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Modeling and Simulation of Energy Use and Indoor Thermal Environment of Highly-Insulated Buildings

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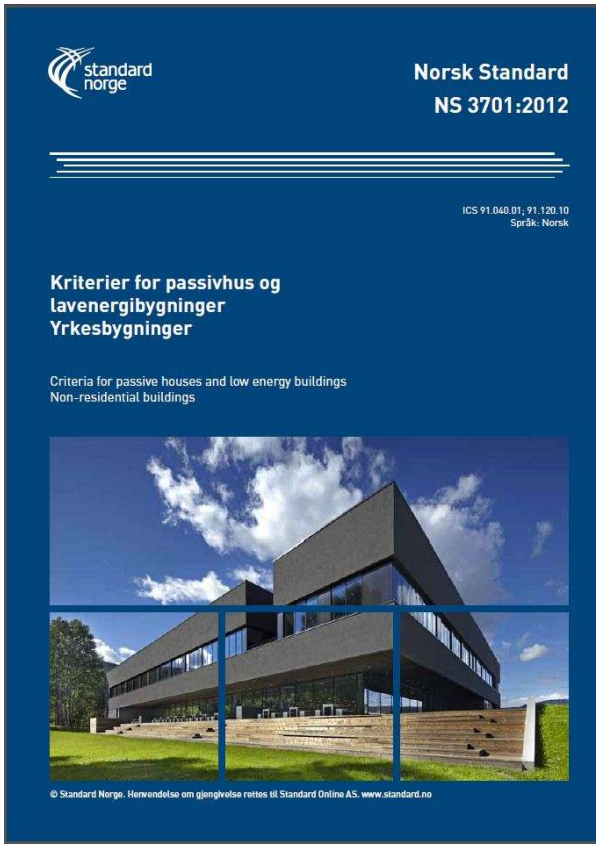
IBPSA-Nordic/NORVAC Seminar, VVS-Dagene 2014, Lillestrøm
22th of October 2014

ZEB The Research Centre on Zero Emission Buildings

FME CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

Current and upcoming context (1)

- **Norwegian Passive House standard**
- NS 3700:2013 and NS 3701:2012



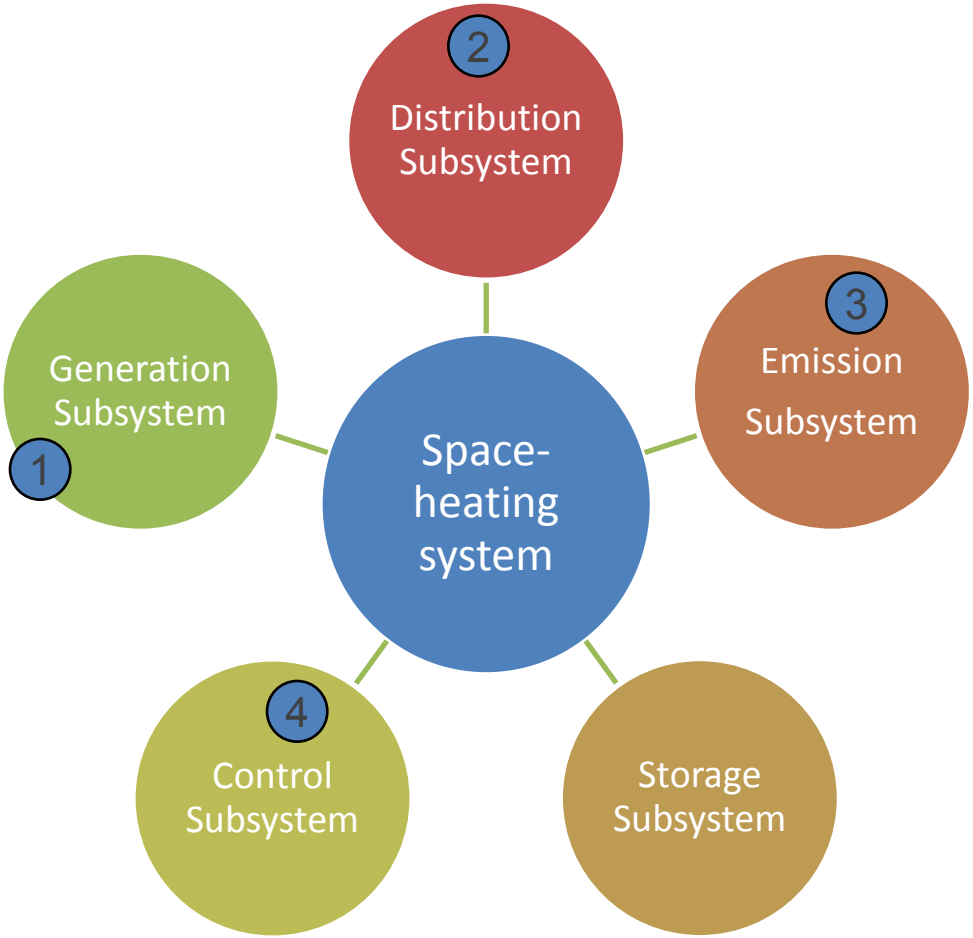
Current and upcoming context (2)

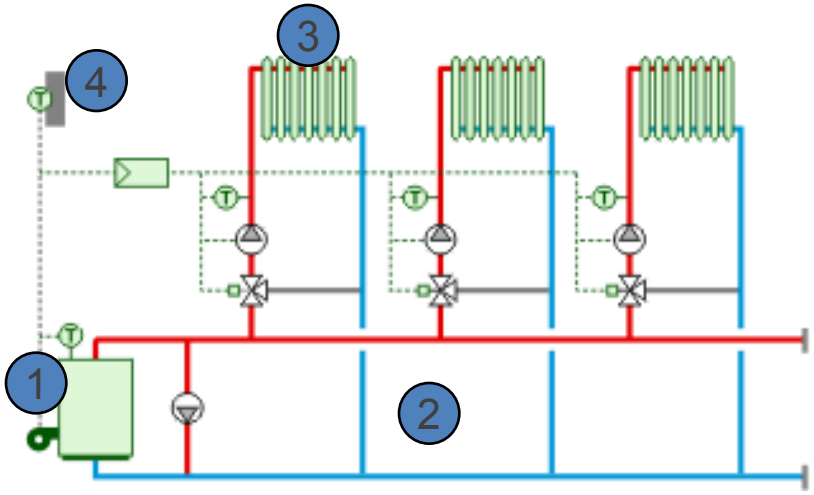
- Recast of the EPBD directive in EU
  - Introduces *Nearly-Zero Energy Buildings* (nZEB)
  - All new public buildings in 2018
  - All new buildings in 2020

- **Nearly-Zero Energy Buildings (nZEB)**
  - A building with a very high energy performance (i.e. very low energy use)
  - The very low amount of energy required by a nZEB must be covered by a very significant extent by energy from renewable sources, produced on-site or nearby
  - Performance indexes for energy efficiency
  - Performance indexes on balance between energy use and produced

Current and upcoming context (3)

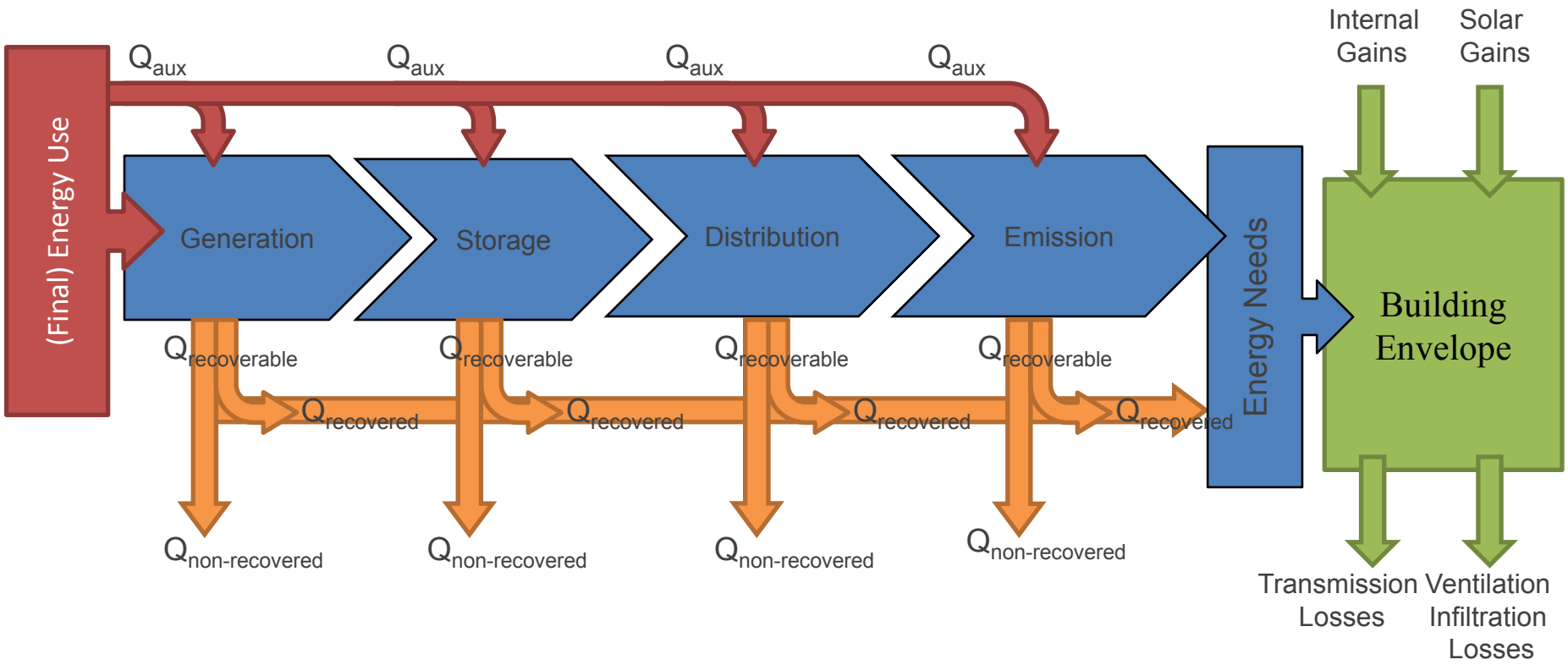
- Decomposition of a system into subsystems





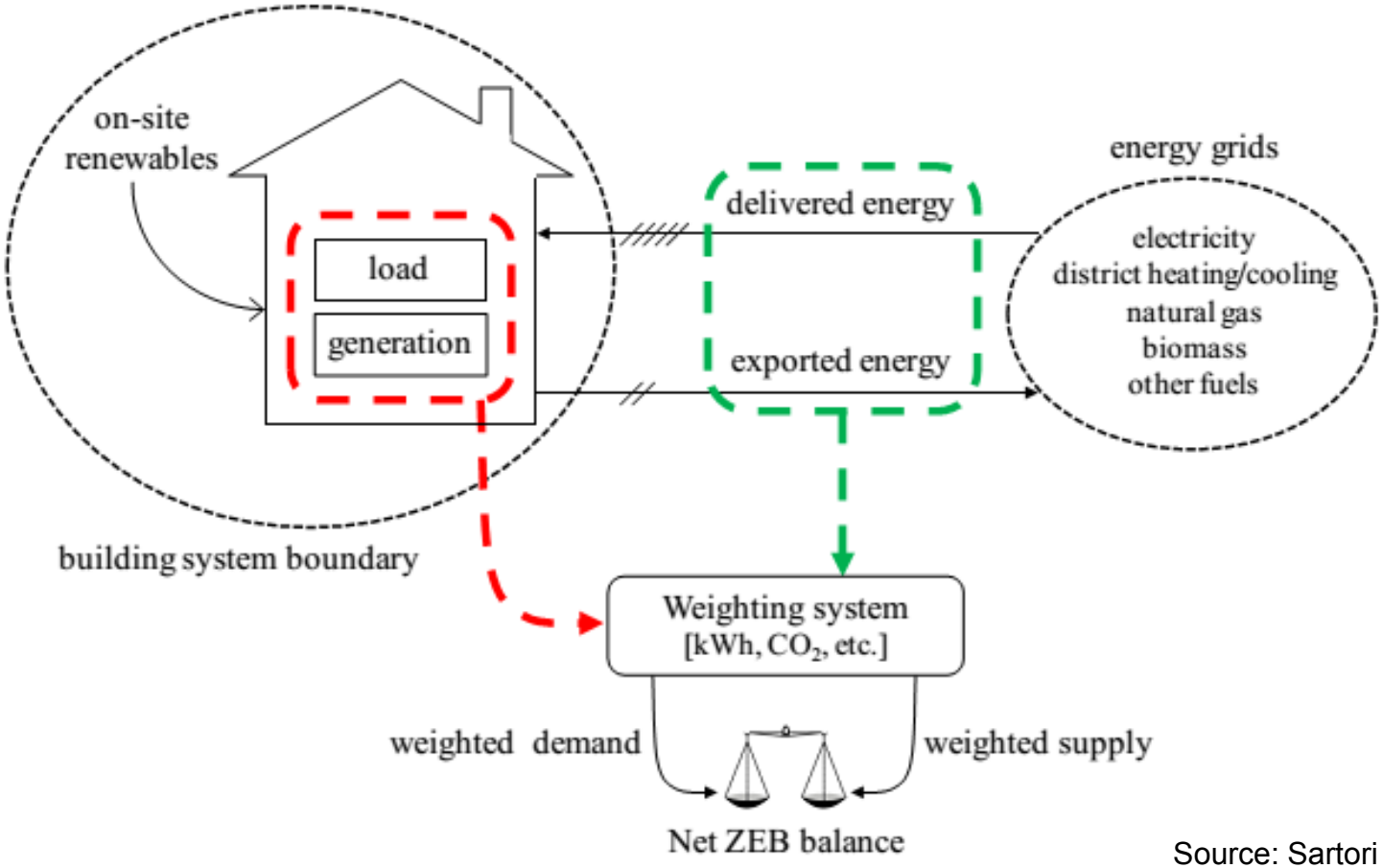
Current and upcoming context (4)

- Energy performance indexes on efficiency :
  - Energy needs, energy used and primary energy



Current and upcoming context (5)

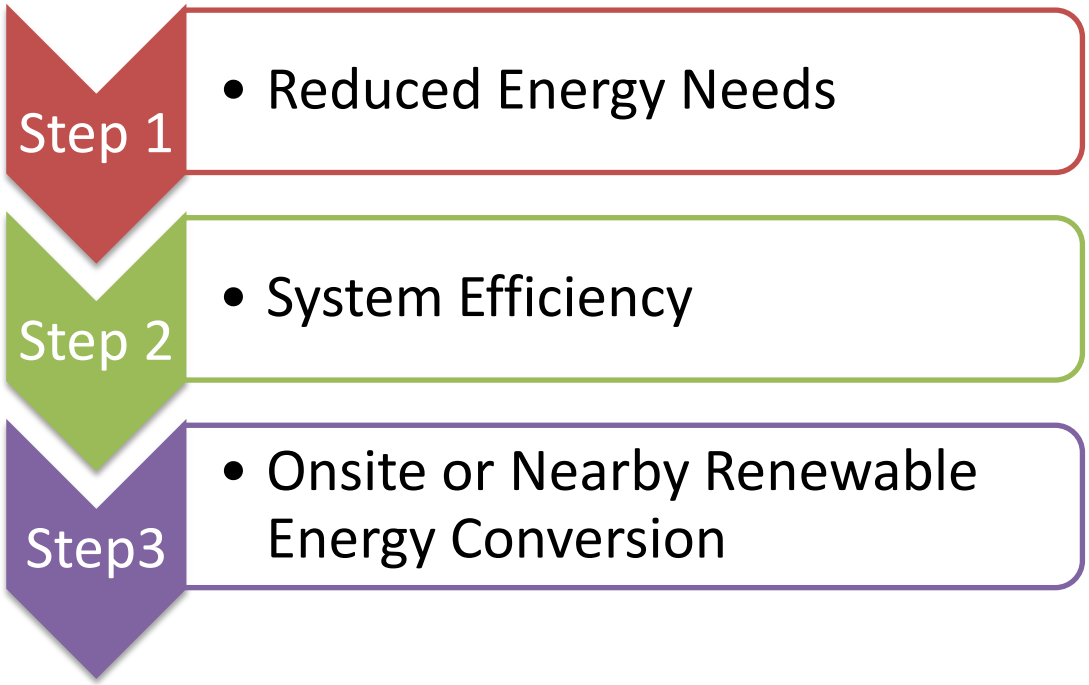
- nZEB balance concept



Source: Sartori et al., 2012

Current and upcoming context (6)

- Necessary steps towards nZEB
- Also in **Zero Emission Building** research center developments



Standpoint

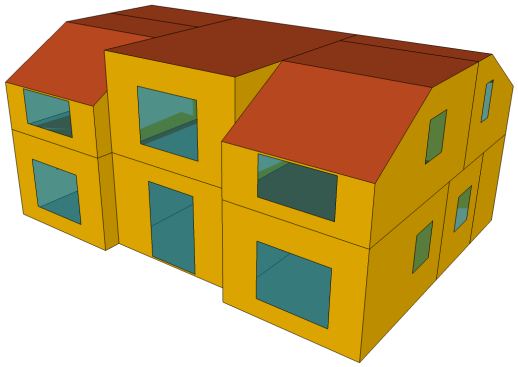
1. New building concepts are based on highly-insulated building envelopes to reduce the **energy needs**
   - Highly-insulated walls, high-performance windows and ventilation system, airtightness

2. The active space-heating and cooling systems are **not adapted** to highly-insulated building envelopes
   - Challenges and opportunities using highly-insulated envelopes

3. The design of active heating and cooling systems should be adapted for highly-insulated building envelopes to minimize **energy use**
   - Not just a question of downsizing the current systems to lower power

Challenges for active heating (1)

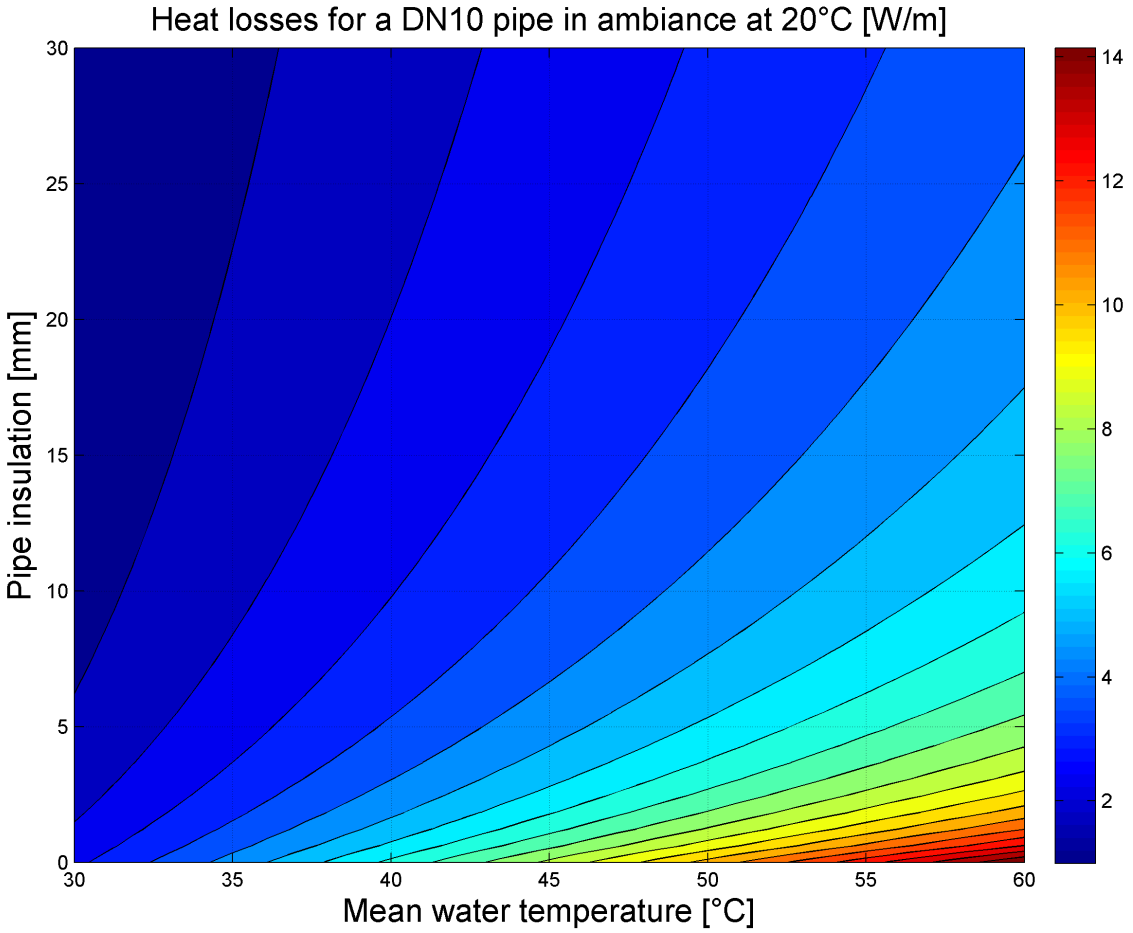
- Example of residential building at passive house level
  - Detached house with 160 m² heated area located in Oslo
  - Net SH needs < 19.8 kWh/m².year
  - SH power in *standard design conditions* (STD) without gains ~20W/m²
  - Mean internal gains 4.2 W/m²
  - Net DWH needs = 29.8 kWh/m².year (NS3031)



- **DHW load becomes dominant over SH needs**
  - Could be wise to focus more on the DHW efficiency, user needs
  - Could be wise to select a heat pump optimized for DHW production
  - Electric heating and biomass boilers efficiency not sensitive on the temperature production

Challenges for active heating (2)

- Importance of **thermal losses** from pipes



- Assuming 4W/m
- **Classical SH distribution loop** (length ~100m)
- 400W or 2.5W/m²
- With 4000h/year
- 10 kWh/m²

- Also for DHW primary loop
- *Centralized* versus *decentralized* heating systems in block of flats

Challenges for active heating (3)

- Importance of **thermal losses** from storage tank
  - 300 liter tank with ~2kWh/day losses (60°C water)
  - ~730 kWh/year

- Importance of **thermal losses** from DHW draw-off
  - 10 tapping from sink (DN10, pipe length 20m)
  - 4 tapping for shower (DN10, pipe length 5m)
  - Distribution at 45°C gives ~200 kWh/year

Challenges for active heating (4)

- Strong risk of **oversizing** the nominal power
- How to evaluate the **space-heating load**?
  - *Standard Design Conditions* (STD) is a **cold wave**
  - With or without internal gains (4.2 W/m²)?
- Should not apply **intermittent heating** (night setback)?!
  - Restart power essentially depends on thermal mass of building envelope
  - Same magnitude or higher than the nominal power with constant heating
  - Ex. Residential building could be 2-6 kW, or 12.5-37.5W/m²
  - TRV should not be turned down during the night (intuitive for users?)
- Low power **not always available** on the market
  - Heat pumps usually at 6-8 kW nominal power (except compact models)
  - Pellet boiler and stoves at 6-8 kW nominal power
  - Wood stoves at 4-8 kW nominal power

Challenges for active heating (5)

- Strong risk of oversizing the nominal power
- Reduced length of the heating season
  - From larger contribution of solar and internal gains

- Energy efficient techniques with higher investments are more difficult to **payback**

Opportunities for active heating (1)

- Better **recovery of thermal losses**
- Because a passive house is a "*good heat storage*"

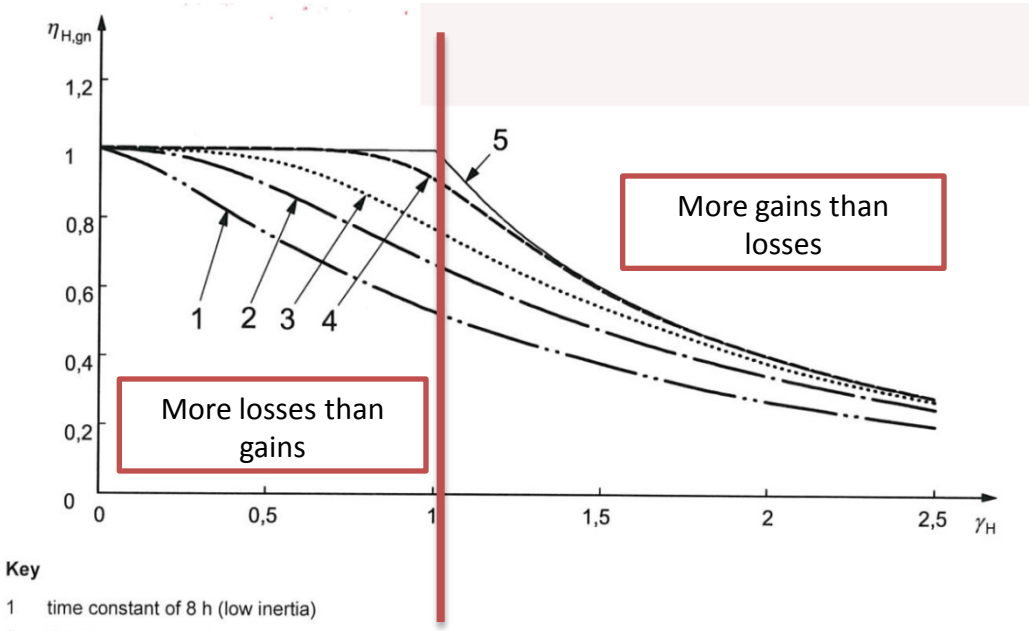


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Figure 5 — Illustration of gain utilization factor for heating mode, for 8 h, 1 d, 2 d, 7 d and infinite time constants, valid for monthly calculation method

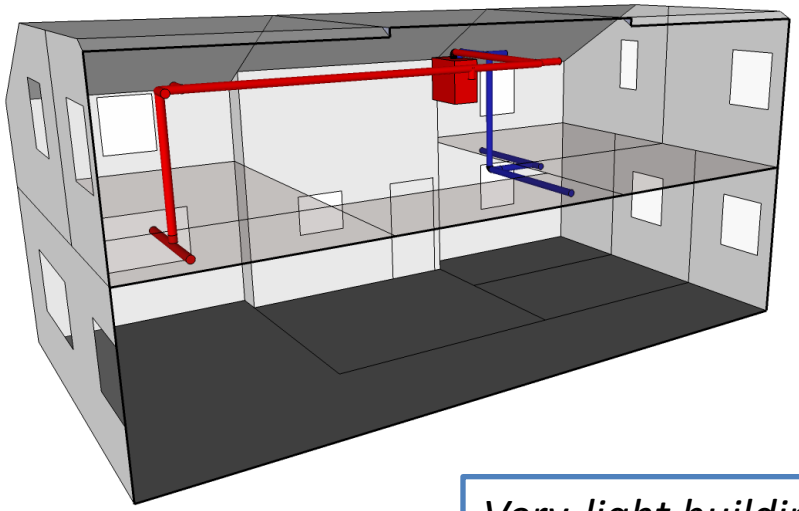
Opportunities for active heating (2)

- Don’t need a heat emitter in front of each window (to prevent cold draft or low radiant temperature)

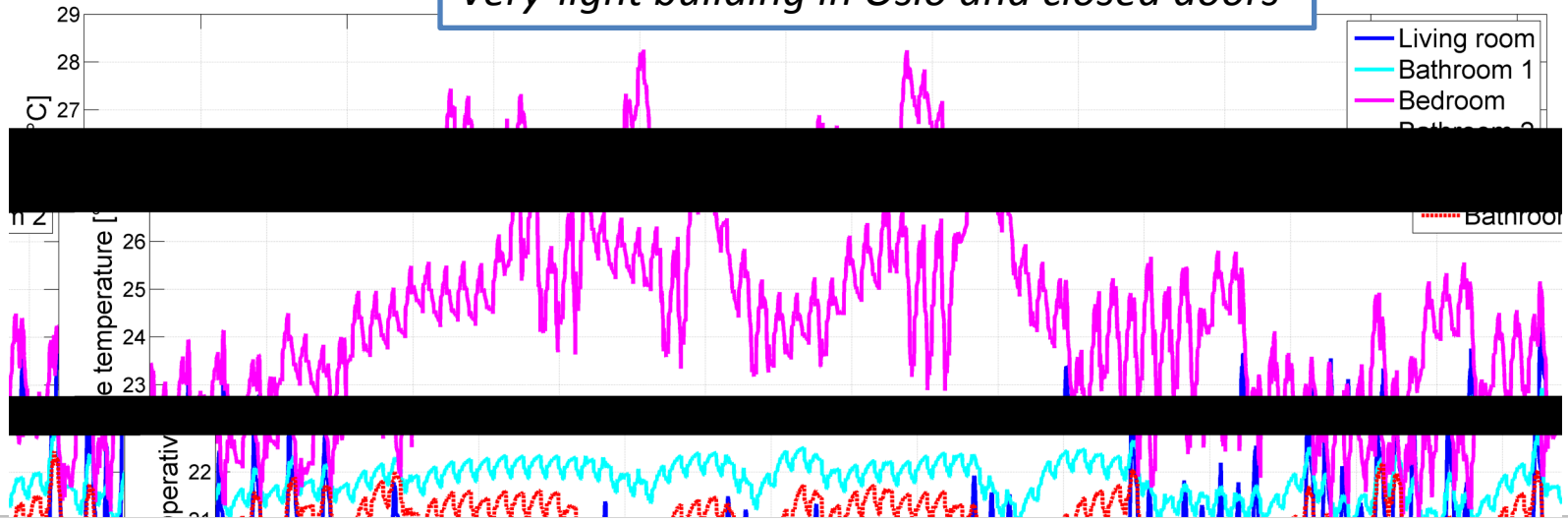
- The **SH distribution loop can be simplified**
  - Basis of the original Passive House concept developed in Germany
  - Simplification using air heating
  - Simplified hot-water distribution loop equipped with radiators
  - Simplification using a wood stove

- This can solve the problem of thermal losses from pipes
- This can reduce the investment cost
- The resulting thermal comfort should be properly assessed

Example for air heating

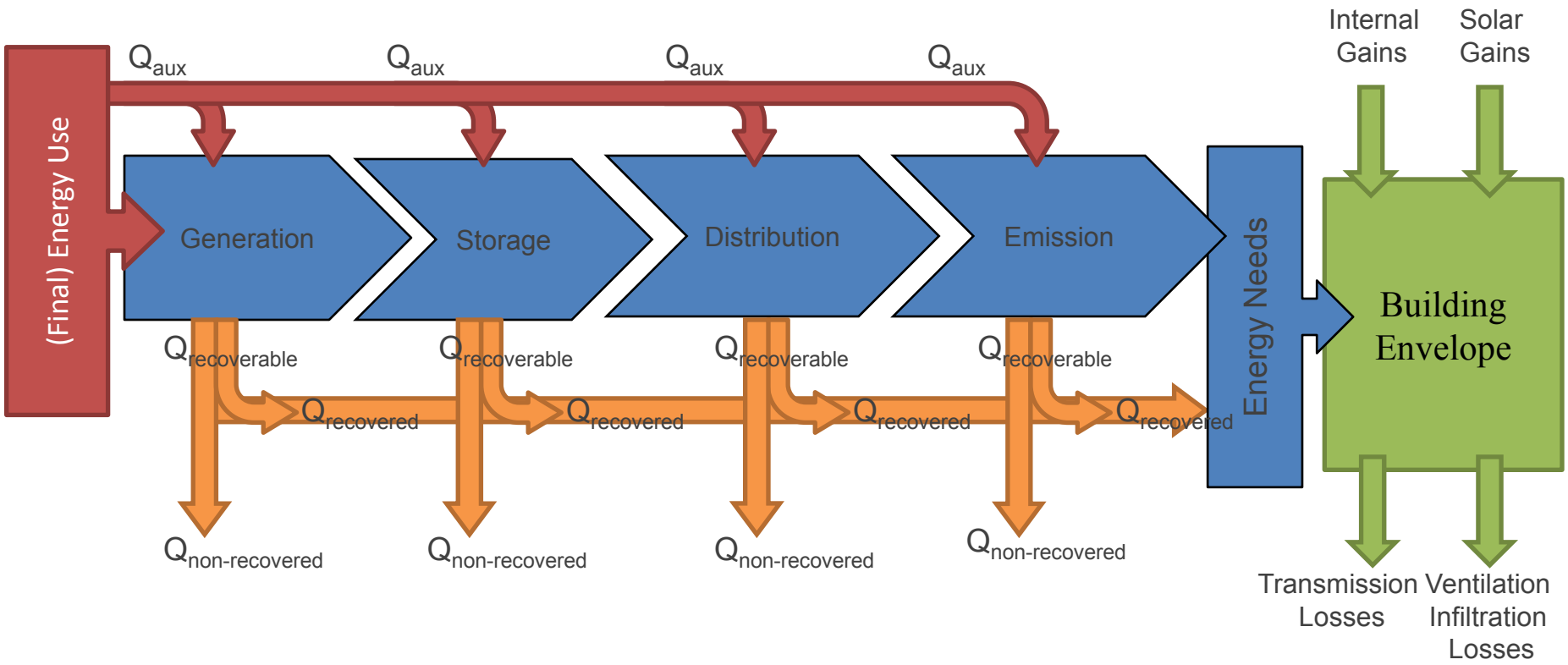


Very-light building in Oslo and closed doors



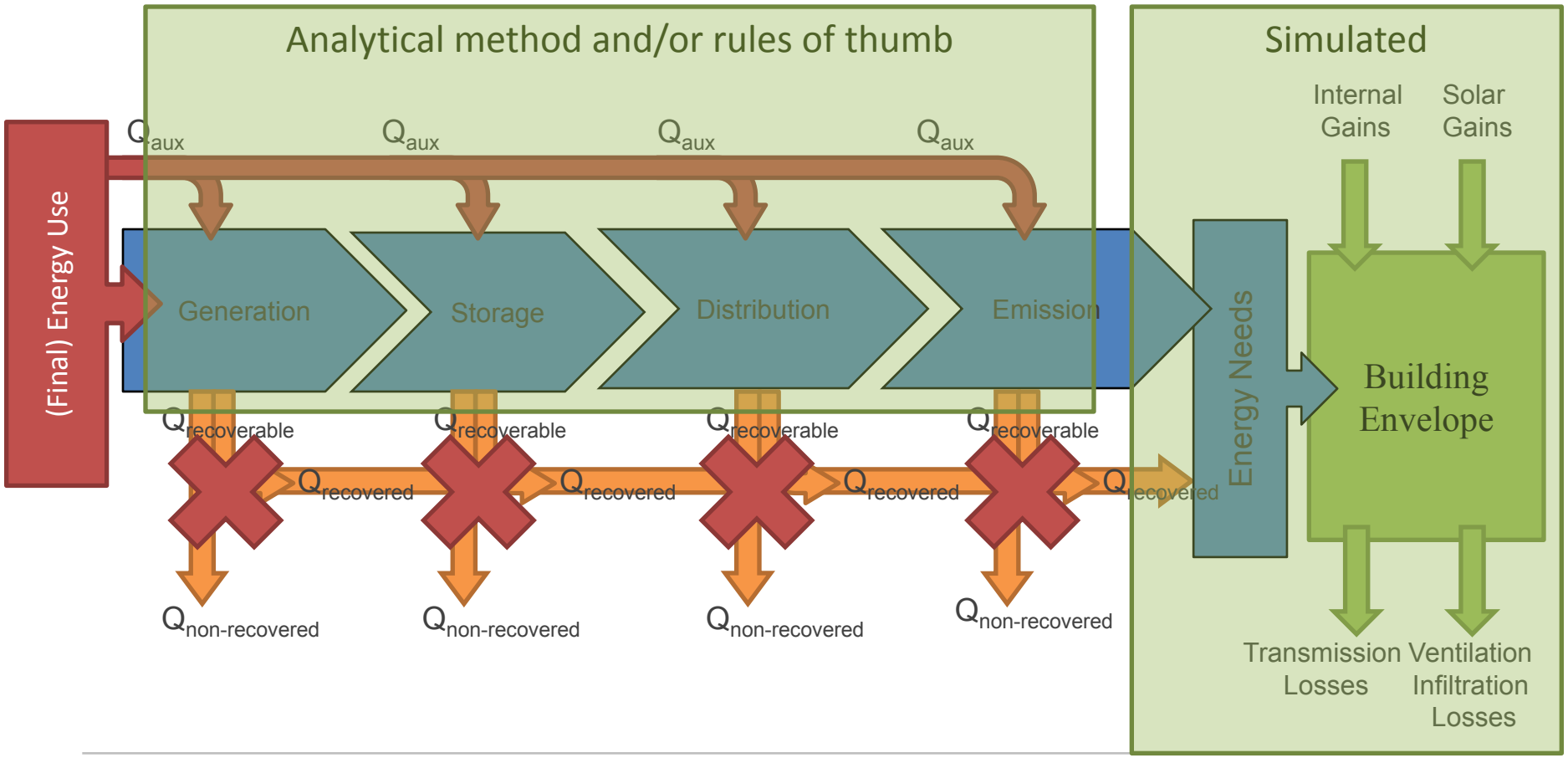
Requirements for Building Performance Simulation

- All these effects are properly taken into account if the heating system is **coupled** to the building envelope physics



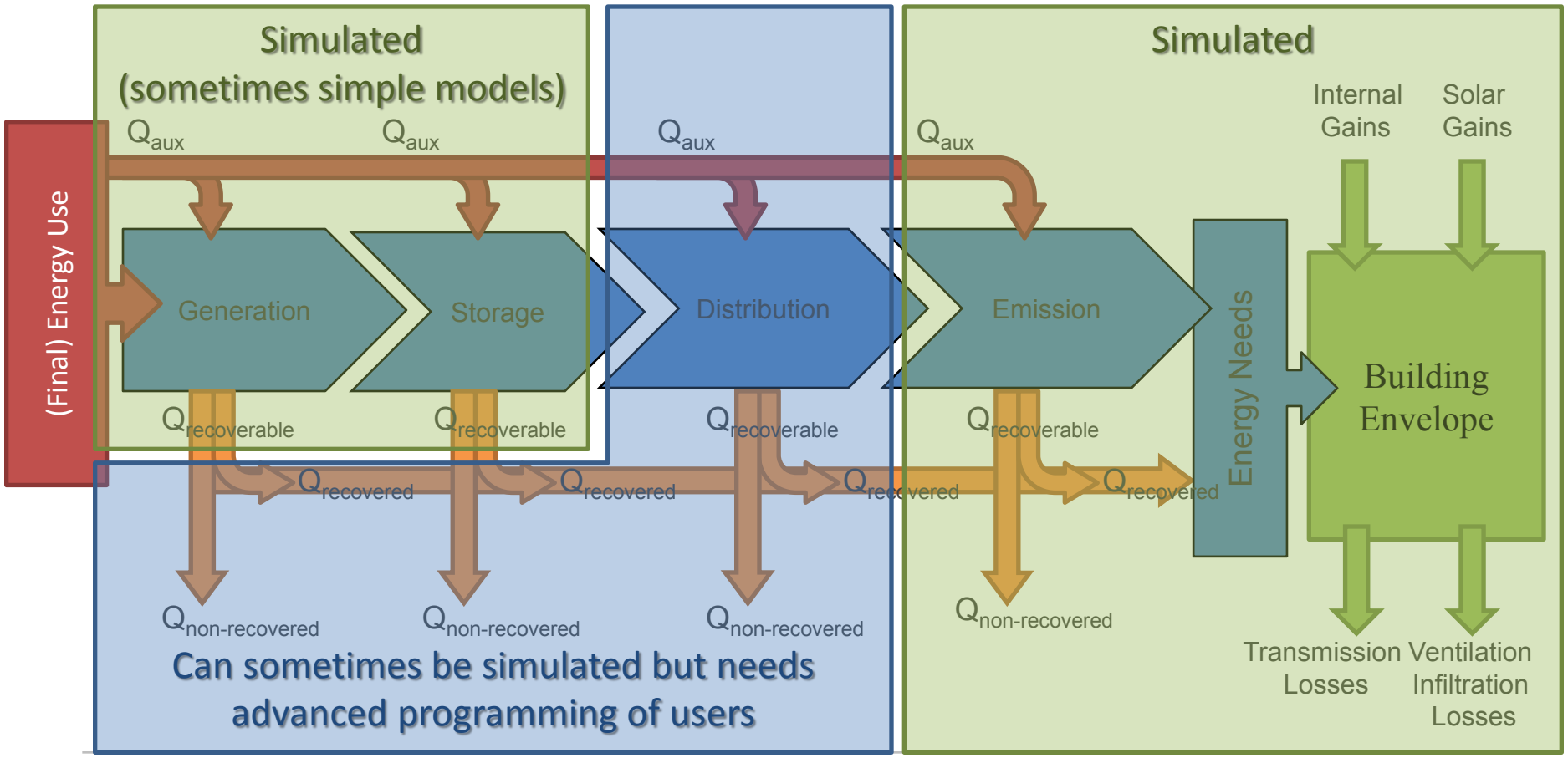
Requirements for Building Performance Simulation

- A current practice in design phase: even more unreliable



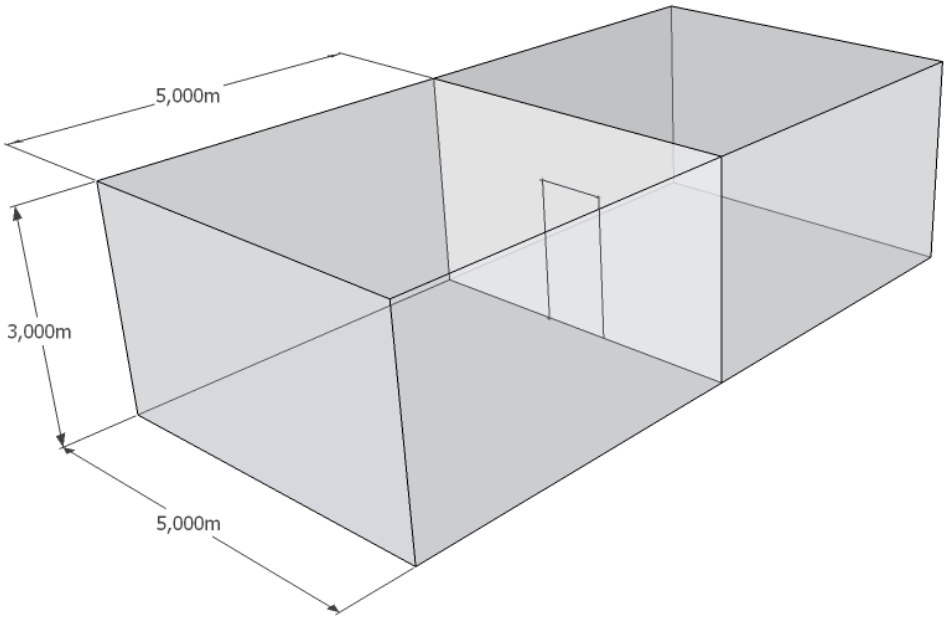
Requirements for Building Performance Simulation

- Still some limitations with most **advanced simulation tools**

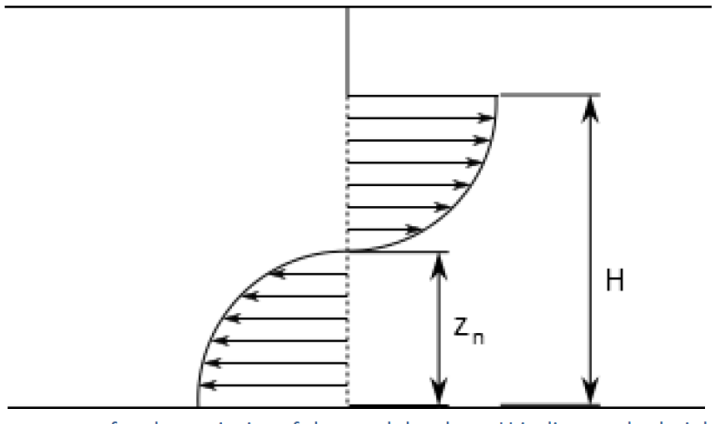


Requirements for Building Performance Simulation

- Some models should be further validated or adapted
- Example: heat transfer between two rooms with open doors



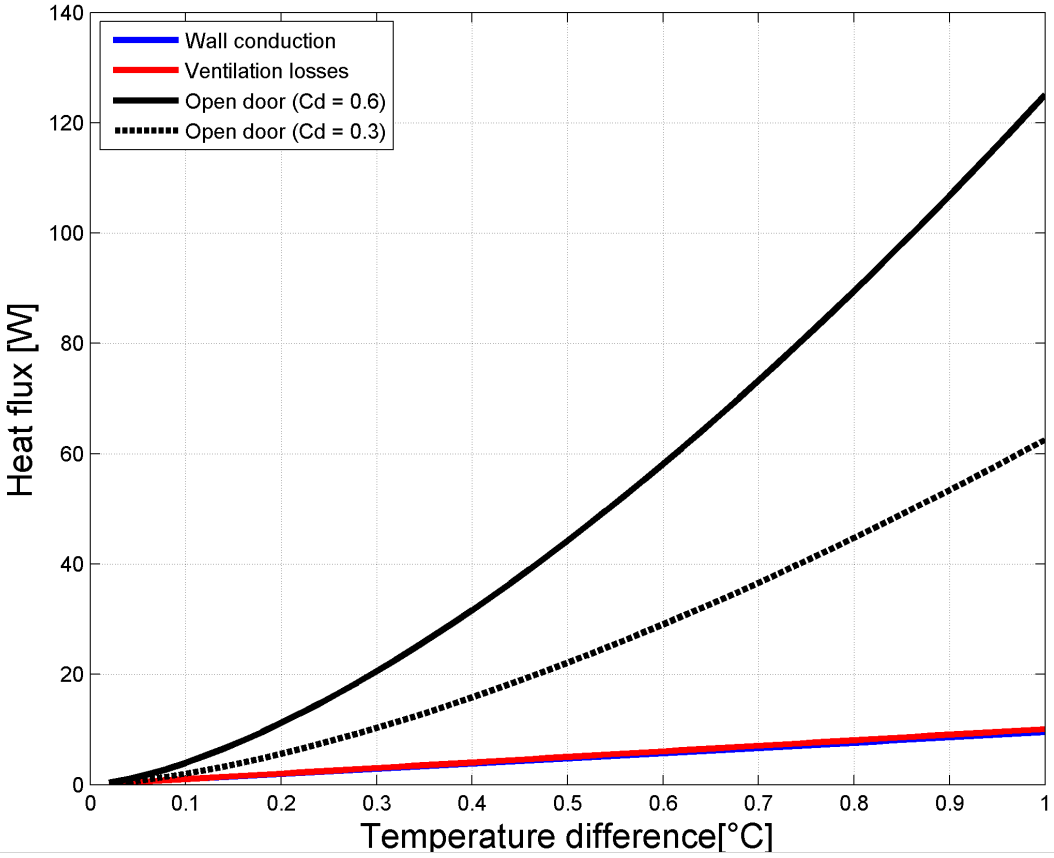
Partition wall with 10 cm mineral wool
1.2 m3/h.m² ventilation (inlet zone1, extract zone2)



Bi-directional flow

Requirements for Building Performance Simulation

- Some models should be validated or adapted
- Example: heat transfer between two rooms with open doors



Conclusions

- Highly-insulated building envelopes becomes a common principle in energy efficient building (i.e. reducing the needs)
- But **energy efficiency of active heating and cooling systems** is still very important in these highly-insulated buildings
- These active heating and cooling systems should be **adapted** to these buildings
  - Not only a question of downsizing the current systems and layouts
- **Building Performance Simulation** is a powerful tool to support this
  - A **coupled approach** should be followed (building + systems)
  - Should still learn how to do that properly during **early-design stage**
  - Existing tools should still be improved as regards thermal losses and specific models improvement