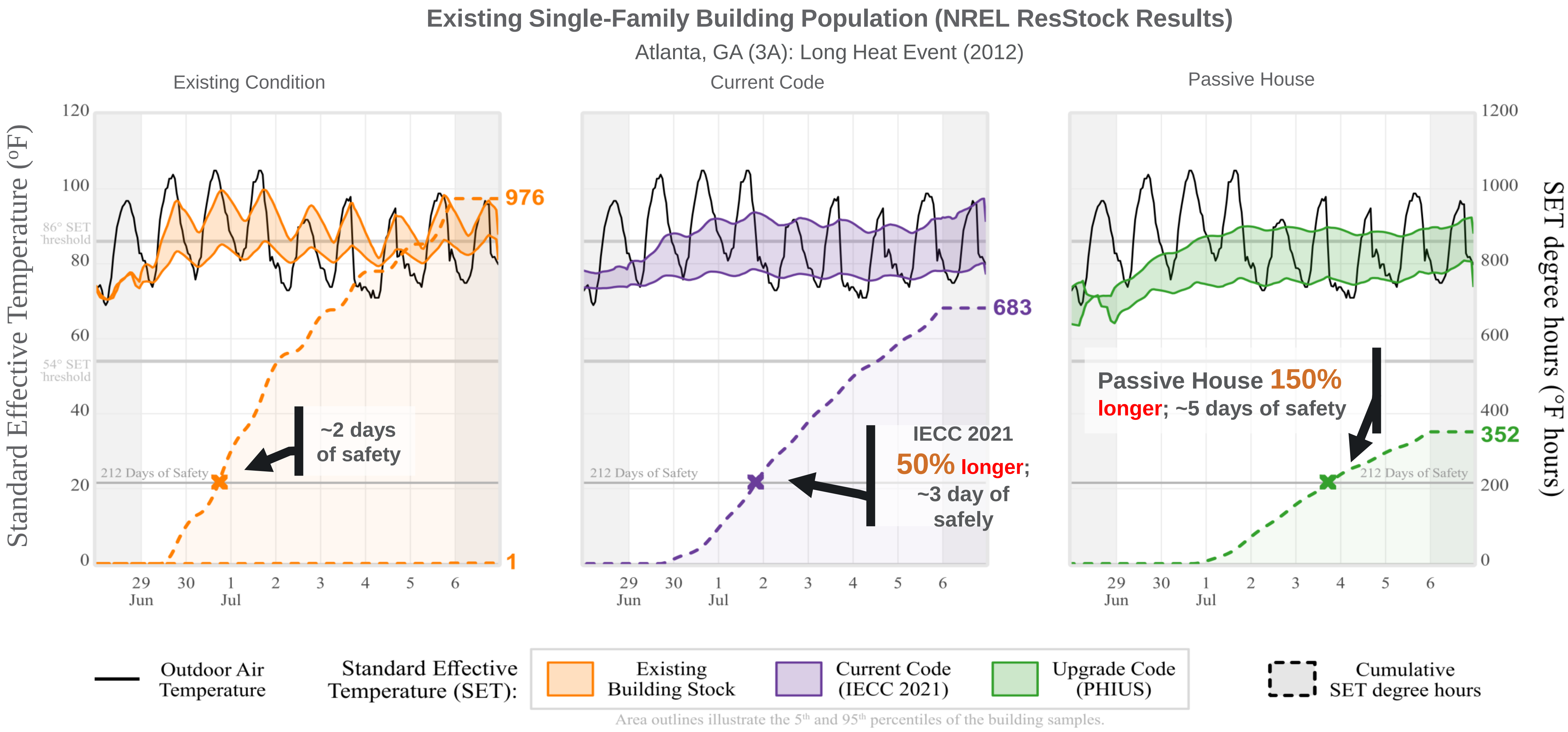


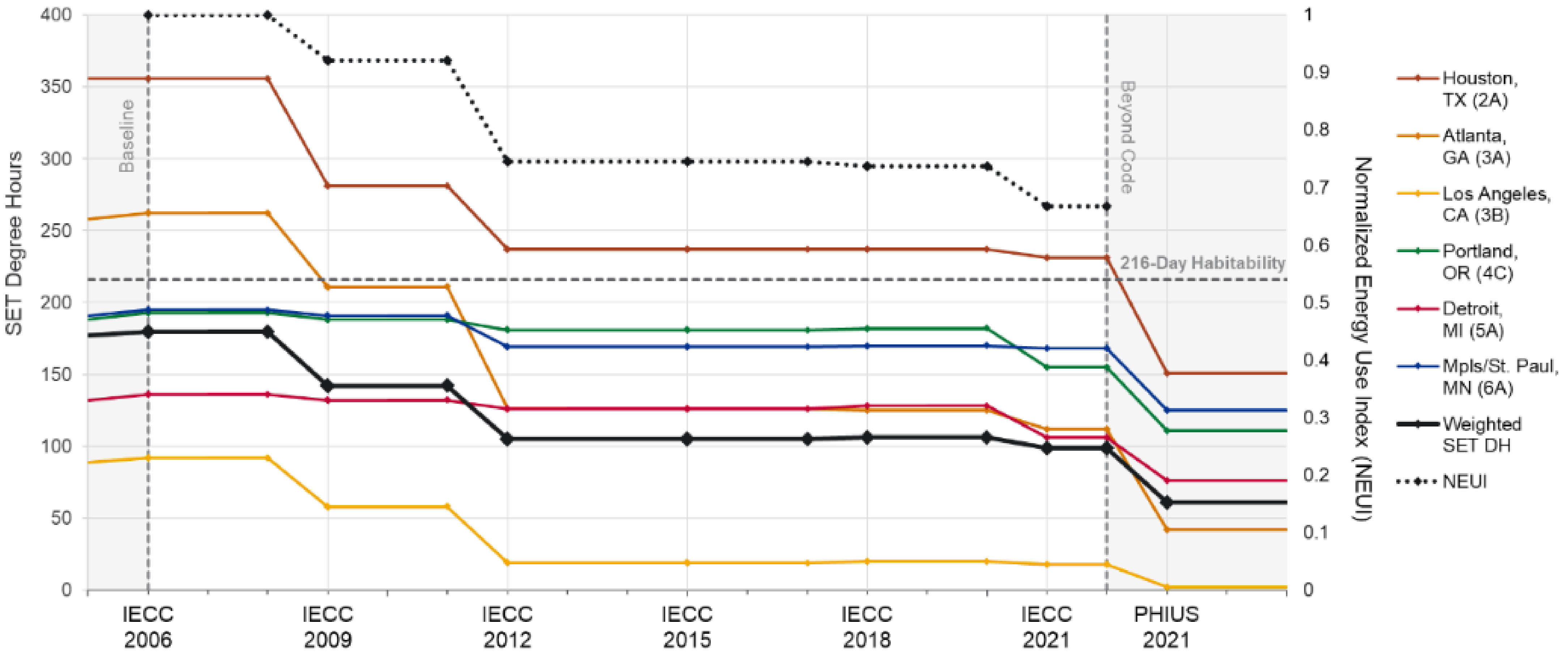
# Compare the relative impact of proposed CRE code measures

Pacific Northwest NATIONAL LABORATORY

What is the fluctuation in indoor comfort conditions during extreme temperature events? How does it affect habitability? Compare **SET, SET degree hours, and days of safety** metric values.



# Demonstrate the value of current and CRE code adoption



# Summary
## Impact assessment in support of CRE code

- Establish CRE code resilience criteria, for example:
  - Number days of safety during no-power and back-up power conditions
  - Critical loads to be met with back-up power
- Meet criteria with passive measures, energy storage, efficiency renewable energy systems, and back up power systems
- Conduct impact assessment
  - Identify, characterize, and annualize extreme event risk
  - Simulate building comfort levels and performance
  - Assess impact of exposure on occupant and property damage
  - Monetize the value of thermal resilience when possible
  - Calculate and compare metrics
- Establish CRE code building efficiency measures
- Use energy load data to inform sizing requirements of renewable energy and back up power systems

# Questions

Ellen Franconi

Ellen.Franconi@pnnl.gov

More resources are available at https://www.energycodes.gov/energy-resilience

ENERGY INSTITUTE : BUILDING STOCK LAB

UCL

EBC

Energy in Buildings and Communities Programme

# Introduction to Part O: Overheating

of the Building Regulations for England

Prof. Paul Ruyssevelt

University College London

With thanks to **Susie Diamond** of **Inkling**

INKLING

# Part O

- Came into force June 15th 2022 (with some transitional arrangements)
- Applies to all new homes including care homes, boarding schools and student accommodation
- Aimed at reducing overheating risk


HM Government

The Building Regulations 2010

**Overheating**

**APPROVED DOCUMENT**

O

**Requirement O1: Overheating mitigation**

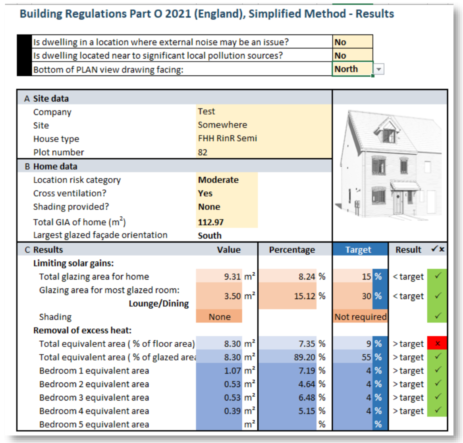
**Regulations: 40B**

2021 edition – for use in England

# Two routes to compliance

- Simplified method
  - Quicker and easier
  - More prescriptive
  - Focus on glazing areas and free areas

- Dynamic thermal modelling method
  - Follows CIBSE TM59
  - Needs specialist modelling software and experienced modeller
  - More flexibility
  - More location specific



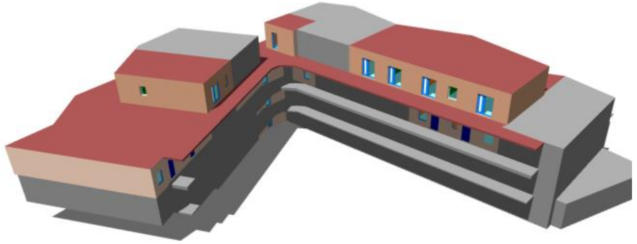
**Building Regulations Part O 2021 (England), Simplified Method - Results**

| | |
|---|---|
| Is dwelling in a location where external noise may be an issue? | No |
| Is dwelling located near to significant local pollution sources? | No |
| Bottom of PLAN view drawing facing: | North |

| A Site data | |
|---|---|
| Company | Test |
| Site | Somewhere |
| House type | FHH RinR Semi |
| Plot number | 82 |

| B Home data | |
|---|---|
| Location risk category | Moderate |
| Cross ventilation? | Yes |
| Shading provided? | None |
| Total GIA of home ($m^2$) | 112.97 |
| Largest glazed façade orientation | South |

| C Results | Value | Percentage | Target | Result | ✓✗ |
|---|---|---|---|---|---|
| **Limiting solar gains:** | | | | | |
| Total glazing area for home | 9.31 $m^2$ | 8.24 % | 15 % | < target | ✓ |
| Glazing area for most glazed room: **Lounge/Dining** | 3.50 $m^2$ | 15.12 % | 30 % | < target | ✓ |
| Shading | None | | Not required | | ✓ |
| **Removal of excess heat:** | | | | | |
| Total equivalent area ( % of floor area) | 8.30 $m^2$ | 7.35 % | 9 % | > target | ✗ |
| Total equivalent area ( % of glazed area | 8.30 $m^2$ | 89.20 % | 55 % | > target | ✓ |
| Bedroom 1 equivalent area | 1.07 $m^2$ | 7.19 % | 4 % | > target | ✓ |
| Bedroom 2 equivalent area | 0.53 $m^2$ | 4.64 % | 4 % | > target | ✓ |
| Bedroom 3 equivalent area | 0.53 $m^2$ | 6.48 % | 4 % | > target | ✓ |
| Bedroom 4 equivalent area | 0.39 $m^2$ | 5.15 % | 4 % | > target | ✓ |
| Bedroom 5 equivalent area | $m^2$ | % | % | | |



# Additional requirements - noise

- Noise limits set for bedrooms at night only

> **3.3** Windows are likely to be closed during sleeping hours if noise within bedrooms exceeds the following limits.
>
> a. 40dB $L_{Aeq,T}$, averaged over 8 hours (between 11pm and 7am).
>
> b. 55dB $L_{AFmax}$, more than 10 times a night (between 11pm and 7am).

- Many existing UK homes exceed these criteria
- Passive solutions are often still possible
- Mechanical ventilation/cooling solutions may be needed at night
- ANC/IOC Guide: association-of-noise-consultants.co.uk/demonstrating-compliance-with-the-noise-requirements-of-approved-document-o/

# Additional requirements - security

- Windows relied upon for night-time ventilation must be secure
- Bedrooms on ground floors or that are easily accessible can be made secure with:
  - Fixed or lockable louvred shutters
  - Fixed or lockable grilles or railings

# Additional req – Protection from falling



## Windows that open more than 100mm must also:

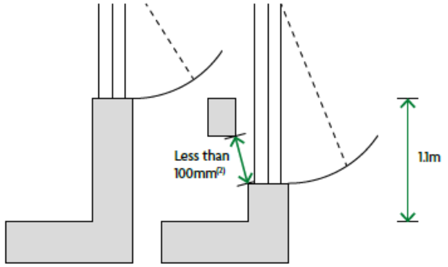
- Have handles that operate with a maximum reach outwards of 650mm from inside face of wall
- Sill heights or guarding >1100mm (acceptable build tolerance is +0 / - 100mm)

## Guarding can include:

- Shutters with a child –proof lock
- Fixed guarding
- But should not allow children to easily climb it

**Table 3.1 Guarding heights**

| Change in floor level between inside and outside | Guarding height[1] |
| --- | --- |
| Less than 600mm | See Approved Document K |
| More than 600mm | 1.1m |



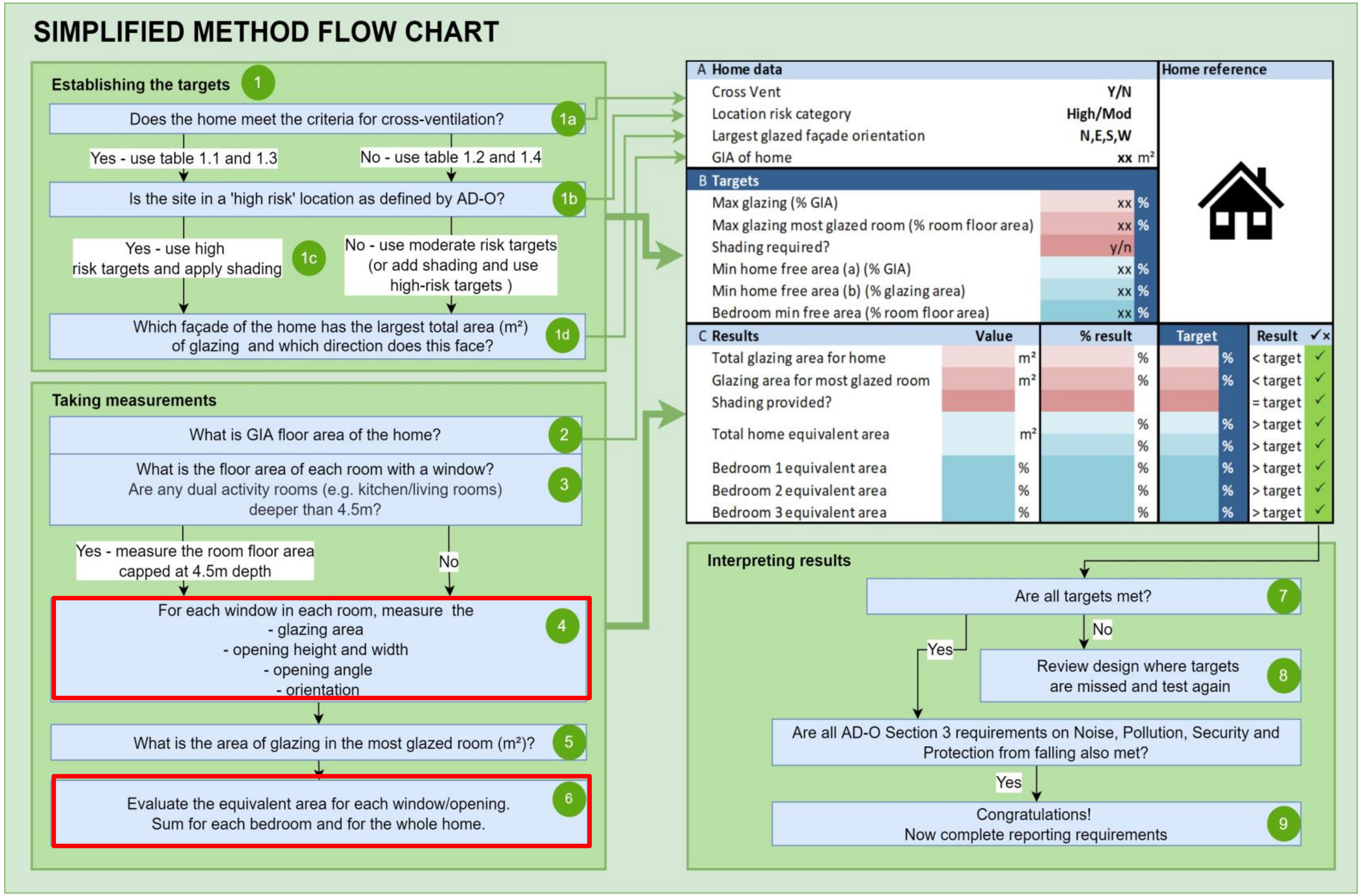

NOTES:

1. This approved document has increased levels of protection from falling compared to Approved Document K. Where applicable, the higher standard applies.
2. Guarding should be sized to prevent the passage of a 100mm sphere.

# Simplified method

- Not ‘simple’
- All units must be assessed
- Two requirements
  - Maximum limits on glazing areas (plus shading in London)
  - Minimum limits of free areas
- These targets vary depending on
  - Location of the site
  - Presence of cross-ventilation
  - Orientation of most glazed facade
  - The floor area of the unit (GIA), bedrooms and most glazed room

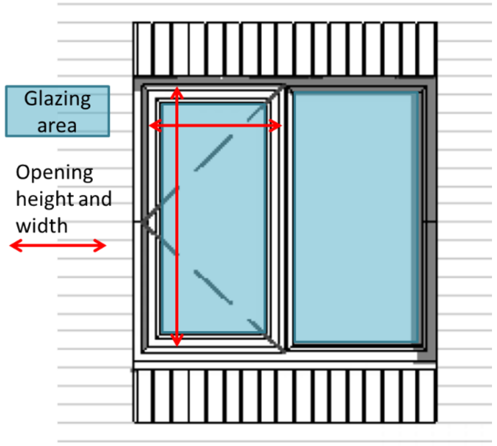
# Simplified method

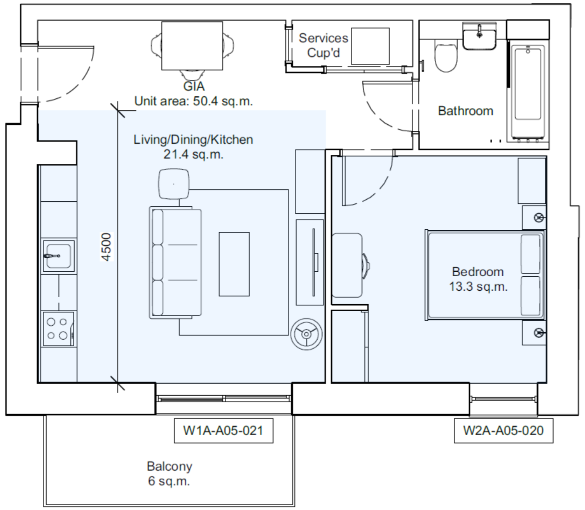


# Simplified method

## Detailed measurements needed for each unit and each window

- Glazed area (m²) for each windowpane
- Width and height of each sash opening
- Floor area for each room
- GIA of whole home
- Equivalent areas calculated by tool

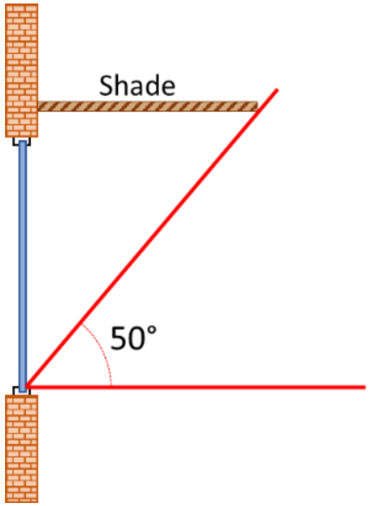


# Simplified method

## Shading

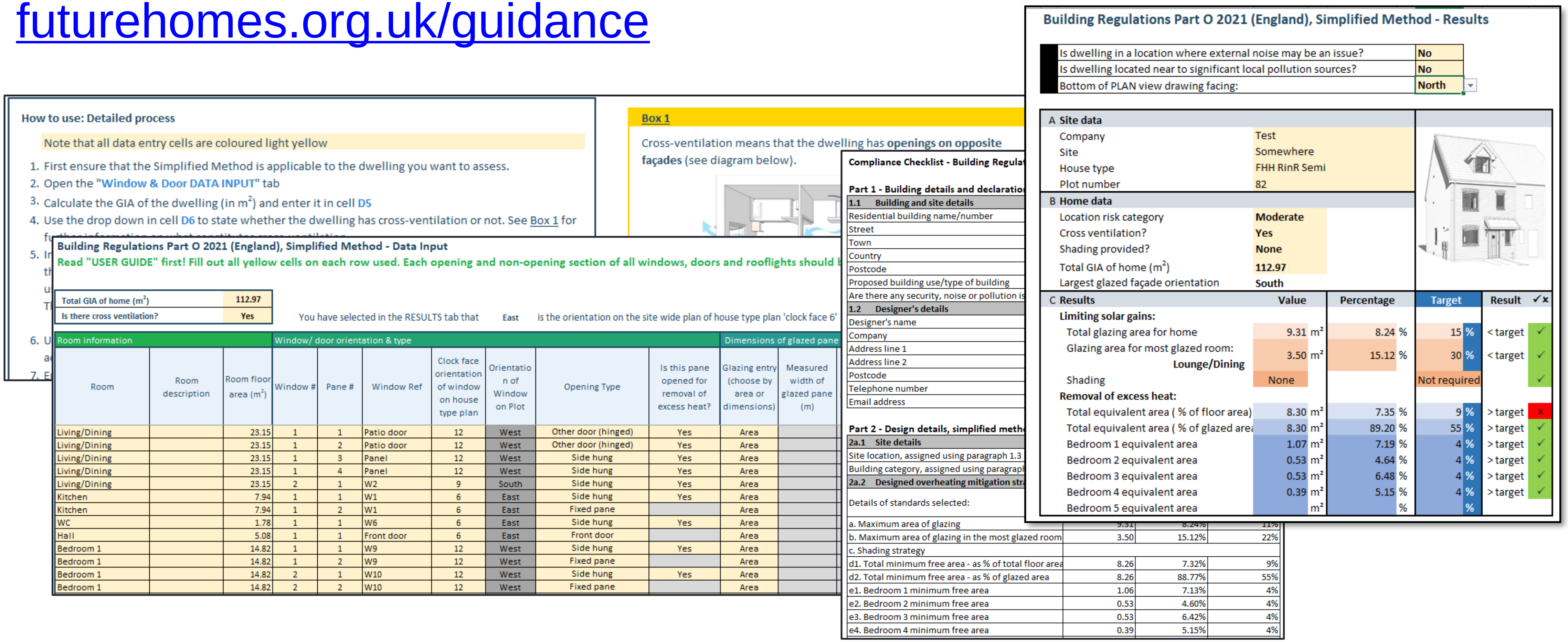
- Required in London
  - External shutters with means of ventilation
  - Glazing with low-g specification (<0.4) – centre-pane
  - Overhangs to south-facing facades
- Applies to all glazing orientated NE to NW via South




# Simplified method – FHH spreadsheet

Available from the Future Homes Hub website

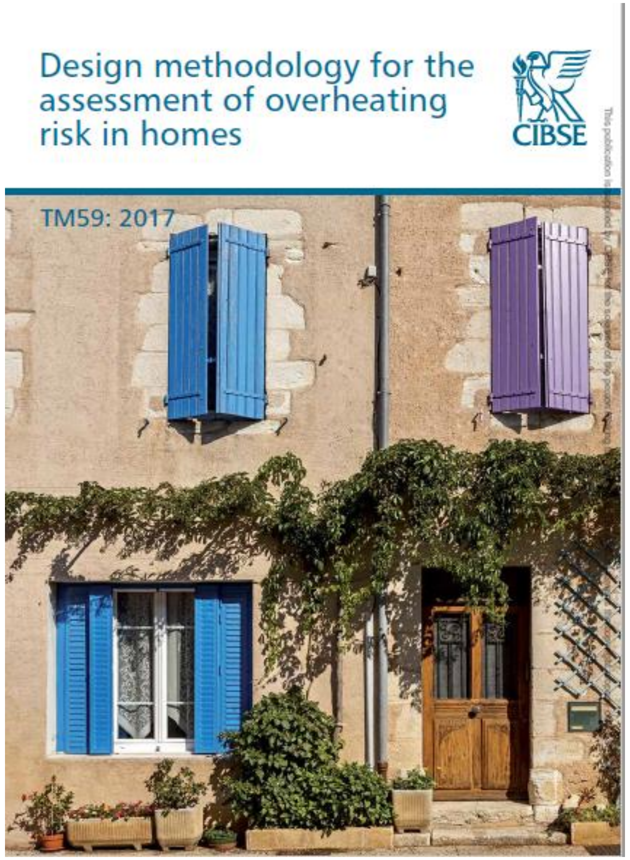
futurehomes.org.uk/guidance



# Dynamic Thermal Modelling method

- Assess sample set of units
- Based on CIBSE TM59
- Two Criteria
- No blinds or curtains!
- Results for each occupied room
- Modeller should provide commentary on spaces that don't pass

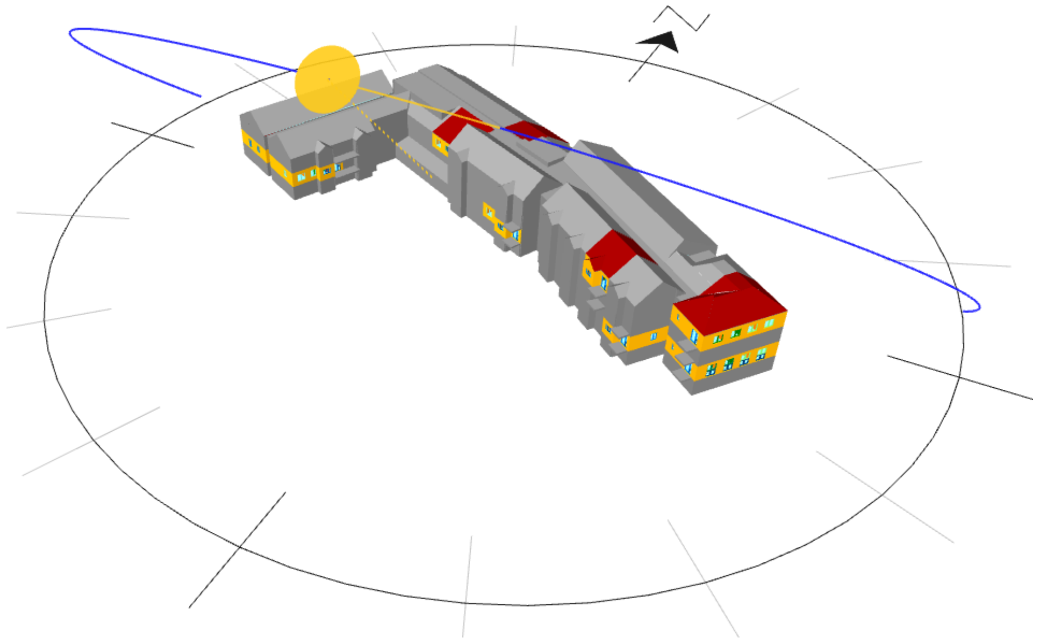
| Zone Name | Occupied Summer Hours | Max. Exceedable Hours | Criterion 1: #Hours Exceeding Comfort Range | Max Exceedable Night Hours | Criterion 2: Number of Night Hours Exceeding 26 °C for Bedrooms. | Result |
|---|---|---|---|---|---|---|
| A_Bedroom | 3672 | 110 | 58 | 32 | 74 | Fail |
| A_Kitchen | 1989 | 59 | 22 | N/A | N/A | Pass |
| A_Living | 1989 | 59 | 23 | N/A | N/A | Pass |
| B_Bedroom 1 | 3672 | 110 | 18 | 32 | 42 | Fail |
| B_Bedroom 2 | 3672 | 110 | 21 | 32 | 63 | Fail |
| B_LKD | 1989 | 59 | 24 | N/A | N/A | Pass |



# Dynamic Thermal Modelling method

## Selecting a sample of units

- Units with highest risk of overheating
  - Most solar exposure (glazing area vs shading, orientation)
  - Lowest free areas or greatest constraints to opening windows
- Covering all unit types
- Attention to ground floor (security)
- GHA one page tool helpful for informing choice



ENERGY INSTITUTE : BUILDING STOCK LAB

# Dynamic Thermal Modelling method

## Weather data

- Local to site
- CIBSE 2020s High emissions, 50th %ile DSY1

## More Design Options

- Ceiling fans
- External shading devices
- Mechanical ventilation and/or cooling

## Differences to original TM59

- Small changes to how window openings are modelled
- No blinds or curtains!

# Reporting requirements

A compliance checklist must be completed for building control

- FHH template for simplified method results
- Detailed modelling report required under dynamic modelling method

**Compliance Checklist - Building Regulations Part O (England), Simplified Method**

**Part 1 - Building details and declarations**

| | |
|---|---|
| **1.1 Building and site details** | |
| Residential building name/number | |
| Street | |
| Town | |
| Country | |
| Postcode | |
| Proposed building use/type of building | |
| Are there any security, noise or pollution issues? | |
| **1.2 Designer's details** | |
| Designer's name | |
| Company | |
| Address line 1 | |
| Address line 2 | |
| Postcode | |
| Telephone number | |
| Email address | |

**Part 2 - Design details, simplified method**

| | | | |
|---|---|---|---|
| **2a.1 Site details** | | | |
| Site location, assigned using paragraph 1.3 | Moderate Risk | | |
| Building category, assigned using paragraph 1.4 | | | |
| **2a.2 Designed overheating mitigation strategy** | | | |
| Details of standards selected: | This dwelling | | Target |
| | $m^2$ | % | % |
| a. Maximum area of glazing | 9.31 | 8.24% | 11% |
| b. Maximum area of glazing in the most glazed room | 3.50 | 15.12% | 22% |
| c. Shading strategy | | | |
| d1. Total minimum free area - as % of total floor area | 8.26 | 7.32% | 9% |
| d2. Total minimum free area - as % of glazed area | 8.26 | 88.77% | 55% |
| e1. Bedroom 1 minimum free area | 1.06 | 7.13% | 4% |
| e2. Bedroom 2 minimum free area | 0.53 | 4.60% | 4% |
| e3. Bedroom 3 minimum free area | 0.53 | 6.42% | 4% |
| e4. Bedroom 4 minimum free area | 0.39 | 5.15% | 4% |

# Timeline

(Pre project)

Portfolio appraisals

- Test standard home designs
- Build library of preferred solutions

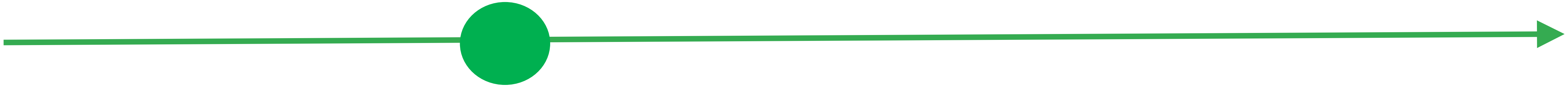
# Timeline

**Site selection**

- Seek advice from an acoustic consultant on night-time noise conditions

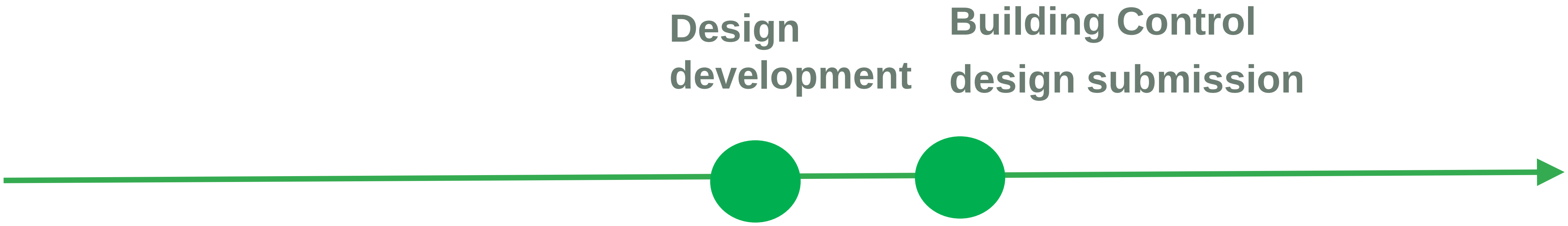
# Timeline

**Early design, up to planning application**



- Identify passive design opportunities and agree key design principles
- Agree the design of openings and other features
- Test a sample of units for compliance
- Do not carry out Part O tests in isolation

# Timeline




- Engage with Building Control well ahead of submission
- Test all units (or agreed samples) and prepare submission

ENERGY INSTITUTE : BUILDING STOCK LAB

# Timeline


- Monitor change and test impacts, up to final submission
- Develop home user guide

# Which method?

## Simplified

- Cheaper to assess
- No specialist software needed
- No experienced modeller needed
- All units must be assessed

## Dynamic thermal modelling

- More design flexibility
- Choice of weather file to match site location
- Smaller sample of units assessed
- Easier to pass?

ENERGY INSTITUTE : BUILDING STOCK LAB

# Resources

- GHA One-page early design tool for:
  - Existing homes
  - Retrofit
- CIBSE TM59
- Future Homes Hub Guidance
- MHCLG FAQs
- Inkling blogs!

# Thanks to Susie and Claire

- Building Physics Consultancy
  - Susie Diamond
  - Claire Das Bhaumik
- Services
  - Design stage overheating risk assessments for all building types now including Part O reports
  - Thermal performance and TM54 analyses
  - NABERS modelling and Independent Design Review (IDR) services
  - Advanced HVAC modelling
  - Part L2A compliance modelling and advice
  - Research
- www.inklingllp.com

# Some User Feedback

Thanks to engineers from Hoare Lea

The views expressed in the following slides are those of three individual engineers and do not necessarily reflect the views of Hoare Lea as a company

HOARE LEA
A TETRA TECH COMPANY

Forging a future to be proud of.
For people and planet.
Challenge accepted.
HOARELEA.COM

# User views of Part O in practice

How has the introduction of Part O impacted the overall determination of Building Regulations compliance eg: how much time does it add to the process?

- Added much more time to the process, can take weeks to come to a compliant strategy.
- Additional iterations of TM59 are needed.
- Post-planning permission, changes are sometimes needed and this is tricky.
- Acoustic considerations beyond TM59.
- Balance acoustics and thermal comfort is challenging.
- Daytime and nighttime operation of opening windows adds complexity.
- Engineers assess compliance but architects providing early design are less familiar .

The views expressed in this slide are those of three individual engineers and do not necessarily reflect the views of Hoare Lea as a company

ENERGY INSTITUTE : BUILDING STOCK LAB

# User views of Part O in practice

## Is any extra data needed easy or difficult to obtain?

- Additional data required if TM59 templates don't apply:
  - more data on equipment specified by architect
  - For Mech Vent with Hear Recover (MVHR) and Acoustic Rapid Vents (ARV) data may be required from manufacturer
- More data required at stage 2.
- Acoustics and daylight need to be considered earlier which requires specialist appointment earlier to make sure data is available.

The views expressed in this slide are those of three individual engineers and do not necessarily reflect the views of Hoare Lea as a company

# User views of Part O in practice

Is the data required more or less certain than data used for Part L (thermal regulations) for instance?

- Part O uses templates like Part L but these can be adjusted in Part O, eg:
  - Occupancy can be varied
- Templates may not match design and if not adjusted then uncertainty is introduced.
- Part O requires higher accuracy and more detailed data than Part L.
- Detail is required to make sure that MEP is properly designed and can be accommodated in the building.

The views expressed in this slide are those of three individual engineers and do not necessarily reflect the views of Hoare Lea as a company

# User views of Part O in practice

What are the most challenging aspects of demonstrating compliance with Part O?

- Achieving compliance with natural ventilation alone is difficult because weather files have higher air temperatures.
- Window opening profiles not triggered until inside reaches 22C and continue when external temperature exceeds 26C. Resulting in need to tempered air or cooling.
- No allowance for internal blinds makes compliance difficult.
- Safety requirements restrict extent of window opening which limits ventilation potential.
- Nighttime acoustic limits are very strict.
- Gather data at an early stage difficult.
- Communicating constraints to architects.

The views expressed in this slide are those of three individual engineers and do not necessarily reflect the views of Hoare Lea as a company

# User views of Part O in practice

How has compliance been viewed by contractors who have to implement the measures required to achieve compliance?

- No major issues if drawings, specifications and BIM are accurate.
- Contractors are gaining familiarity

The views expressed in this slide are those of three individual engineers and do not necessarily reflect the views of Hoare Lea as a company

# User views of Part O in practice

## What extra measures, if any are needed to achieve compliance?

- Acoustic vent panels often needed to comply acoustic and safety requirements.  These panels can be open day and night. However, shift to EVs may negate these as air and noise pollution reduce.
- Mech vent with boost and air tempering have been required for acoustically constrained cases in London.

The views expressed in this slide are those of three individual engineers and do not necessarily reflect the views of Hoare Lea as a company

# User views of Part O in practice

Are there building types for which it is more difficult to achieve compliance, eg: single aspect flats?

- Studio flats, typically seen in co-living or student residences, with full-fitted kitchens are difficult due to the high internal gains confined to a small space.
- Small spaces with large glazing ratios are also problematic because of solar gains.
- West/ South/ Southwest facing flats especially with large fixed panes.
- Affordable accommodation schemes have cost constraints that make it difficult.

The views expressed in this slide are those of three individual engineers and do not necessarily reflect the views of Hoare Lea as a company

# User views of Part O in practice

Are there situations where the only solution is mechanical cooling?

- Yes, certain locations have higher temperature weather files which are simply more difficult to achieve compliance via natural and mechanical ventilation. Combined with a lack of adjacent buildings or external shade to protect the building from solar gains, the only solution has been active cooling.
- Yes, usually acoustically constrained sites in London for example, they also need some level of air tempering to pass both criteria a and b.

# User views of Part O in practice

## Any other observations?

- Too many to include all here!
- Some key issues:
  - Integration of compliance with other regulations is vital, eg: Part L (thermal), Park K (safety), Part F (ventilation)
  - Mechanical ventilation with tempered air or cooling may be the only solution and these require space: higher ceilings for ducts and floor space for AHUs.
  - Compliance requires designing for current weather files (2020) but future weather files are typically only for 'reporting purposes'. However, future weather files are more closely reflective of the current weather trends so overheating may still occur in the future for the buildings we design today with today's standards.
  - Insufficient guidance in part O regarding which TM59 criteria to use in mixed mode cases.

The views expressed in this slide are those of three individual engineers and do not necessarily reflect the views of Hoare Lea as a company

ENERGY INSTITUTE : BUILDING STOCK LAB

# The End

Thanks again to: Susie Diamond

www.inklingllp.com

@InklingLLP

## Thank you for listening!

Paul Ruyssevelt

p.uyssevelt@ucl.ac.uk

UCL

# Discussion on new technologies for improving climate resilience in buildings

Mat Santamouris

The University of New South Wales

EBC

Energy in Buildings and Communities Programme

# Recent Progress on Cool and Super Cool Materials to mitigate Urban Heat

On the magnitude of Urban Climate Change, Its impact on Energy, Health, Productivity, Vulnerable Population, Economy and Environmental Quality. Heat Mitigation and Adaptation Potential and Proposals to Counterbalance Urban Heat

M. Santamouris, UNSW, Sydney, Australia


Rises the cooling energy consumption in cities ,

Decreases the efficiency of power plants

Rises the peak electricity demand

Increases the emission of pollutants of the power plants

Increases the concentration of ozone

Intensifies heat related mortality and  morbidity

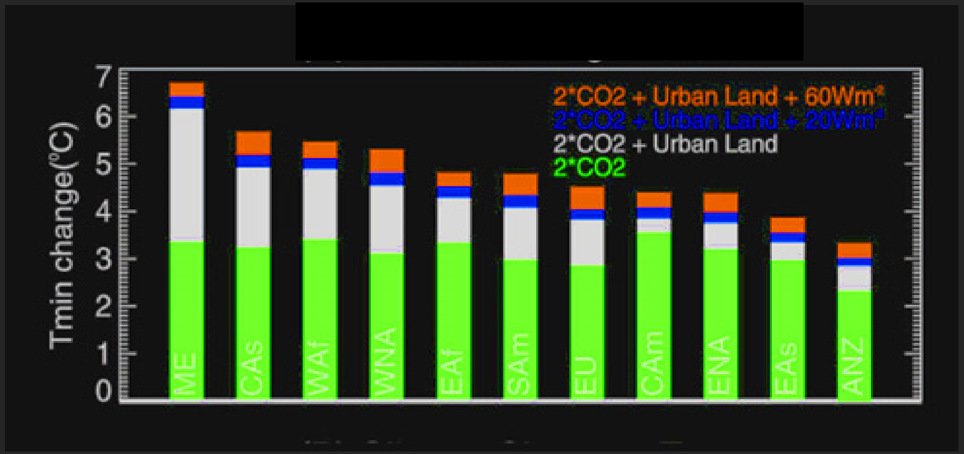
Causes serious Mental Health Problems

Lowers the productivity of population

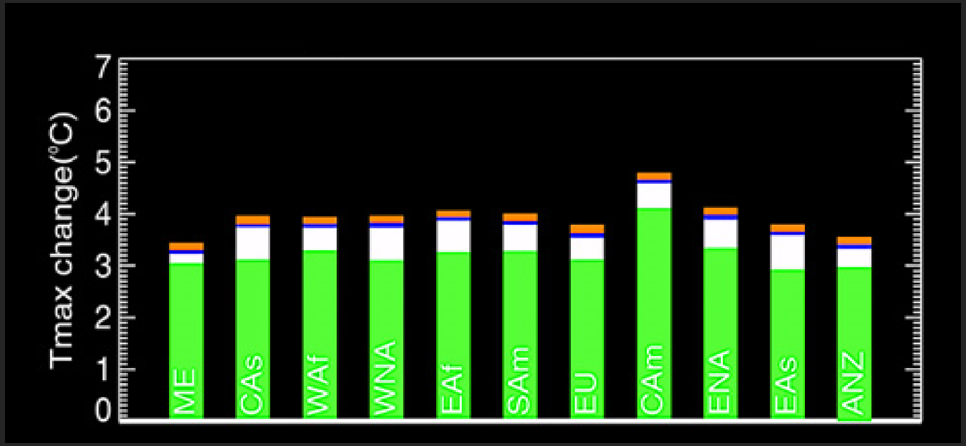
Increases the Risk of Accidents

Affects the survivability of vulnerable population

Potential Increase of Min Nighttime Temperature ( C )




Potential Increase of Max Daytime Temperature ( C )

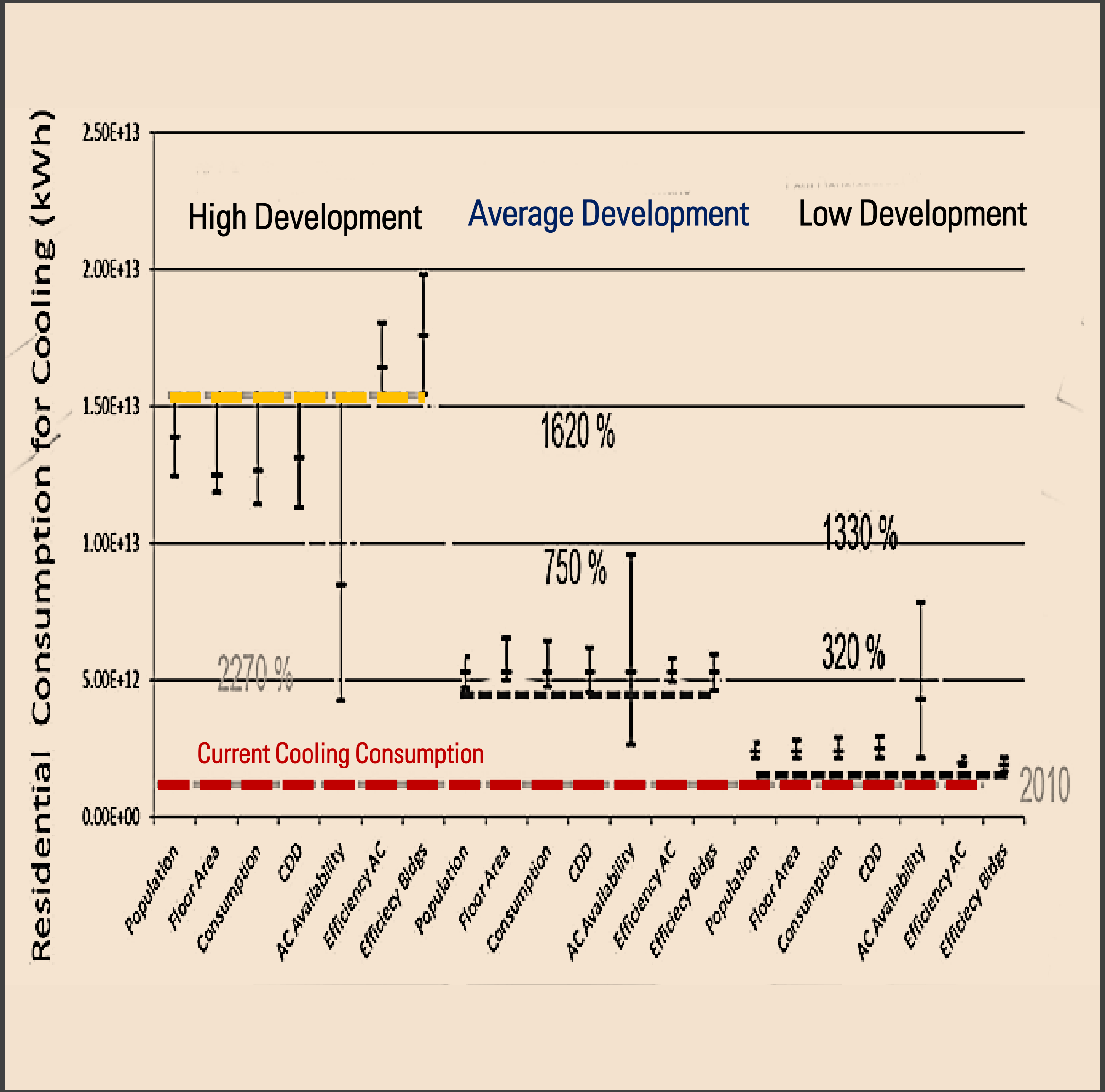



## Simulated Increase of the Urban Temperature and UHI caused by the combined impact of greenhouse gas and urban expansion forcing, (RCP 8.5)

- Increase in the Surrounding Rural zone (2 x CO2)
- Increase in the City ( 2 x CO2)
- Increase in the City ( 2 x CO2)+ 20 w/m2 anthropogenic heat
- Increase in the City ( 2 x CO2)+ 60 w/m2 anthropogenic heat

Middle East (ME), Central Asia (CAs), West Africa (WAf)
West North America (WNA), East Africa (EAf), South America (SAm),
Europe (EU), Central America (CAm), East North America (ENA),
Australia and New Zealand (ANZ)

Climate change in cities due to global warming and urban effects. Mark P. McCarthy, Martin J. Best, and Richard A. Betts, GEOPHYSICAL RESEARCH LETTERS, VOL. 37, L09705




Cooling Energy Consumption of Buildings by 2050

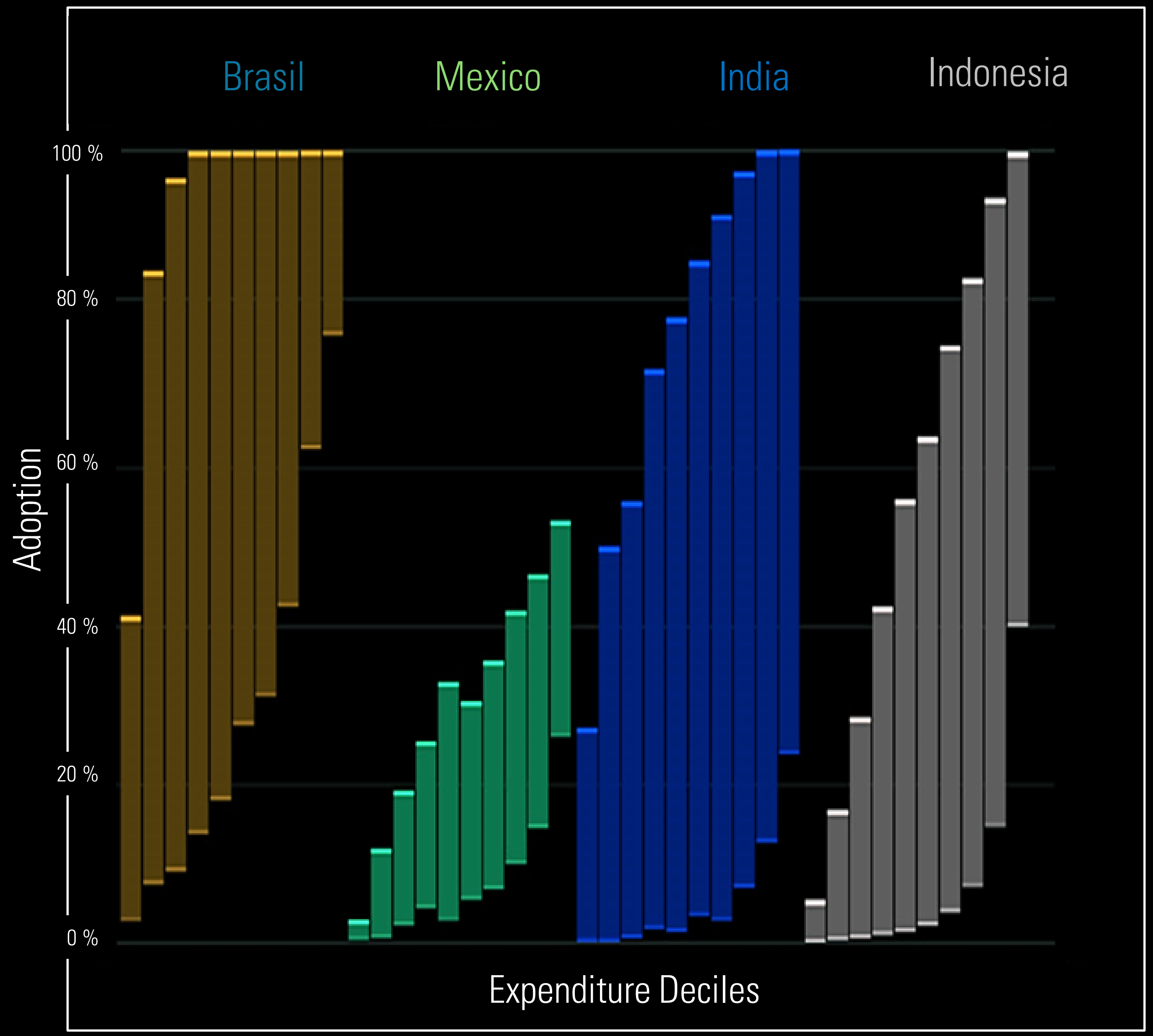
Data shows that extreme heat drives higher air conditioner demand, with sustained average daily temperatures of 30 C typically boosting weekly sales by around 16 %.

Cooling energy consumption in buildings may rise by 200% and up to 2,000% by 2050, depending on the evolution of the main economic and climatic drivers.

.

The total cost of urban overheating is estimated between 500 – 700 billion US $ per year, and may increase up to 1.3 Trillion US $ by 2050

M. Santamouris : Cooling of Buildings. Past, Present and Future, Energy and Buildings, 128 (2016)




The Current and Future Penetration of A/C in Emerging Economies per Income Group demonstrates that low income population will not have access to air conditioning.

By 2040, a nonnegligible fraction of the population will be left behind.

On 2040, between 64 and 100 million households out of the total number of households living in the four countries considered in the latest waves of 343 million will face an adaptation cooling deficit

NATURE COMMUNICATIONS | (2021) 12:6460 | https://doi.org/10.1038/s41467-021-26592-2 | www.nature.com/naturecommunications

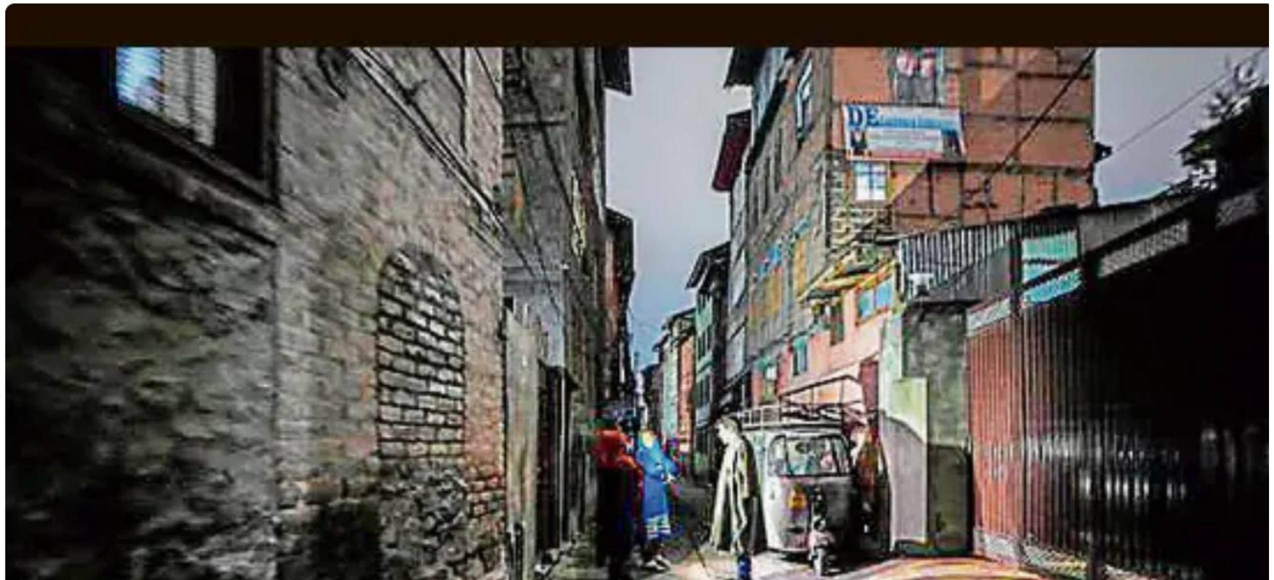
# Valley plunges into darkness amid 10 to 15-hour power cuts

By Ashiq Hussain, Srinagar

Feb 27, 2024 06:48 AM IST

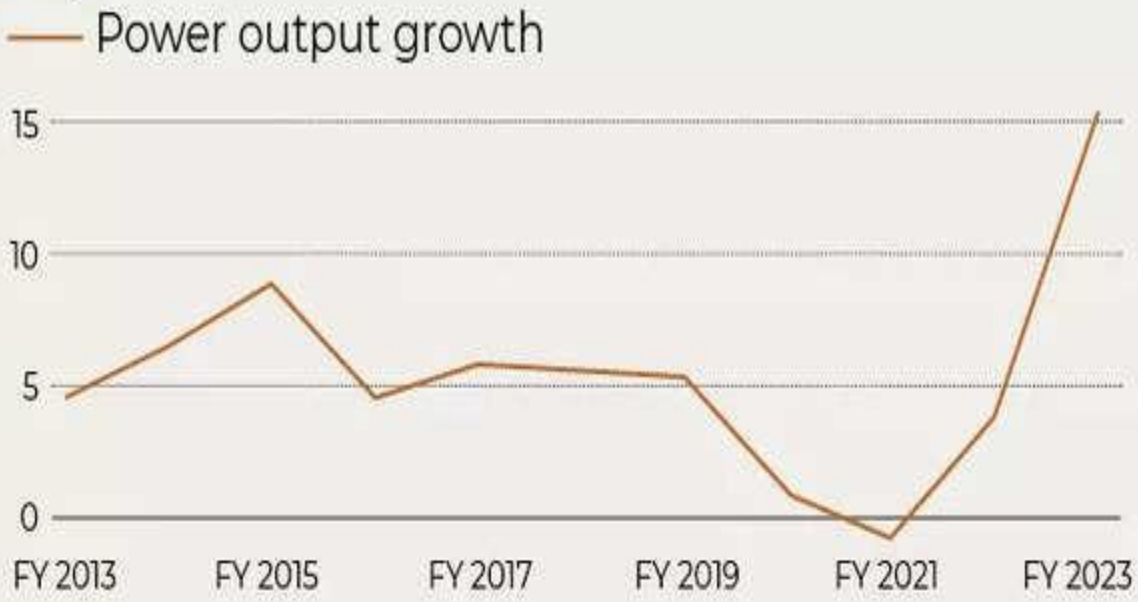


For the past few days, people across the valley are reeling under 10-15 hours of power cuts every day, up from 4.5 to 8 hours curtailments earlier in both metered and non-metered areas

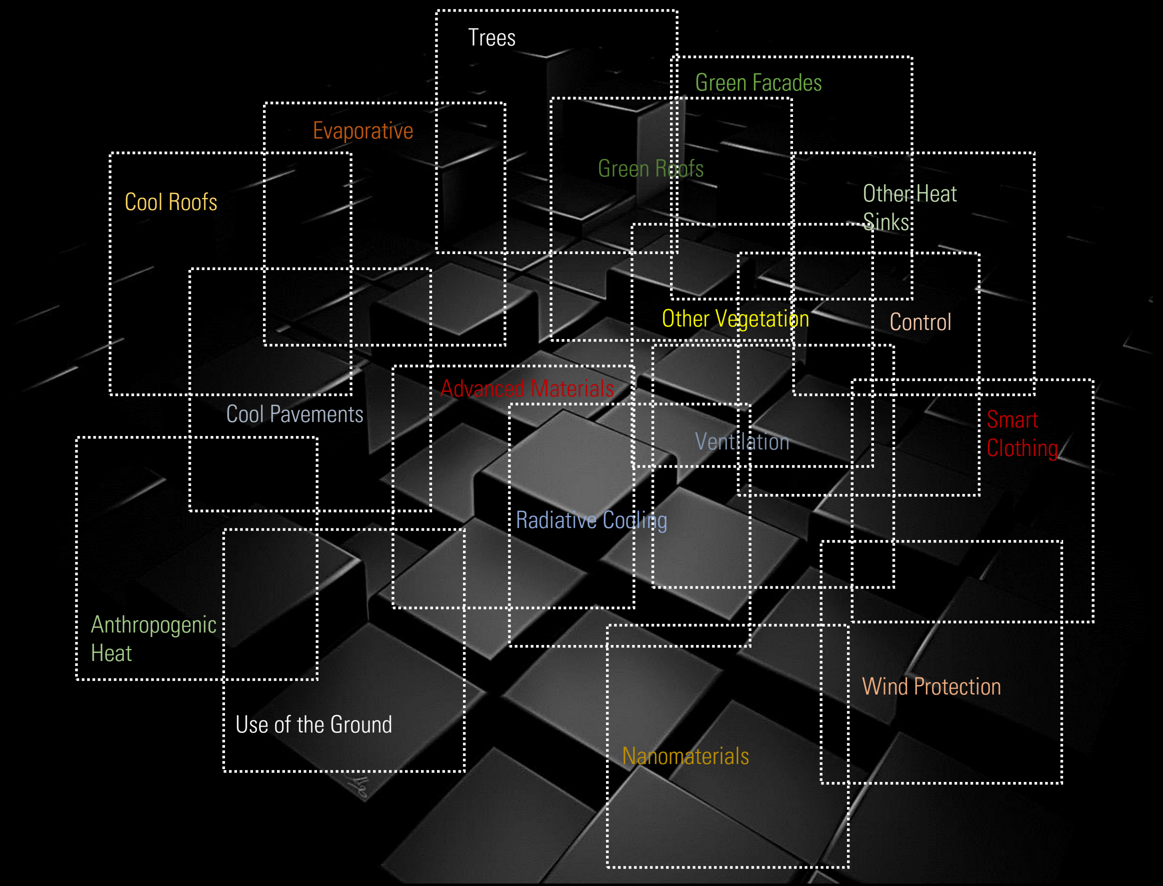


## Unprecedented growth in power demand seen in FY23

Overall power generation is seen surging 15.2% to to 1,644 billion killowatt hours (kWh) during the year ended March 2023, a power ministry note showed, with demand set to rise at the fastest pace in at least 38 years.




Note: All figures in %, FY23 figure is an internal government estimate
Source: Central Electricity Authority, internal government note/Reuters




To counterbalance the impact of urban overheating, heat mitigation techniques are developed, and successfully implemented.

Mitigation technologies involve the use of advanced urban materials like:

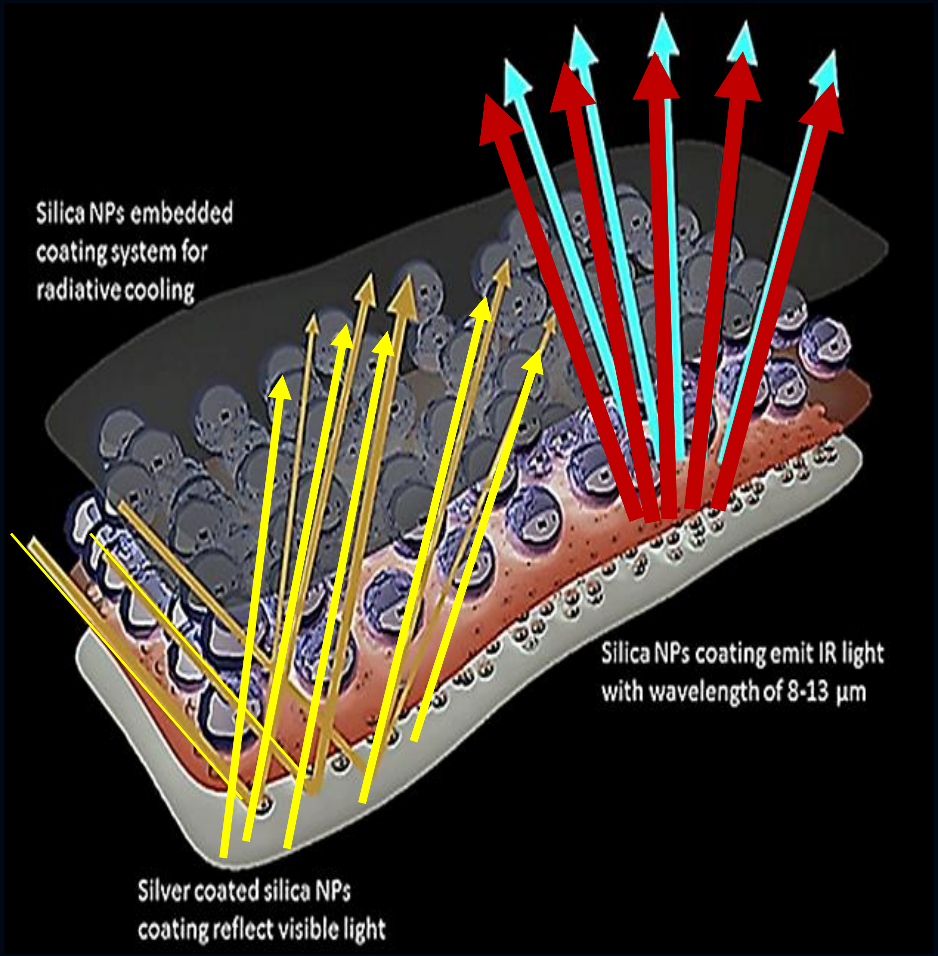
Reflective, thermochromic, photonic, plasmonic and fluorescent materials,

The increase of the urban green infrastructure,

The use of evaporative systems,

Dissipation of the excess urban heat to low temperature heat sinks,

Or, a combination of the previous technologies.




Passive Radiative Coolers, or Super Cool Materials, present a very high solar absorptance combined with a high emissivity in the atmospheric window, 7-13 µm.

The recent development of

Super Cool Materials

like the photonic and fluorescent materials, permits the decrease of the surface temperature of buildings and urban structures up to 15 C below the ambient temperature under the summer sun

The implementation of SCM in cities can reduce the peak ambient temperature up to 4-5 C and provide very significant energy and health benefits.

The developed samples of the Super Cool Materials have been extensively tested outdoors in Alice Springs, Australia, under desert conditions, to characterize their cooling performance.

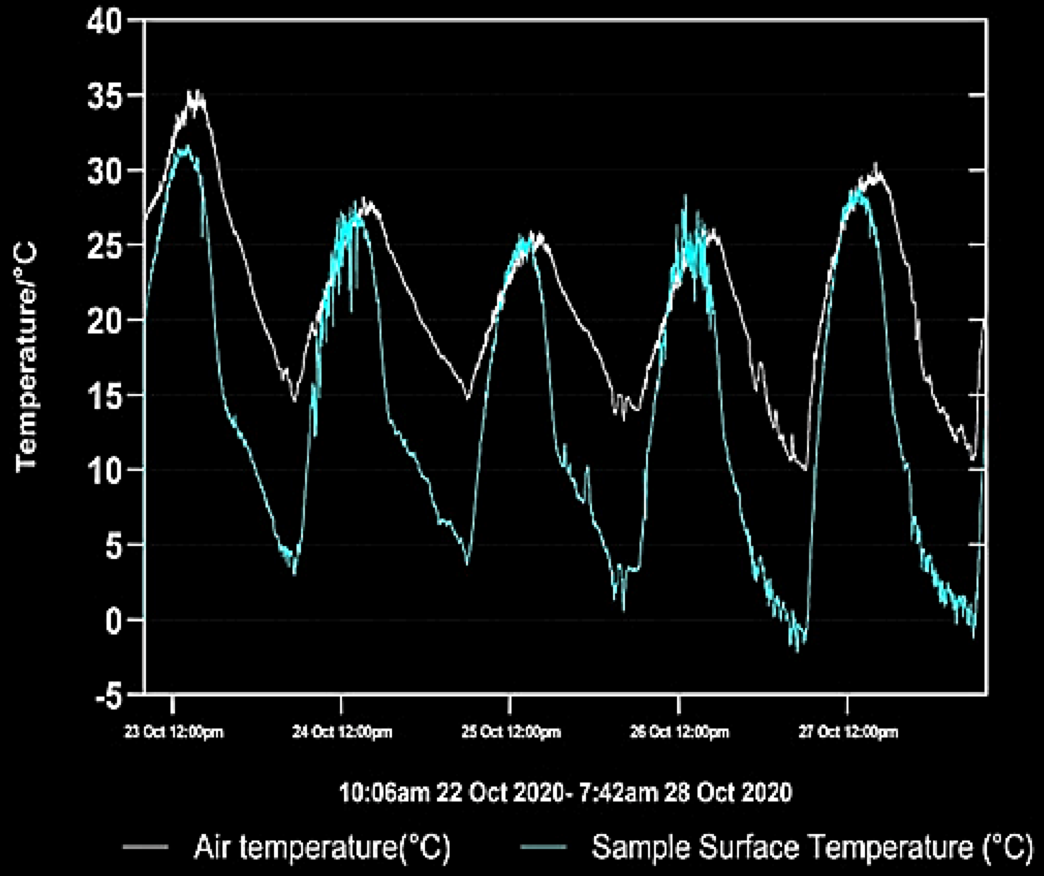
Six Samples with Different Characteristics have been designed.

The microstructure of the samples was analyzed by field emission SEM (FESEM; FEI Nova NanoSEM 230, 3 kV) and their element composition was studied by EDS - Energy Dispersive Spectrometry).

Desert climatic conditions permit testing under high day time ambient temperature and solar radiation intensity.

However, the desert atmosphere contains a high concentration of SiO2 that is highly absorbing in the atmospheric window, thus decreasing the cooling performance of the materials.

Silica TPX Sample + ESR + Silver Pet Film




Testing has been carried out during five consecutive days.

Day time ambient temperature varied between 25 to 35 C

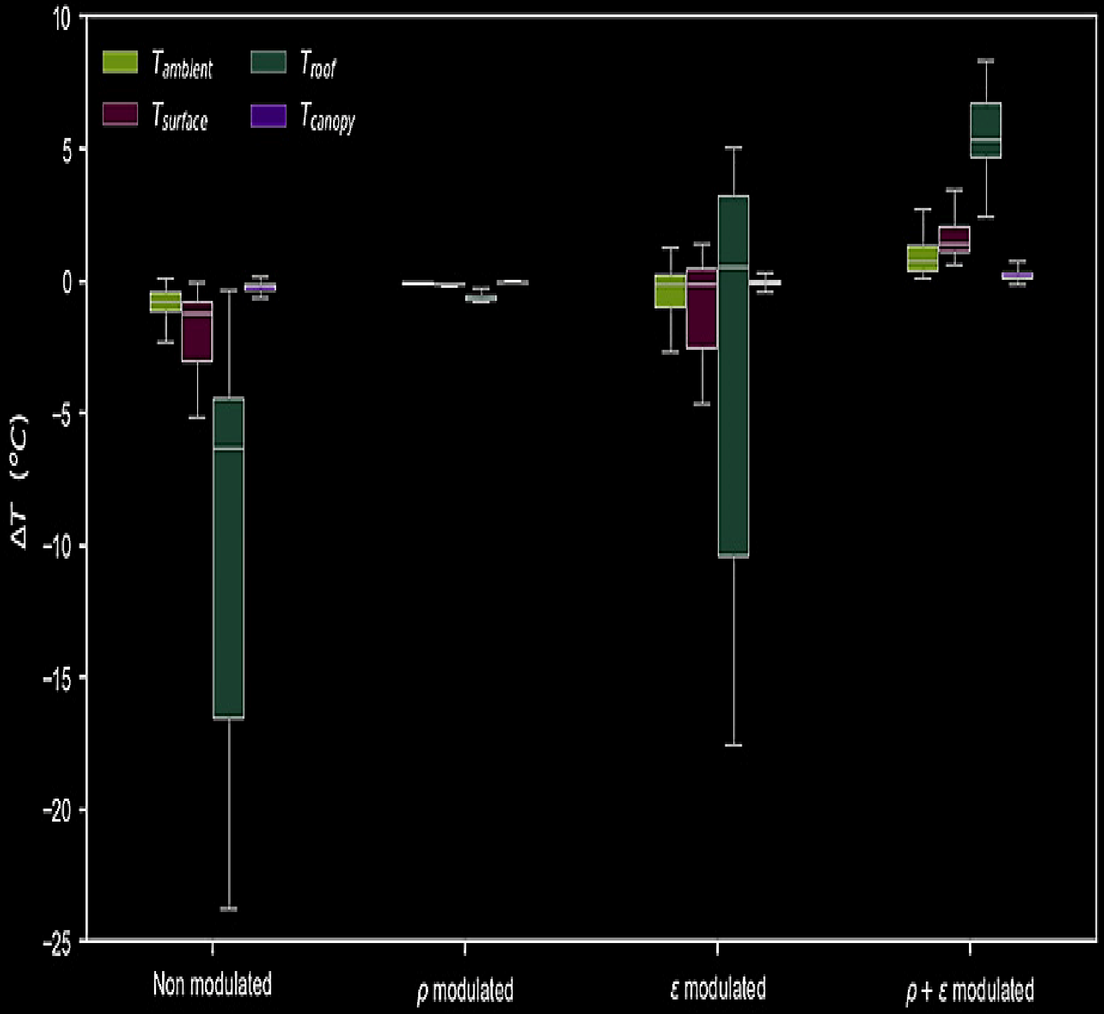
The peak solar Radiation intensity was between 800 to 100 W/m2

During the Day Time:

The Surface temperature of the developed Super Cool Materials was in average 6 C lower than the ambient one while during the peak ambient temperature the cooling of the SCM was 3-4 C.

During the Night Time:

The Surface temperature of the SCM was almost 10 C lower than the ambient one.




Because of their high solar reflectance and the white or metal color, PDRC materials cause undesired aesthetic and visual problems and can be used only on high level roofs, while may increase the heating energy demand of buildings in temperate and continental climates

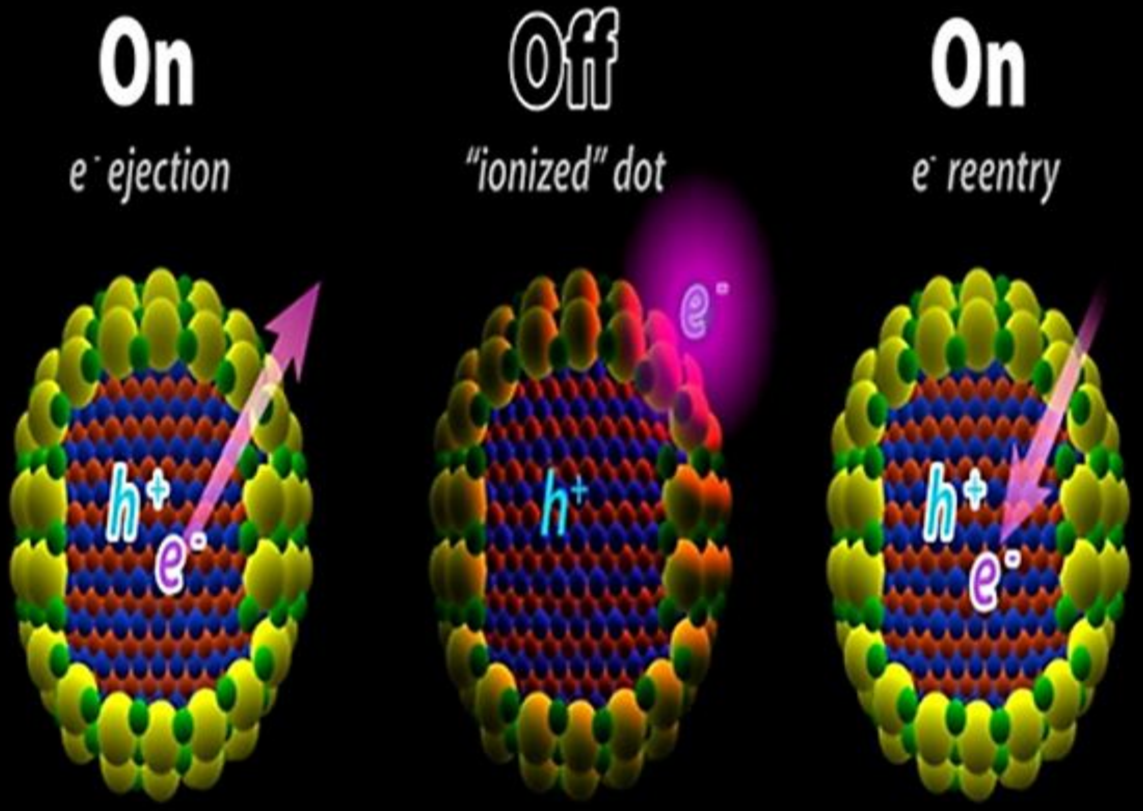
Modulation of the Reflectance and Emissivity of the PDRC's offers important energy benefits during both the Cooling and Heating period.

Use of SCM may decrease the ambient temperature up to 2 C

Results of WRF simulations for Kolkata India


Ansar Khan, Laura Carlosena, Jie Feng, Samiran Khorat, Rupali Khatun, Quang-Van Doan, Mattheos Santamouris : Optically modulated passive broadband daytime radiative cooling materials can cool cities in summer and heat cities in winter, Sustainability, 2022, 14, 1110

Ansar Khan, Laura Carlosena, Samiran Khorat, Rupali Khatun Quang-Van Doan, Jie Feng, Mattheos Santamouris On the Winter Overcooling Penalty of Super Cool Photonic Materials in Cities, Advances Solar Energy Vol 1, 2021




Passive Colored Radiative Coolers, PCRC, based on the use of fluorescent materials, convert part of the absorbed UV and visible solar radiation into emitted light, providing color and reducing the thermal balance of the materials and the potential visual annoyance

## Quantum dots (QD)

are very small semiconductor particles, only several nanometers in size, so small that their optical and electronic properties differ from those of larger particles. They are a central theme in nanotechnology.

Many types of quantum dot will emit light of specific frequencies if electricity or light is applied to them, and these frequencies can be precisely tuned by changing the dots' size, shape and material, giving rise to many applications.

Samira Garshasbi , Shujuan Huang , Jan Valenta , Mat Santamouris : On the combination of quantum dots with near-infrared reflective base coats to maximize their urban overheating mitigation potential, Solar Energy, Volume 211, 15 November 2020, Pages 111-116

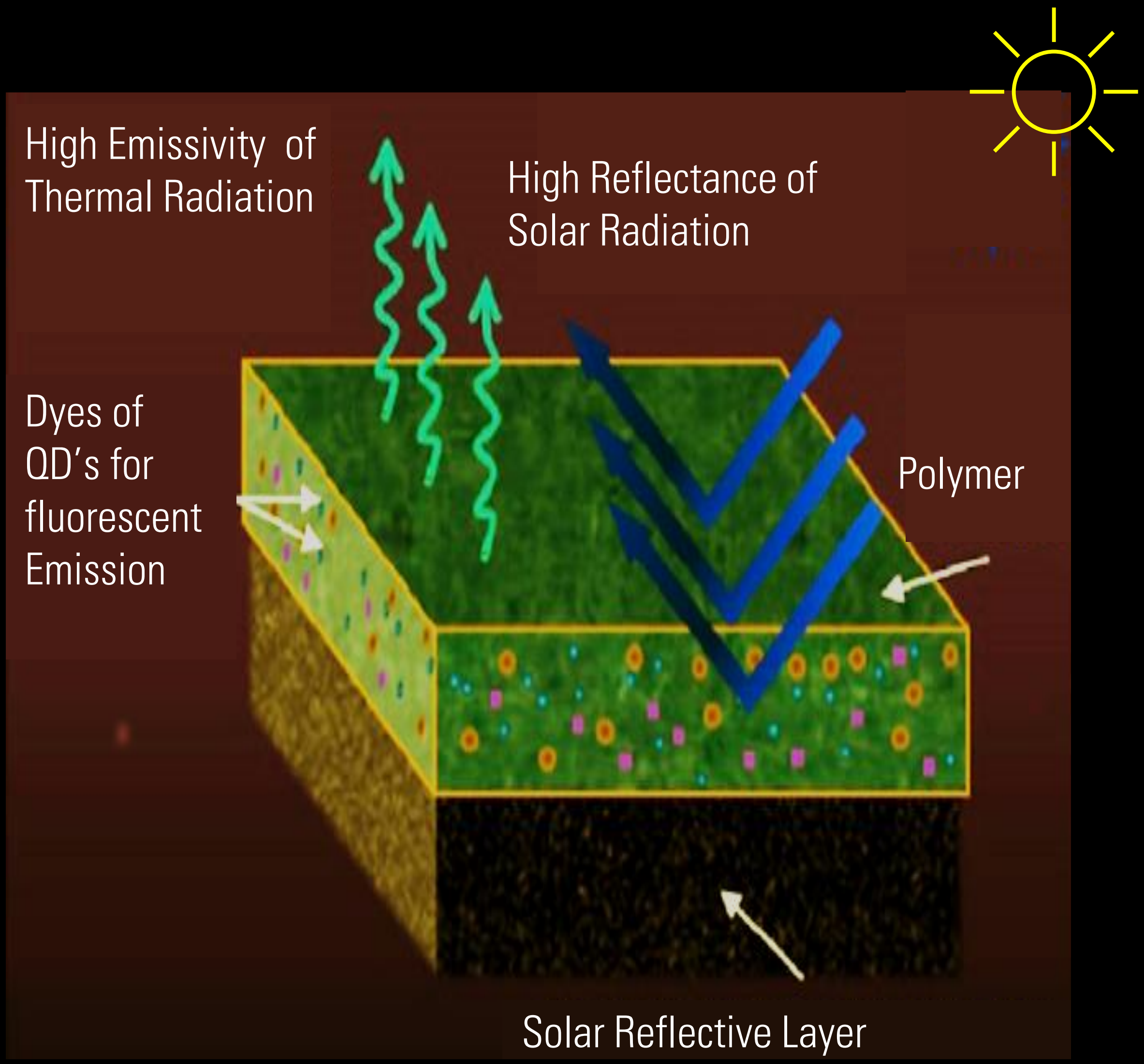



Figure idea :Colored radiative cooling coatings using phosphor dyes : J. Xu, R. Wan, W. Xu, Z. Ma, X. Cheng, R. Yang, X. Yin

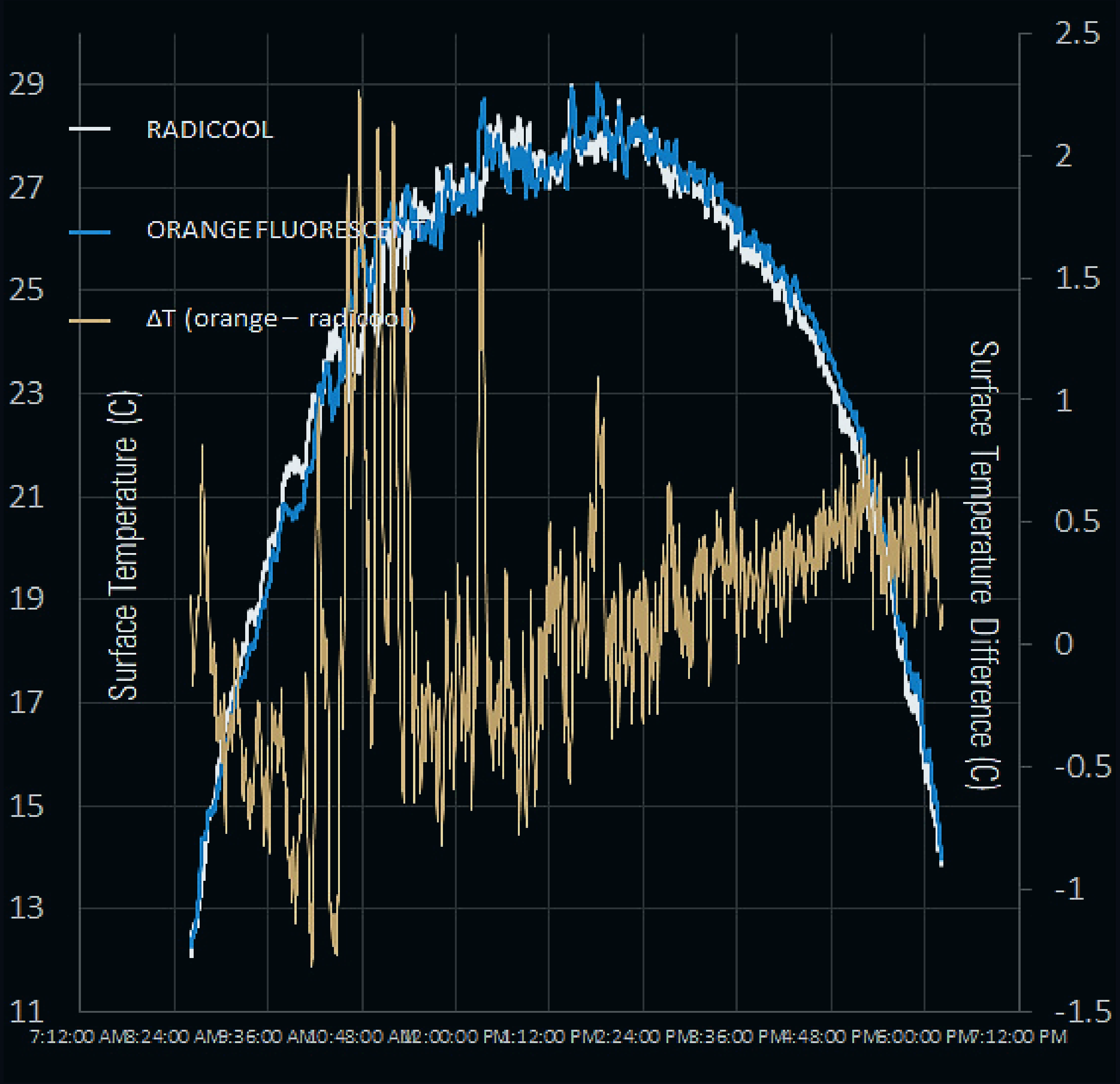
Colored Radiative Coolers based on the use of fluorescent materials have been developed and tested.

Materials were designed in order to present:

- High Reflectance to Solar Radiation
- High Emissivity in the Atmospheric window, and
- High radiative losses because of the fluorescent emission

The developed colored radiative coolers were composed by two or three specific layers:

- A reflective layer, and
- A high emissivity and/or a high PLQY layer on the top to provide fluorescent emission at various colors and also high emissivity in the atmospheric window




25/5/2023 – Alice Springs- Orange Fluorescent SC Material

Max Amb. Temp : 27.4 C

Max SR : 740 W/m2

RH (noon) : 20 %,

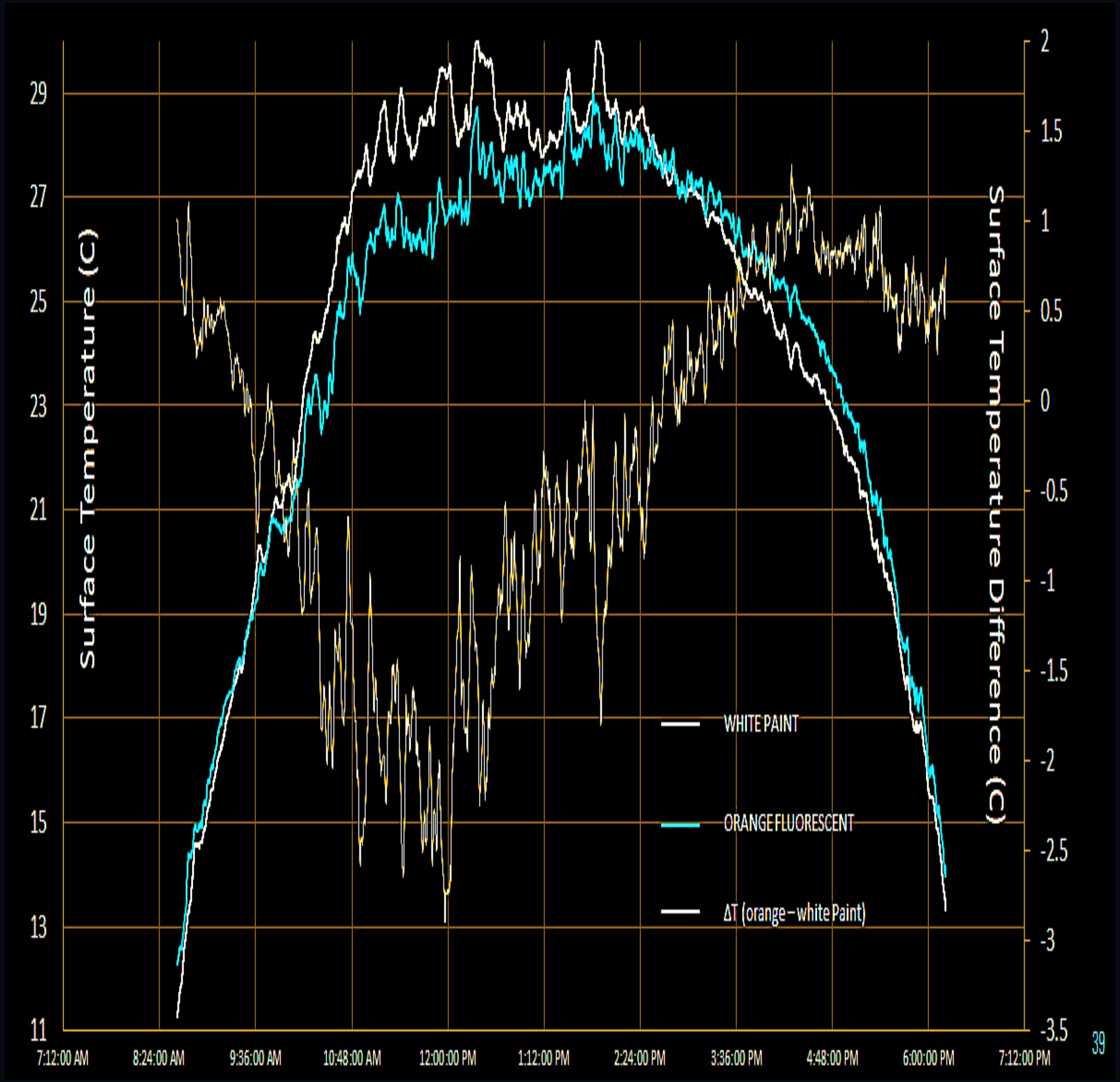
Max Atm Rad : 370 W/m2

Comparison of the Orange Colored SCM against the White SCM

During the day time the average temperature of the white SCM was 24 C

while of the Orange SCM was 24.1 C

The orange Super Cool material exhibited during the day time period up to 1.5 C sub-ambient temperature.




25/5/2023 – Alice Springs- Orange Fluorescent SC Material against conventional white paint.

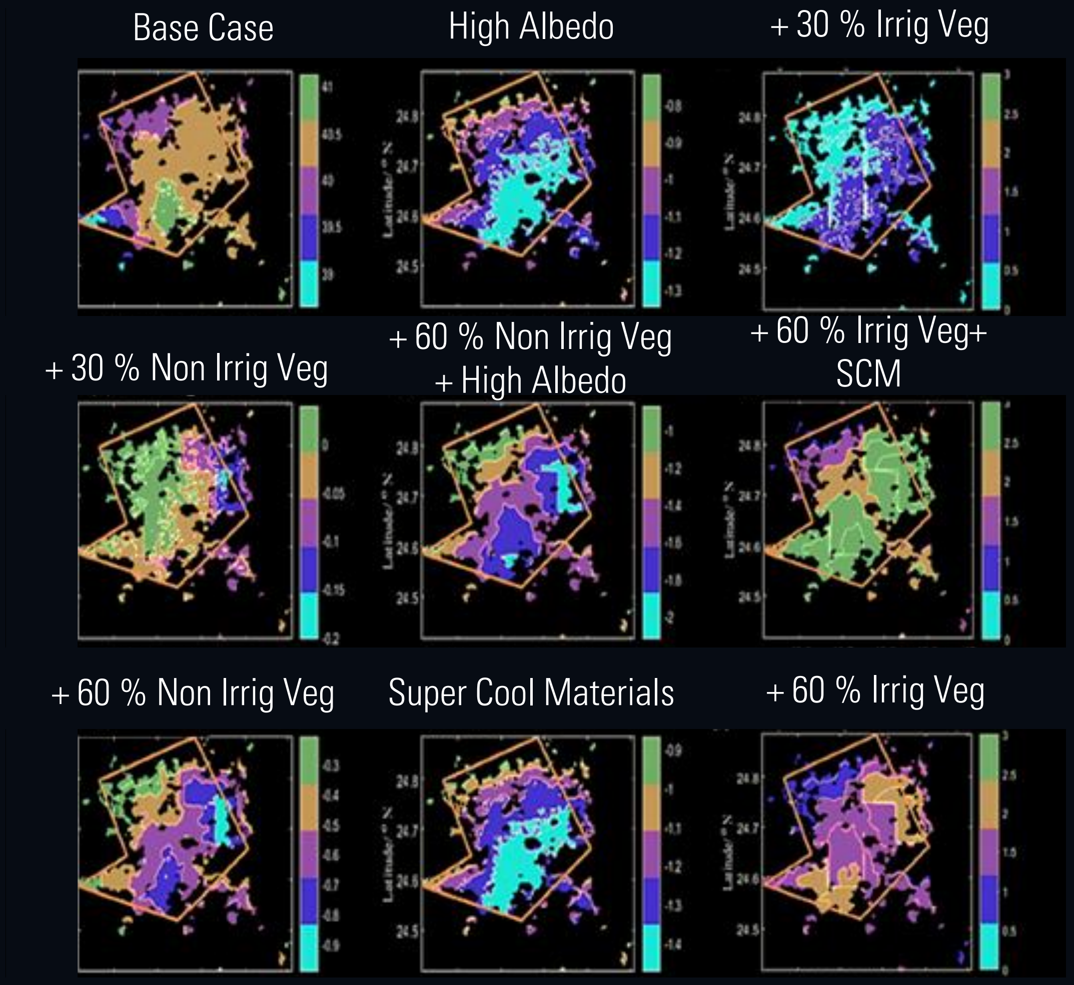
Max Amb. Temp : 27.4 C
Max SR : 740 W/m2
RH (noon) : 20 %,
Max Atm Rad : 370 W/m2

Comparison of the Colored against Conventional White Paint

During day time the average temperature of the white paint was 24.6 C

while of the Orange SCM was 24.1 C

During noon time the orange Super Cool material was almost 3 C of lower surface temperature than the white paint.




The developed Super Cool Materials have been considered as the primary heat mitigation strategy to decrease the ambient temperature and reduce the energy consumption of buildings in numerous cities.

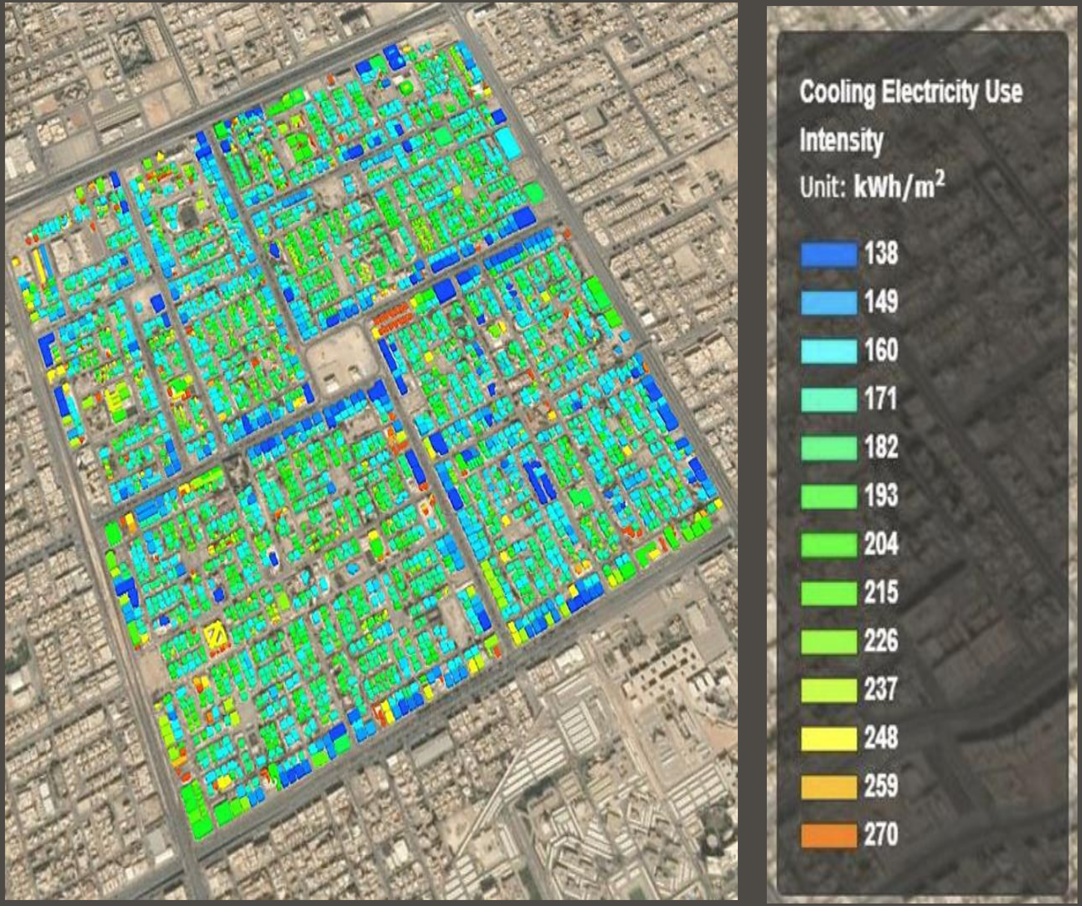
## Results from the Heat Mitigation Study in Riyadh, KSA

- Use of white super cool materials in the roofs of the city, can reduce the peak daytime summer temperature up to 2.8 C

- Combined use of white SCM on the roof of buildings, with well irrigated greenery, can reduce the peak day summer ambient temperature up to 4.6 C

- Increase of the albedo in the city by 0.4 can reduce the peak daytime ambient temperature up to 1.5 C.

S. Haddad et al : **Quantifying the Energy Impact of Heat Mitigation Technologies at the Urban Scale,** Nature-Cities, 2024




The combined use of white super cool materials on the roofs of buildings with well irrigated additional greenery provides serious energy benefits during the summer period and decreases considerably the cooling demand of buildings. .

## Results from the Heat Mitigation Study in Riyadh, KSA

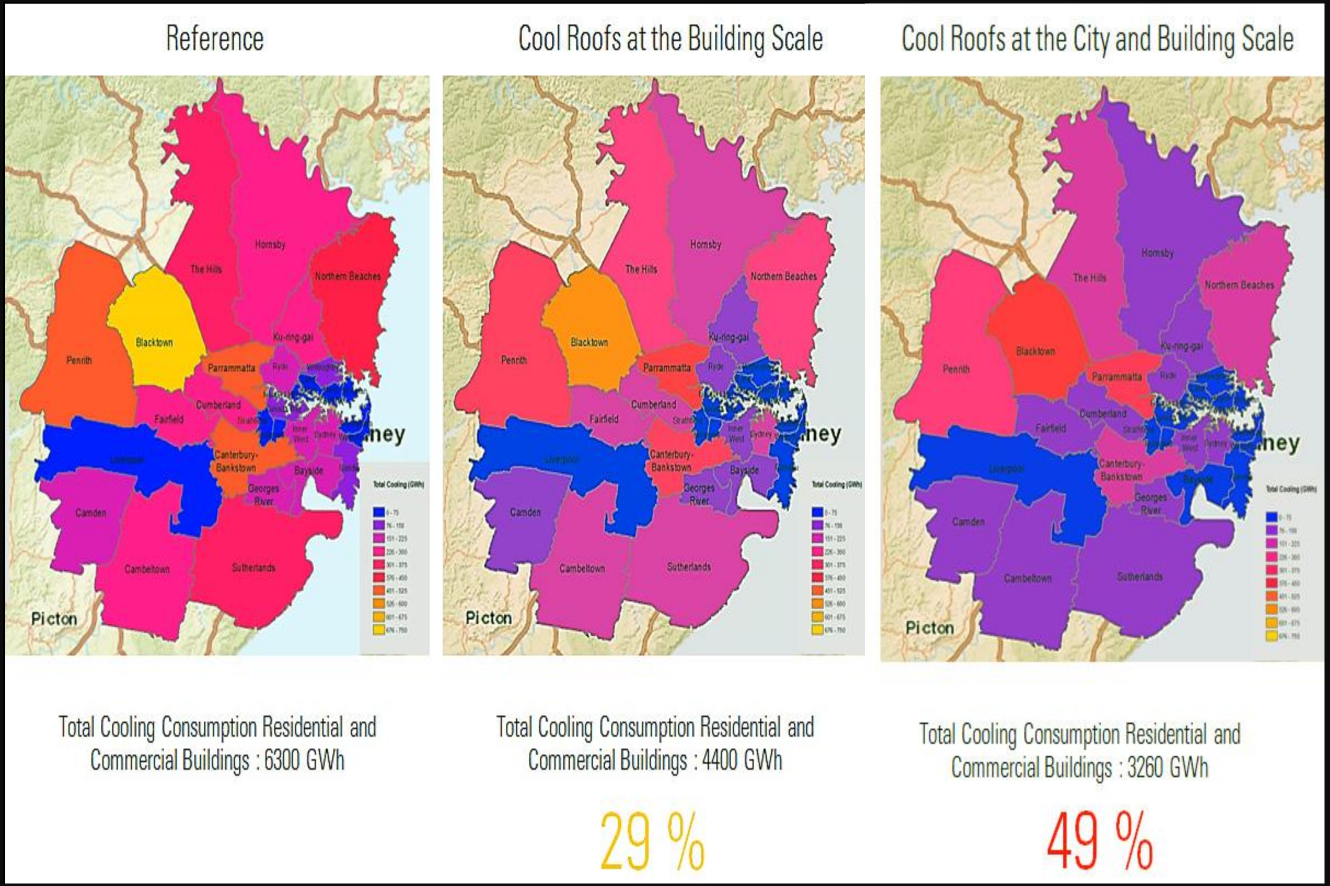
- Use of white super cool materials in the roofs of the city, can reduce the cooling demand of buildings up to 10 %

- Combined use of white SCM on the roof of buildings, with well irrigated greenery, can reduce the cooling demand of buildings up to 17 %.

- Combined use of white SCM on the roof of buildings, with well irrigated greenery and energy adaptation measures can reduce the cooling demand of buildings up to 35 %.

S. Haddad et al : **Quantifying the Energy Impact of Heat Mitigation Technologies at the Urban Scale,** Nature-Cities, 2024

Energy Impact of Heat Mitigation Technologies



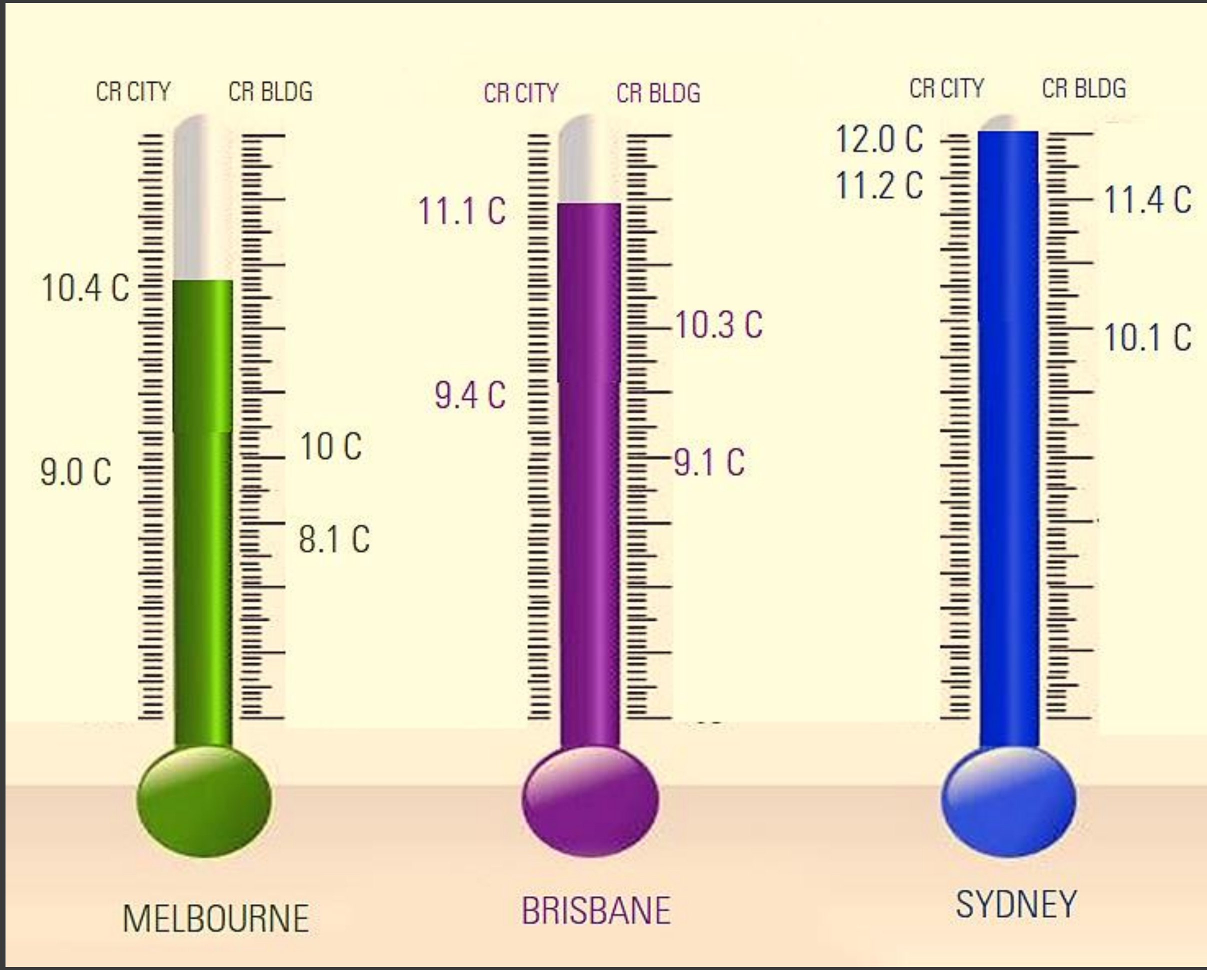

A study has been performed by the Department of Industry in Australia to assess the impact of cool roofs in the major Australian cities has concluded that:

## Main Results of the Study

In average, when cool roofs are implemented in all buildings of Sydney, can contribute to reduce the sensible cooling load of the residential and commercial buildings in the city by 29 %

When, the indirect impact of cool roofs is taken into account involving the decrease of the ambient temperature and the increase of the efficiency of the A/C, then the contribution can reach 49 %

S. Garshasbi, Jie Feng, Riccardo Paolini, Jean Jonathan Duverge ,Carlos Bartesaghi-Koc, Samaneh Arasteh, Ansar Khan, M. Santamouris : On the energy impact of cool roofs in Australia, Energy and Buildings, Volume 278, 1 January 2023, 112577




A study has been performed by the Department of Industry in Australia to assess the impact of cool roofs in the major Australian cities has concluded that:

## Main Results of the Study

The implementation of cool roofs in low income houses in Australia, not insulated buildings can decrease the peak indoor summer temperature up to 12 C.

Cool Roofs can improve tremendously thermal comfort during the warm period of the year and decrease substantially heat related mortality and morbidity

S. Garshasbi, Jie Feng, Riccardo Paolini, Jean Jonathan Duverge ,Carlos Bartesaghi-Koc, Samaneh Arasteh, Ansar Khan, M. Santamouris : On the energy impact of cool roofs in Australia, Energy and Buildings, Volume 278, 1 January 2023, 112577


"Somehow we need to monetise this - and quickly"

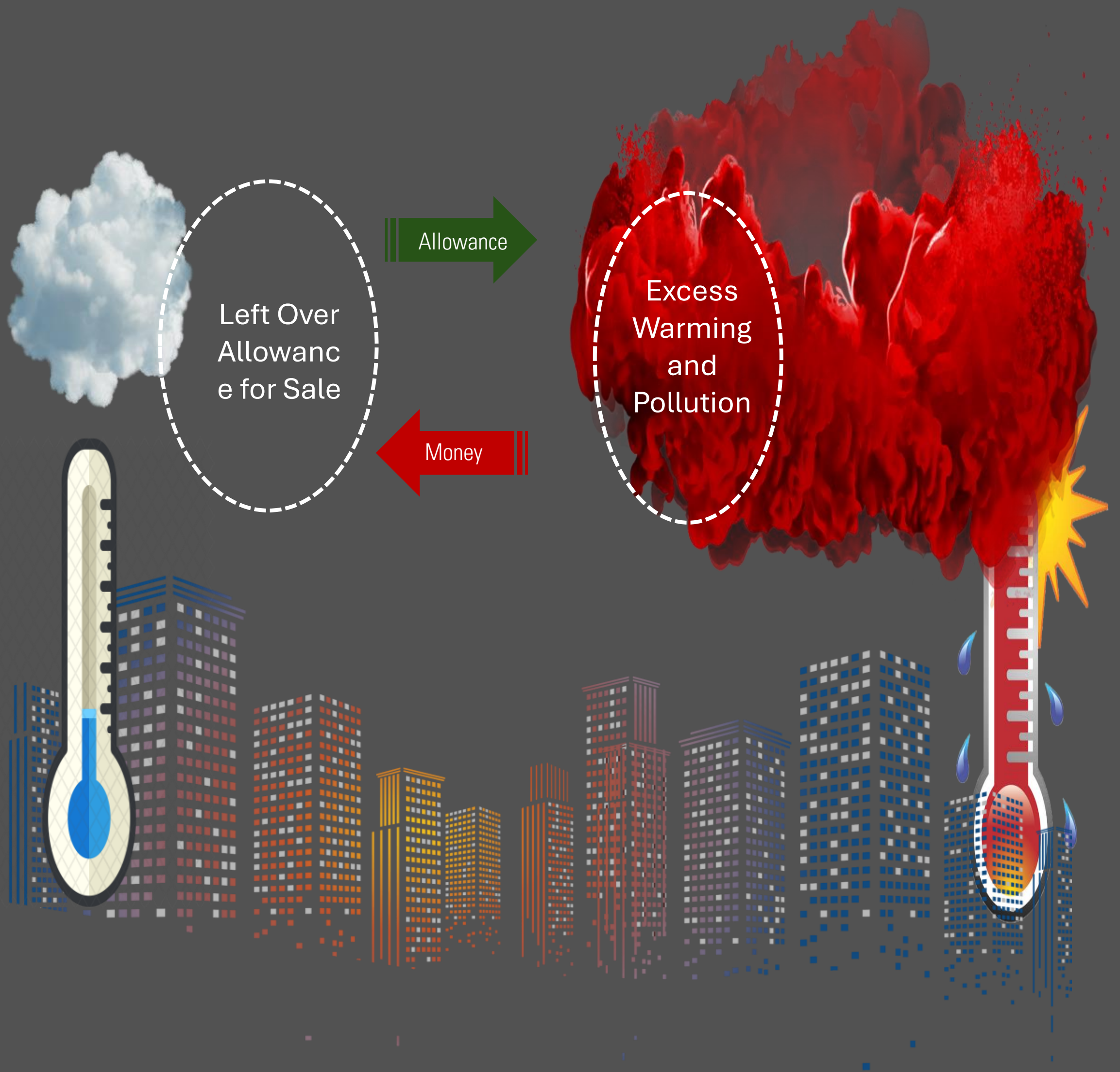
## Establishment of Urban Warming Markets

Setting as a goal a minimum urban overheating and pollution involves limiting the strength of warming and polluting sources and increasing the strength of urban heat sinks to balance the urban heat budget.

Achieving a Zero Urban Thermal and Pollution budget requires to:

Change the way we design, build and operate urban buildings, spaces and infrastructures and transition to less warming and polluting patterns and policies

Put a value on the urban mitigation and adaptation capital that limits the strength of local climate change and environmental quality




## Putting a Price on Urban Warming

The magnitude of overheating and pollution caused by selected major urban activities has to be assessed and controlled.

Liable entities exceeding the threshold and causing urban warming must pay a price for every warming or pollution unit, shortfall cost, or to surrender the appropriate number of allocated units.

## Boosting Sustainable Urban Investments

To accelerate urban cooling and finance urban heat mitigation and adaptation it is critical to value urban overheating with liquidity.

The development of a voluntary Urban Warming Market could bring urban mitigation and adaptation investments sooner to the market and make them more affordable.

EBC

Energy in Buildings and Communities Programme

# Panel Discussion: Energy and Climate Resilience



# Break: 15:50 – 16:10

# Session II.

# Embodied Carbon in Building Energy Codes

EBC

Energy in Buildings and Communities Programme

Energy in Buildings and Communities Programme

# Global Vision and Perspectives from Australia

**Stanford Harrison**
BECWG Co-chair
Director, Commercial Buildings Policy
Department of Climate Change, Energy, the Environment and Water | Australia

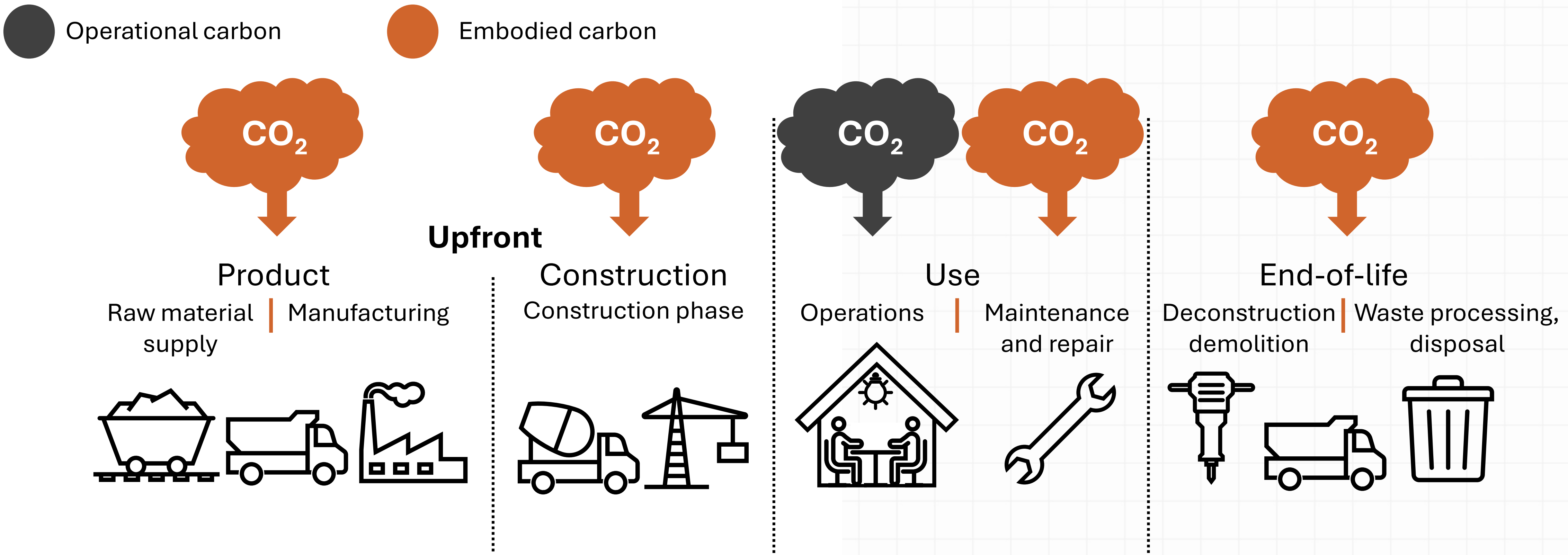
**Suzanne Lavender**
Director, Sustainable Buildings Policy
Environment, Planning and Sustainable Development Directorate | ACT Government | Australia

# Embodied Carbon

Embodied Carbon is the carbon emissions across a building's life cycle, excluding operational carbon.

This includes upfront embodied carbon, use stage embodied carbon and end of life carbon, measured as CO2e.

Upfront carbon emissions stem from the materials and products the building is made from, and how they are constructed and installed.



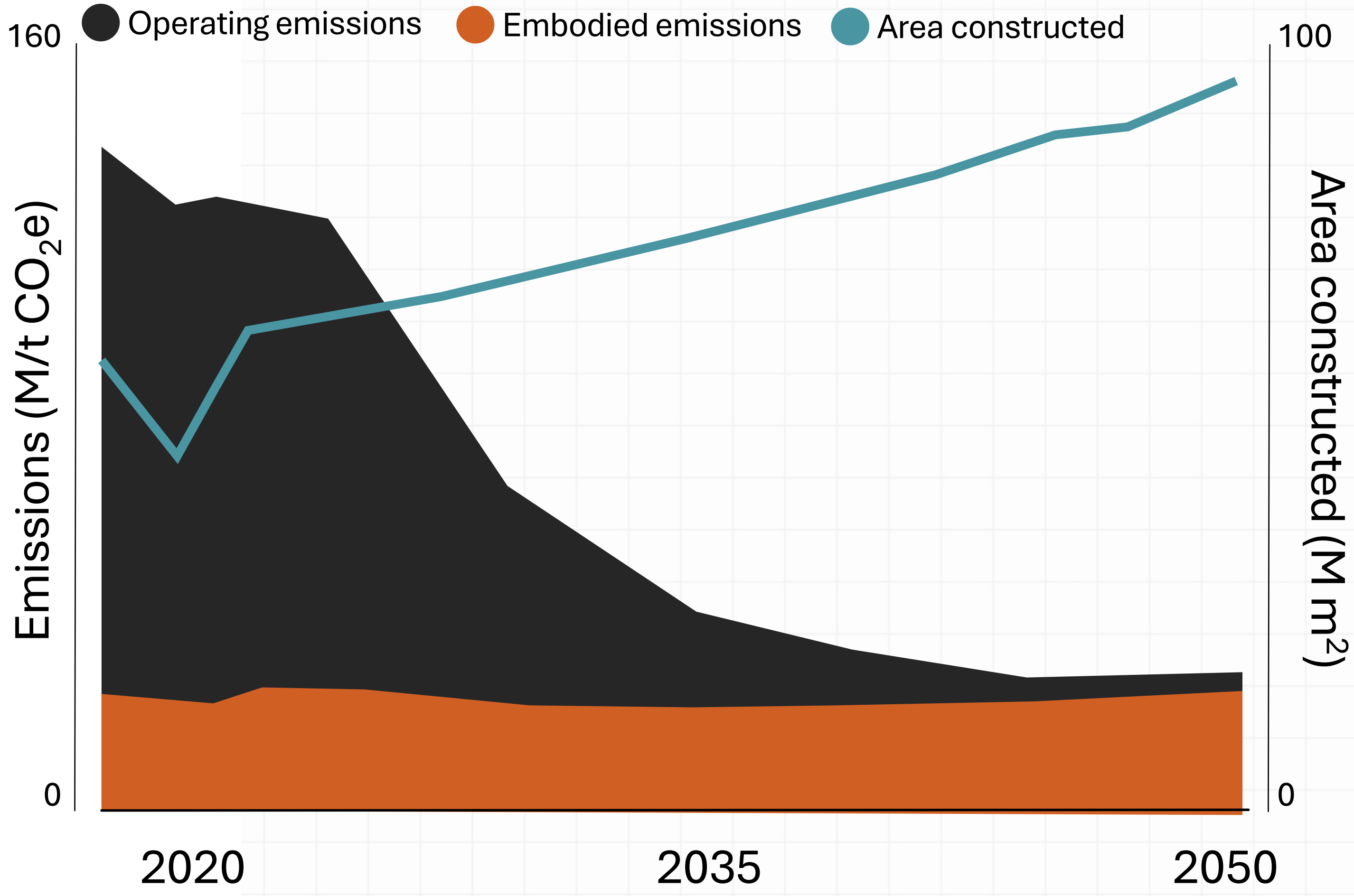

Adapted from: [How to establish Whole Life Carbon benchmarks](#) (BPIE)

# Operational vs embodied in 2050

Embodied carbon from the built environment contributes to 10% of Australia's national emissions annually*.

But as the electricity grid decarbonises this will grow proportionately.

To meet net zero commitments, we need action to reduce embodied carbon emissions.




Source: Embodied Carbon Emissions in Australia's Built Environment - Issues Paper (ASBEC, 2024)

* Embodied Carbon Projections for Australian Infrastructure and Buildings (IA, 2024)

# More than just materials...

Infrastructure Australia estimated a 23% cost neutral reduction of embodied carbon is possible by 2027, predominantly through material substitution*.

... but to reach our targets and achieve far greater reductions we need a wholistic approach to include:

- **Planning & Procurement**
- **Design & adaptive reuse**
- **Demand for low carbon materials**
- **Fossil fuel free construction**

ACT Government

# Perspectives from Australia

November 2024

# Federal system with national building code

## Australia map

"Ministers agreed to include a **voluntary pathway in NCC 2025** for **commercial buildings** to measure and report on embodied carbon.

Ministers also asked the ABCB to investigate how to incorporate and fund inclusion of a future **minimum standard for embodied carbon in NCC 2028** to further support Australia's transition to net zero.."

Building Ministers' Meeting June 2024

# Voluntary pathway in building code

## Considerations for national consistency

### Low emissions design and construction

Separate consideration from “Energy Efficiency”

### Define the target

Upfront Embodied Carbon - modules A1, A2, A3, A4, A5

### Define the function

Measure, disclose, reduce

### Define performance

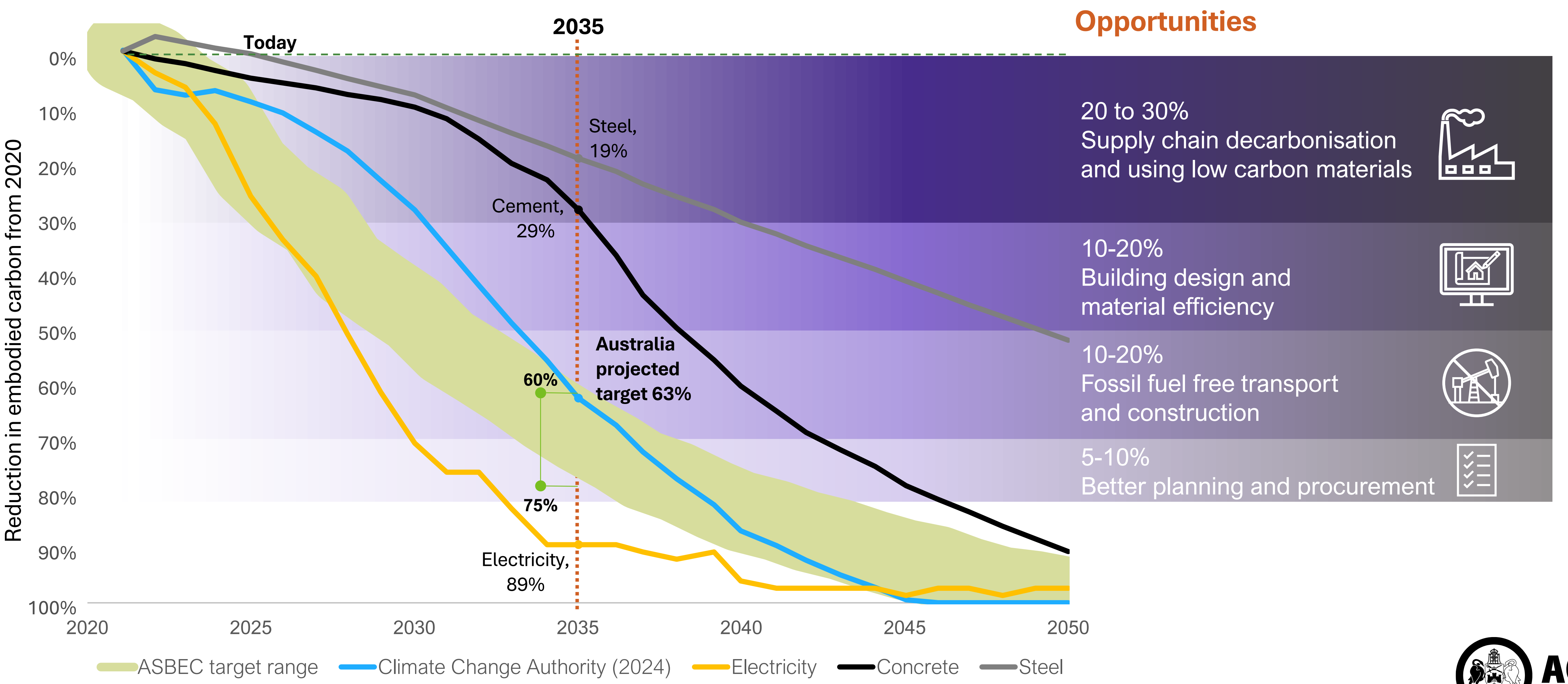
Better design, material efficiency, materials selection, disclosure

### Define verification method

Green Star, NABERS Embodied Carbon, public disclosure

ACT Government

# Steep trajectory ahead




- **Australia's Projected Target**: Based on estimates in the Climate Change Authority's 2024 Issues Paper (Figure 6), considering announced state and territory targets. Link
- **Electricity Grid Decarbonization**: Data from AEMO's 2022 Integrated System Plan (ISP). Link
- **Cement Decarbonization Pathway**: Adapted from Mission Possible's 2021 report, *Making Net Zero Concrete and Cement Possible*. Link
- **Steel Decarbonization Pathway**: Adapted from the International Energy Agency's sustainable development scenario for iron and steel. Link
- **ASBEC Target Range**: Derived from analyses of varied trajectories, adjusted for projected construction growth.

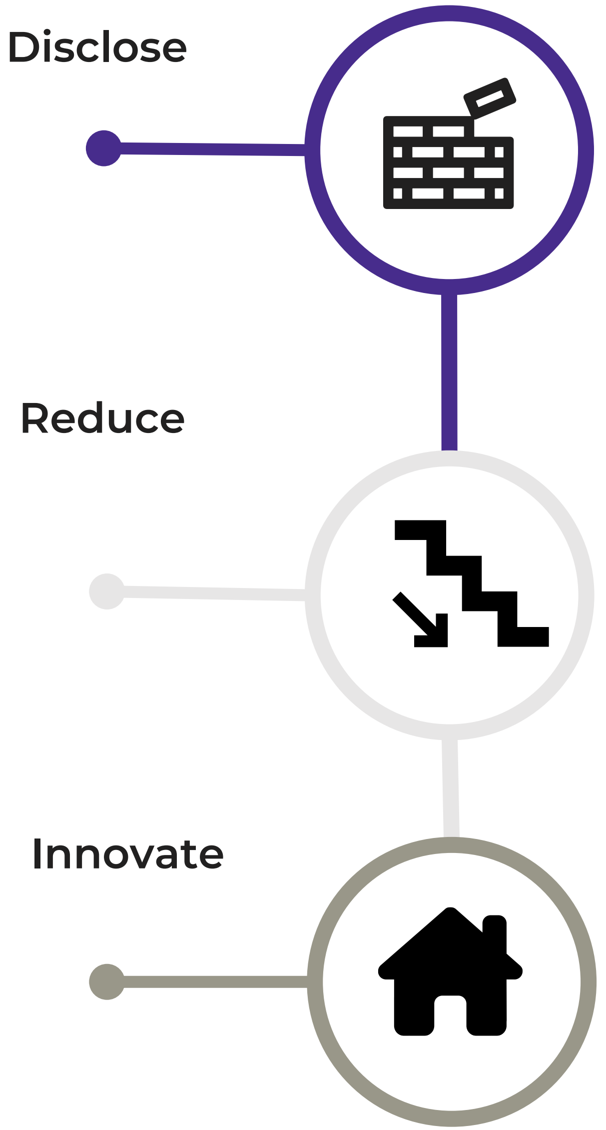
ACT Government

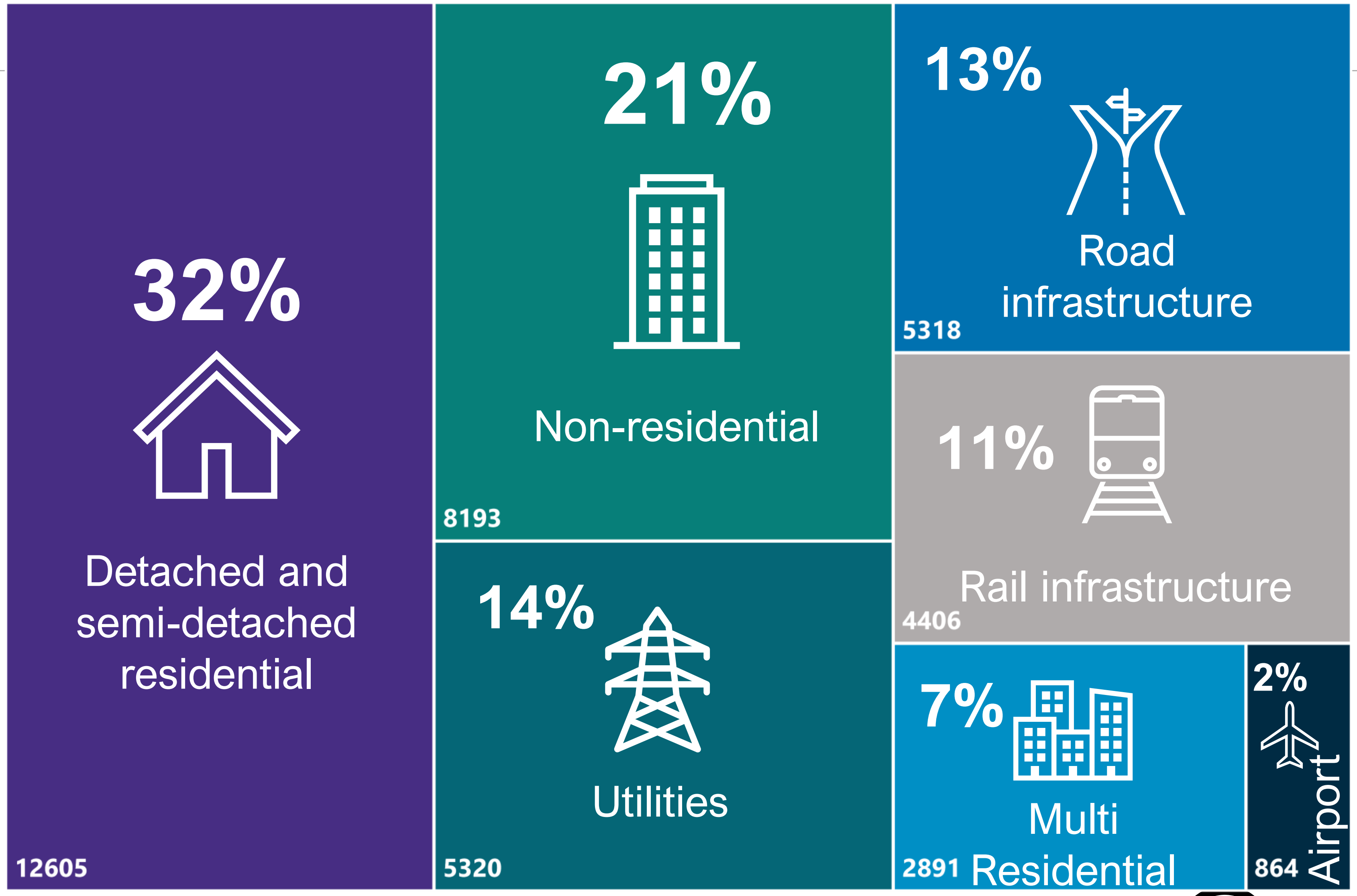
# The policy landscape

| Lifecycle modules | Product A1-A5 | Construction A4-A5 | Use B1-B5 | Operational B1-B6 | End-of-life C1-C4 |
|---|---|---|---|---|---|
| New commercial | Scope 3 | Scope 1, Scope 2, Scope 3 | | Scope 1, Scope 2 | |
| New residential | Scope 3 | Scope 1, Scope 2, Scope 3 | | Scope 1, Scope 2 | |
| New apartments | Scope 3 | Scope 1, Scope 2, Scope 3 | | Scope 1, Scope 2 | |
| Existing commercial | | | Scope 3 | Scope 1, Scope 2 | Scope 3 |
| Existing residential | | | Scope 3 | Scope 1, Scope 2 | Scope 3 |
| Existing apartments | | | Scope 3 | Scope 1, Scope 2 | Scope 3 |
| Emissions profile key | Scope 1 | | Scope 2 | | Scope 3 |

ACT Government

# Housing




kt ($CO_2e$)

Source: Embodied Carbon Projections for Australian Infrastructure and Buildings, Infrastructure Australia,

# Thank you.

**Any questions?**

Suzanne Lavender

Director, Sustainable Building Policy

Environment, Planning and Sustainable Development Directorate

EPSDDBuildingReform@act.gov.au

EBC

Energy in Buildings and
Communities Programme

# Global Status of Embodied / Whole of Life Carbon Requirements in Building Codes


Adam Hinge

Sustainable Energy Partnerships

Tarrytown, New York USA

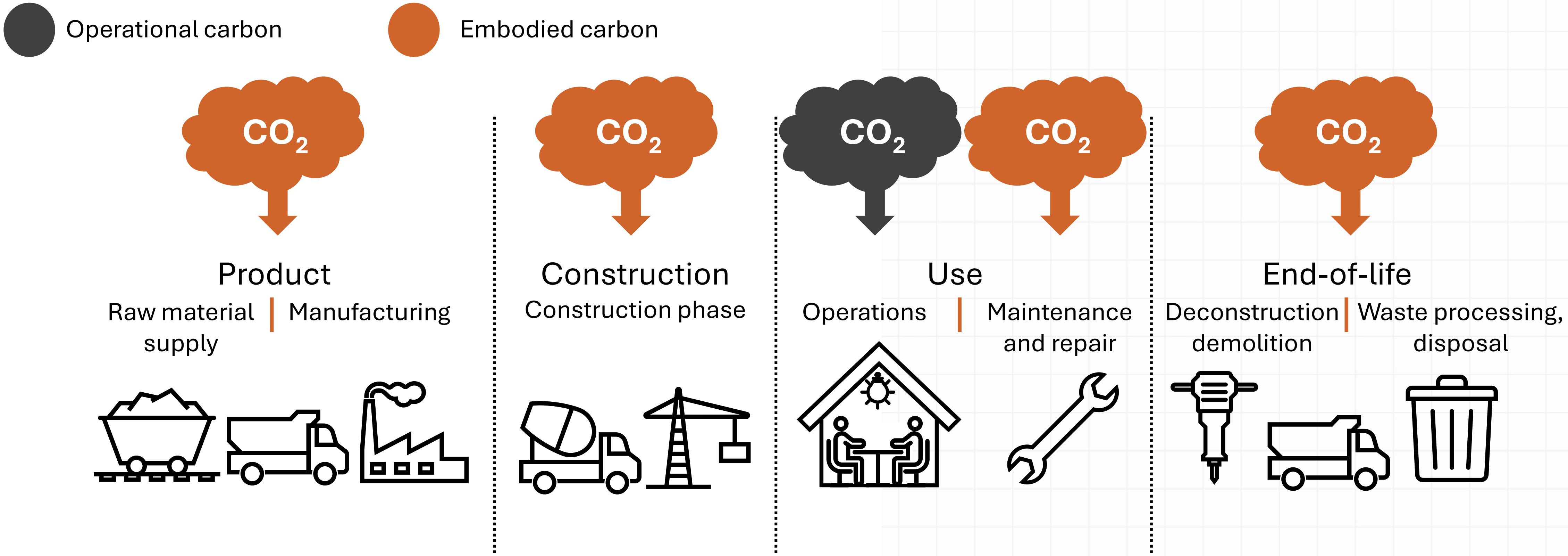
# Rapidly growing policy activity

As BECWG countries and sub-national regions are moving energy codes to lower operational energy use and carbon impact, there is increased awareness and activity around carbon emissions from other parts of building life-cycle.

New policies aimed to address the upfront carbon from building products, construction process, and building end-of-life impacts.

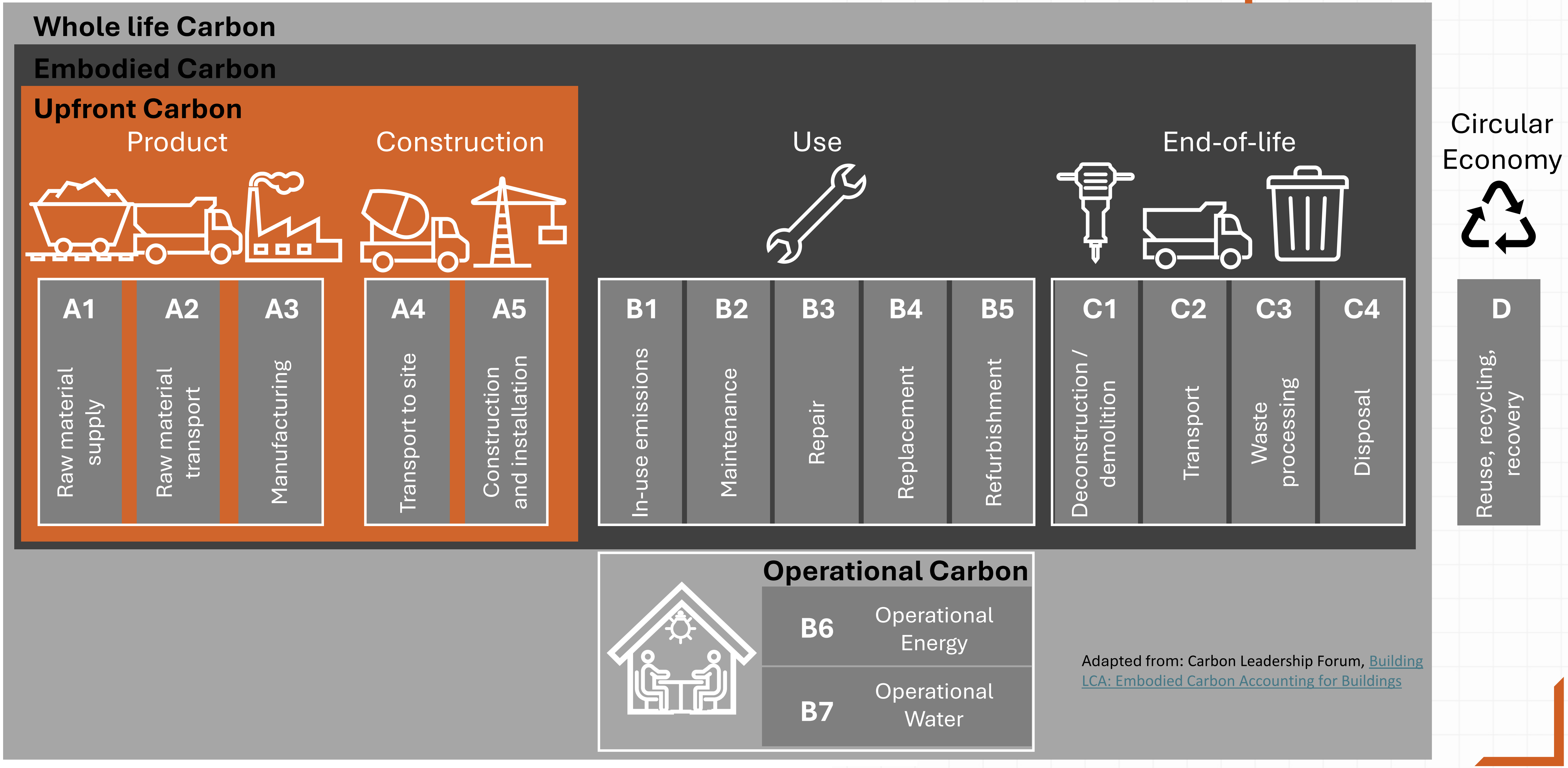
European countries are leading the way, with European EPBD recently adding  requirements that whole life cycle global warming potential be included in energy performance certificates starting in 2028.

# Context: embodied and operational carbon



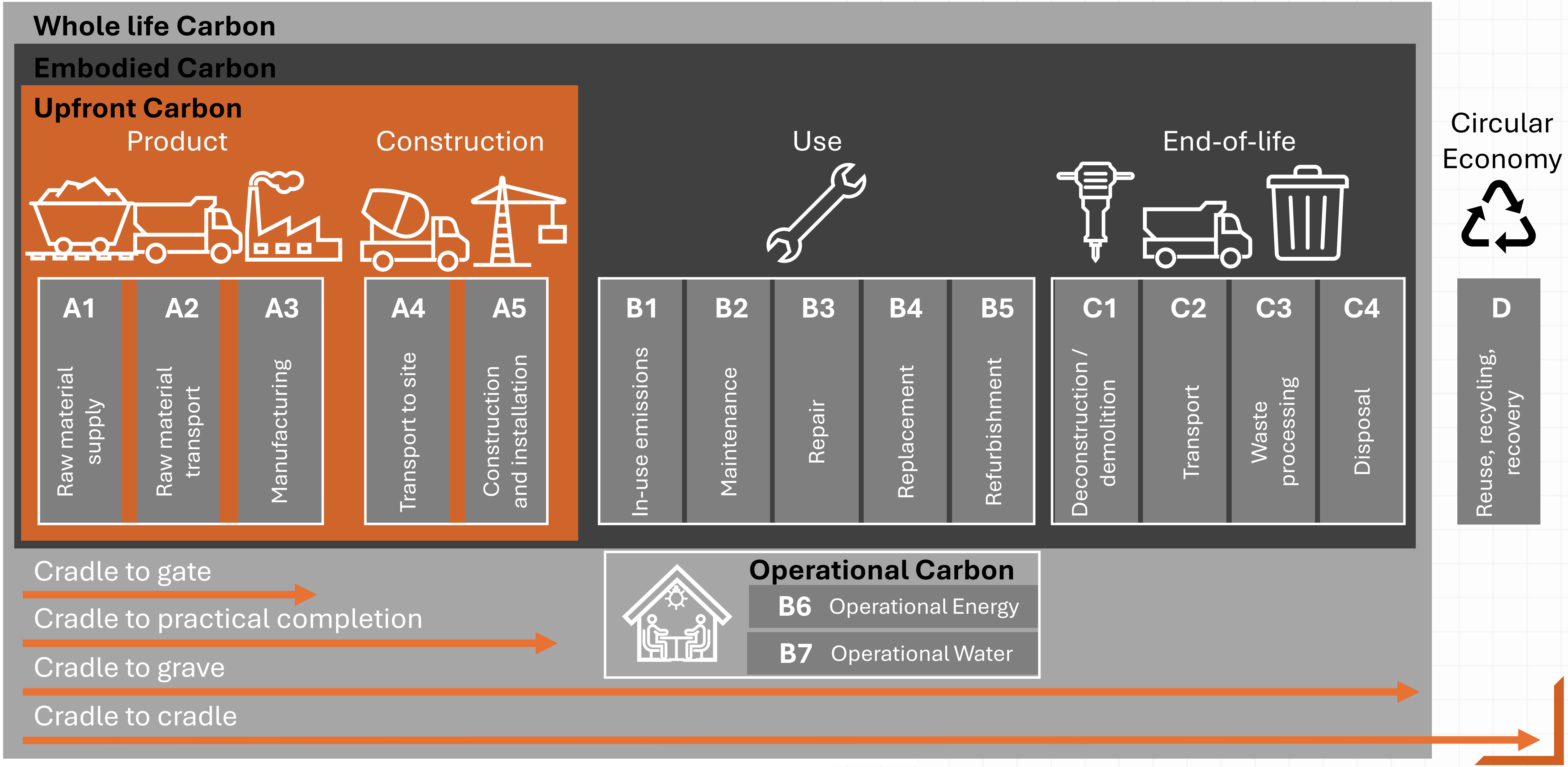

Adapted from: How to establish Whole Life Carbon benchmarks (BPIE)

# Context: Whole life carbon scopes



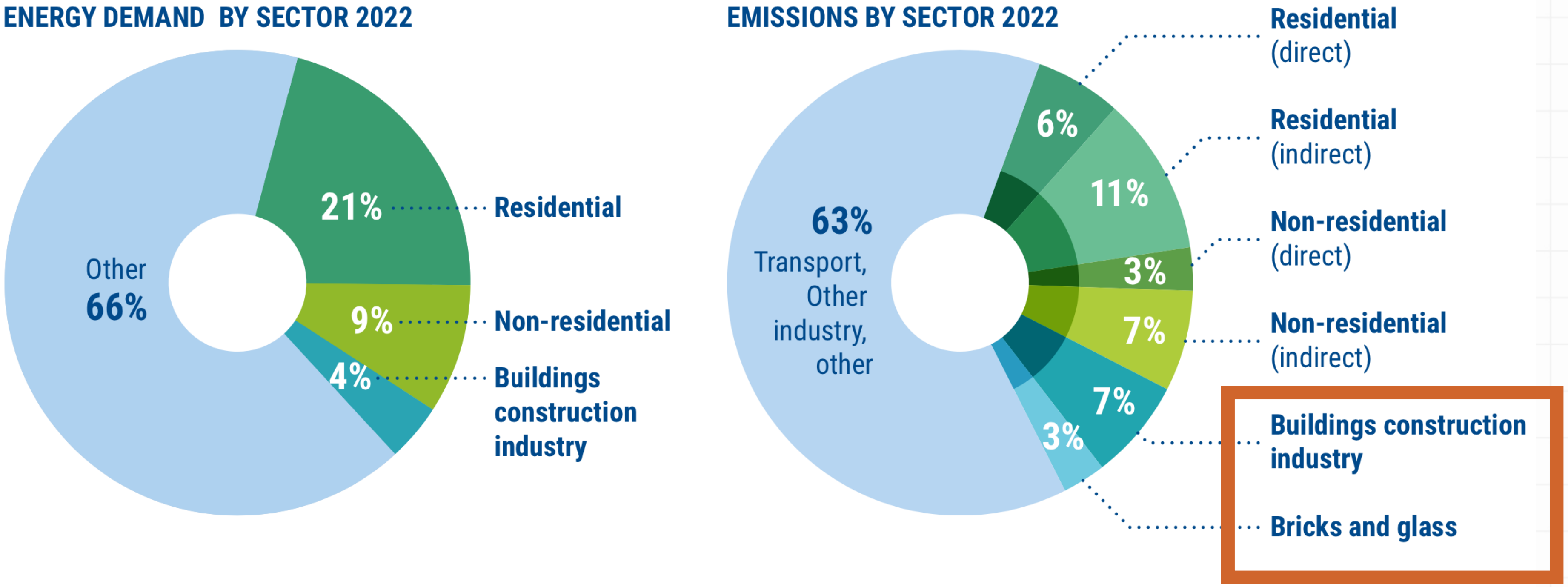

Adapted from: Carbon Leadership Forum, Building LCA: Embodied Carbon Accounting for Buildings

# Context: additional terms



# Why do we care about Embodied/ Whole of Life Carbon?

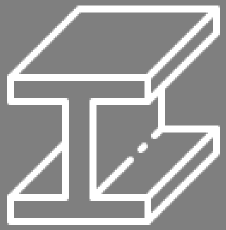
**Figure 1** Share of buildings in total final energy consumptions in 2022 (left) and share of buildings in global energy and process emissions in 2022 (right)




*(Source: IEA 2023a. Adapted from 'Tracking Clean Energy Progress')*

*Notes: Buildings construction industry refers to materials used in construction, including concrete, steel and aluminium. Other materials shown separately.*

# Different types of policies



Reporting/declaration of whole life carbon for some high embodied carbon building materials (concrete, steel, etc.)

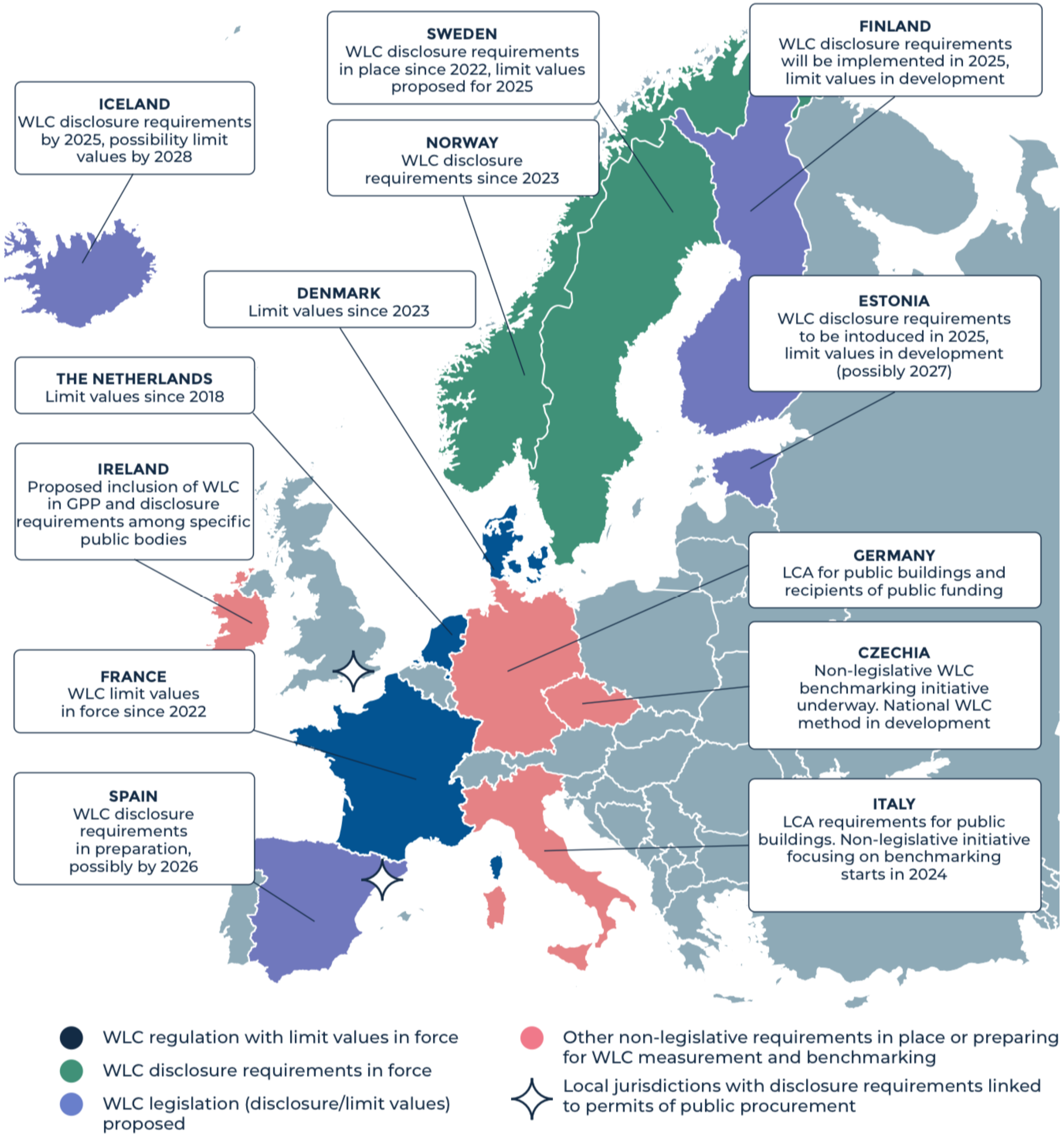
Whole building LCA calculation and reporting

- Sometimes for a subset of buildings to get started

X kg $CO_2e$ / $m^2$

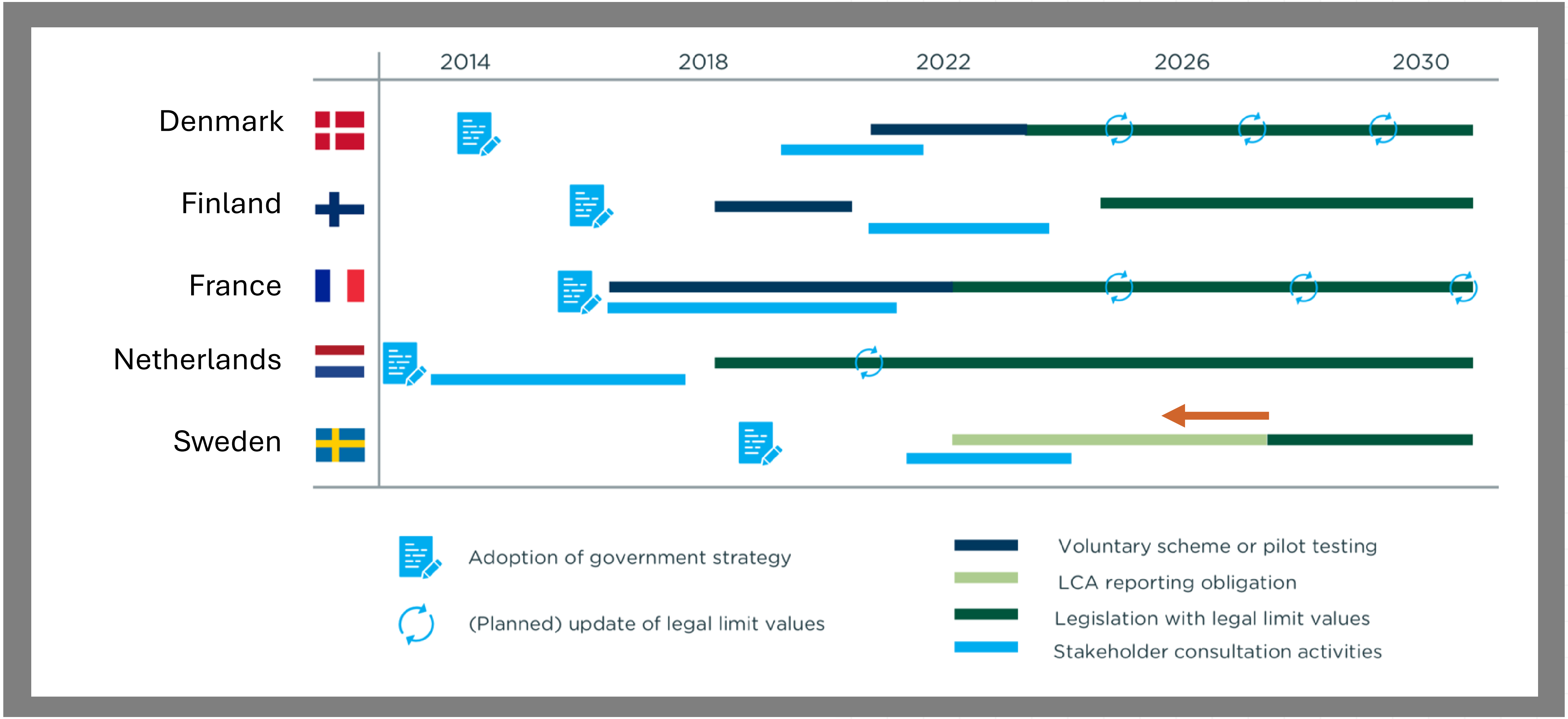
Most stringent: setting limits ("limit values") for whole-life carbon for a building

# Broader overview of European policy activity




Source: How to establish Whole Life Carbon benchmarks (BPIE)

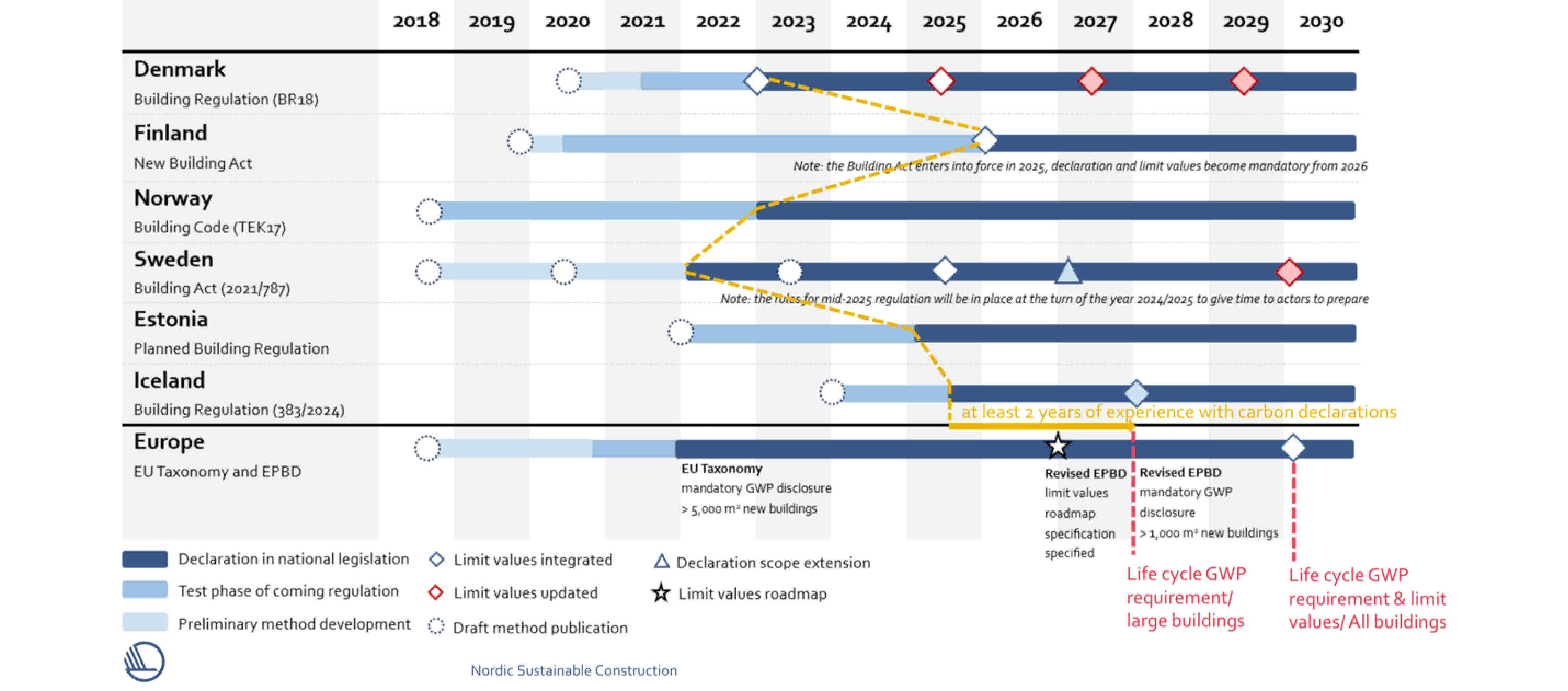
# Where are requirements in place?




From: Whole life carbon models for the EU27 to bring down embodied carbon emissions from new buildings: Review of existing national legislative measures (Ramboll)

# Nordic Initiatives

## Timeline of existing & proposed carbon declaration and limit values integration




From: Decarbonisation of the Nordic Building Stock and Setting Limit Values

# Overview of key features of European policies

| | Denmark | Finland | France | Netherlands | Sweden |
|---|---|---|---|---|---|
| Legal framework | Bæredygtighedsklassen | Ilmastoselvitys | Réglementation environnementale 2020 | Milieuprestatie Gebouwen | Klimatdeklarationen1 |
| Legislative status | In force since January 2023 | Proposed | In force since January 2022 | In force since 2018 | In force (climate declarations) since 2022 Proposed (limit values) |
| Applicability | All new buildings - Limit values only apply to new buildings over 1,000 $m^2$ | All new buildings, except single-family houses (low carbon practice already widespread) | New residential, office and educational buildings | New residential and office over 100$m^2$ | All new buildings with exemptions for some public building |
| Building components | A1-3,<br>B4, B6, C3-4,<br>D (separate) | A1-3, A4-5,<br>B4, C1-4,<br>D | A1-3, A4-5,<br>B1-5, B6, B7, C1-4,<br>D | A1-3, A4-5,<br>B1-4, C1-4,<br>D | A1-A3, A4-A5 |
| LCA modules | Substructure, superstructure, internal finishes and building services | Alignment with building information available at building permit stage in BIM models – Proxy values for technical systems | All components described in the building permit request | Substructure, superstructure, installations | Substructure and superstructure |
| Current legal limit values | From 2023 to 2025:<br>12 kgCO2/m2/year<br>(Revision by 2025) | Under development | Current limit values for embodied impacts:<br>640 kgCO2/m2 (SFH)<br>740 kgCO2/m2 (MFH) | Residential:<br>0.8 EUR/m2/year<br>Offices:<br>1 EUR/m2/year | To be developed before 2027 (now to be implemented by mid-2025) |

Adapted from: Whole life carbon models for the EU27 to bring down embodied carbon emissions from new buildings (Ramboll)

# Creating Regulation: Key Steps to Consider

### 1. Build up competence

- Learning resources adapted to national contexts
- Certification schemes to foster competition

### 2. Secure stakeholder involvement

- Balance current readiness with future requirements
- Monitoring and revisiting regulation

### 3. Ensure access to generic data and standard values

- Phasing out of the conservativity factor in generic data
- Use of standard component values for as-built reporting
- Alignment of structure and content of databases

### 4. Improve availability and digitization of EPDs

- Subsidies or automated tools designed to generate EPDs

### 5. Create a case basis and structure for the limit values

- Real case sample for feasible limit values
- Need for differentiation of limit values

### 6. Determine the initial scope and method

- Start with limited scope
- Need to highlight upfront carbon reduction

### 7. Establish a suggested limit value pathway

- Incremental implementation of methods and limit values
- Impact assessments to support gradual expansion

### 8. Expand the regulation to renovations

- Avoid creating burdens for renovations with enviro-benefits
- Develop a harmonised approach

Adapted from: Decarbonisation of the Nordic Building Stock and Setting Limit Values (Nordic Sustainable Construction)

# Whole Life Carbon Regulatory Aspects

| WLC methodology aspects | WLC disclosure requirements and limit values | Compliance / governance regime | Links to policy instruments | Central collection/ public | Reporting and aggregation |
|---|---|---|---|---|---|
| Design features | Building typology covered<br>Functional unit (per capita/ m2, embodied/ operational separate or combined)<br>Reduction pathways / timeline (optional, with limit) | Reporting stage (permit, as-built)<br>Compliance control regime (% checked)<br>Third-party verification (yes/no) | Energy Performance Certificates<br>Digital Building Logbooks | Central collection of cases<br>Ability to statistically analyse WLC data<br>Link WLC data with policymaking / evaluation | Timeline for revision and evaluation |

Adapted from: How to establish Whole Life Carbon benchmarks (BPIE)

# Design Features of Existing Whole Life Carbon Regulations

**Scope:**
Building type and size
What building types?

**Study Period:**
Usually 50 years
NL 75 for residential

**Reporting templates**
Specified template?
Part of permitting?

**Scenario assumptions:**
Grid decarbonization, biogenic carbon

**Static vs dynamic**
Include LULUC impacts & carbon storage benefits?

**WLC metric**
Often total life cycle GHG emissions (kgCO2eq/m2/yr)

**Building elements**
Include substructure?
What other elements?

**Life cycle modules**
Just A1-A3?
A4-A5, B1-B7, C1-C4?

**Calculation tools**
What tools allowed/required?

**Databases**
Data sources and default values

Adapted from: How to establish Whole Life Carbon benchmarks (BPIE)

## Forthcoming BECWG report: *International Review - Mandatory Whole of Life/ Embodied Carbon Requirements in Building Codes*

Research underway now – working draft outline of report available for comments.

If new mandatory policy in development in your country or region, please let us know.

- Draft report for review expected January 2025; will be distributed to the BECWG for comments
- Final report expected to be published Q2 2025

# Plan to address:

- Overview of different types of Whole of Life/Embodied Carbon policies
- Summary of policies in leading jurisdictions, including France, Netherlands, Nordic Countries
- Public sector requirements in California, Singapore, Ireland, and mandatory procurement rules/policies
- Lessons learned in leading countries/regions

# Questions?

## Follow-up for more information:
## Adam Hinge: hingea@aol.com

**Key References:**

Carbon Leadership Forum, Building LCA: Embodied Carbon Accounting for Buildings
https://carbonleadershipforum.org/download/987497178

Comparing differences in building life cycle assessment methodologies
https://brandcentral.ramboll.com/share/Xq3jpUKSqvPu5dpmRaD

Decarbonisation of the Nordic Building Stock and Setting Limit Values
https://www.nordicsustainableconstruction.com/Media/638617274520986470/Decarbonisation%20of%20the%20building%20stock%20september%202024.pdf

Global Alliance on Buildings & Construction 2024 Global Status Report
https://wedocs.unep.org/bitstream/handle/20.500.11822/45095/global_status_report_buildings_construction_2023.pdf

How to establish Whole Life Carbon benchmarks (BPIE)
https://www.bpie.eu/wp-content/uploads/2024/09/How-to-establish-whole-life-carbon-benchmarks_final.pdf

Whole life carbon models for the EU27 to bring down embodied carbon emissions from new buildings: Review of existing national legislative measures
https://7520151.fs1.hubspotusercontent-na1.net/hubfs/7520151/RMC/Content/Whole-life-carbon-models-Review-of-national-legislative-measures.pdf

# Whole Life Carbon Requirements in Building Regulations – Experiences from Denmark

**PostDoc Maria Balouktsi**
Harpa Birgisdottir
Aalborg University & Annex 89

BUILD

EBC Energy in Buildings and Communities Programme

BUILD BYGGERI, BY OG MILJØ AALBORG UNIVERSITET

# 12 YEARS OF FOCUS ON BUILDING LCA IN DENMARK

**2011-2012**
Green Building Council Denmark
DGNB certification incl. LCA on buildings

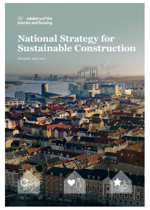
**2014**
The Danish Government:
Political strategy for buildings with
Vision for a Voluntary Sustainability Class in the Building Code

**2015**
National LCA-tool LCAbyg launched in April 2015
Several publications


**LCAbyg**

**2020**
The Danish Government: Voluntary Sustainability Class
Industry Climate partnership: Recommendations to the government

**2021**
The Danish Government:
National strategy for sustainable construction



# Report from BUILD (2020): Whole Life Carbon Assessment of 60 Danish Buildings

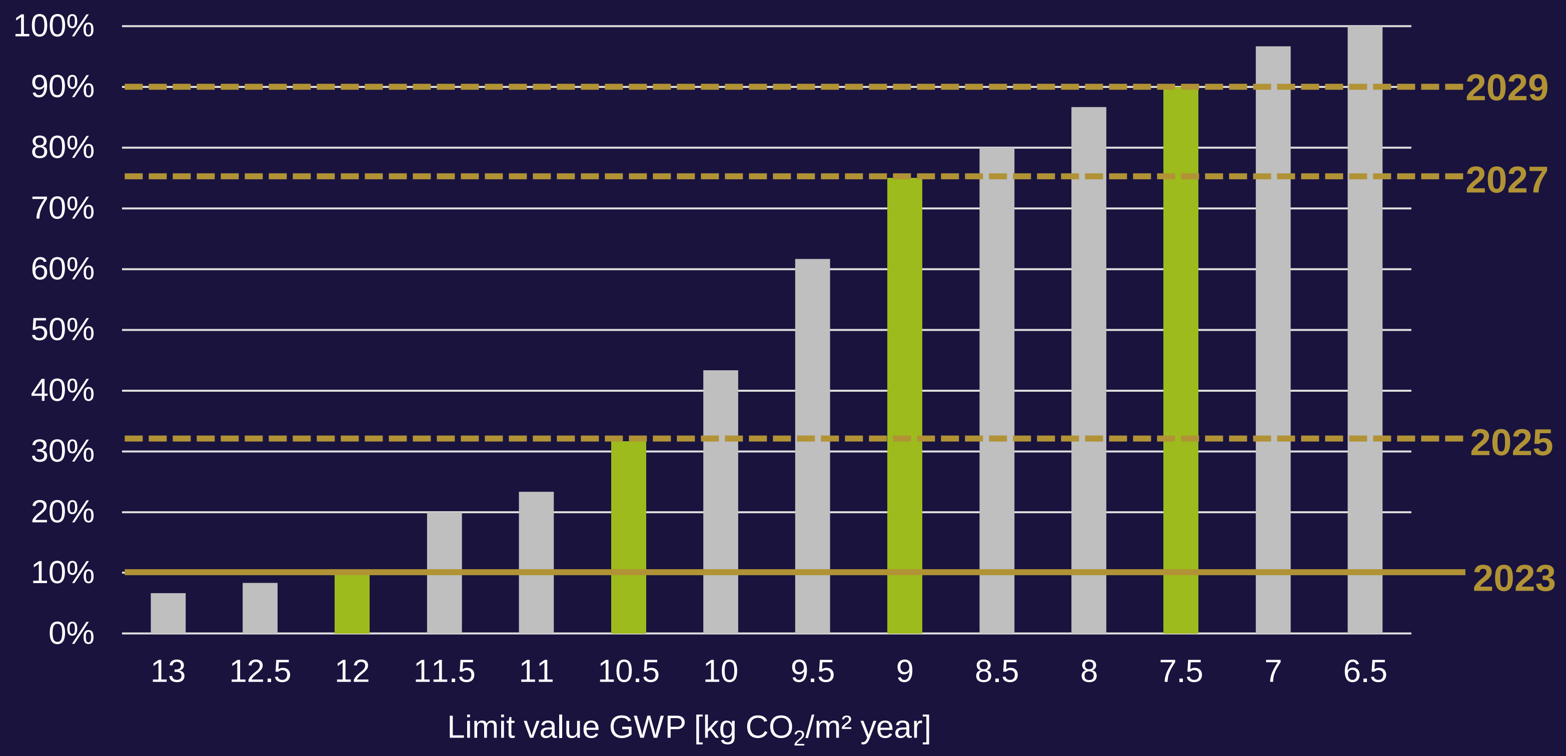

## Purpose

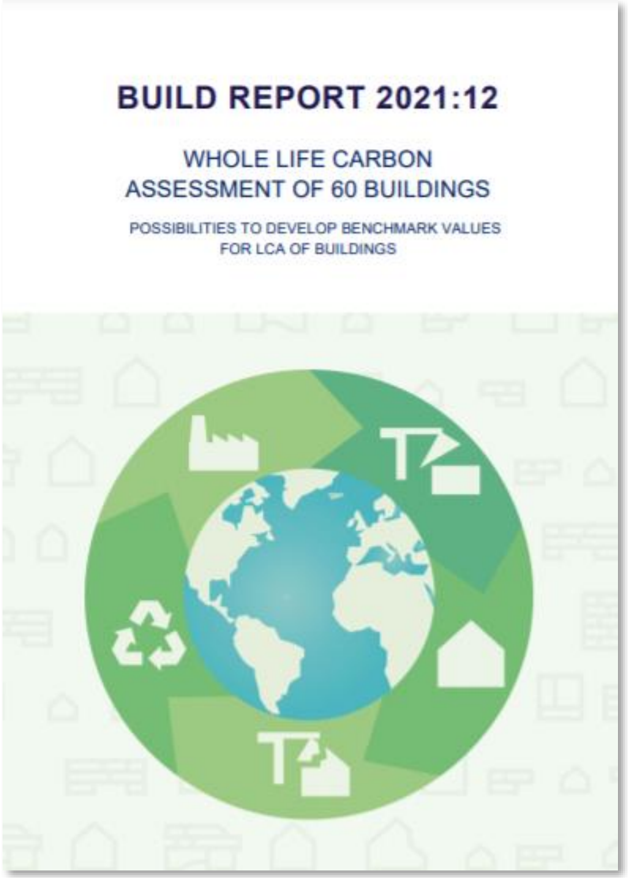
- ❖ To establish sufficient data background on the climate impact of buildings in Denmark over their life cycle.
- ❖ On the basis of this, possible reference values were calculated and suggested

# LIMIT LEVELS AGREEMENT (2021)

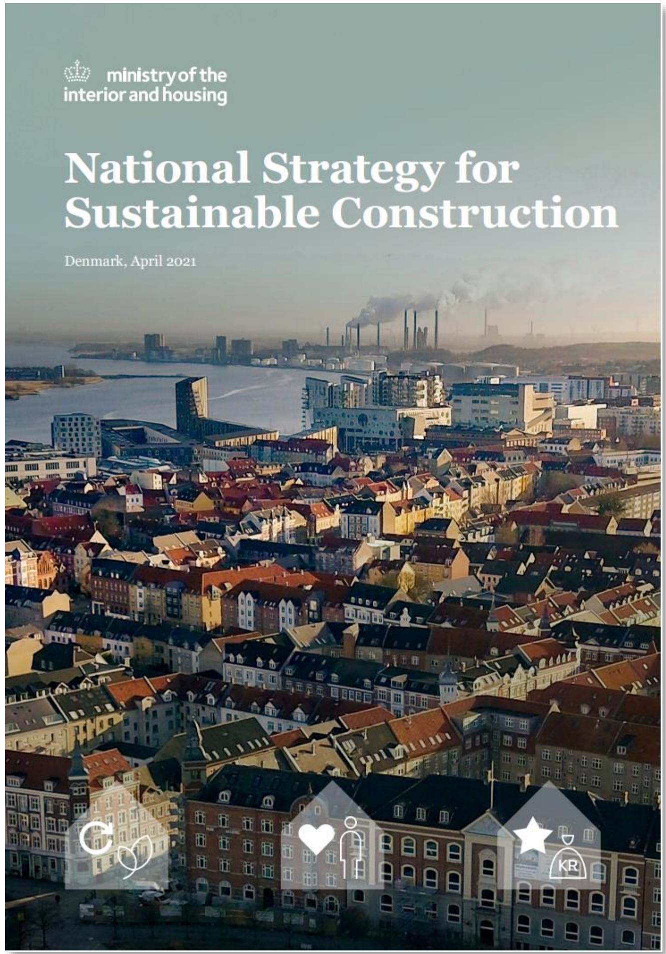
Initial roadmap for carbon limit levels.

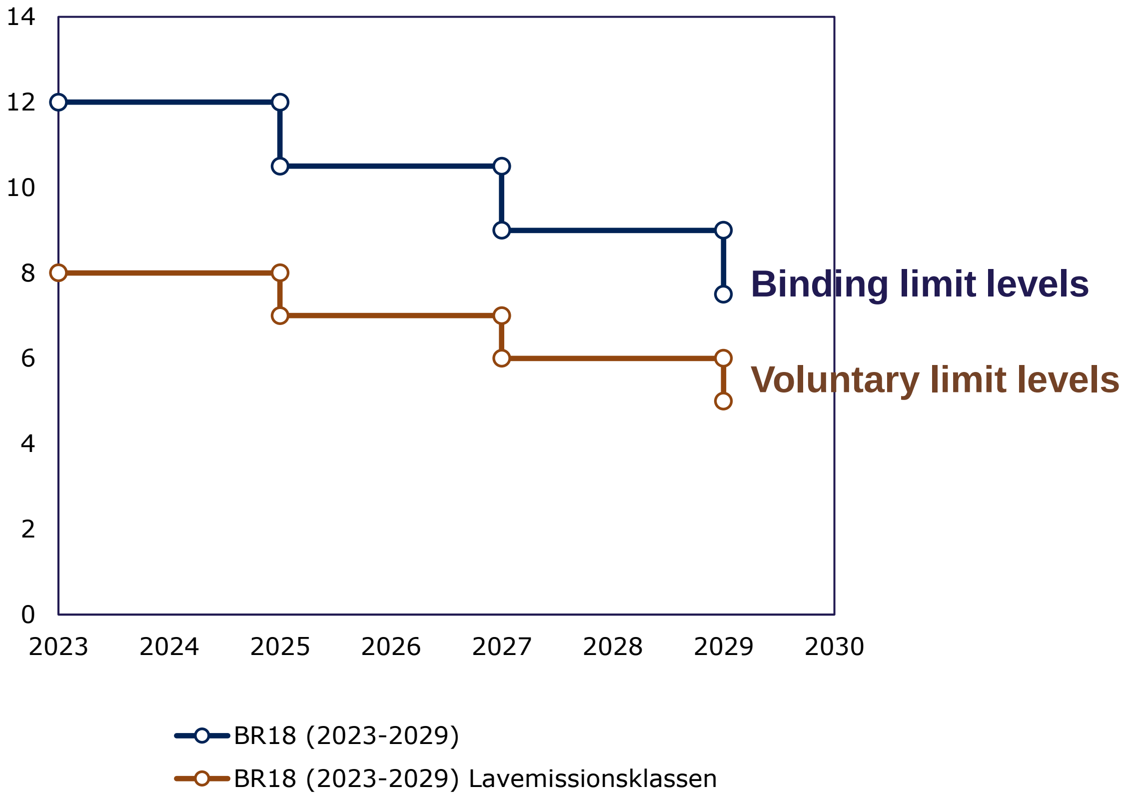
Given as the share of new buildings, which will exceed the limits.

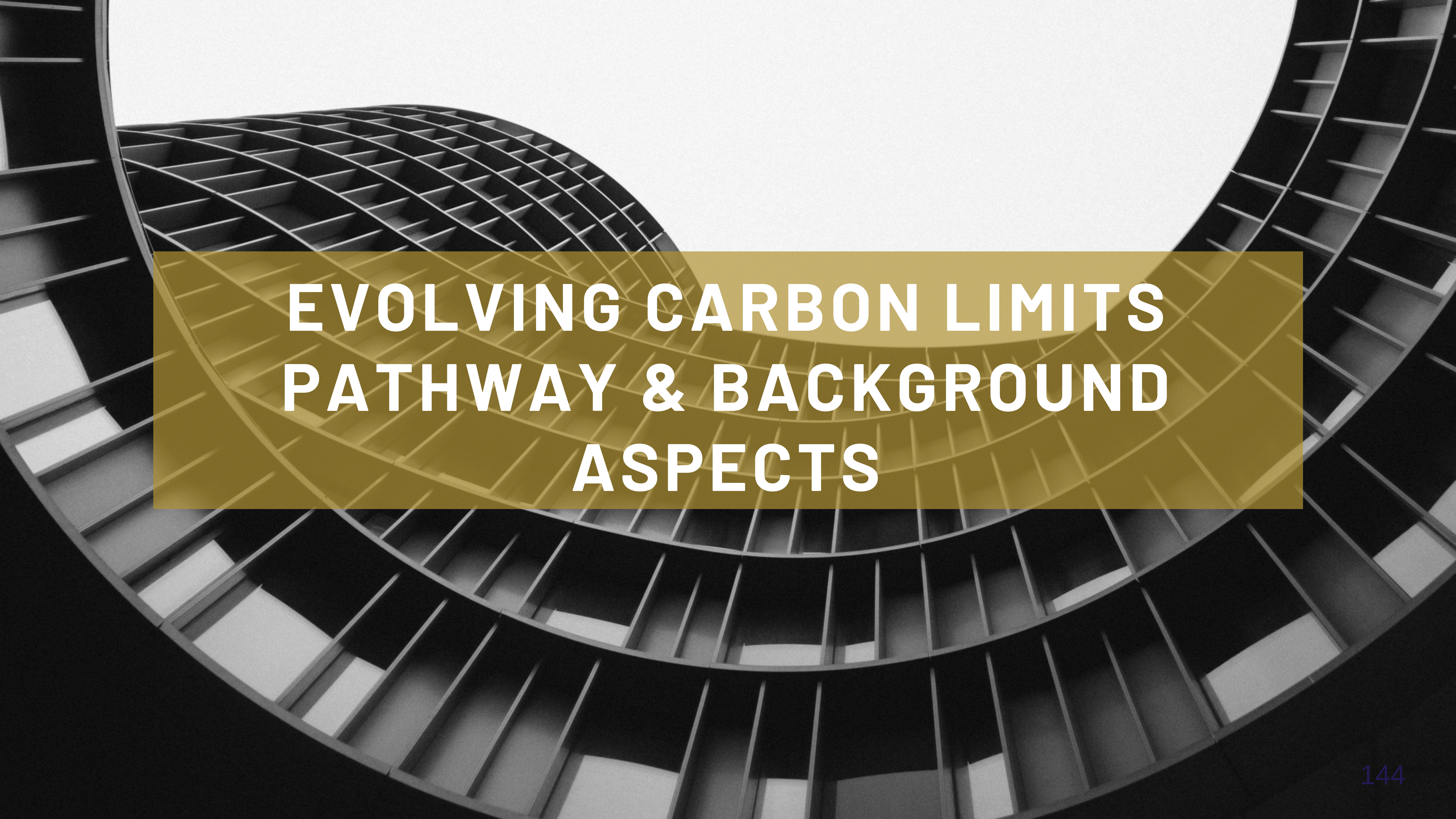


# Climate requirements for new construction in the National Strategy for Sustainable Construction from 2021





# EVOLVING CARBON LIMITS PATHWAY & BACKGROUND ASPECTS

# Updated Climate Requirements Pathway and Scope (Updated in 2024)

## January 2023

**1/10 buildings to perform better**

New buildings over 1000 m² GFA

- One universal carbon limit
- Scope: A1-A3, B4, B6, C3-C4

All new buildings subject to energy requirements

Module D also declared separately

**12 kg$CO_2$e/(m² yr.)**

## July 2025

**Avg.: 7.1 kg$CO_2$e/(m² yr.)**

**17/20 buildings to perform better**

New buildings/ Extensions over 50 m² GFA

- Building type differentiated carbon limits
- Scope: A1-A3, B4, B6, C3-C4

**1/2 construction sites to perform better**

Independent limit value for constr. process (A4-5)

## By mid 2027

Avg.: 6.4 kg$CO_2$e/(m² yr.)

~ 10% ↓

Potential extension to further modules following European developments

## By mid 2029

Avg.: 5.8 kg$CO_2$e/(m² yr.)

~ 10% ↓

limit value | carbon declaration

AALBORG UNIVERSITY

# Summary of Main Developments in Scope After Initial Implementation

## FIRST IMPLEMENTATION

**Buildings included**
Only larger buildings
(57% of the new stock)

**Universal carbon limits**
Based on 60 cases, not showing systematic variation

**Life cycle system boundary**
Limit value: A1-3, B4, B6, C3-4

Expansion at various levels

## 2025 IMPLEMENTATION

**Buildings included**
Large share of new buildings, even summer houses and some extensions
(68% of the new stock)

**Differentiated carbon limits**
Based on 165 representative, showing systematic variation

**Life cycle system boundary**
Limit value 1: A1-3, B4, B6, C3-4
Limit value 2: A4-5

# PRECONDITIONS FOR FACILITATING THE INTRODUCTION OF LIMIT VALUES AND SMOOTH IMPLEMENTATION

# Competences

**National initiatives**

- ✓ Voluntary schemes (DGNB, VSC)
- ✓ Active knowledge centre, trainings, events

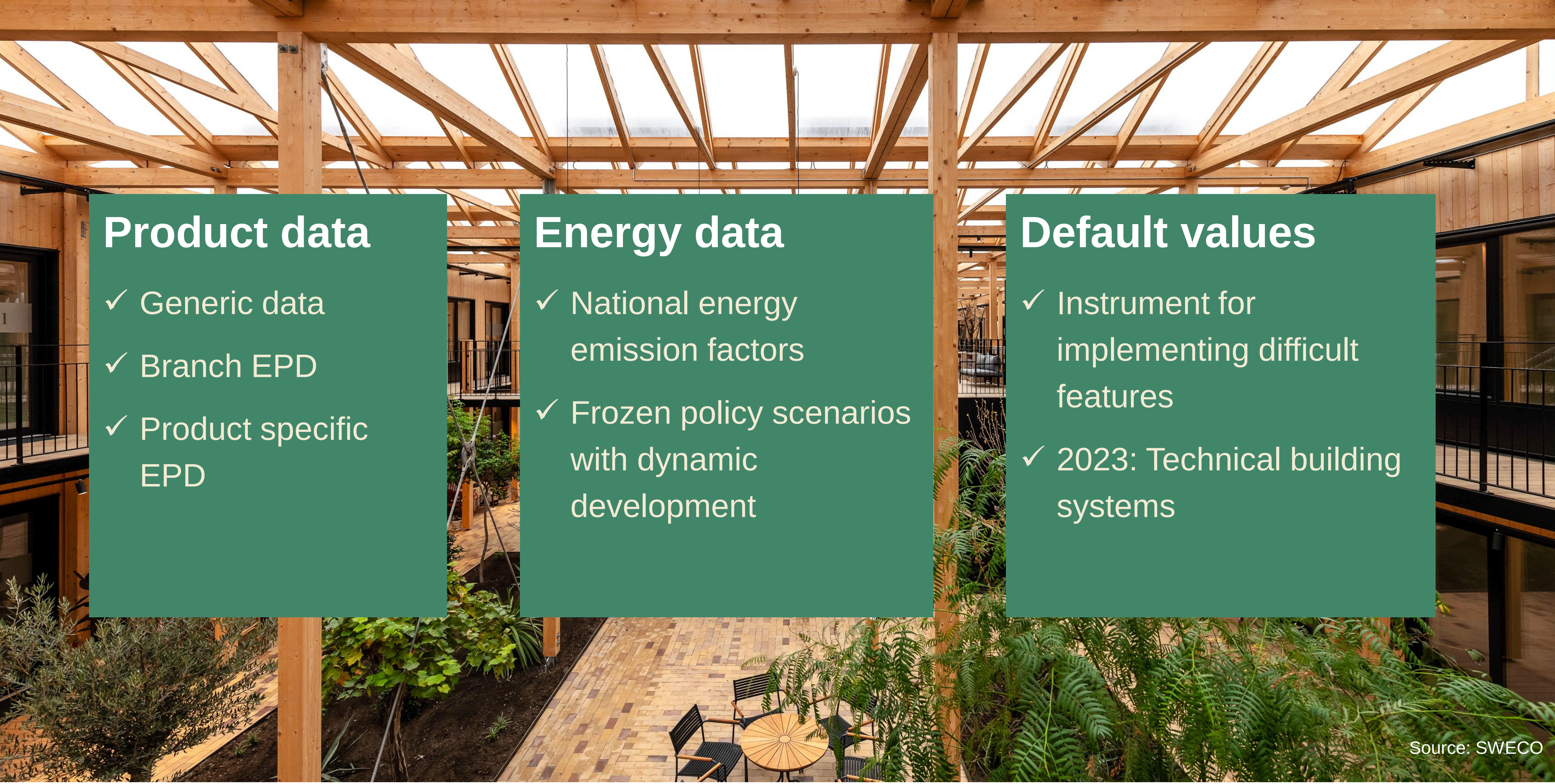
**International cooperation and harmonization**

- ✓ Nordic sustainable construction
- ✓ Annex 89 – Ways to net-zero WLC buildings

# LCA tool

- ✓ Pivotal for stakeholder readiness
- ✓ Free
- ✓ User-driven development
- ✓ Now multiple tool providers

AALBORG UNIVERSITY



## Product data

- ✓ Generic data
- ✓ Branch EPD
- ✓ Product specific EPD

## Energy data

- ✓ National energy emission factors
- ✓ Frozen policy scenarios with dynamic development

## Default values

- ✓ Instrument for implementing difficult features
- ✓ 2023: Technical building systems

Source: SWECO

# Ongoing Knowledge Development About New Construction

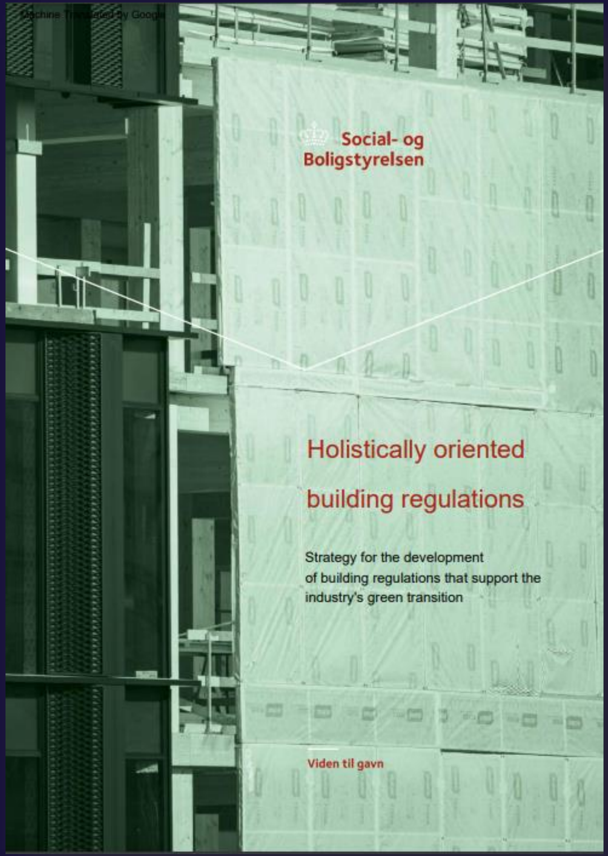
New research out now that examines:
Resource consumption on the construction site

Climate impact from new construction forms the analytical basis for the determination of the limit value in BR18 from 2025

Climate impact from life cycle modules that are not included in BR18 right now and investigates what impact they have on the climate impact of new construction.

# NEXT STEP: FOUR THEMES FOR BASIC REVISION OF THE BUILDING REGULATION (2024-2028)

Ongoing Implementation in Response to Stricter Climate Regulations Requires a Holistic Approach





1: **Balanced technical requirements for new construction's safety, health, energy consumption and climate impact** to support new building practices.

2: **Adapted and simplified technical requirements for building renovation and repurposing** to better use existing building stock

3: **Simplified process for approving construction cases**: Coordination of requirements for municipal construction case processing and the certification schemes

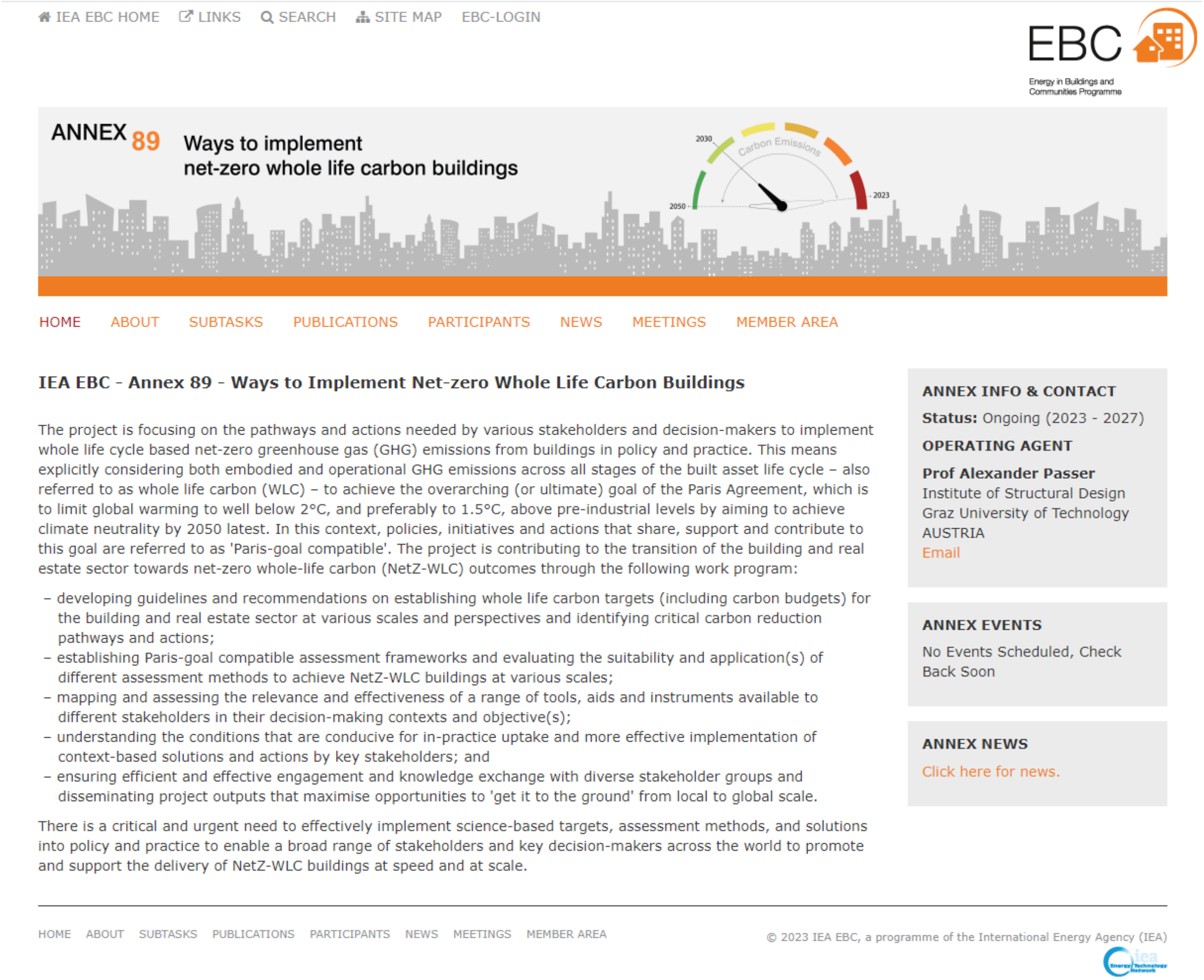
4: **Support of industry and municipalities in the use of digital processes and tools**. E.g. standardized digital reporting template

# Concluding Remarks

- While Denmark offers valuable insights, its approach to carbon limits may not be directly applicable in other countries due to differing contexts, resources, and regulatory environments

- Ongoing Annex 89 research: **International Mapping of Best Practice Policy Instruments Supporting Buildings Whole Life Cycle Decarbonization**

- Aim: collect experiences from different contexts, identify what works and what doesn't



IEA EBC HOME   LINKS   SEARCH   SITE MAP   EBC-LOGIN

EBC
Energy in Buildings and Communities Programme

ANNEX 89 Ways to implement net-zero whole life carbon buildings

HOME   ABOUT   SUBTASKS   PUBLICATIONS   PARTICIPANTS   NEWS   MEETINGS   MEMBER AREA

**IEA EBC - Annex 89 - Ways to Implement Net-zero Whole Life Carbon Buildings**

The project is focusing on the pathways and actions needed by various stakeholders and decision-makers to implement whole life cycle based net-zero greenhouse gas (GHG) emissions from buildings in policy and practice. This means explicitly considering both embodied and operational GHG emissions across all stages of the built asset life cycle – also referred to as whole life carbon (WLC) – to achieve the overarching (or ultimate) goal of the Paris Agreement, which is to limit global warming to well below 2°C, and preferably to 1.5°C, above pre-industrial levels by aiming to achieve climate neutrality by 2050 latest. In this context, policies, initiatives and actions that share, support and contribute to this goal are referred to as 'Paris-goal compatible'. The project is contributing to the transition of the building and real estate sector towards net-zero whole-life carbon (NetZ-WLC) outcomes through the following work program:

- developing guidelines and recommendations on establishing whole life carbon targets (including carbon budgets) for the building and real estate sector at various scales and perspectives and identifying critical carbon reduction pathways and actions;
- establishing Paris-goal compatible assessment frameworks and evaluating the suitability and application(s) of different assessment methods to achieve NetZ-WLC buildings at various scales;
- mapping and assessing the relevance and effectiveness of a range of tools, aids and instruments available to different stakeholders in their decision-making contexts and objective(s);
- understanding the conditions that are conducive for in-practice uptake and more effective implementation of context-based solutions and actions by key stakeholders; and
- ensuring efficient and effective engagement and knowledge exchange with diverse stakeholder groups and disseminating project outputs that maximise opportunities to 'get it to the ground' from local to global scale.

There is a critical and urgent need to effectively implement science-based targets, assessment methods, and solutions into policy and practice to enable a broad range of stakeholders and key decision-makers across the world to promote and support the delivery of NetZ-WLC buildings at speed and at scale.

**ANNEX INFO & CONTACT**
**Status:** Ongoing (2023 - 2027)
**OPERATING AGENT**
**Prof Alexander Passer**
Institute of Structural Design
Graz University of Technology
AUSTRIA
Email

**ANNEX EVENTS**
No Events Scheduled, Check Back Soon

**ANNEX NEWS**
Click here for news.

HOME   ABOUT   SUBTASKS   PUBLICATIONS   PARTICIPANTS   NEWS   MEETINGS   MEMBER AREA

© 2023 IEA EBC, a programme of the International Energy Agency (IEA)

# Embodied carbon data and whole lifecycle carbon requirements in building codes

**Thomas Lützkendorf**
KIT Karlsruhe & BEU Weimar, Germany – ST1, IEA EBC Annex 72
Greg Foliente
University of Melbourne, Australia – ST1, IEA EBC Annex 89

# Buildings Breakthrough & Paris Forum 2024

## Building and Climate Global Forum with Dèclaration de Chaillot



The ministerial declaration aims to create momentum for buildings decarbonisation and climate resilience by reinforcing international collaboration and making calls for commitments, both from governments and state and non-state actors in the building and construction sectors.

“The central role of the buildings sector in GHG emissions reduction, and the importance of adaptation for human settlements.

The need to implement sound policies and actions to avoid lock-in effects:

- to **drastically and systematically decrease GHG emissions from existing and new buildings**;
- to enhance carbon uptake and storage in the urban environment;
- to **adapt existing and new buildings** to current and future climate change.”

Ministers of participating countries gathered in Paris, France - on 7 and 8 March, 2024 - for the first “Buildings and Climate Global Forum”, and calling for further endorsements.

FORUM MONDIAL
BÂTIMENTS ET CLIMAT
BUILDINGS AND CLIMATE
GLOBAL FORUM

# Context

## The role and position of WLC assessment



- Overall assessment of buildings including technical and functional aspects
    - Sustainability assessment of buildings
        - Environmental performance assessment of buildings
            - **Whole life carbon assessment (carbon performance assessment)**
                - Embodied carbon assessment
                    - Upfront emission assessment

# WLC assessment

## Extending the system boundaries



**Primary energy demand**

(renewable/non renewable)

… in operation

… in whole life cycle based on life cycle model

**Greenhouse gas emissions**

Biogenic carbon content

Use of primary raw materials

…

**Key is describing / specifying performance targets / outcomes (at different levels <building vs product> & phases)… then data follows**

# WLC assessment

## The role of building energy codes

ANNEX 89 EBC

**Embodied carbon**

**Operational carbon**

***Building Energy Codes***

***Energy Performance Certificate***

Low / nearly / near / .. zero energy building

**Low / nearly / near / net … zero GHG emission building**

# WLC assessment

## Codes in Europe at building level

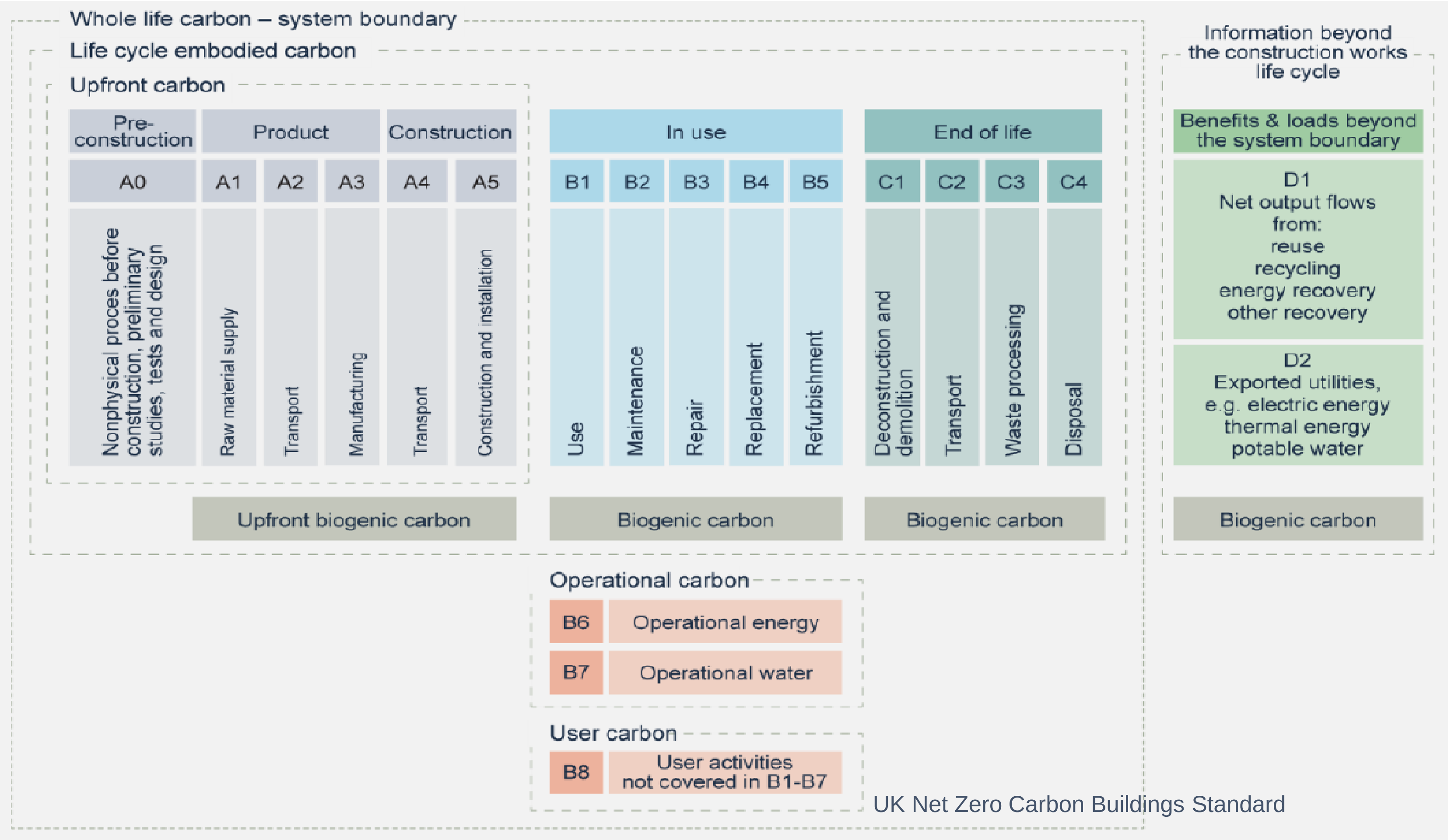
- Energy Performance of Buildings Directive by European Commission including requirements for WLC-calculation and reporting
- Delegated Act for WLC calculation rules by European Commission (in preparation for 2025)
- EN 15978 Environmental performance assessment including WLC assessment (in preparation for end of 2024)

---

- *Specific approaches in member states (diverse examples)*

# WLC asessment

## System boundaries and modules, based on EN 15978



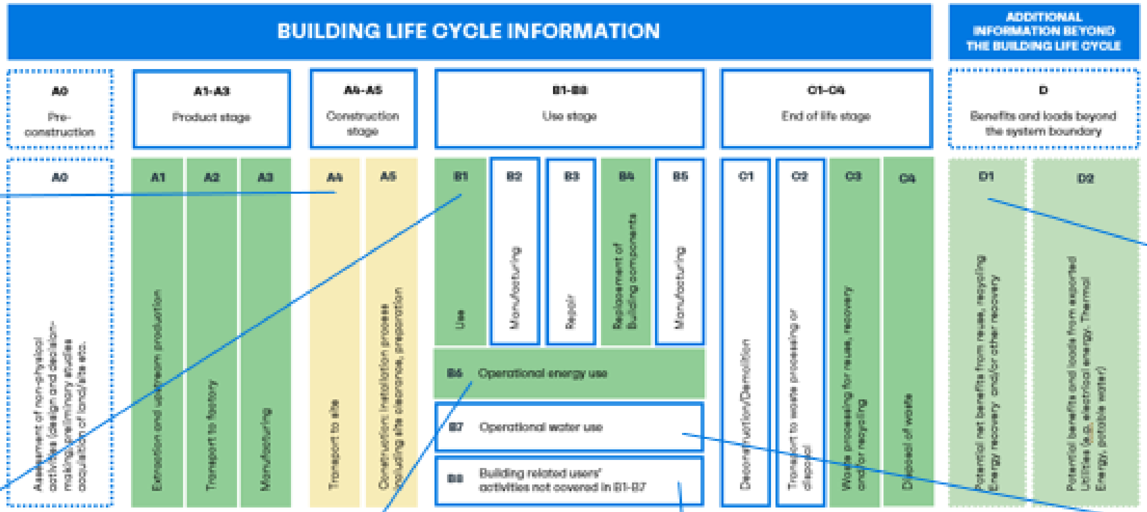

UK Net Zero Carbon Buildings Standard

The introduction of the "biogenic carbon content" indicator creates an additional need for data for construction products. This also applies to information on refrigerants used – see next slide.

# WLC assessment



## Modules – the next level of detail – following draft for EN 15978




**A5.1**: Pre-construction demolition

**A5.2**: Construction activities

**A5.3**: Waste and waste management

**A5.4**: Transport of construction workers

**B1.1**: Emissions from materials and carbonation

**B1.2**: Fugitive emissions of refrigerants

**B6.1**: Regulated* building-integrated systems (services)

**B6.2**: Non-regulated* building-integrated systems (services)

**B6.3**: Other energy use related to building user activities

**D1.1**: Reuse

**D1.2**: Recycling

**D1.3**: Energy recovery

**B7.1**: Essential building-integrated systems

**B7.2**: Other building-integrated systems

**B7.3**: Non-building-integrated systems

**B8.1**: Transport of persons to and from the building

**B8.2**: Charging of electric vehicles within the building site

**B8.3**: Others, such as use of "consumables" like paper for offices, or furniture and equipment not fixed to the building

# WLC assessment

## Data needs

ANNEX 89 EBC

**Embodied carbon**

- LCA-data for construction products
- LCA-data for transports
- LCA-data for construction processes
- Expected service lives of components
- Emissions factors for coolant's

- *Biogenic carbon content of products*

**Operational carbon**

- Emission factors for types of energy
- Factors for potentially avoided emissions

**As before, key is defining performance targets / outcomes… then data follows (with matching definition & units)**

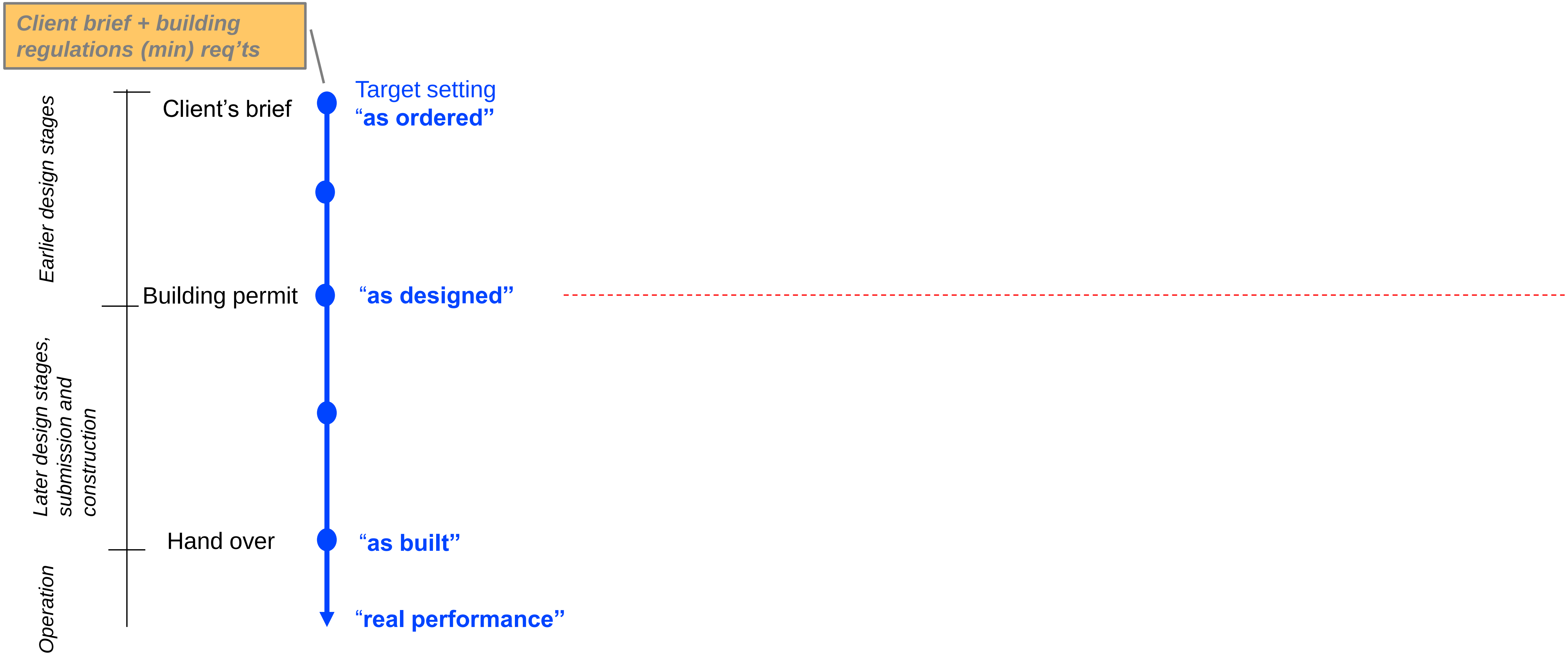
# WLC assessment

## Types of data for construction products

| Types of data | Level of detail |
|---|---|
| ❖ Generic data | ❖ $GWP_{100}$, total |
| ❖ Average data based on sector EPD's (with range) | |
| ❖ Product-specific data based on EPD's | ❖ *$GWP_{100}$, fossil* |
| ❖ Project-specific data based on manufacturer information | ❖ *$GWP_{100}$, biogenic* |
| | ❖ *$GWP_{100}$, luluc* |
| ❖ *System EPD's for building components* | |
| ❖ *EPD's with configurator included for complex products* | ❖ *Biogenic carbon content* |
| ❖ *Sample solution for EPDs, offered by industry association* | |

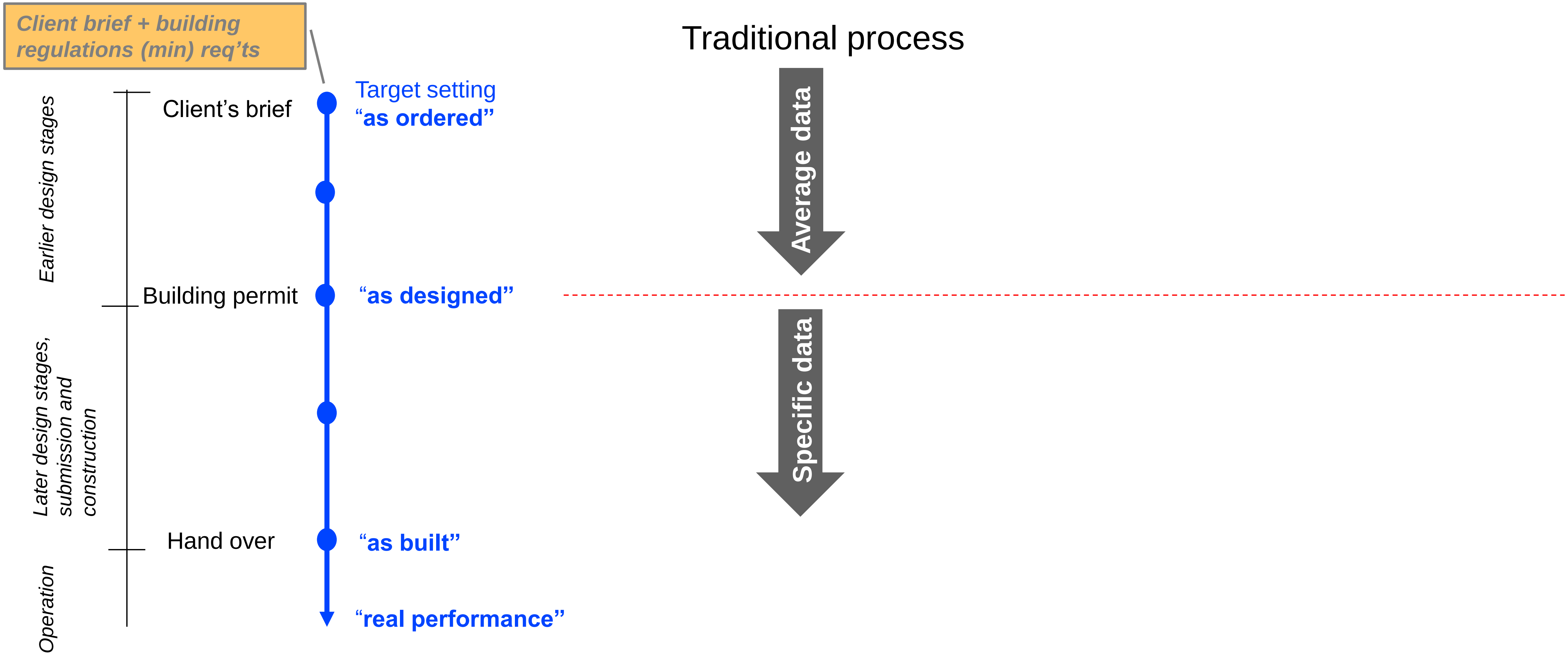
# WLC assessment

## Integration into process of design and decision making – data needs



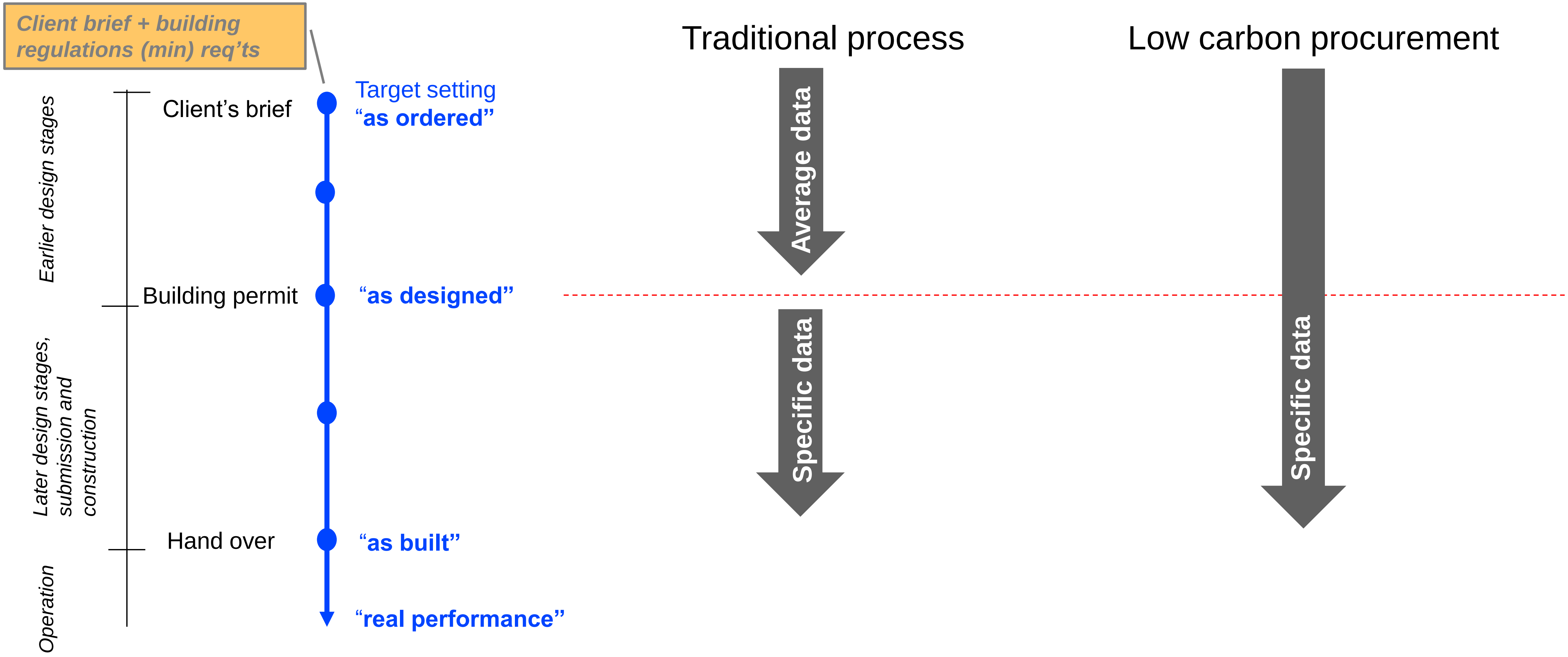
# WLC assessment

## Integration into process of design and decision making – data needs



# WLC assessment

## Integration into process of design and decision making – data needs



# Construction product related data

## Codes at product level

ANNEX 89 EBC

- **EN 15804 A2**: Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products
- **EN 15941**: Sustainability of construction works - Data quality for environmental assessment of products and construction work - Selection and use of da
- **ISO 22057**: Sustainability in buildings and civil engineering works — Data templates for the use of environmental product declarations (EPDs) for construction products in building information modelling
- EU Construction Product Regulation (CPR)

---

- *Specific approaches in member states*

# Construction product related data

## Data quality in line with EN 15941 and/or LEVEL(s)

**EN 15941:2024** Sustainability of construction works. Data quality for environmental assessment of products and construction work. Selection and use of data

*technological*
*geographical*
*time-related*
*representativeness*

**LEVEL(s)**
Framework for sustainability assessment and reporting in Europe

https://susproc.jrc.ec.europa.eu/product-bureau/sites/default/files/2020-10/20201013%20New%20Level(s)%20documentation_Indicator%201.2_Publication%20v1.0.pdf

| Rating aspect | *Brief description of each aspect* | Rating score | | | |
|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 |
| *Technological representativeness* | Degree to which the dataset reflects the true population of interest regarding technology (e.g. the technological characteristics, including operating conditions) | No evaluation made | The data used does not reflect satisfactorily the technical characteristics of the system (e.g. Portland Cement, without other specifications) | The data used reflects partially the technical characteristics of the system (e.g. Portland Cement type II, without further specifications) | The data used reflects the technical characteristics of the system (e.g. Portland Cement type II B-M) |
| *Geographical representativeness* | Degree to which the dataset reflects the true population of interest regarding geography (e.g. the given location/site, region, country, market, continent) | No evaluation made | The data used refer to a totally different geographic context (e.g. Sweden instead of Spain) | The data used refers to a similar geographic context (e.g. Italy instead of Spain) | The data used refers to the specific geographic context (e.g. Spain) |
| *Time-related representativeness* | Degree to which the dataset reflects the specific conditions of the system being considered regarding the time/age of the data (e.g. the given year compared to the reference year of the analysis) | No evaluation made | There are more than 6 years between the validity of the data used and the reference year to which the data applies. | There are between 2 and 4 years between the validity of the data used and the reference year to which the data applies. | There are less than 2 years between the validity of the data used and the reference year to which the data applies. |

# Construction product related data

## Subdivision of GWP and range of data – EPD from AUSTRALIA!

***Table 4: Environmental impacts, 1 m³ of rough-sawn, kiln-dried hardwood.***

| | Production | Landfill (typical) | Landfill (NGA) | Energy recovery | Recycling | Reuse |
|---|---|---|---|---|---|---|
| Parameter [Unit] | A1-A3 | C4 | C4 | C3 | C3 | C3 |
| GWP [kg $CO_2$-eq.] | -888 | 58.4 | 460 | 1,230 | 1,230 | 1,220 |
| GWPF [kg $CO_2$-eq.] | 209 | 58.4 | 58.6 | 7.46 | 7.46 | 0 |
| GWPB [kg $CO_2$-eq.] | -1,100 | -0.00716 | 401 | 1,220 | 1,220 | 1,220 |
| ODP [kg CFC11-eq.] | 7.42E-11 | 2.81E-11 | 2.81E-11 | 3.21E-13 | 3.21E-13 | 0 |
| AP [kg $SO_2$-eq.] | 1.79 | 0.186 | 0.212 | 0.0469 | 0.0469 | 0 |
| EP [kg $PO_4^{3}$-eq.] | 0.419 | 0.0244 | 0.0310 | 0.0110 | 0.0110 | 0 |
| POCP [kg $C_2H_4$-eq.] | 3.10 | 0.0114 | 0.0896 | 0.00407 | 0.00407 | 0 |

***Table 24: Inter-site variability for softwood (modules A1-A3).***

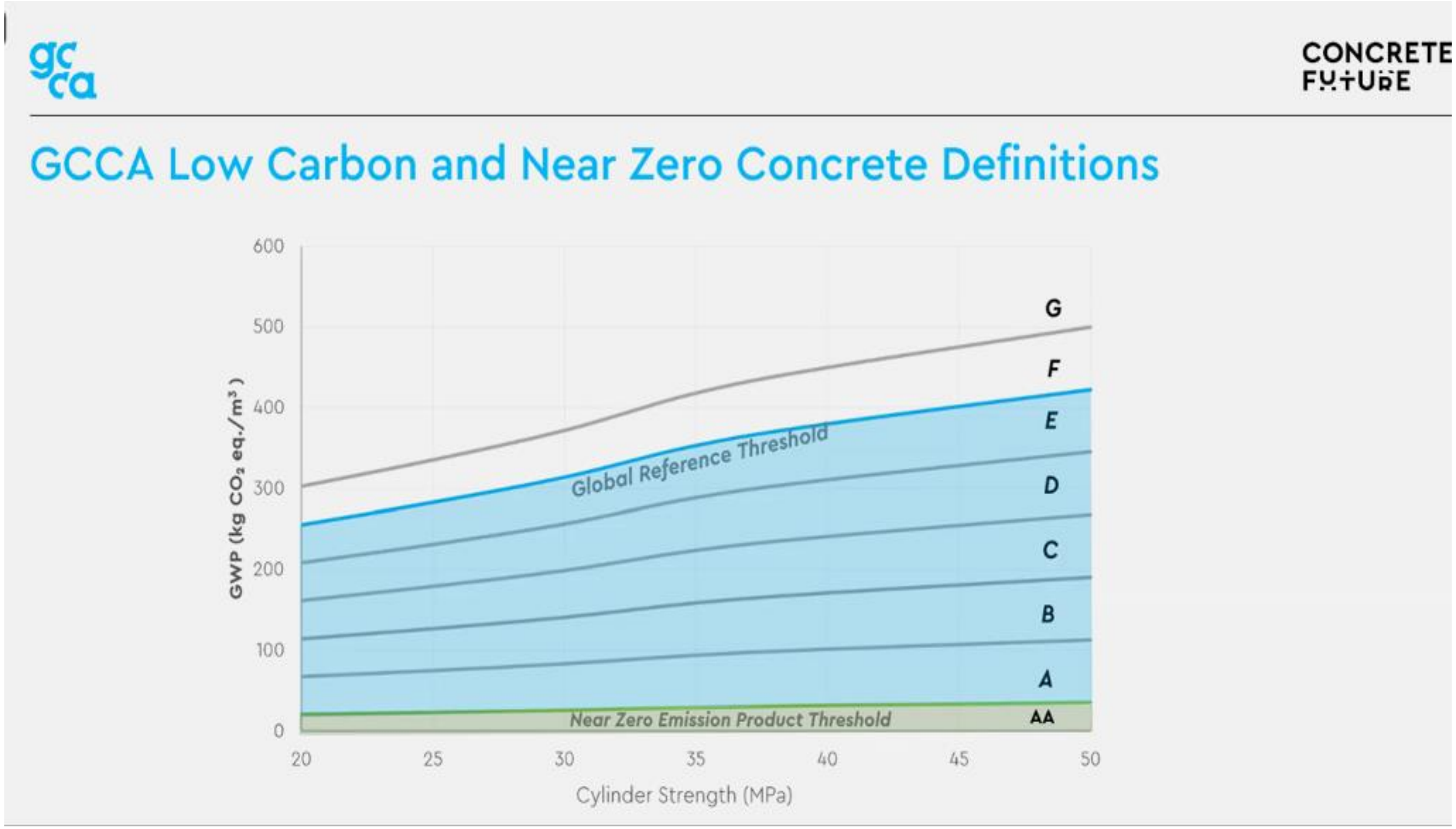
| | Sawn, kiln-dried hardwood | | | Dressed, kiln-dried hardwood | | | Sawn, green hardwood | | |
|---|---|---|---|---|---|---|---|---|---|
| Parameter [Unit] | Min | Max | CV | Min | Max | CV | Min | Max | CV |
| GWP [kg $CO_2$-eq.] | -32.0% | +33.2% | ±18.3% | -32.2% | +42.8% | ±23.3% | -33.4% | +17.0% | ±17.3% |
| GWPF [kg $CO_2$-eq.] | -41.8% | +90.4% | ±41.9% | -39.7% | +90.2% | ±44.8% | -34.3% | +64.7% | ±32.9% |
| GWPB [kg $CO_2$-eq.] | -31.2% | +14.5% | ±14.8% | -30.9% | +13.1% | ±14.7% | -33.8% | +15.6% | ±16.0% |
| ODP [kg CFC11-eq.] | -50.8% | +178.3% | ±73.1% | -42.6% | +155.5% | ±61.9% | -64.0% | +190.1% | ±81.8% |
| AP [kg $SO_2$-eq.] | -23.9% | +55.4% | ±26.7% | -28.8% | +97.4% | ±37.7% | -25.2% | +56.8% | ±24.7% |
| EP [kg $PO_4^{3}$-eq.] | -24.7% | +54.9% | ±26.4% | -28.5% | +79.5% | ±29.8% | -26.7% | +48.6% | ±25.1% |
| POCP [kg $C_2H_4$-eq.] | -18.9% | +49.5% | ±19.9% | -19.3% | +79.4% | ±28.4% | -20.4% | +49.1% | ±19.8% |

https://epd-australasia.com/wp-content/uploads/2018/04/EDP-2-Hardwood-Dec-2020-2.pdf

There are examples of specifying bandwidths. This allows the analysis of uncertainties and a Monte Carlo simulation in the early design steps.

# Construction product related data

## Performance classes for low carbon products – steel, cement, concrete




Performance classes are currently being introduced for product groups depending on the greenhouse gas emitted during production. This makes it easier to identify or tender low-carbon products.

# Construction product related data

## influenced already by emission factor of electricity



| Jahr | Kohlendioxidemissionen der Stromerzeugung[1] [Mio. t] | Stromverbrauch[2] [TWh] | $CO_2$-Emissionsfaktor Strommix[3] [g/kWh] | Stromverbrauch unter Berücksichtigung des Stromhandelssaldos[4] [TWh] | $CO_2$-Emissionsfaktor Strominlandsverbrauch[5] [g/kWh] | Kohlendioxidemissionen der Stromerzeugung unter Berücksichtigung Handelssaldo[6] [Mio. t] | THG-Emissionfaktor ohne Vorketten [g $CO_2$-Äquivalente /kWh] | THG-Emissionfaktor mit Vorketten [g $CO_2$-Äquivalente /kWh][7] | THG-Emissionen der Stromerzeugung [Mio. t $CO_2$-Äquivalente][7] |
|---|---|---|---|---|---|---|---|---|---|
| 1990 | 366 | 479 | 764 | 480 | 763 | 367 | 769 | 860 | 369 |
| 2016 | 303 | 581 | 522 | 530 | 572 | 277 | 531 | 595 | 309 |
| 2017 | 285 | 584 | 488 | 531 | 537 | 259 | 498 | 557 | 290 |
| 2018 | 271 | 573 | 472 | 525 | 516 | 248 | 481 | 538 | 276 |
| 2019 | 222 | 543 | 408 | 511 | 434 | 208 | 416 | 473 | 226 |
| 2020 | 187 | 513 | 364 | 494 | 378 | 180 | 373 | 429 | 191 |
| 2021 | 214 | 526 | 407 | 508 | 422 | 207 | 416 | 473 | 219 |
| 2022* | 221 | 515 | 429 | 488 | 453 | 209 | 439 | 498 | 226 |
| 2023** | 173 | 454 | 380 | 465 | 371 | 177 | 388 | 445 | 176 |

*vorläufig, ** geschätzt

Quellen: Umweltbundesamt eigene Berechnung April 2024

g $CO_2$/kWh

g $CO_2$/kWh, used in Germany

g $CO_2$**e**kWh with upstream

g $CO_2$**e**/kWh without upstream

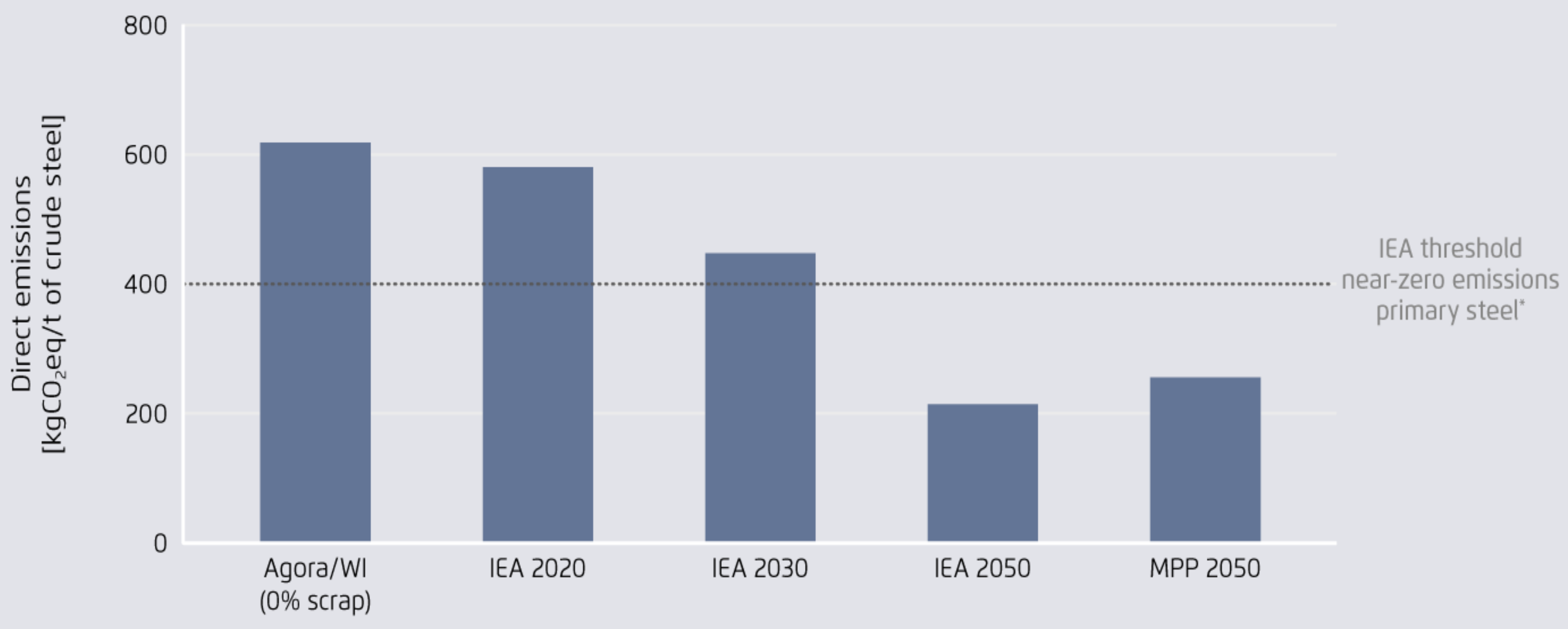
Emission factors for energy – and thus also for products – are influenced by the year of determination (the age), the measured variable ($CO_2$ versus GHG) and the handling of upstream chains.

# Construction product related data

## Dealing with time related aspects (strategy for decarbonisation)

ANNEX 89 EBC

$CO_2$ intensity of the BF-BOF-CCS route in different scenarios




Agora Industry and Wuppertal Institute (2024), based on IEA (2022a) and MPP (2022). Note: The Agora/WI $CO_2$ intensity represents an adjusted BF-BOF-73% CCS route value with 0% scrap in order to ensure comparability with the other values. *The proposed IEA threshold for near-zero emissions primary steelmaking is 400 $kgCO_2eq/t$ of crude steel in case of 0% scrap use. Note that the IEA near-zero emissions threshold is imposed on a direct and indirect emissions basis. For ease of comparison, the indirect emissions from fossil fuel and raw material supply are not depicted here, however these can significantly contribute to the emission intensity of crude steel production.

https://www.agora-industry.org/fileadmin/AutomaticFiles/241/abb-18.png

For selected product groups, forecasts of future emission factors exist as a result of industry-specific strategies for decarbonization. The handling of this in life cycle assessment has not yet been definitively clarified.

# Construction product related data

## Use cases: comparison of products or source of information for building assessment

**Use case 1**: Comparison of products, if comparable

| | PRODUCT STAGE | | | CONSTRUCTION PROCESS STAGE | | USE STAGE | | | | | | | END OF LIFE STAGE | | | | BENEFITS/ LOADS BEYOND LIFE CYCLE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Raw material supply | Transport | Manufacturing | Transport | Construction-Installation process | Use | Maintenance | Repair | Replacement | Refurbishment | Operational energy use | Operational water use | Deconstruction - demolition | Transport | Waste processing | Disposal | Reuse, recovery, Recycling, potential |
| Module | A1 | A2 | A3 | A4 | A5 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | C1 | C2 | C3 | C4 | D |
| Modules declared | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |

Based on life cycle approach in line with PCRs (scenarios)

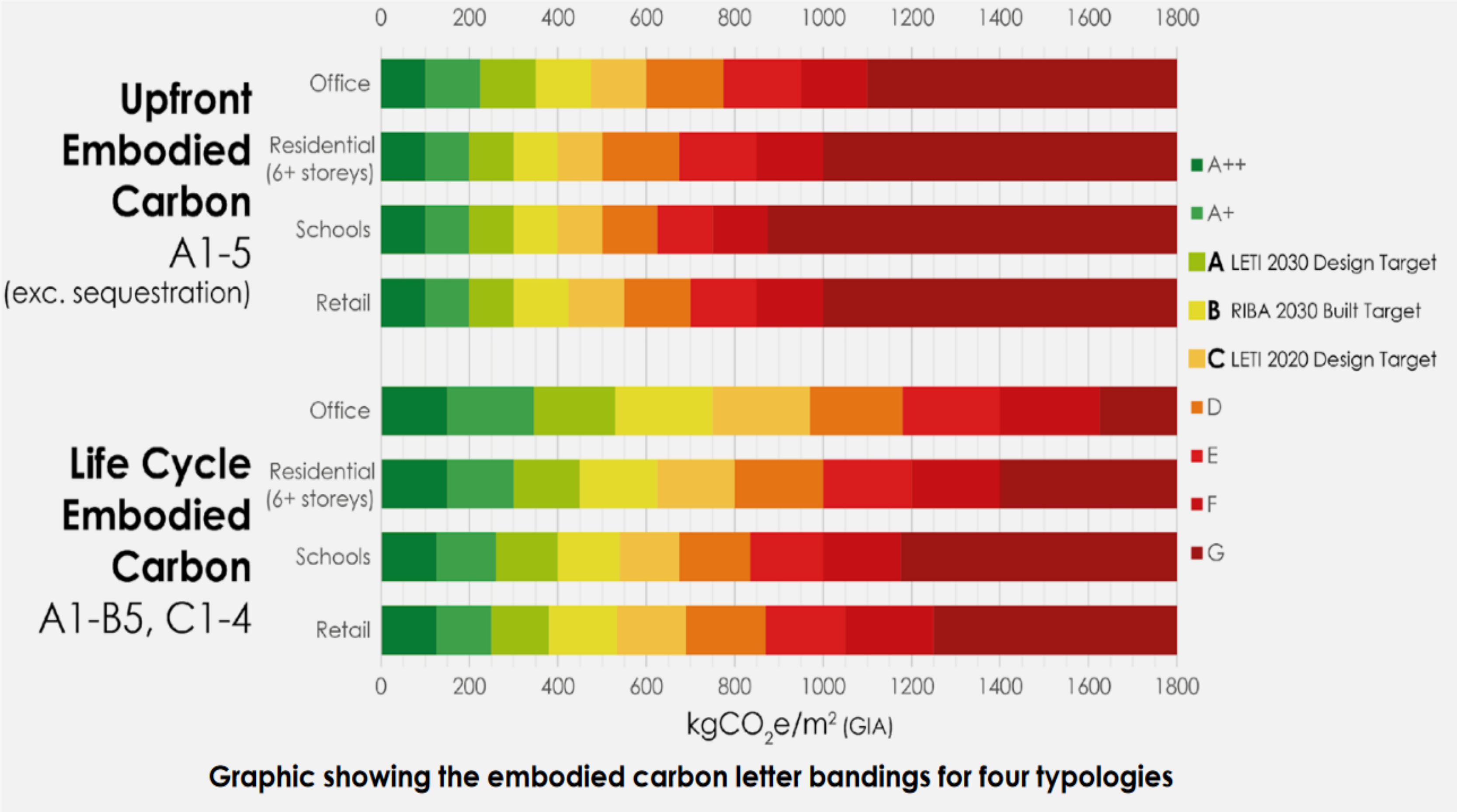
**Use case 2**: Source of information for building LCA

| | PRODUCT STAGE | | | CONSTRUCTION PROCESS STAGE | | USE STAGE | | | | | | | END OF LIFE STAGE | | | | BENEFITS/ LOADS BEYOND LIFE CYCLE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Raw material supply | Transport | Manufacturing | Transport | Construction-Installation process | Use | Maintenance | Repair | Replacement | Refurbishment X | Operational energy use ? | Operational water use ? | Deconstruction - demolition | Transport | Waste processing | Disposal | Reuse, recovery, Recycling, potential |
| Module | A1 | A2 | A3 | A4 | A5 | B1 | B2 | B3 | B4 | B5 | B6 | B7 | C1 | C2 | C3 | C4 | D |
| Modules declared | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X |


*Do not take this information from EPD!*

# Embodied carbon

## System boundaries and performance level

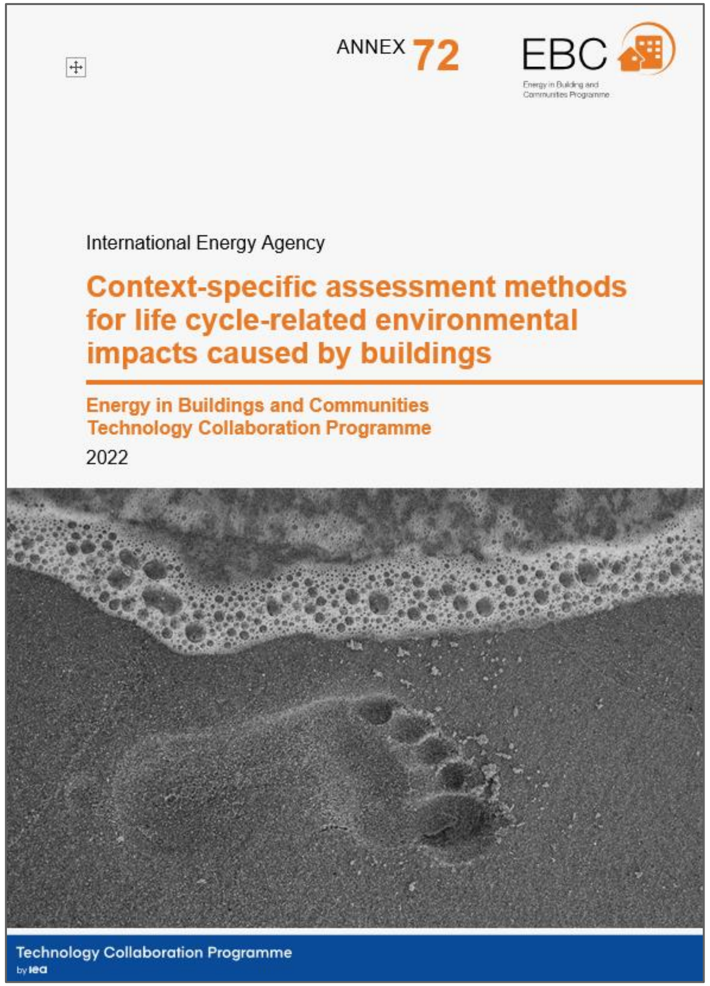


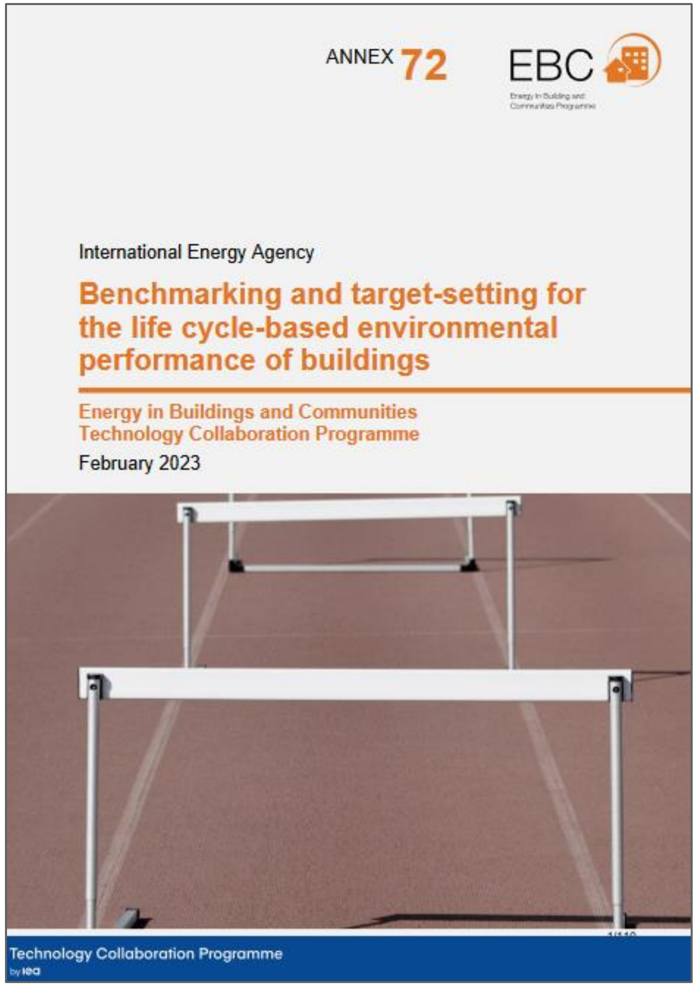

For both the embodied part of greenhouse gas emissions in the life cycle of buildings and for upfront GHG-emissions, there are already empirical values as well as proposals for performance classes available in literature.

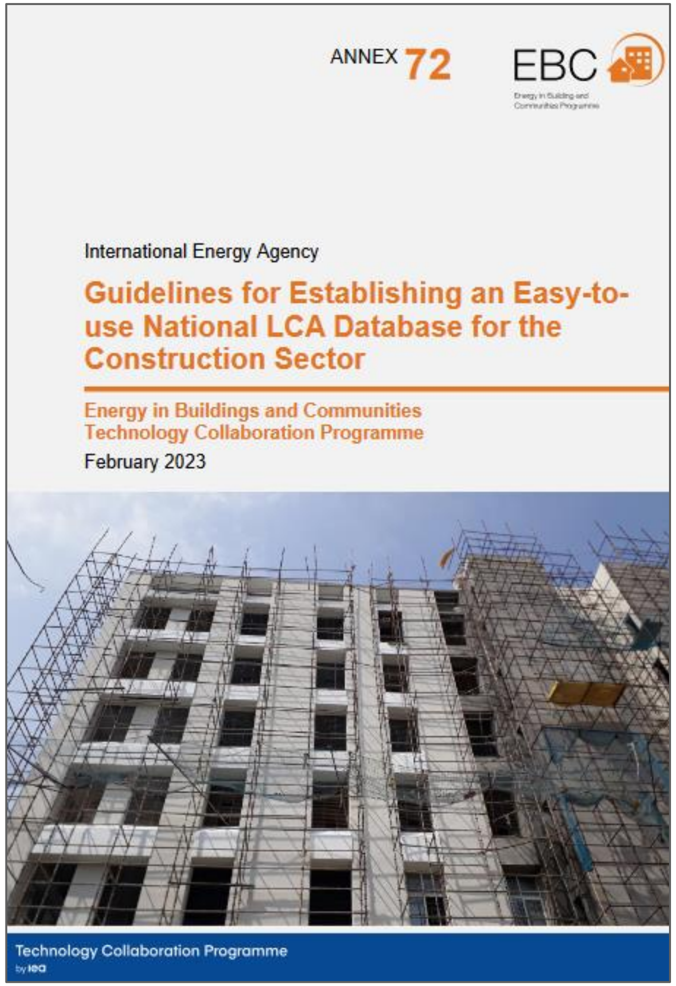
https://www.leti.uk/_files/ugd/252d09_25fc266f7fe44a24b55cce95a92a3878.pdf

# Further reading

## Available results from IEA EBC Annex 72



# Summary and recommendations I

## What comes next?

- Target and indicator form a single unit. If the goal is to protect the climate, effects on the climate must be recorded, evaluated and influenced. The appropriate **impact category** is **climate change** based on the recording of **greenhouse gas emissions** (GHG-emissions) and expressed as **global warming potential** in **kg $CO_2$-equivalents**. Specifications in energy units are not suitable.
- Requirements to limit GHG-emissions in the life cycle of buildings must be derived from a **national reduction pathway** as part of mitigation strategy and a (remaining) **GHG-emission budget for the construction and real estate sector**. The determined values must be compared with **economic and technical feasibility**.
- It makes sense to develop **orientation values for the embodied and operational parts** of GHG-emissions in the life cycle to support the design process and to introduce **binding secondary requirements to limit upfront GHG-emissions**.

Bild von Alexander Lesnitsky auf Pixabay

# Summary and recommendations II



## What comes next?

- A mandatory assessment of GHG-emissions in the life cycle of buildings requires the obligation to provide data for products, processes and energy, among other things. In Europe, environmentally relevant properties are becoming a product feature.
- Requirement values, system boundaries (levels and phases), methods and data form a harmonised unit.
- Both averages and specific values are needed. The introduction of low-carbon products and recycled products will further differentiate the values.
- Dealing with the issue of time still causes problems at the level of evaluating buildings and providing data on products.

Bild von Alexander Lesnitsky auf Pixabay

# Summary and recommendations III

## What comes next?

- The term "Building Energy Codes" is less appropriate in terms of addressing the issue of greenhouse gas emissions and can lead to misunderstandings.
- A transition to "Building Carbon Codes" is possible, but not recommended. In a next stage, the use of primary raw materials will certainly be addressed. "Environmental performance related codes for buildings – part 2: carbon codes" is recommended (if part 1 will cover the energy codes)

Bild von Alexander Lesnitsky auf Pixabay

EBC

Energy in Buildings and Communities Programme

# Panel Discussion:
# Embodied Carbon in Building Energy Codes

EBC

Energy in Buildings and
Communities Programme

# Key research questions and next steps for collaboration

Meredydd Evans

# Concluding remarks

Stanford Harrison

Energy in Buildings and Communities Programme

# Closing

Today we covered:

Building Energy Code Working Group

- Planned activities
- 2-year work plan
- New sign ups
- Country contributions

Sessions:

- Energy and Climate Resilience
- Embodied Carbon in Building Energy Codes

# What's Next

**Now**

Please join us for refreshments at Melbourne Connect

**Time:** 6pm – 7pm AEDT

**Location:**

700 Swanston St, Carlton VIC 305

**Tomorrow**

**Date:** 19 November 2024

**Time:** 8:30am – 5pm AEDT

**Location:**

Rydges Melbourne CBD
186 Exhibition St,
Melbourne VIC 3000

Energy in Buildings and Communities Programme

# Thank you!