Buildings XV Conference

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ASHRAE

OAK RIDGE National Laboratory

Key Note Session 1

Building Physics – the key to Sustainability

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Who are we?

Ernst Jan de Place Hansen

Senior Researcher at Danish Building Research Institute (SBi) / Aalborg University since 2000. Before that 5 years at Technical Univ. of DK (DTU). PhD in frost resistance of porous building materials.

Expertise in:

- Internal thermal insulation of historic buildings
- Building regulations
- Service life of materials and constructions
- Faults and defects in buildings
- Moisture conditions in the building envelope
- Winter construction

Who are we?

Eva Birgit Møller

Professor in Arctic Building Design at DTU since 2019. Before that 11 years at SBi and 14 years as consulting engineer. PhD in Hygrothermal Performance and Soiling of Exterior Building Surfaces

Expertise in:

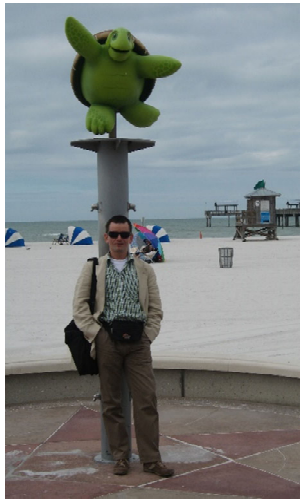
- Hygrothermal behavior of the building envelope
- Mold and other moisture related indoor climate problems
- Condition assessment of buildings
- Building technology
- Laboratory testing of building materials
- Arctic building design.

Our relation to the Buildings [N] Conferences





Two Danish colleagues on our 1st visit in Florida in 2010, enjoying the conference and the surroundings, but also travelling around looking for building defects and wild animals, and may be also something else …





Our relation to the Buildings [N] Conferences

At least, in 2013 we came back, found more building defects and got closer to the animals.

And we were more that just colleagues …

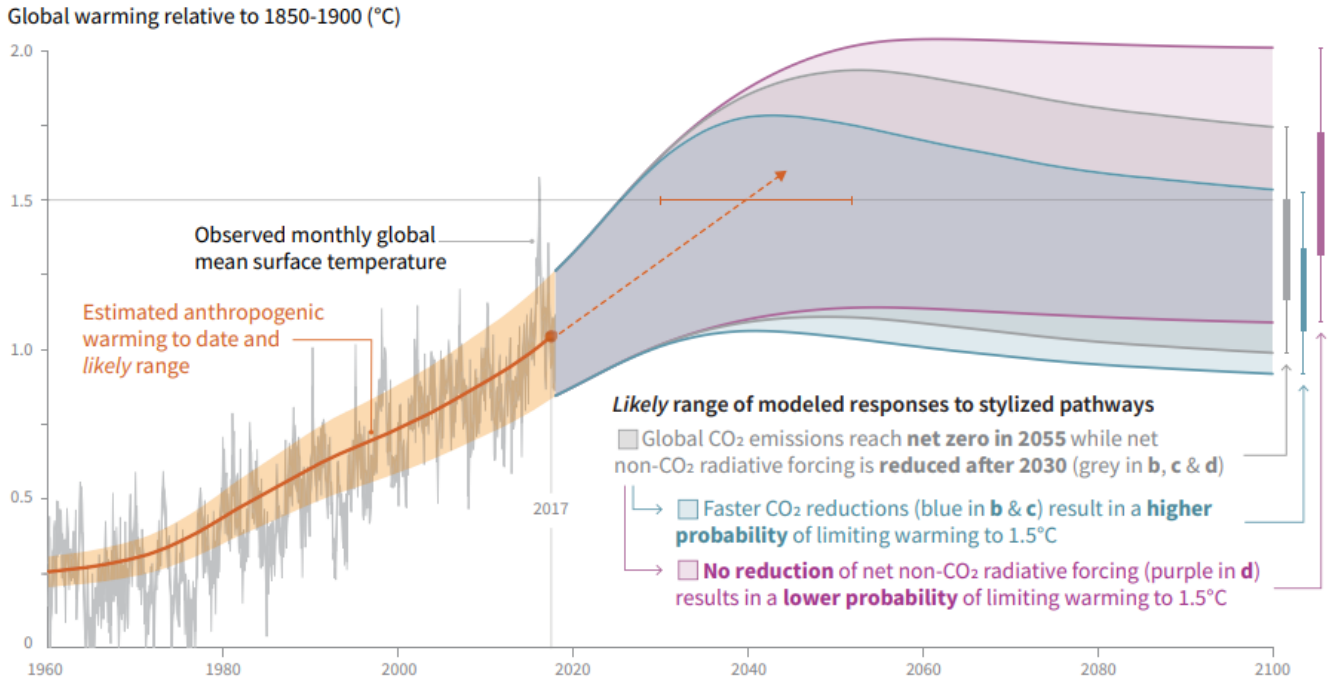



Our relation to the Buildings [N] Conferences

… and in 2016 we got married ☺ - in Denmark

Introduction: What we talk about in Europe

Climate change ⇒ **We need to do something NOW**

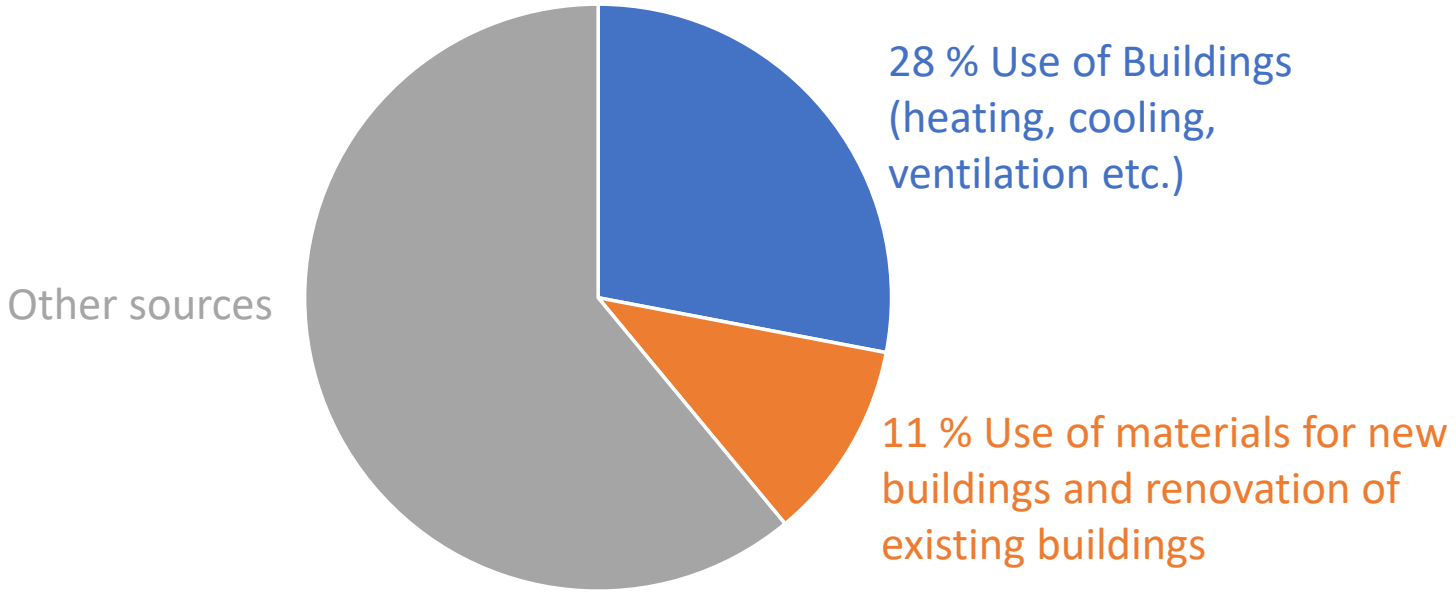


IPCC (2021)

Introduction: What we talk about in Europe

Climate change ⇒ **We need to do something NOW**

Globally: **39 %** of the total climate load (CO_2-emission) relates to buildings



Introduction: What we talk about in Europe

Climate change ⇒ **We need to do something NOW**

Short term

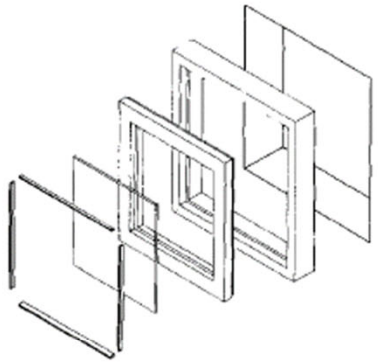
- Adaptation of buildings and building design
- Simulations involving future weather data

Building physics ⇓

Upgrade buildings to withstand the new climate

Long term

- Development of building materials and replacement methods to reduce the CO_2 emissions



Sustainability ⇓

Prevent even more drastic climate change in the future

Sustainability cannot stand alone: Case with CLT elements

Photo: Byggeskadefonden

Photo: John Ehbrecht

Photo: Steffan Iwersen

Illustrations: BYG-ERFA

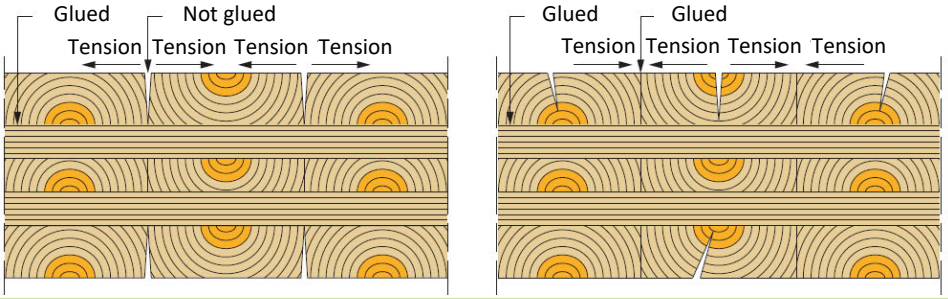
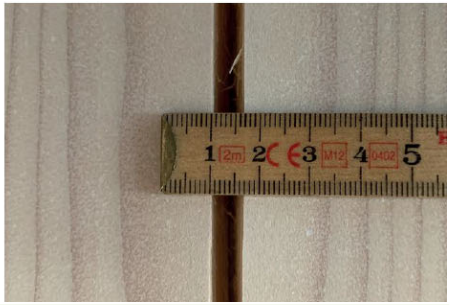


Photo: BYG-ERFA



Outline/Agenda

- What is **sustainability** and how to measure
- How is EU dealing with sustainability?
- How is it implemented in Danish Building Regulations?
- What might sustainability ensure – or not?
- Estimation of **service life** – and what are the challenges?

- What is **building physics**? And what might it ensure – or not?
- Cases where building physics was forgotten/ignored
- Case with insufficient robustness
- Case where building physics works – and ensures sustainability

- Challenges when combining sustainability, climate change, service life and building physics
- Next step and Conclusion

What is sustainability?

What is sustainability?

Brundtland Commission (1987)

- **meeting the needs of the present without compromising the ability of future generations to meet their own needs**

UN 17 Sustainable Development Goals (2015), e.g.

- **Sustainable consumption and production**: doing more and better with less
- **Climate Action plans**:
  cut emissions and adapt to climate impacts through nationally determined contributions. To limit warming to 1.5° Celsius above pre-industrial levels

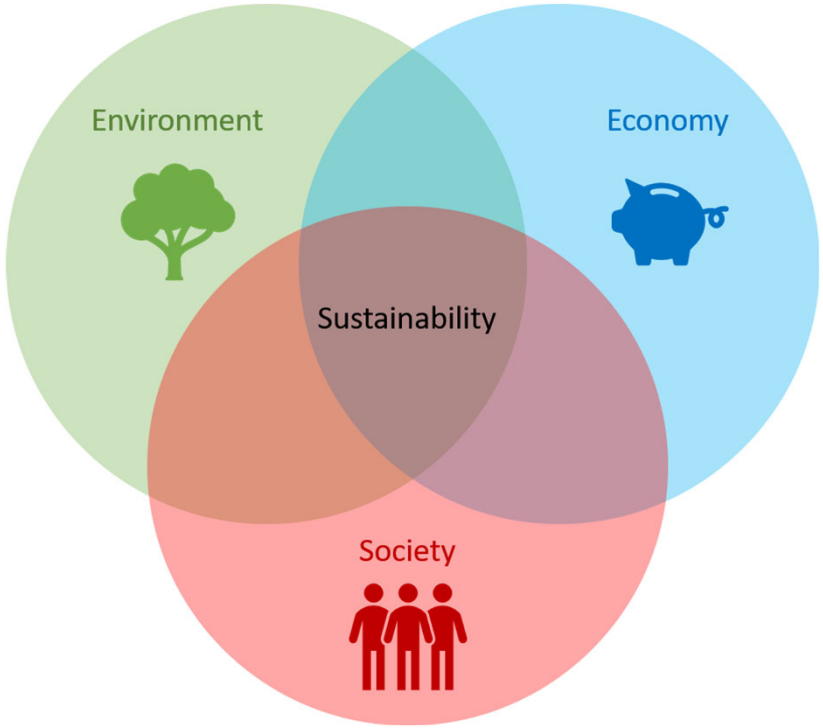
How to measure sustainability

Sustainability is not just environmental impact:

- Environment
- Economy
- Society

Sustainability on a formular: Certification

- Different systems: LEED, BREEAM, DGNB, HQE, ….
- Different grades: e.g. Silver, Gold, Platinum

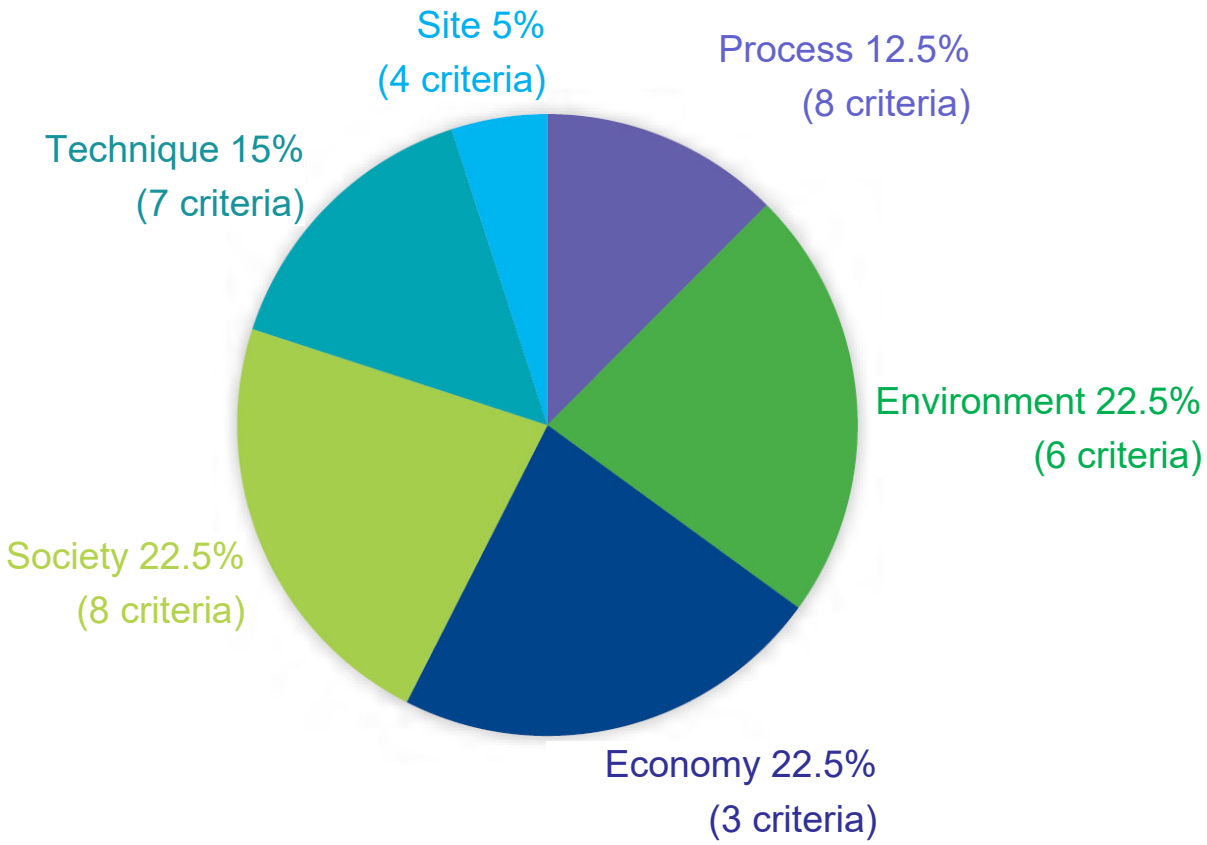


Example: DGNB certification of buildings

36 different criteria

Highest score:

1. LCC: 9.6 %
2. LCA: 9.5 %
3. Flexibility (economy) 6.4 %
4. Robustness (economy) 6.4 %
5. …



How is EU dealing with sustainability?

European Green Deal (2020)

- Ensuring no net emissions of greenhouse gases by 2050, and economic growth decoupled from resource use. This includes:
  - **European Climate Law:** enshrine the 2050 climate-neutrality objective into EU law
  - **European Climate Pact**: engage all parts of society in climate action
  - **2030 Climate Target Plan**: reduce greenhouse gas emissions ≥ 55% by 2030
  - **EU Strategy on Climate Adaptation**: make Europe a climate-resilient society by 2050, adapted to the impacts of climate change
  - a **Renovation Wave to improve the energy performance of buildings across the EU:** double renovation rates by 2030 and ensure better energy- and resource efficiency

EU Construction Products Regulation (2011)

- A revision is ongoing (2022), expected to introduce sustainability elements to align with the requirements of the European Green Deal

How is sustainability implemented in Danish Building Regulations?

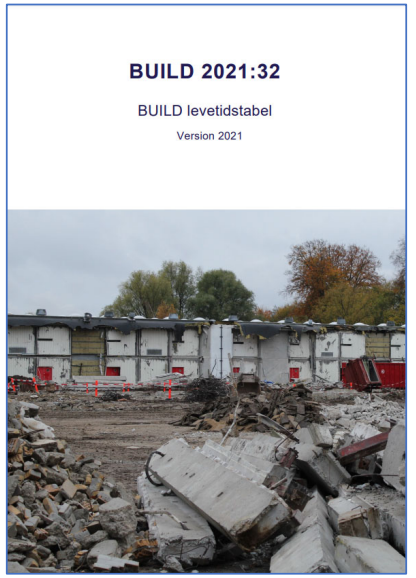
From 1.1.2023: Requirement to document the climate load, for all new buildings [kg CO_2-equvivalents/m^2/year] using EN 15978:2011.

- Calculated for a period of 50 years, involving valid EPD's conducted according to EN 15804:2012
- Replacement of building components and building materials is included according to service life tables given by BUILD, or service life documented in test reports

Valid data on service life is vital for calculation of climate load

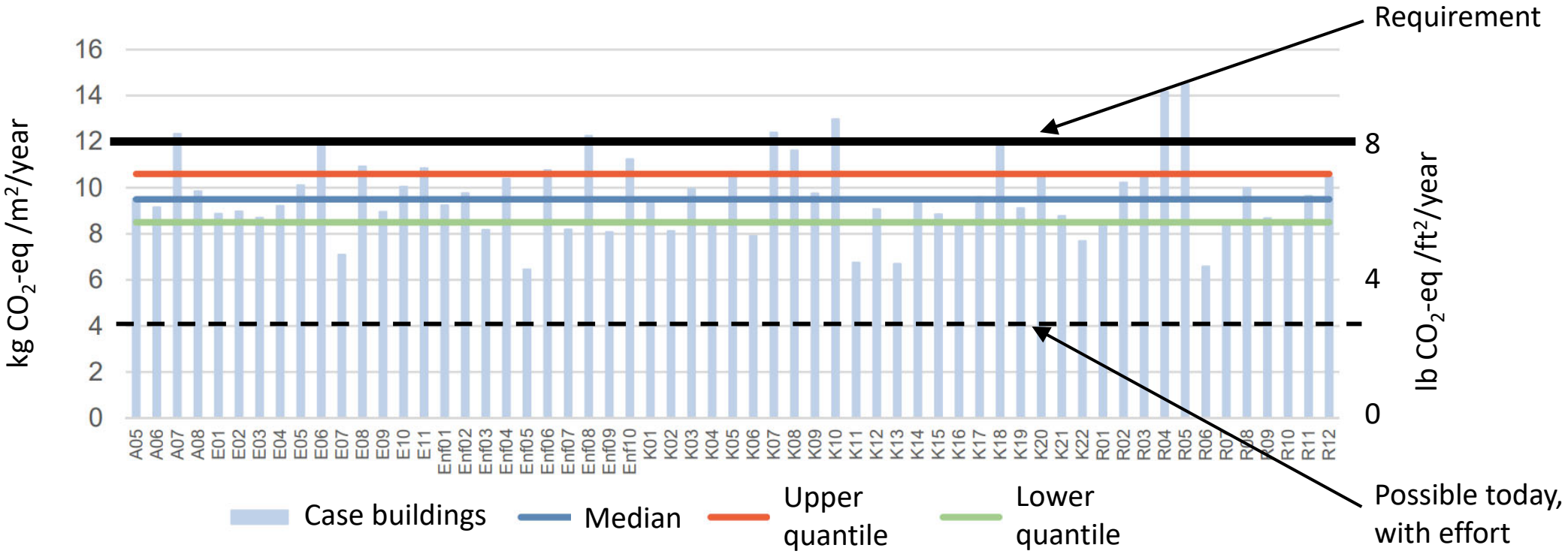
Further, for all new buildings > 1000 m^2 (10,764 ft^2):

- Mandatory: climate load < 12 kg CO_2 eq/m^2/year (8 lb CO_2 eq/ft^2/year)
- Low emission: climate load < 8 kg CO_2 eq/m^2/year (5.4 lb CO_2 eq/ft^2/year)
- Expected to be tightened in 2025, 2027 and 2029. From 2025 also smaller buildings are included.



How is sustainability implemented in Danish Building Regulations?

Is 12 kg CO_2 eq/m^2/year (8 lb CO_2 eq/ft^2/year) sufficiently ambitious?



Based on Zimmermann et al. (2020)

What might sustainability regulations ensure – or not?

Ensures reduction of CO_2 emissions:

- Production
- Construction
- Operation (including energy savings)
- End of life

Not ensured:

- Durability
- Robustness
- Buildability

Service life is important

Sustainability = f(# of replacements of components, ...)

Factor method for estimated service life (ISO 15686-8)

$$ESL = RSL \times \phi_A \times \phi_B \times \phi_C \times \phi_D \times \phi_E \times \phi_F \times \phi_G$$

ESL estimated service life

RSL reference service life

A Inherent performance level

B Design level

C Work execution level

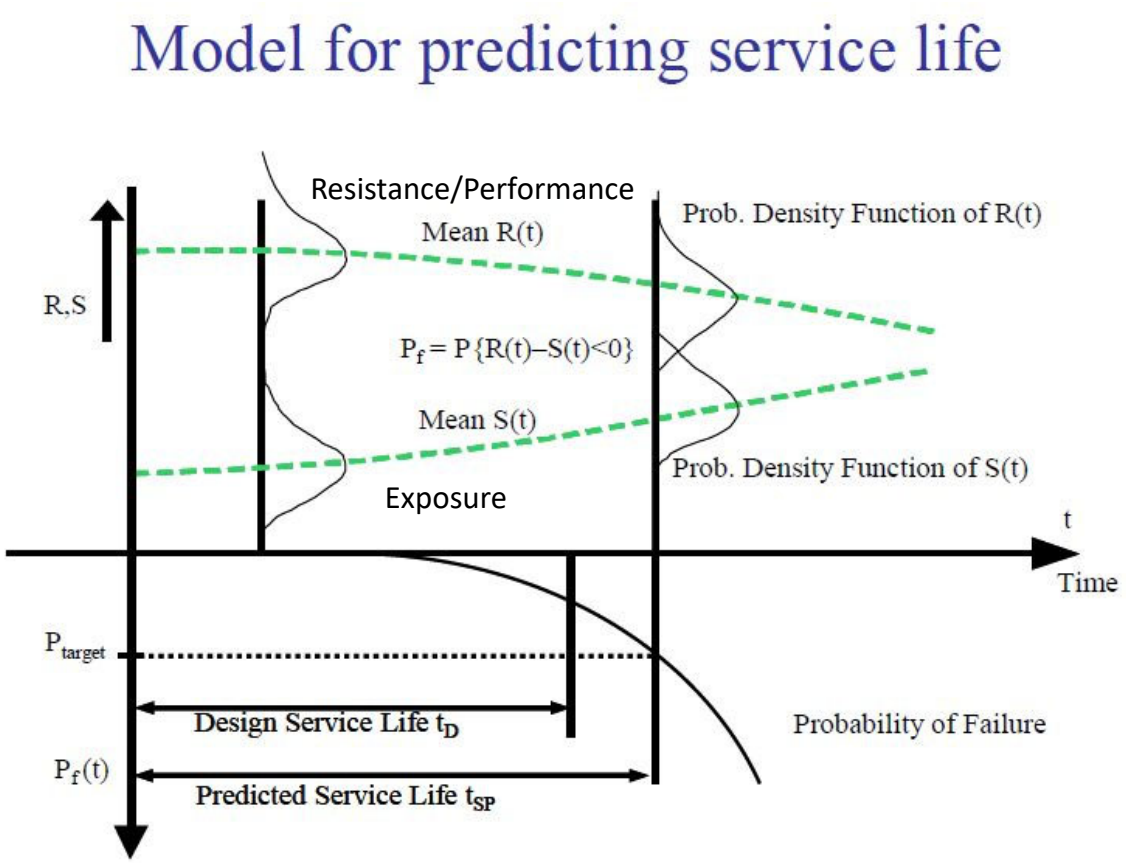
D Indoor environment

E Outdoor environment

F Usage conditions

G Maintenance level

ISO 13823: General principles on the design of structures for durability



Challenges regarding service life

- **Technical** service life can be modelled, e.g. using the factor method or ISO 13823
- What about the **real** service life? Replacement for other reasons, e.g. functional or aesthetic
- How often does that take place and what about **sustainability**?
- What about **robustness** regarding mistakes during project design or at the building site?
- Should we accept solutions with shorter technical service life, depending on **building use**?
- How to ensure performance of **recycled** products?
- How to assess the service life of **new** products?

Photo: Bolius

Sustainable materials – What are the challenges

Biobased materials are generally regarded as sustainable:

- Take up CO_2 as they grow
- Release CO_2 as they degenerate

} In total CO_2 neutral

However:

- What about biodiversity?
- Can we grow enough of a specific material?
  E.g. seagrass
- What about durability?
  Nature strikes back

Photo: BYG-ERFA

What is building physics?

Photo: Bolius

What is building physics?

Building physics or building science covers:

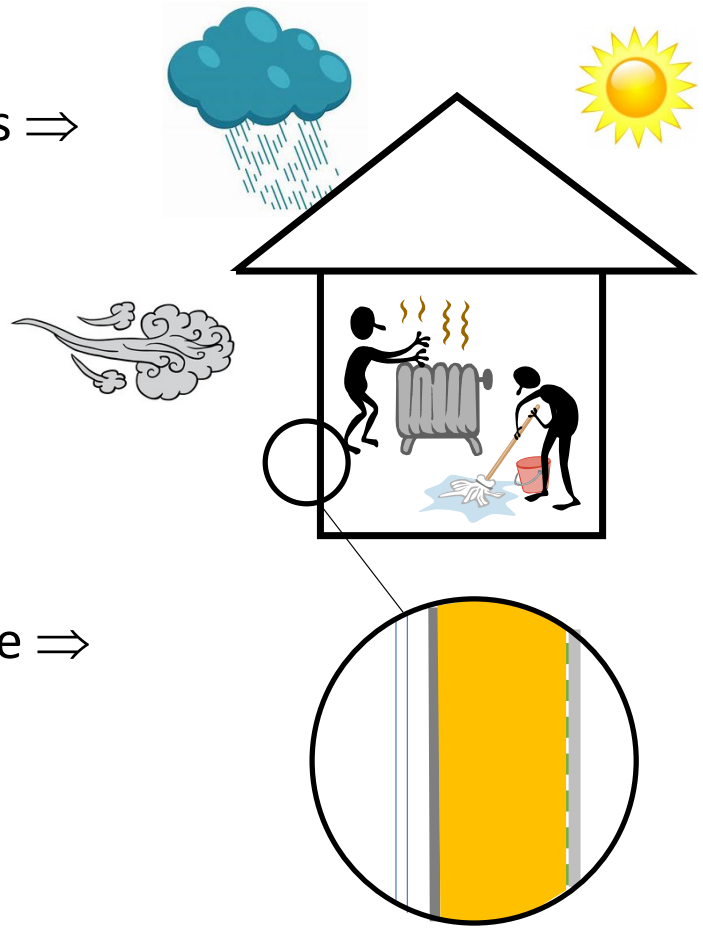
- Heat, Air and Moisture transport (HAM) in buildings ⇒

  Influence of:

  Outdoor climate
  - Sun
  - Precipitation
  - Wind

  Indoor climate
  - Heating and cooling
  - Moisture production

Effects
- Hygrothermal performance of the building envelope ⇒
  - Durability (rot, frost, salt efflorescence)
  - Mold
- Hygrothermal indoor climate



What might building physics ensure – or not?

Proper use of building physics means:

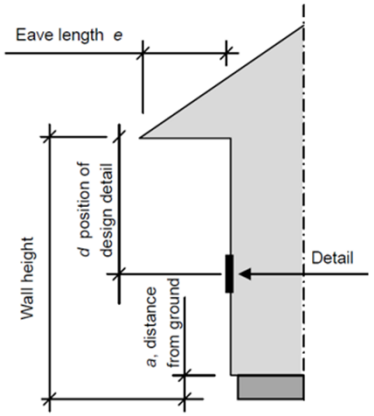
- Appropriate design
- Proper use of materials and combinations hereof

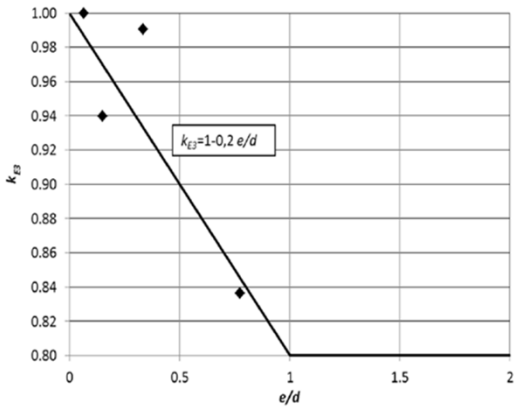
Ensures:

- Robustness
- Long technical service life

Not ensured:

- Architecture
- Buildability





Brischke et al. (2017)

Buildings physics was forgotten/ignored
Flat roofs in DK

Photo: BYG-ERFA

- Flat roofs became popular in the late 1950s
- Roofing felt as roof deck
- Building regulations until 1972: slope towards drain
- 1972-1981:
  - No minimum requirement for roof slope
  - Insufficient quality of roofing materials for completely flat roofs
  - Expensive renovation projects: claims ≈ 4% of the contract sum ☹

  ⇒ Many roofs leaked ☹
- Since 1982: Sufficient slope towards drain, later specified as ≥ 1:40
- 1986:
  - Building Defects Fund, mandatory insurance system for social housing projects
  - Guidance on quality assurance, for governmental and publicly subsidized building projects
- Claims on flat roofs today: 0.1-0.2 % ☺
- Service life increased from 10-15 years to 30-40 years ☺

Buildings physics was forgotten/ignored $MgCl_2$ containing boards as wind barrier

- Introduced in DK around 2007
- Alternative as wind barrier on the cold side of the insulation layer in a light-weight wall
- Strong, fire resistant, light, cheap, good for the working environment ☺
- However
  - $MgCl_2$ = salt that easily takes up moisture when RH is high ☹
  - Salty liquid is released; screws, fittings and staples corrode, might initiate wood root ☹
  - Boards may disintegrate => fire resistance, wind protection, stabilizing properties are lost ☹
- From 2015 Building Defects Fund do *not* cover new claims; a legal sequel is on-going
- Cost of replacing boards alone in Danish social housing dwellings estimated to around 1 billion DKK (140 million USD) ☹

Photos: Tommy Bunch-Nielsen and Byggeskadefonden

Case with insufficient robustness

Not all buildings are perfect!

How will faults affect the sustainability?

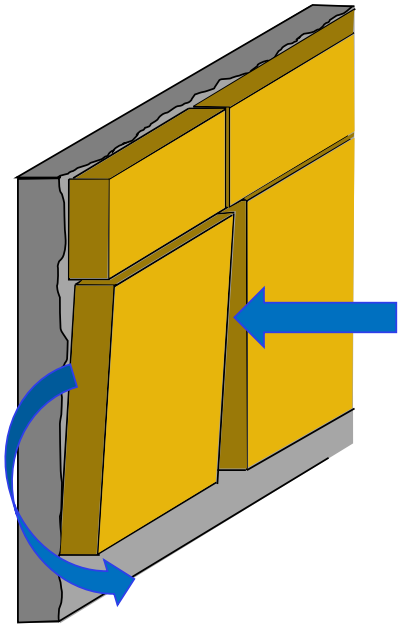
Example: LCA calculation on 1 m² wall of concrete building with external insulation

New technology, important details were overlooked

Insulation material not as efficient as planned

Possibilities:

1. No correction of the error
2. Correction by taking down cladding and installing a wind barrier, after which new cladding is installed.
3. Correction by taking down cladding and insulation and smoothen the concrete surface, after which new insulation and cladding is installed.

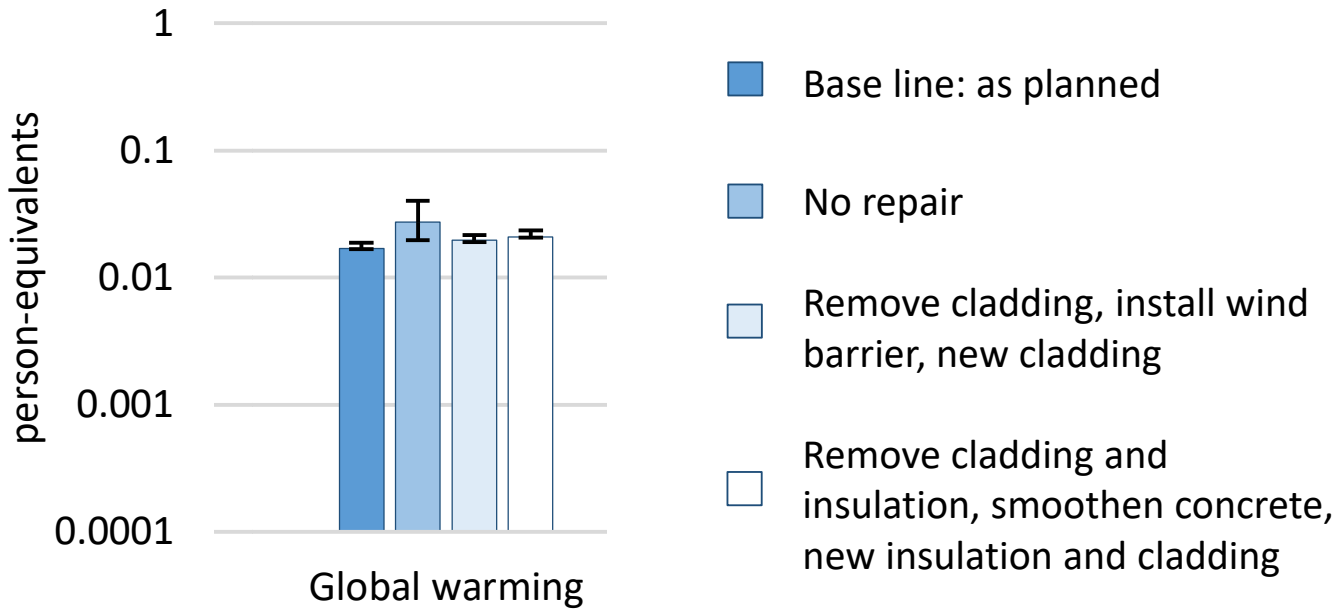


Case with insufficient robustness

Fault resulted in impact on LCA analysis:

- Global warming increase by 25 % (scenario 1 – no repair)
- Energy mix in Nuuk: 67% hydro power, 29% fossil fuels, and 4% heat recovery from waste incineration

The location is important



Ryberg et al. (2022)

Case where building physics works – and ensures sustainability

Deep renovation of apartment buildings from 1960s,

- external insulation (e.g. saving energy and improving indoor climate) (environmental, economic and social sustainability)
- redesign of facades (economic and social sustainability)
- redesign of the area to invite surrounding neighborhood to use it (social sustainability)

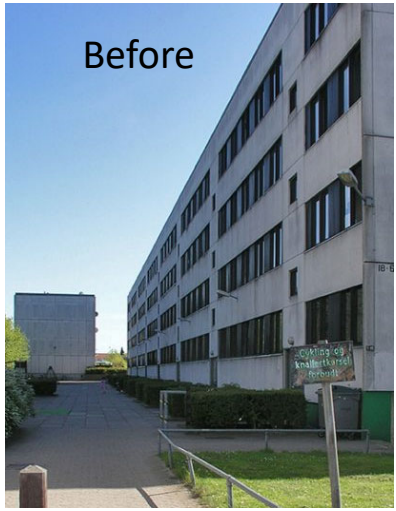
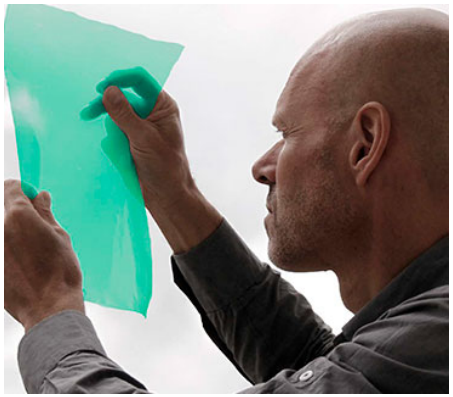


Photo: Tegnestuen Vandkunsten

Challenges when combining sustainability, climate change, service life and building physics

- How to handle
  - Reuse/recycling
  - Remaining service life and quality
- Do we need to develop new test methods and building designs due to climate change?
- Do we need to live more dense (high rise buildings and small apartments rather than suburbs) to minimize transport and energy use?
- How will that affect the hygrothermal conditions of the building envelope?



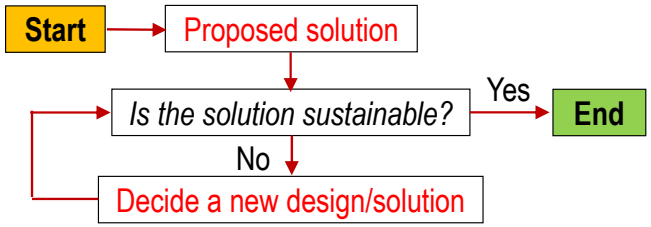
Next step

- Assessment of robustness
- Accelerated ageing, taking climate change into account
- Documentation of specific building materials used at relevant specific positions within the building envelope

⇒ Materials can endure the specific (hygrothermal) conditions and no degradation of other materials

Next step – Decision chart

- If we **only** had to consider **sustainability**, disregarding building physics
- Very simple chart



Next step – Decision chart including building physics

To ensure that building physics of the proposed solution is dealt with,

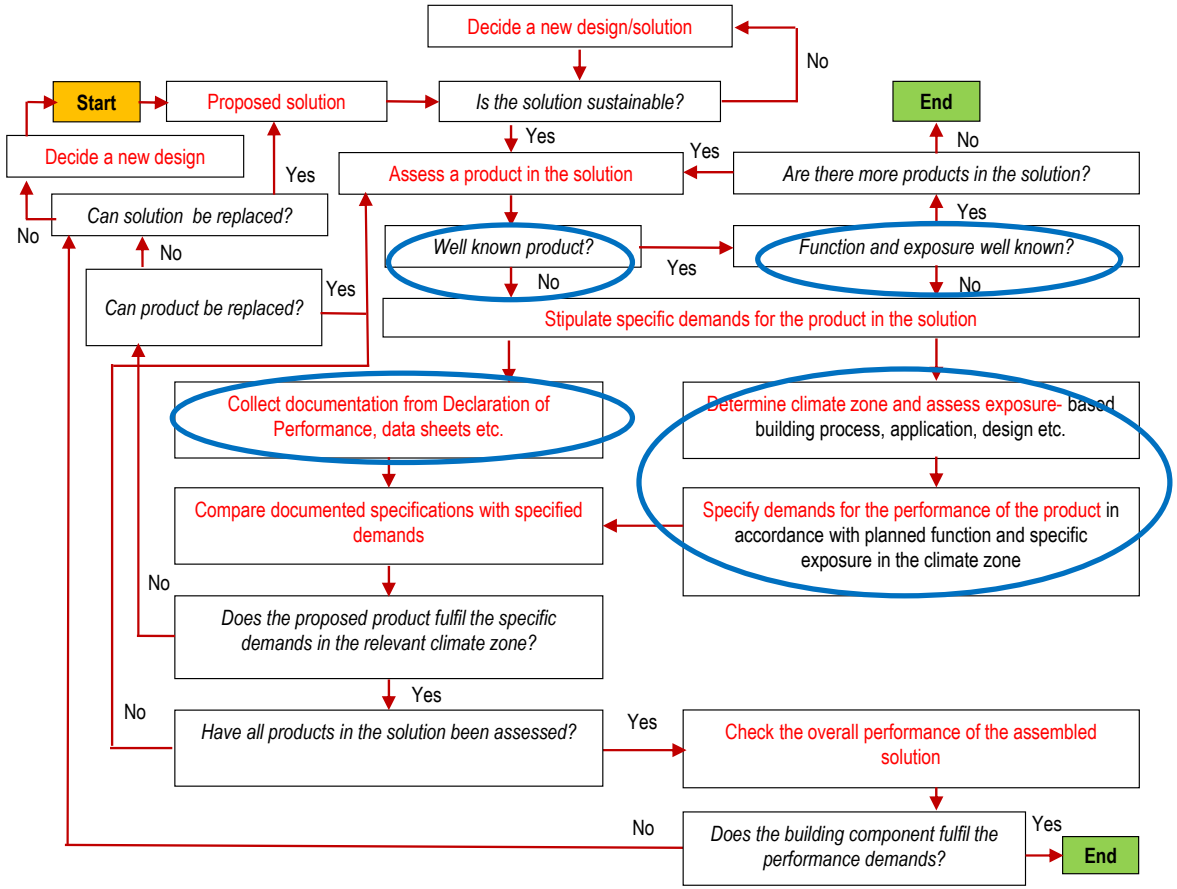
decision chart becomes more complicated

- Documentation of **performance**
- Assessment of **function and exposure**

if

- a product or
- its function and exposure

is **not** well known



Based on de Place Hansen et al. (2020)

Conclusion

No **sustainability** without **building physics**:

- Building physics is used to determine **energy performance**
- Building physics can ensure **long technical service life** if the materials are durable
- **Neglect** of good building physical principles can result in **short technical service life** of components
- Calculations of sustainability depend on the **expected service life**

⇓

Research involving building physics can be seen as a way to promote sustainability

Questions?

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