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TU/e Technische Universiteit Eindhoven University of Technology

Smart Buildings - Smart Energy Symposium, TU Eindhoven
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Robust Net-Zero Energy Buildings

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Advisors
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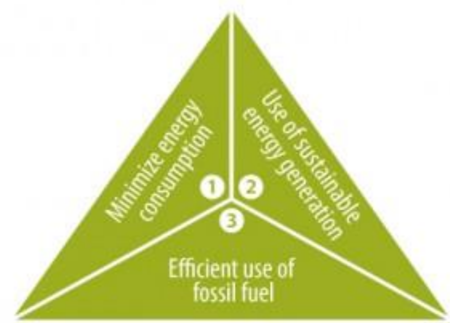
Contents

Building codes, frameworks, regulations…

EPBD

Passivhaus Institut

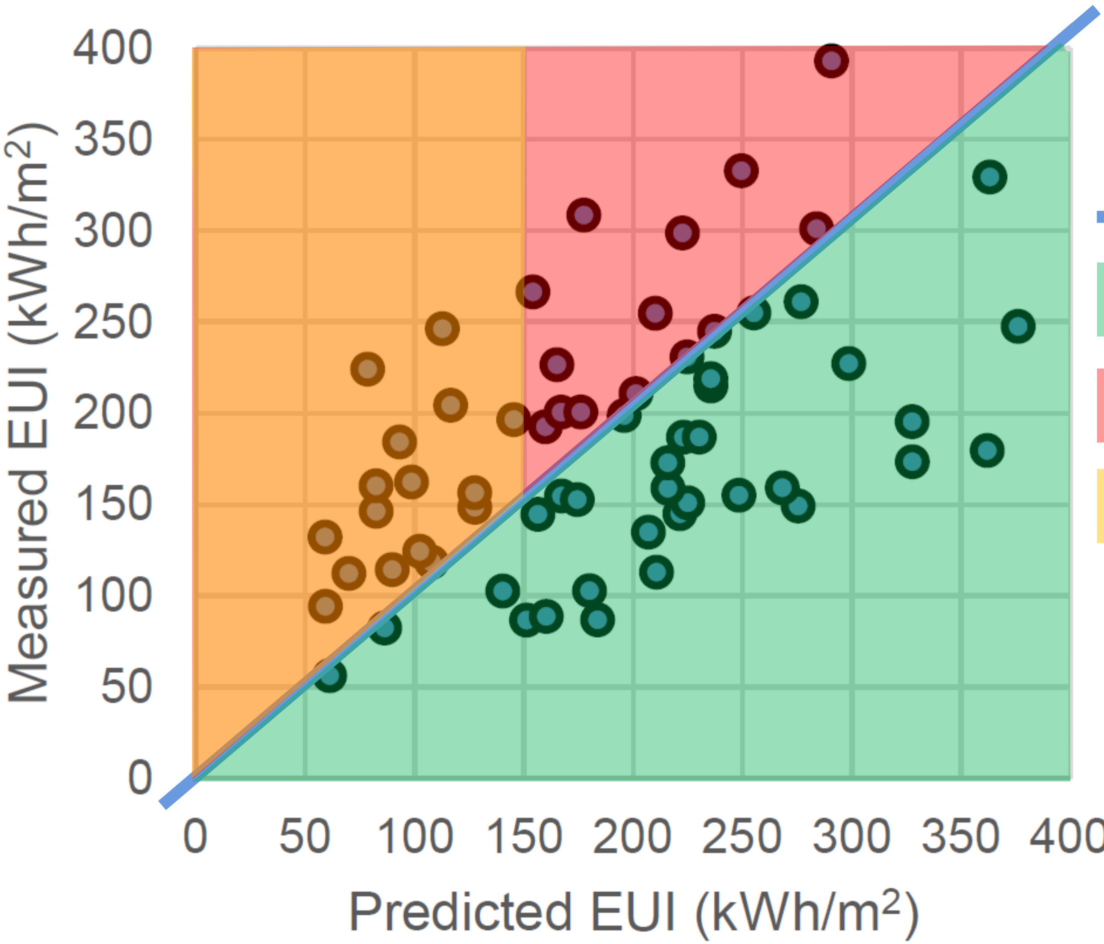


LEED™ FOR HOMES

"Low Energy Buildings"

Low energy buildings

Energy performance deviation



Measured = Predicted

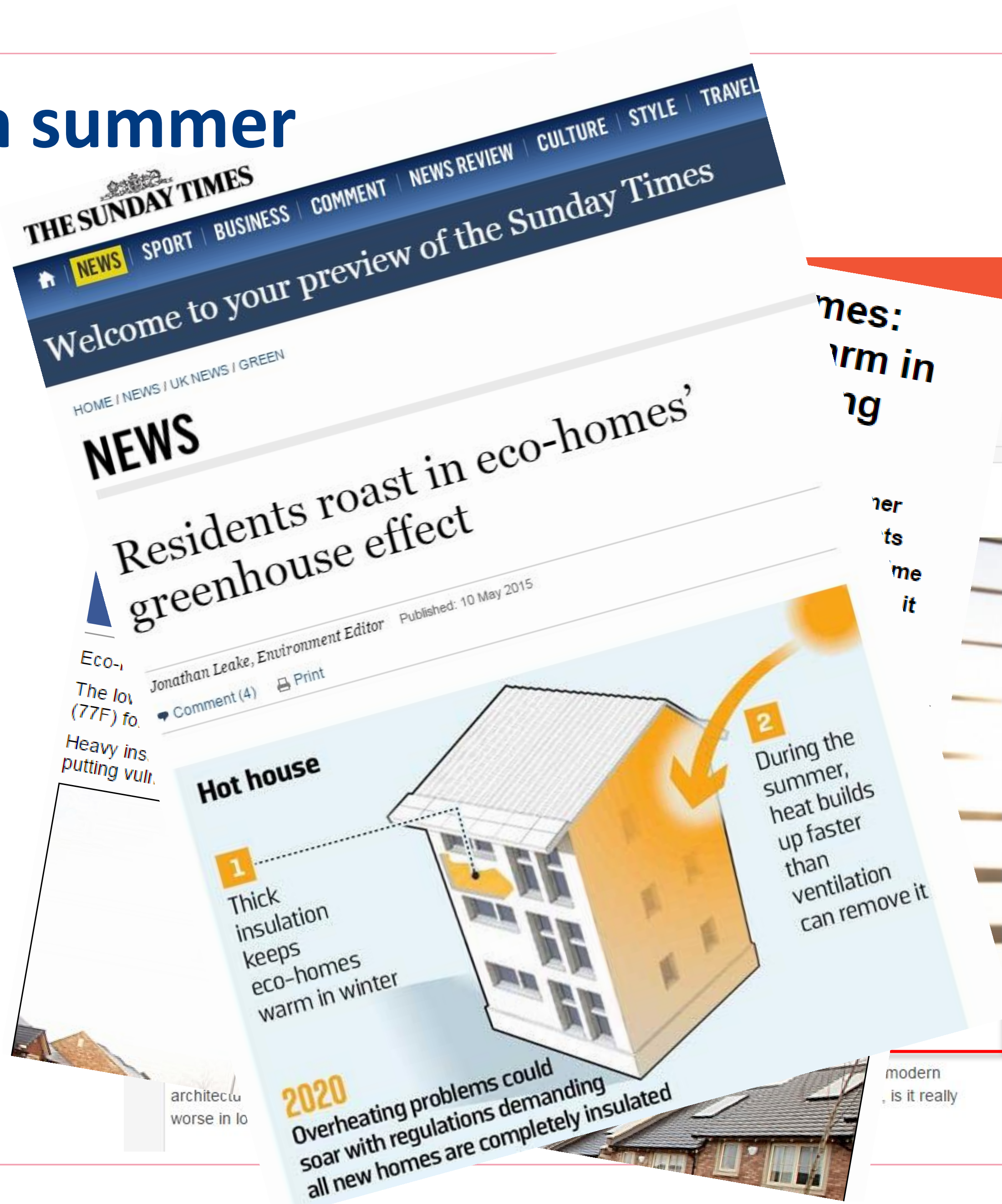
Measured < Predicted

Measured > Predicted

Low energy buildings tend to consume more than predicted!!!

Turner et al (2008), LEED certified office buildings.

Overheating risks in summer



THE SUNDAY TIMES

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NEWS

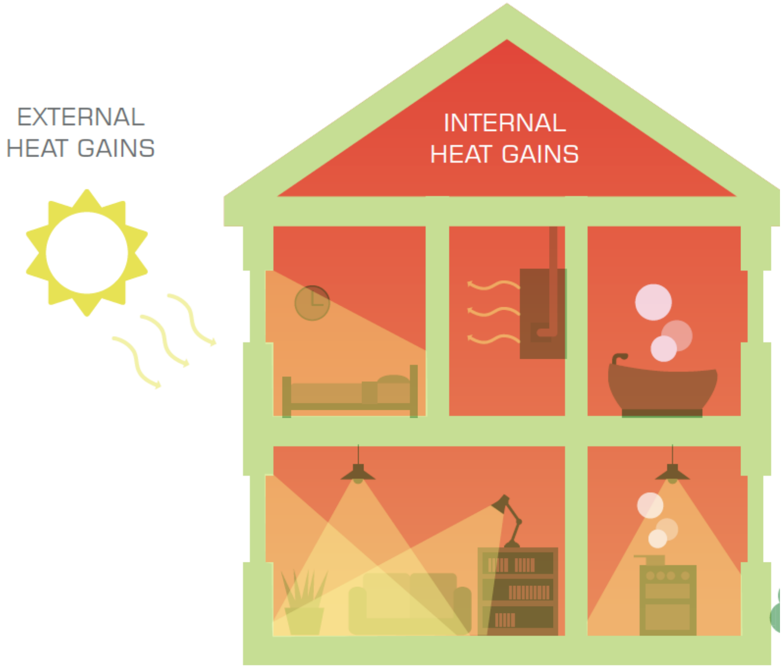
Residents roast in eco-homes' greenhouse effect

Jonathan Leake, Environment Editor Published: 10 May 2015

Comment (4) Print

Plausible reasons

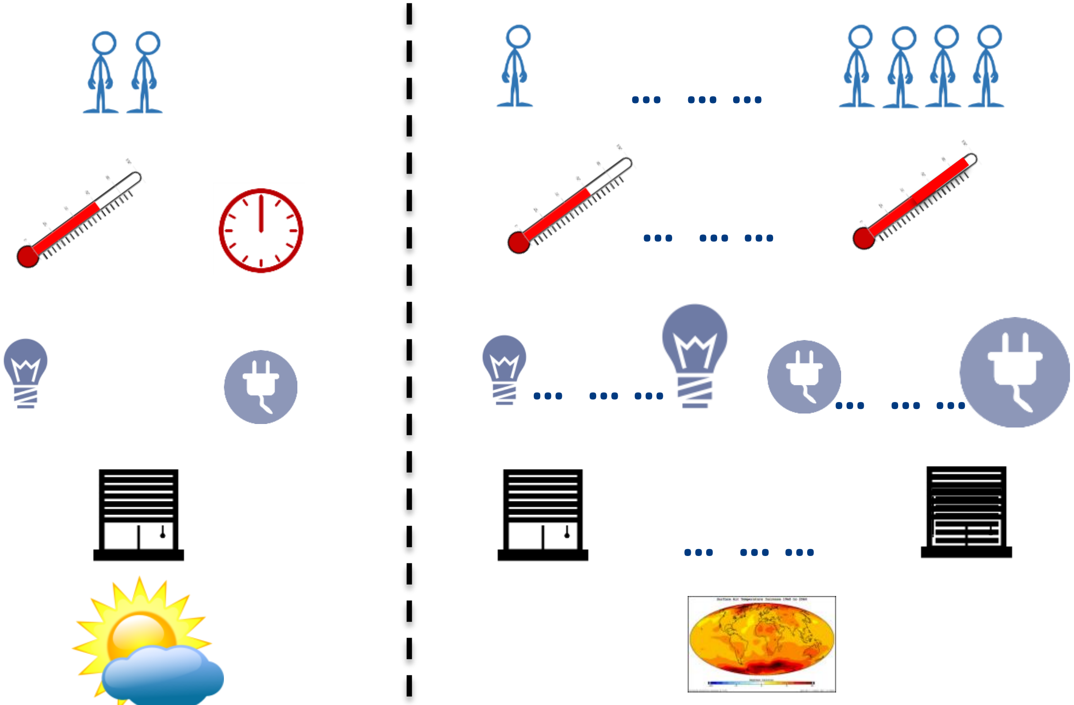
- Highly insulated and air tight building envelopes



Plausible reasons

- Current design practice

Design phase | **Future (operational phase)**



Historical weather data | Climate change, heat wave…

- Not meeting intended performance in the future

NZEB today ≠ NZEB future

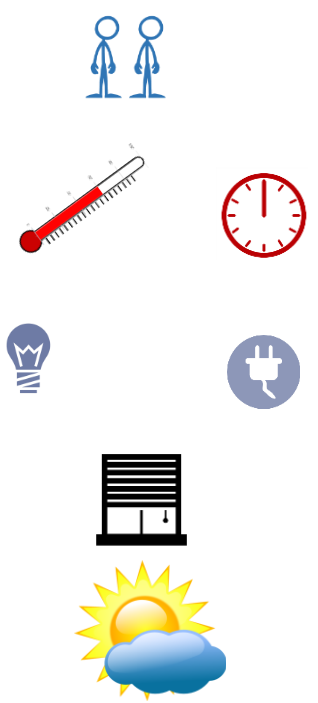
- Risk of failure of energy (e.g. HVAC) systems

- Thermal discomfort

Plausible solution

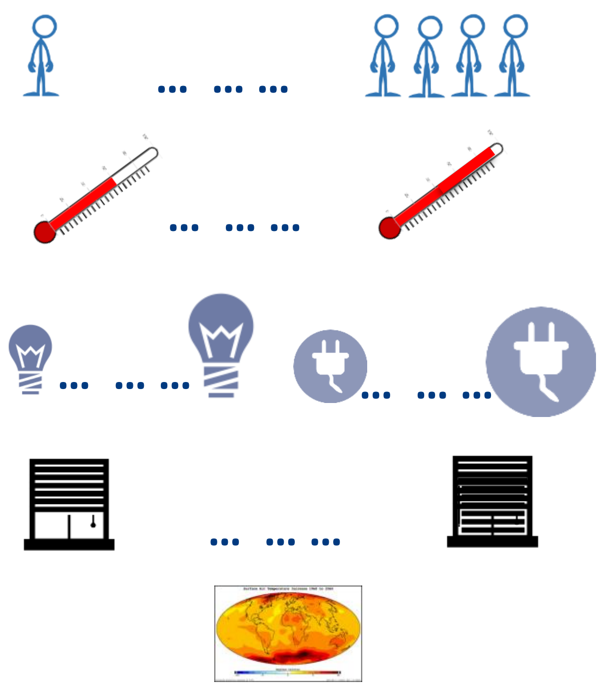
- Robust designs

Design phase



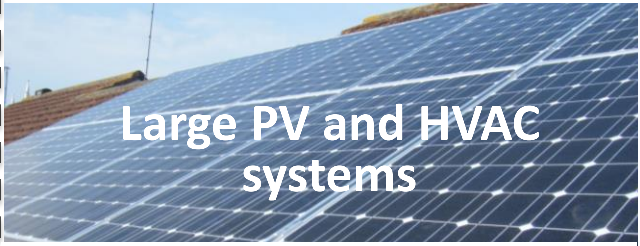
Historical weather data

Future (operational phase)



Climate change, heat wave…

Solution



- ➢ Oversized systems
- ➢ Very high investment costs
- ➢ Not “*smart*” approach

Research methodology

➢ Smart approach

To ensure intended performance in the future

- Less variations in energy consumption
- Comfort conditions

Performance robustness assessment

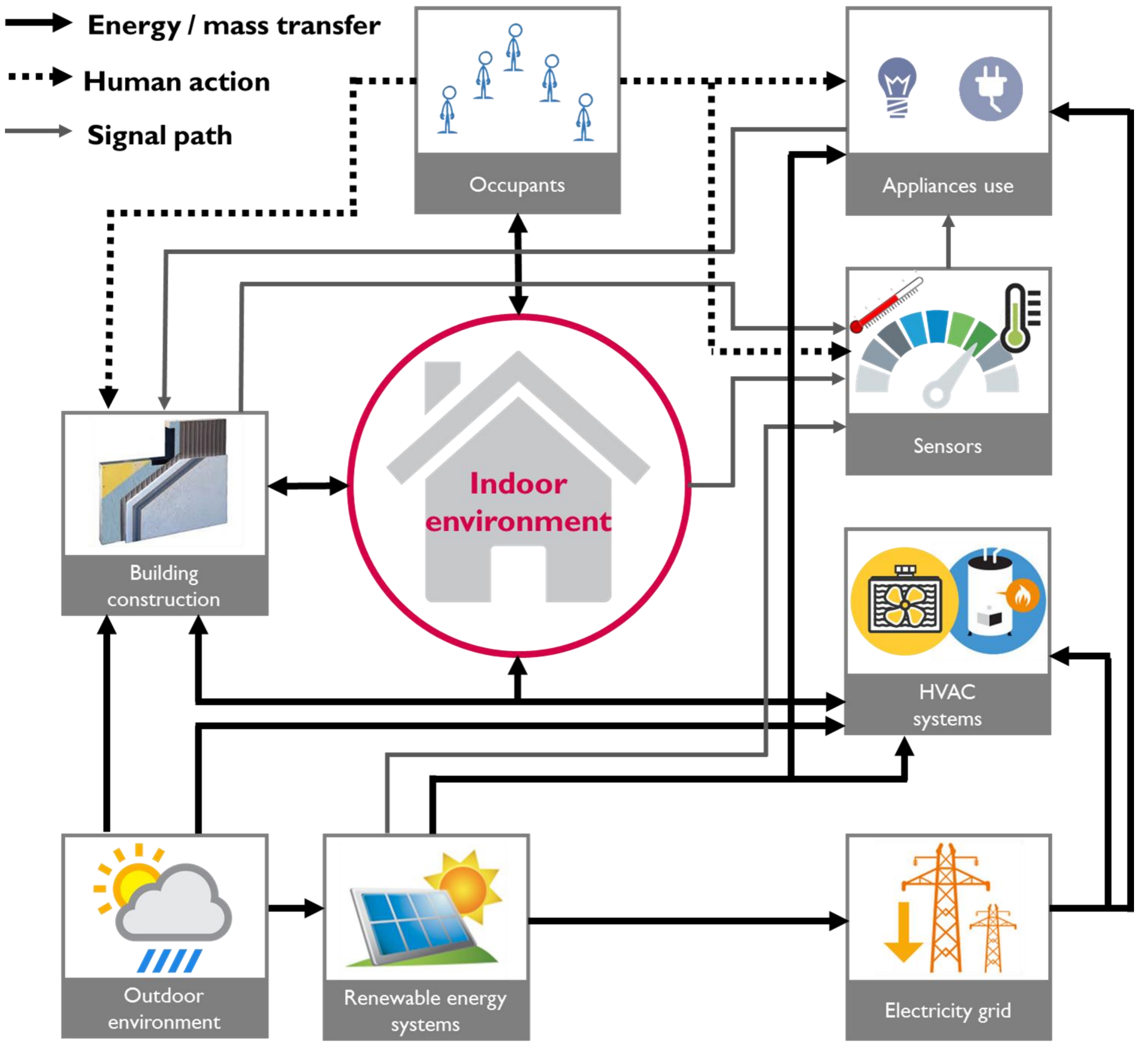
- Uncertainties in occupant behavior
- Climate change

Robust designs

- Minimizes performance variation
- Intended performance in the future

➢ Computational (building performance and energy system simulation) performance robustness assessment methodology is developed

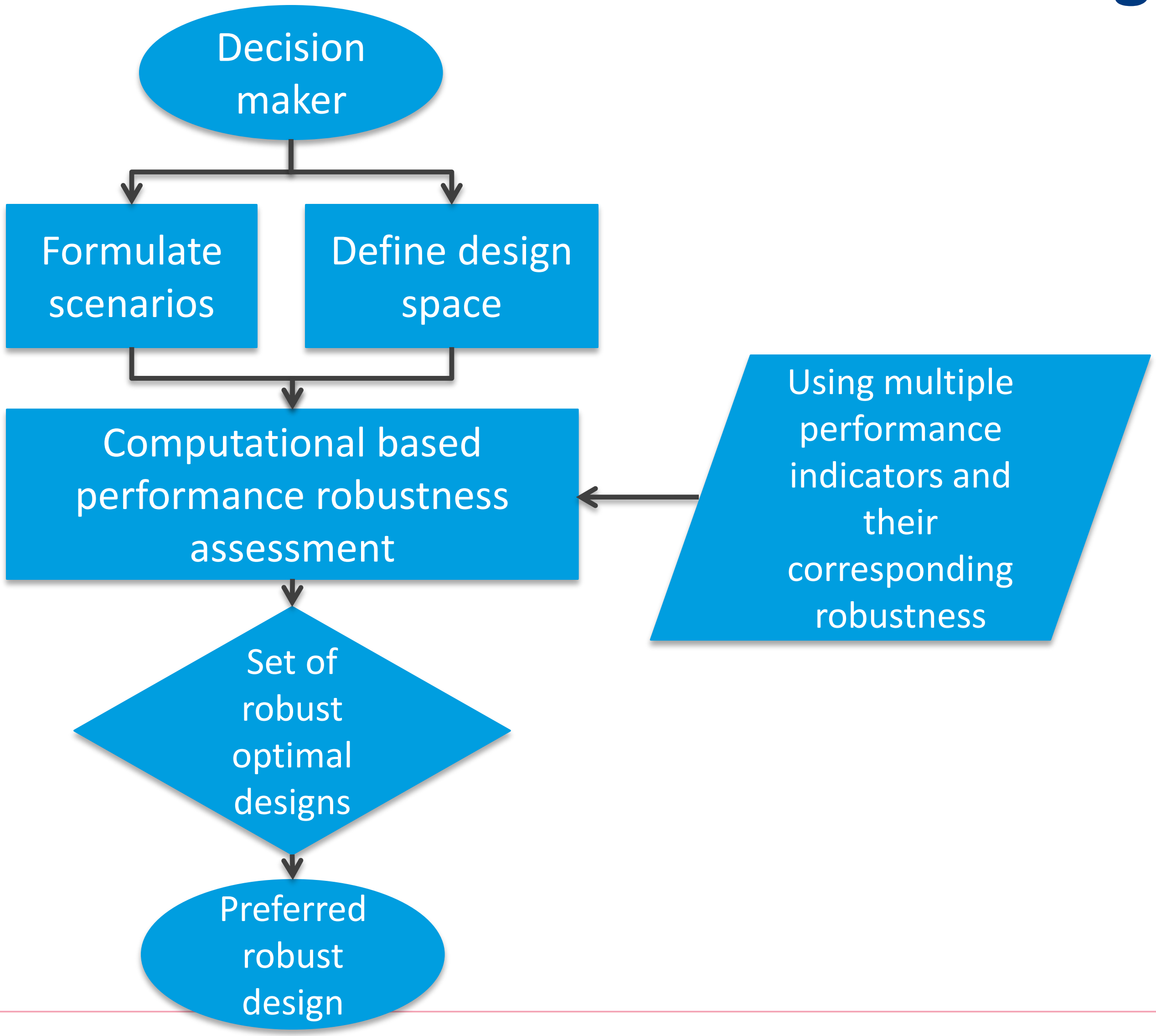
Building performance and energy system simulation



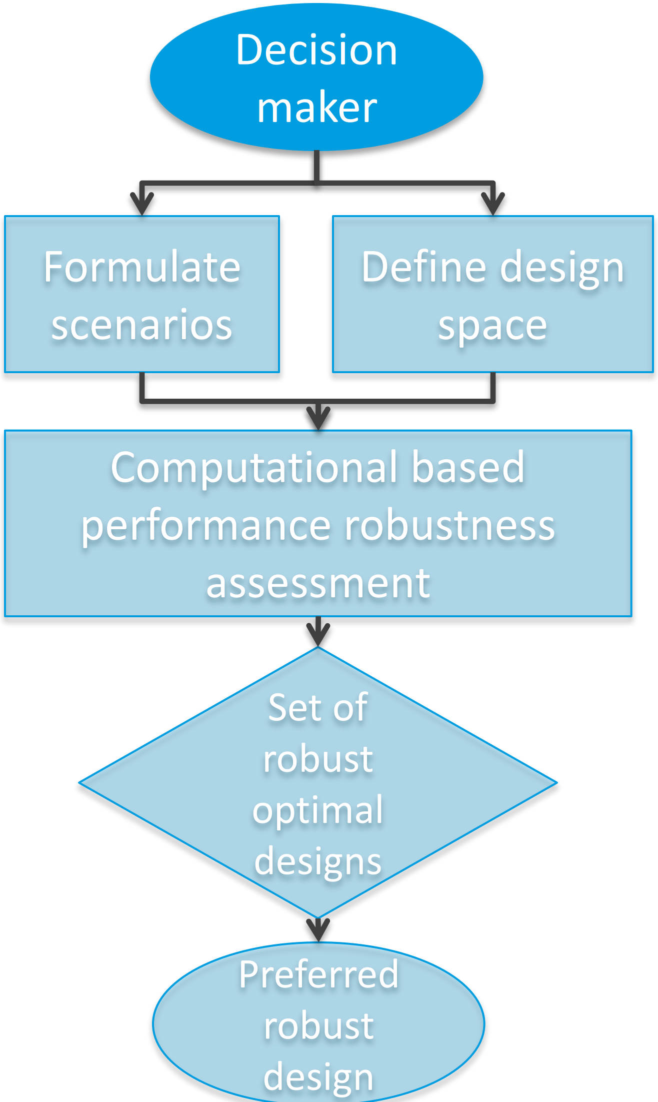
TRNSYS 17

modeFRONTIER

Performance robustness assessment methodology



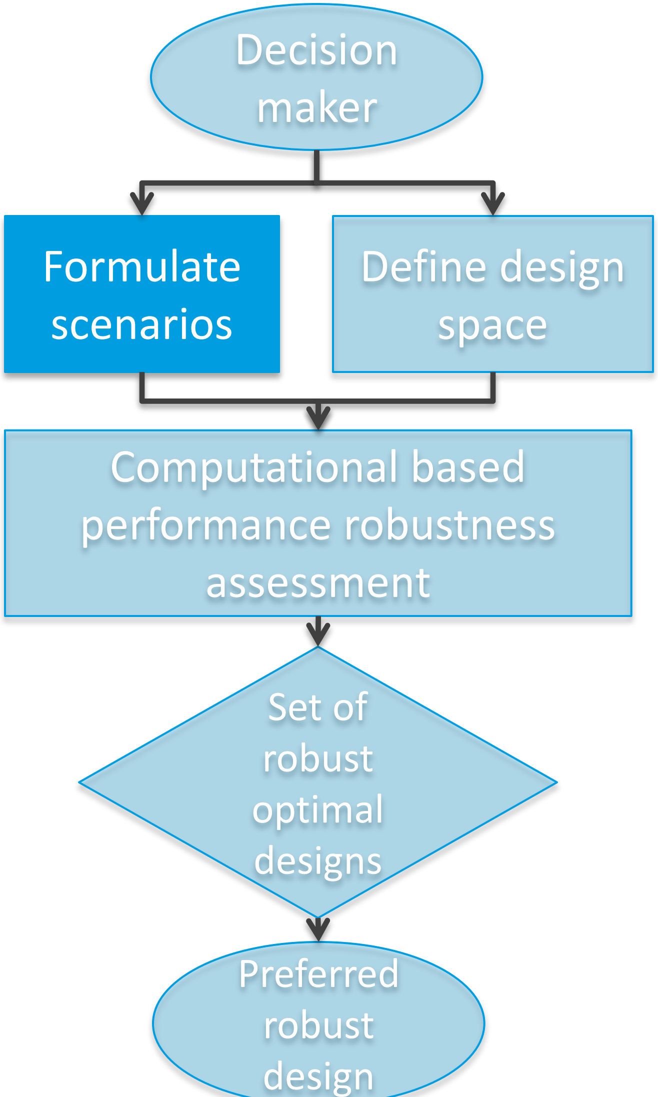
Decision makers



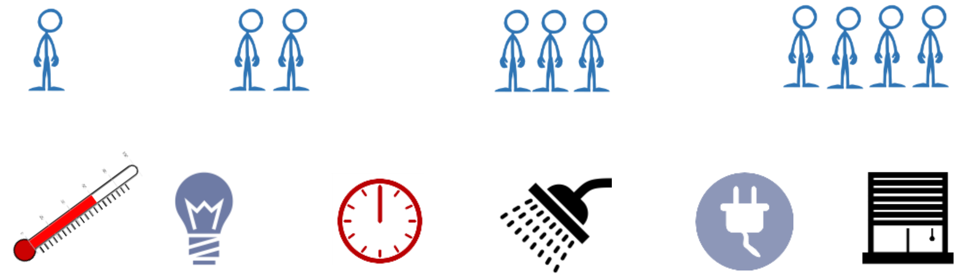
1. Thermal comfort
2. Operational (global) cost
3. Additional investment cost
4. Onsite energy matching
5. CO_2 emission reductions
6. Peak loads

…….

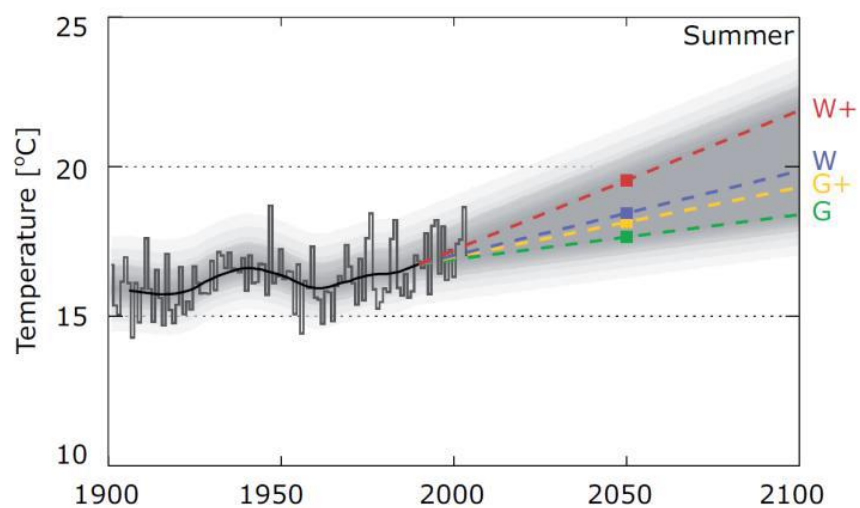
Future scenarios



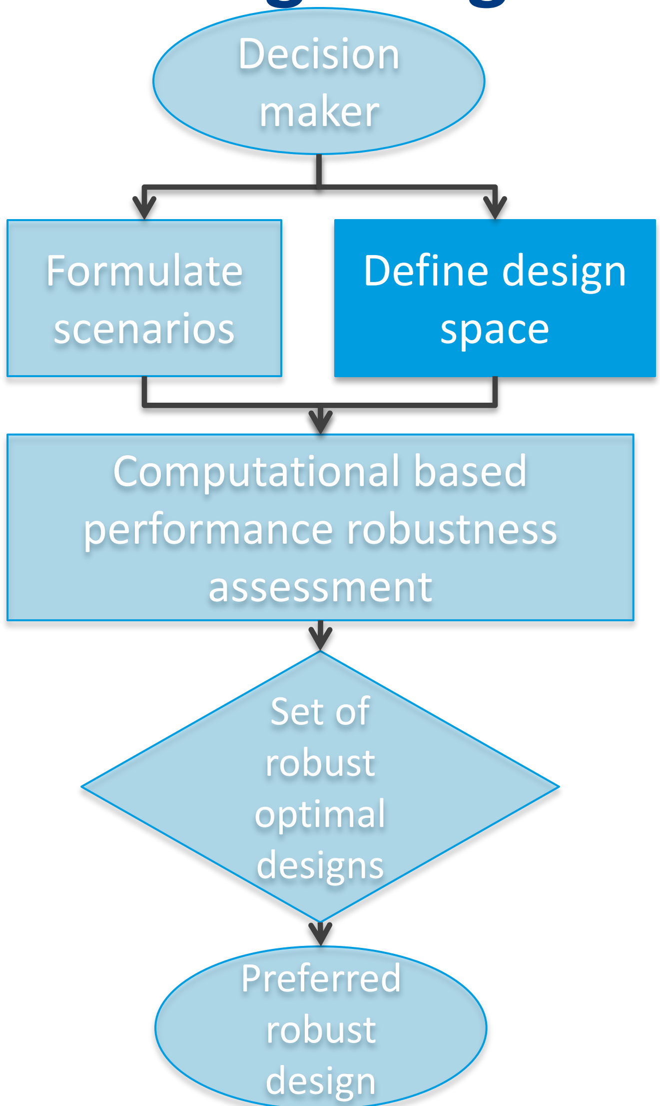
Occupant scenarios

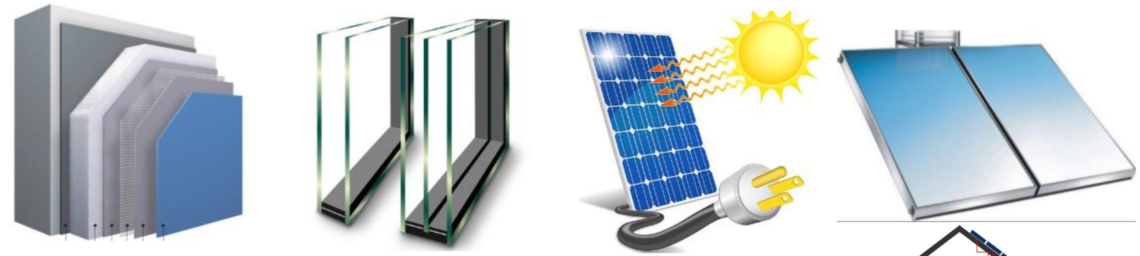


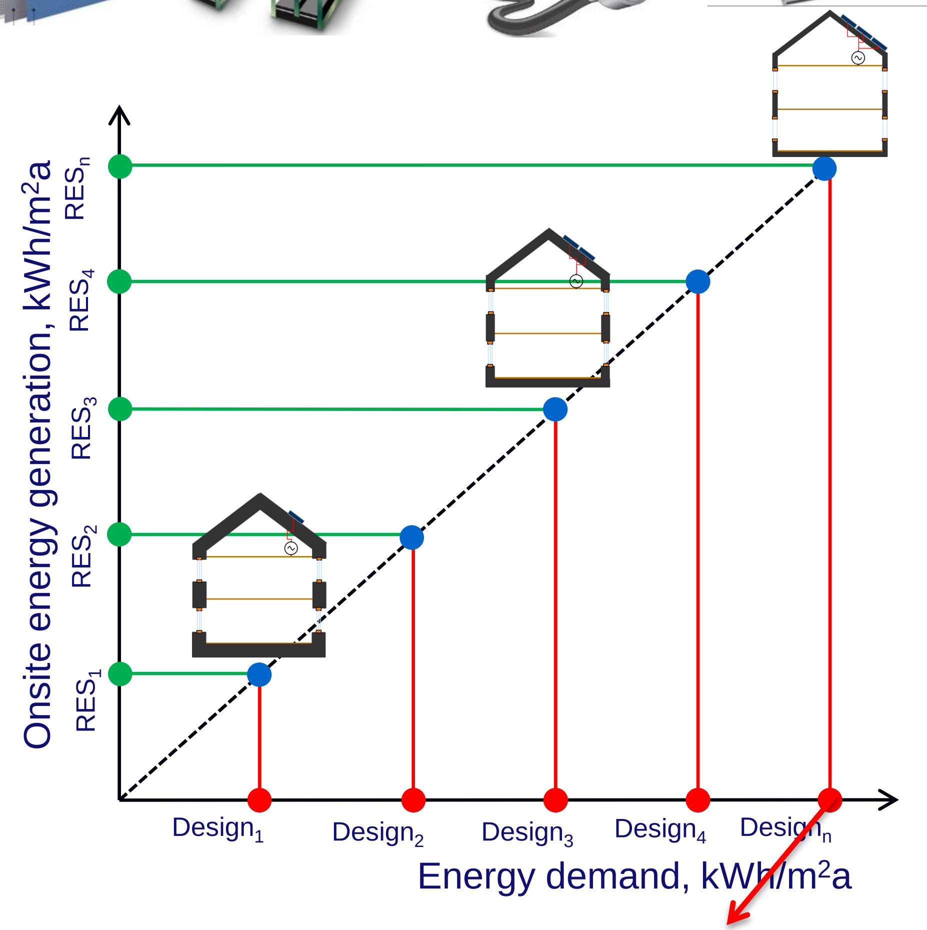
Climate scenarios



Building designs

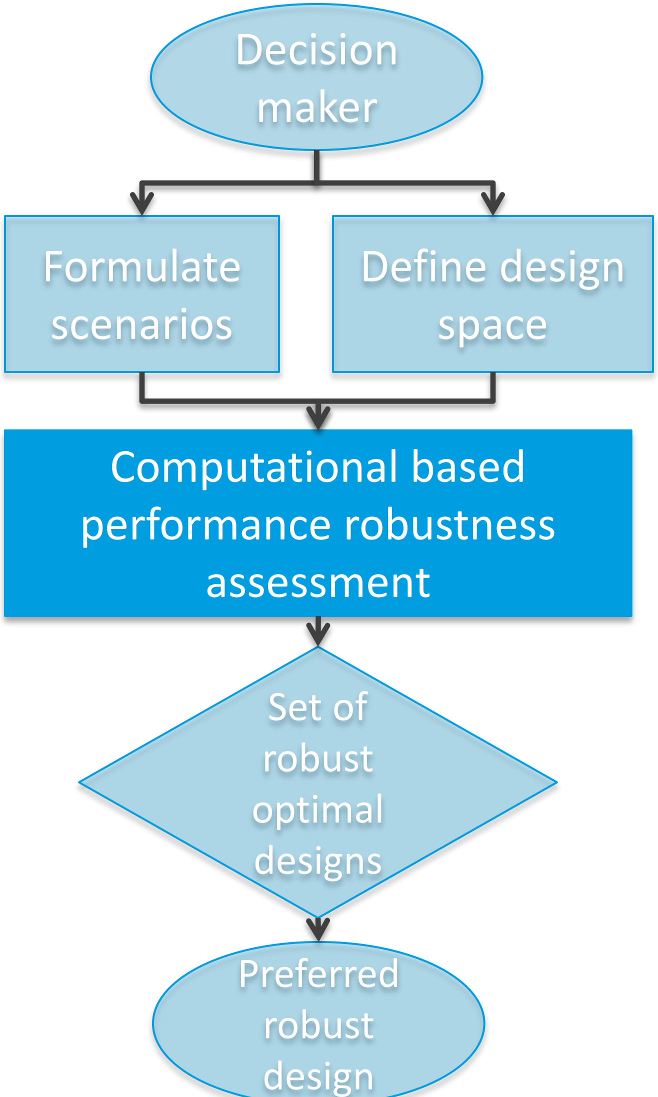






Number of design configurations, n>1000

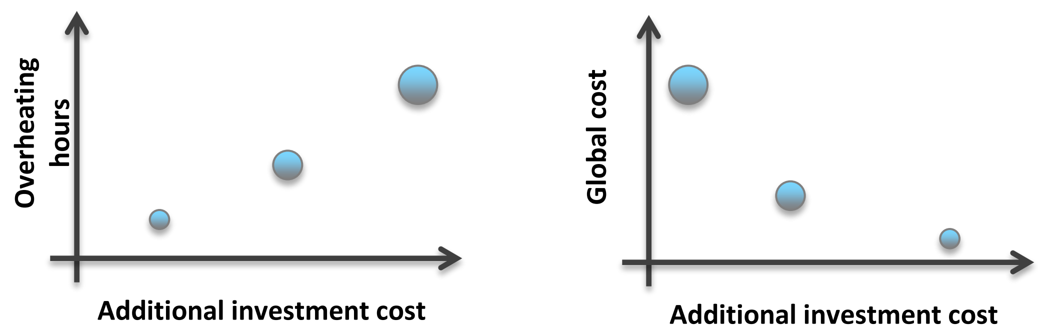
Performance assessment



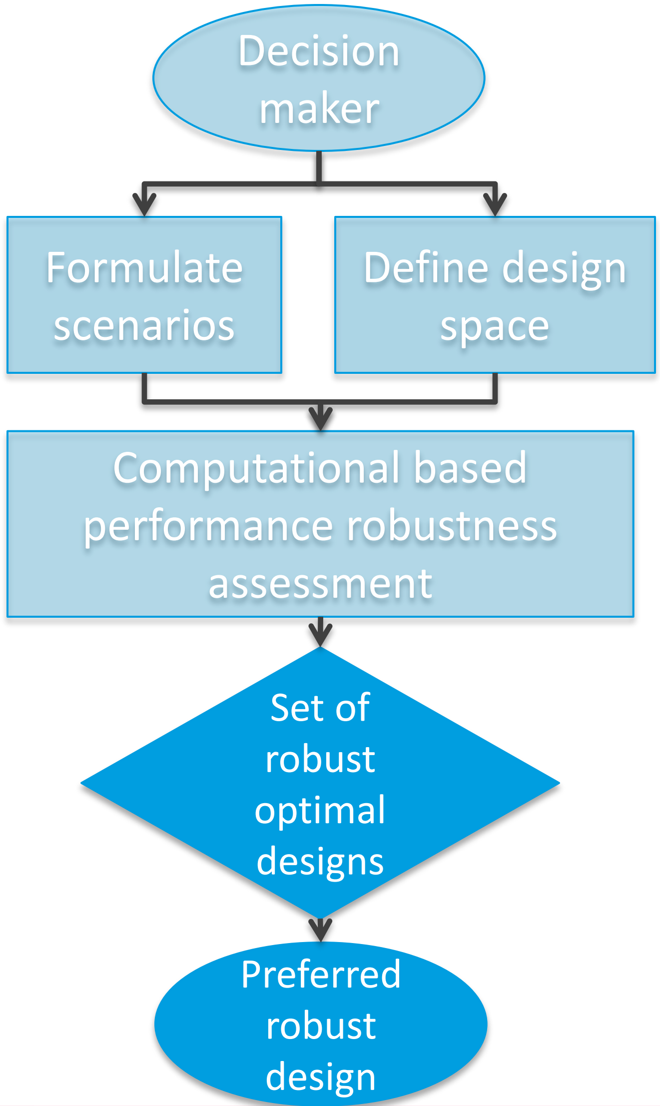
Multi criteria assessment

- Multiple performance indicators
  1. Overheating hours [h]
  2. Global cost [€/30 years]
  3. Additional investment cost [€]

- Performance robustness

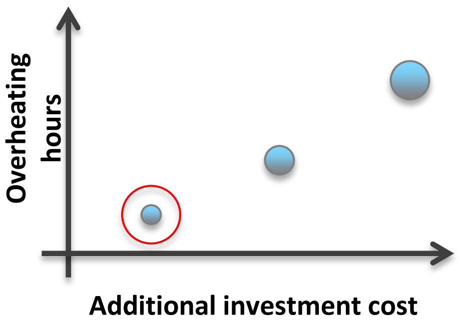


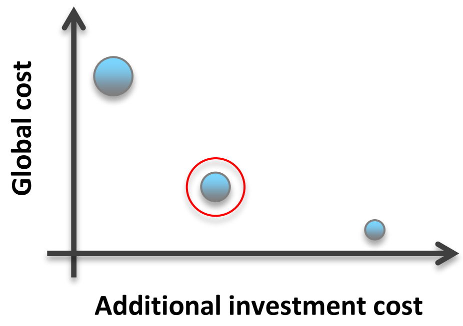
Selection of robust designs



Identified using methods (e.g. Mini-max regret method) adopted from risk analysis, structural design etc.

- Decision maker can choose a design based on ***actual performance*** and ***performance robustness*** and trade off with ***additional investment cost*** required for the design





Practical use - suitability and usability assessment with users group

HALMOS ADVISEURS

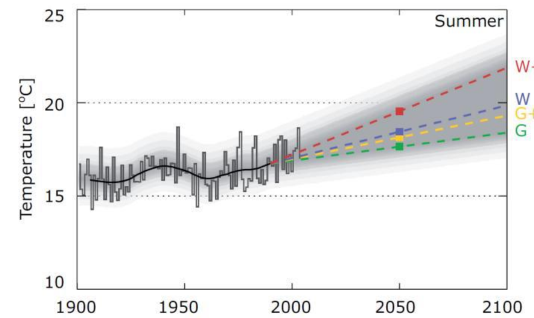
HOMIJ Technische Installaties

Smits van Burgst

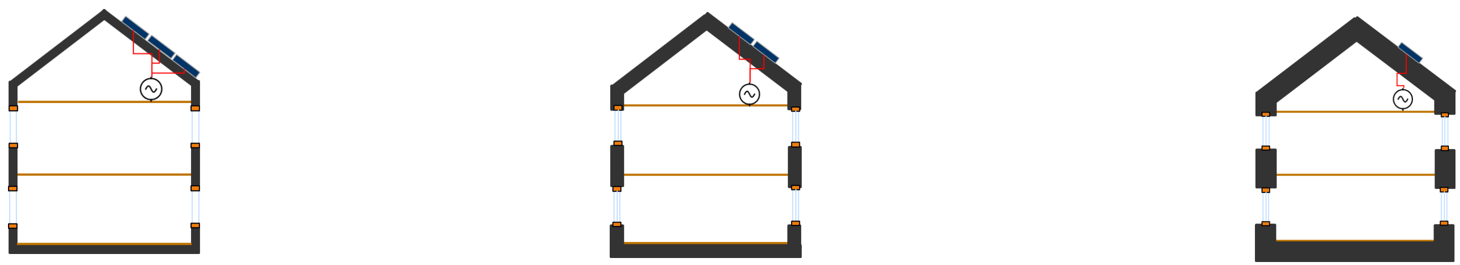
vabi elements

Overview

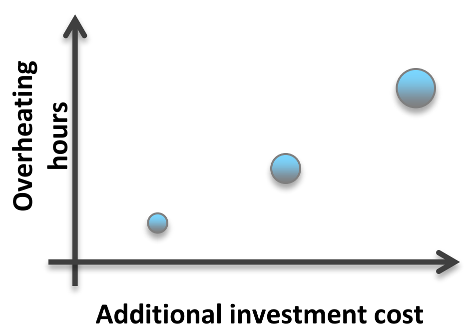
Scenarios

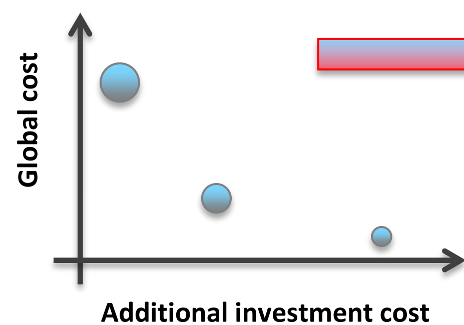


Designs



Performance assessment





Preferred design with optimal performnace and performnace robustness

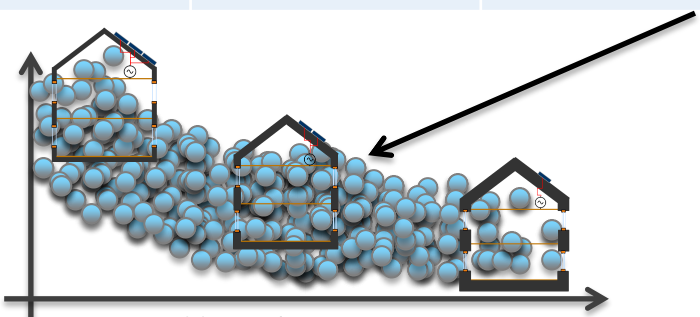
HOME OWNERS

Case study for demonstration of methodology

Existing corner terraced house that needs to be renovated

Case study for demonstration of methodology

Design variants	House built in *1992*	Renovation measures
Rc Wall, m^2K/W	2.53	3 - 10
Rc Roof, m^2K/W	2.53	3 - 10
U window, W/m^2K	2.8	2.4 - 0.4
Infiltration, ach	1	0.12 – 0.36
PV system, m^2	--	16 - 31
Heating system	Gas boiler	Air source heat pump
Ventilation system	Mechanical extraction	Balanced system with heat recovery
DHW system	Gas boiler	Solar, 1 - 6 m^2

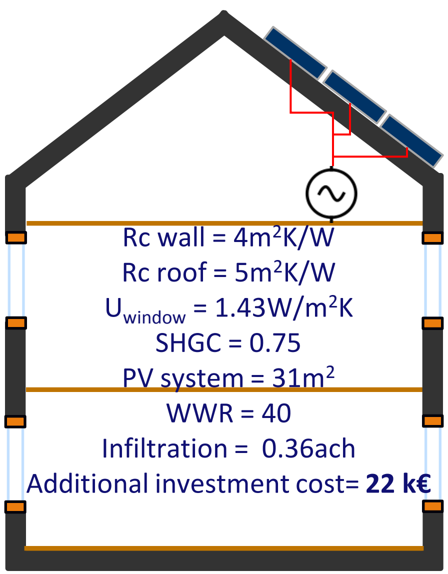


Scenarios

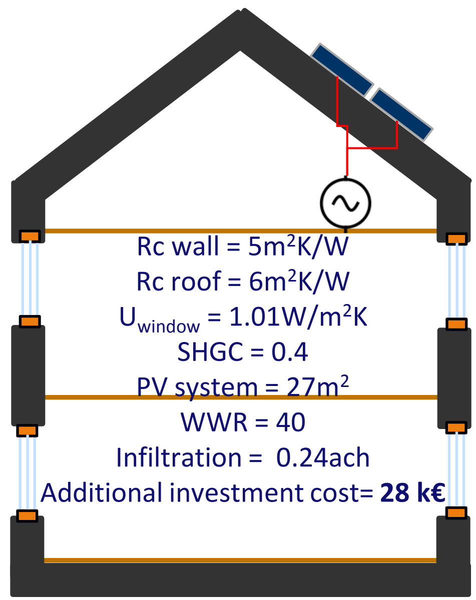
- 1 - 4
- 18 - 22°C
- All day, evening
- 1 - 3 W/m^2
- 60 - 180 L/p/day
- 1 - 3 W/m^2
- ON/OFF
- G, W, G+, W+

Selected renovation options for demonstration

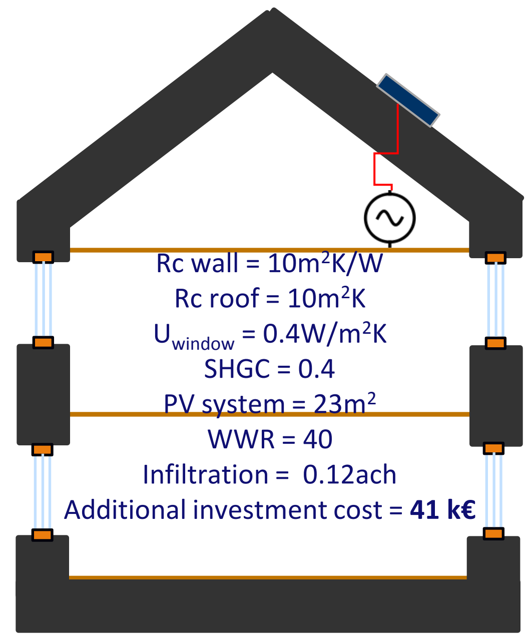
Low insulation



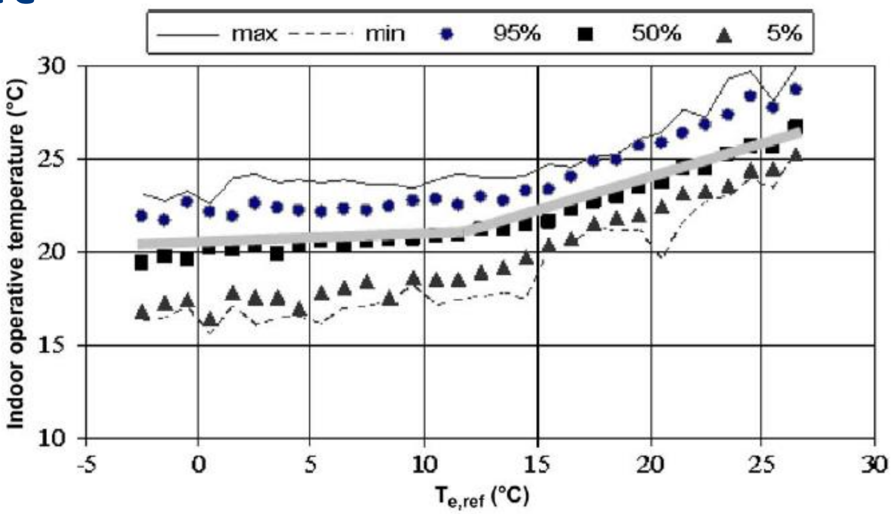
Medium insulation



Very high insulation



Performance assessment



Peeters et al., (2009), Applied Energy

1. Overheating hours (h)

- $T_{indoor} > T_{max}$
- Weighted for every excess degree $(T_{indoor}-T_{max})*h$

2. Additional investment cost (€)

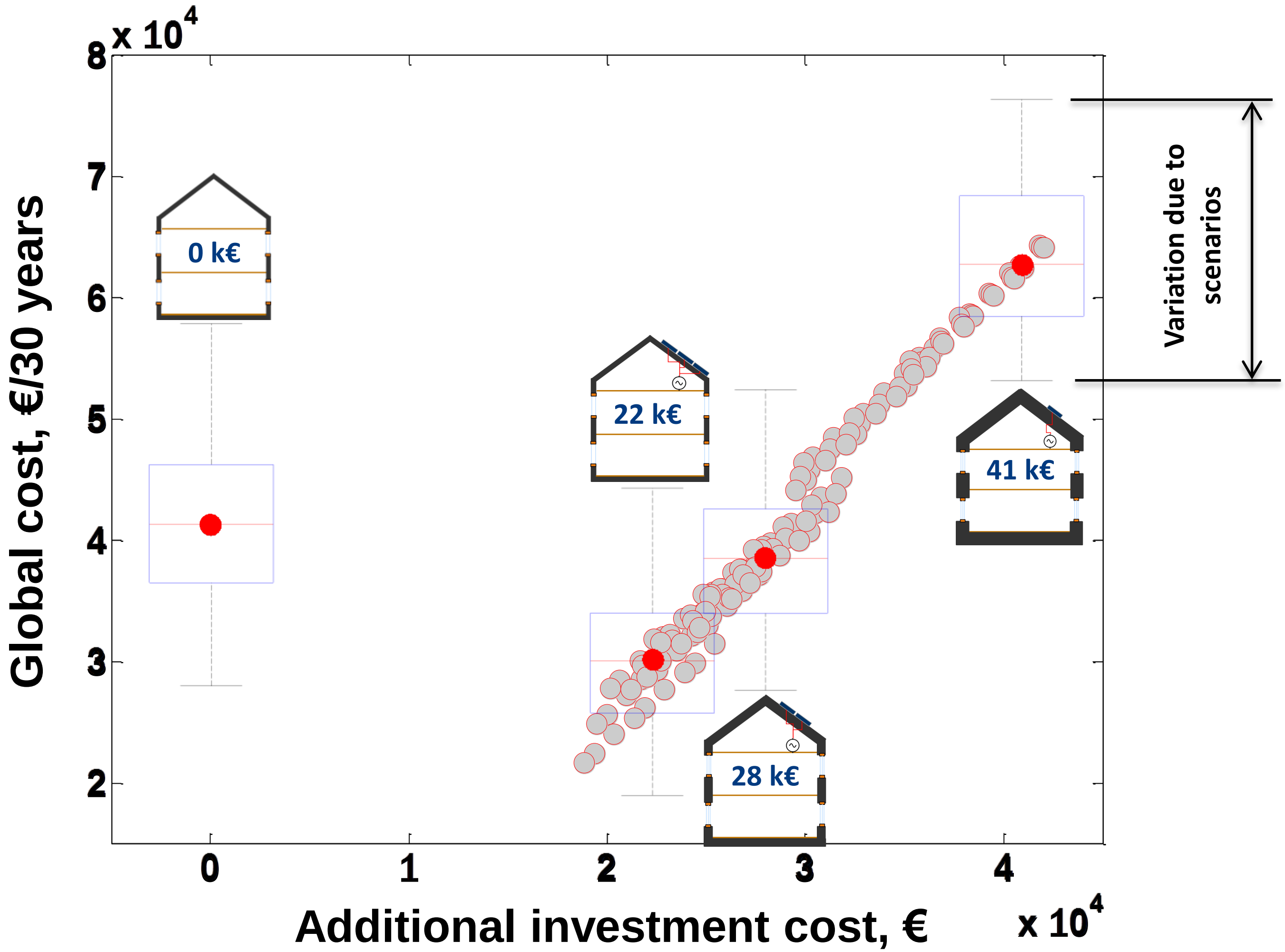
- Cost of renovation (e.g. cost of insulations, windows, air tightness, DHW system, PV system)

3. Global cost (€/30 years)

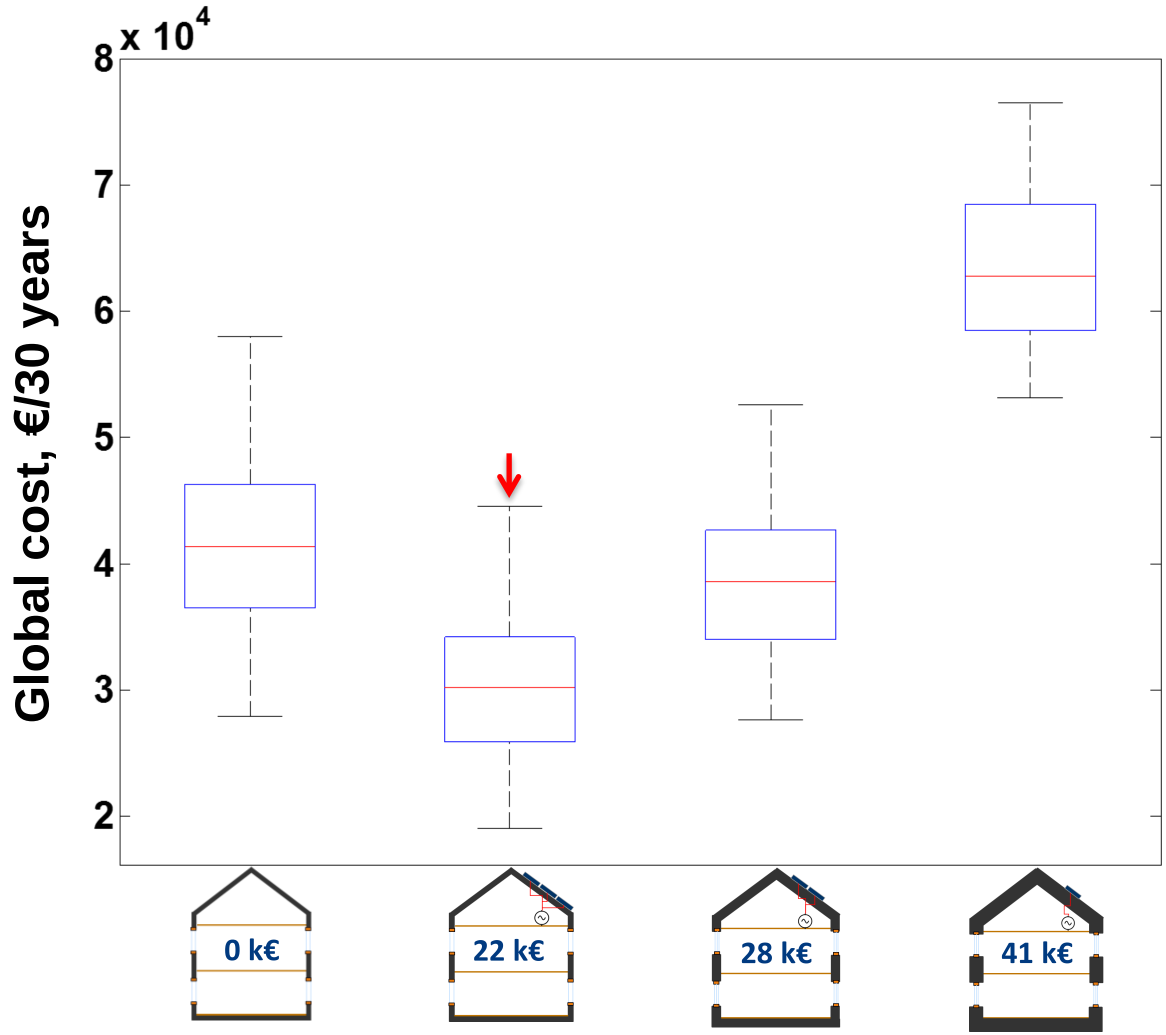
- Investment + Replacement + Maintenance + Operating costs
- Calculated for 30 years period – service life span of energy systems

HOME OWNERS

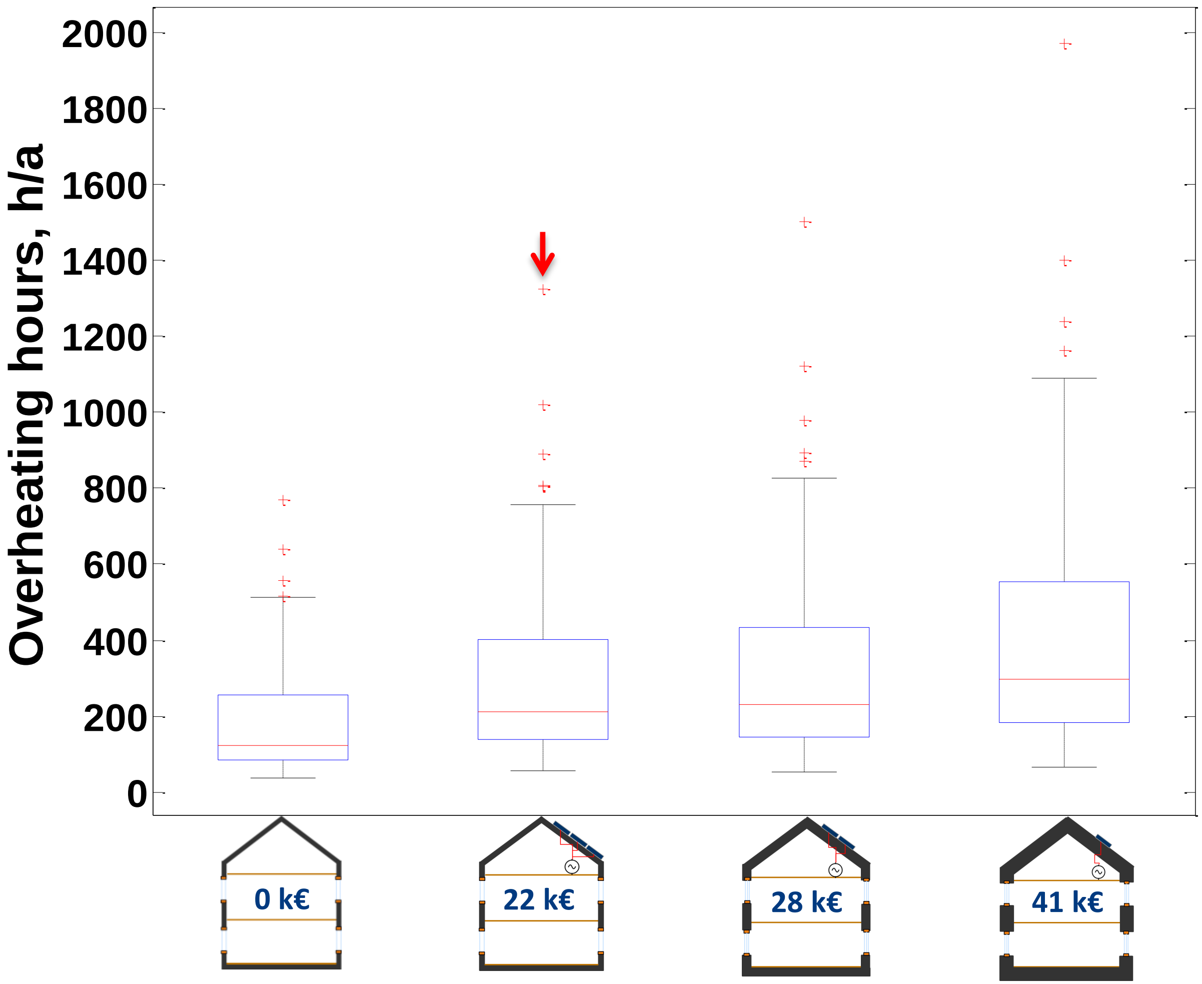
Results - global cost



Results - global cost

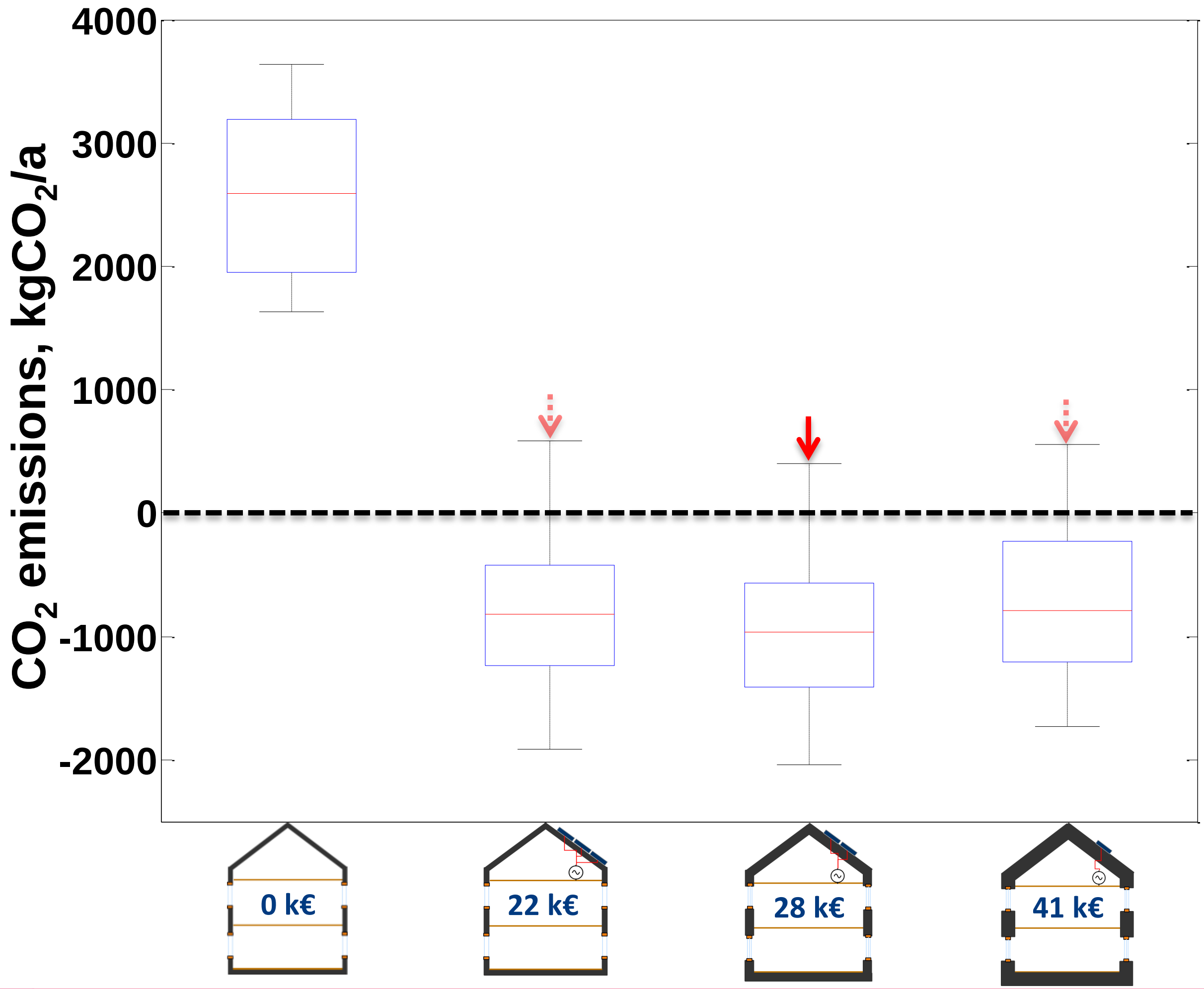


Results - overheating hours



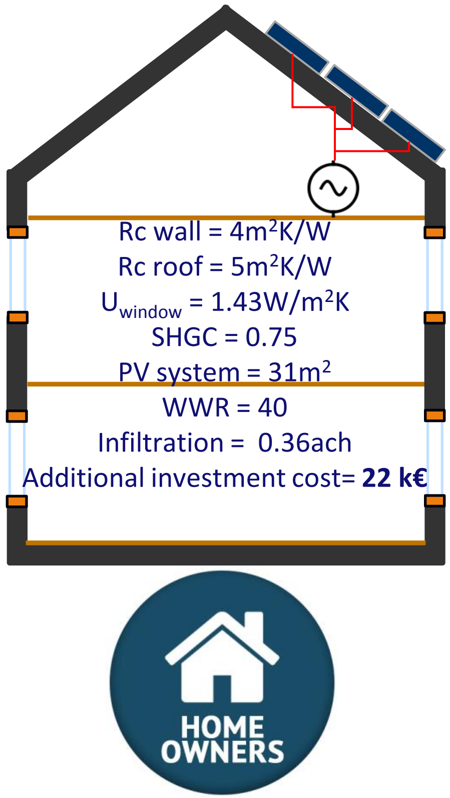
Results - Policy maker - CO_2 emission reductions

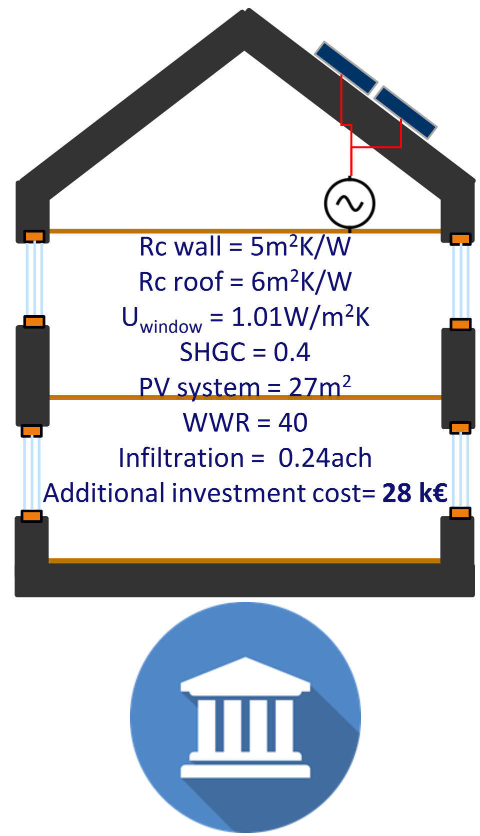
$$CO_2\ emissions = Energy\ consumption \times EF - Energy\ generation \times EF$$



- EF = CO_2 emission factor
- Embodied emissions are not taken into account
- Negative emissions indicate reduction of emissions by building

Preferred robust design*





* Preferred robust designs among three selected renovation options. Robust designs might vary if the whole design space is considered.

- This work presents a novel methodology for identifying robust building designs

- Compared to conventional design practice, this method
    - ensures intended performance in the future – towards future proof buildings e.g. $\text{NZEB}_{\text{today}} = \text{NZEB}_{\text{future}}$
    - guarantees required comfort conditions

- Using the current methodology, a decision maker can
    - choose a robust design by prioritizing a performance indicator
    - carry out a trade off with robustness of other performance indicators
    - trade off between additional investment to improve:
        - building insulation levels
        - energy generation systems
        - robustness of the design

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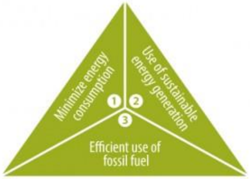
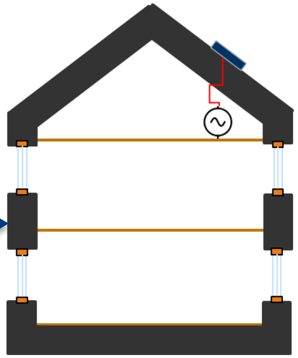


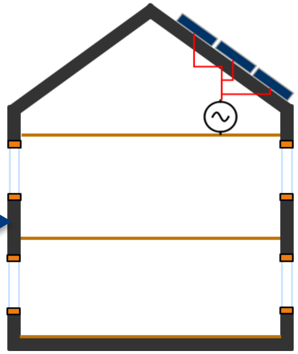
Regulations and frameworks

Passivhaus Institut



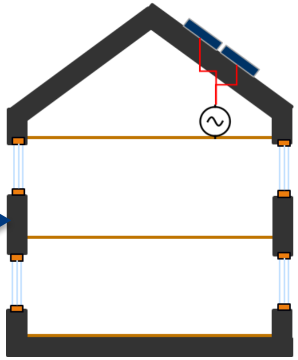
- Regulations and frameworks aim for very high insulated buildings
- Overheating risks are observed in these buildings
- **Are they future proof?**

Robust design



- Low insulation buildings are more preferred robust designs for homeowners

Robust design



- Medium insulation buildings are more preferred robust designs for homeowners

Thank you
Questions?

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Robust buildings

In the present context

*"A building is **robust** if it is able to handle uncertainties in building operation and external conditions and delivers intended performance (energy, comfort…) "*

In this work, the focus is on performance (energy, comfort etc.) robustness rather than structural robustness of a building

Robust building designs

Advantages

- Guarantees required performance for the whole building life span

- Reduces the performance gap between predicted and measured

- Enhances decision making process - making informed choices among different building designs