



NTNU – Trondheim  
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# Part I:

# Energy Flexible Buildings

# IEA EBC Annex 67

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# Future power systems

- Transition to a sustainable energy system requires a shift to renewable energy
  - Sources with fluctuating availability call for increasing flexibility of energy systems



# Electricity generation and consumption

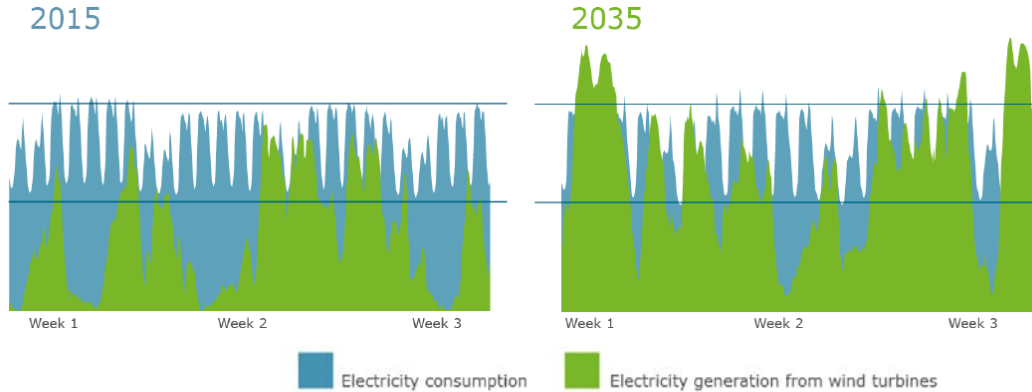


Figure 1. Example of the total electricity generation and consumption in 2015 and 2035 in Denmark [2]

## → Need for (energy) flexibility

- High penetration of renewable energy sources in the power grid
  - Transition from *generation on demand* towards *consumption on demand* in order to match instantaneous electricity generation
    - Flexible energy consumption required

# Buildings have ability to become energy flexible

- Building Performance Institute Europe [1]:
  - Future buildings (e.g. termed nZEBs 2.0) should *play a significant role* in transforming the European energy market as they become interactive players in *balancing the grid by DSM*

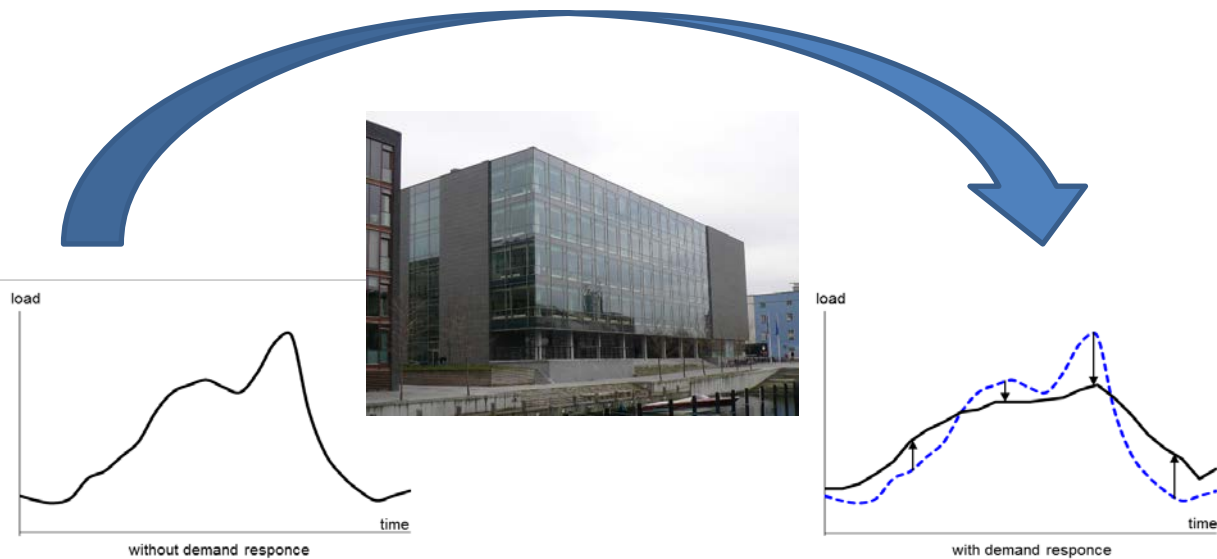


Figure 2. Principle of demand response [2]

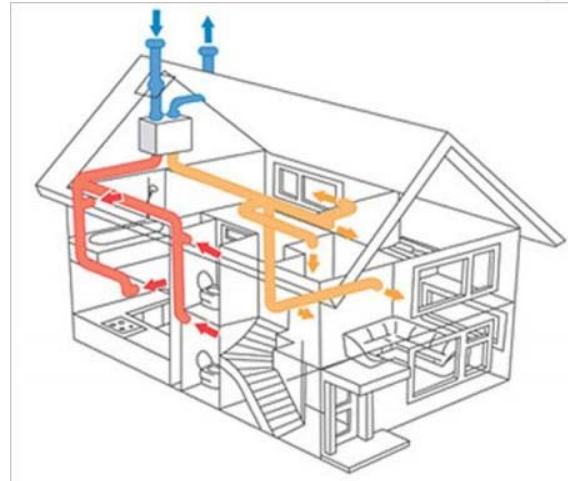
# Residential buildings

- Examples [2]:

- Heat pumps
- Ventilation systems
- Electric cars
- White goods

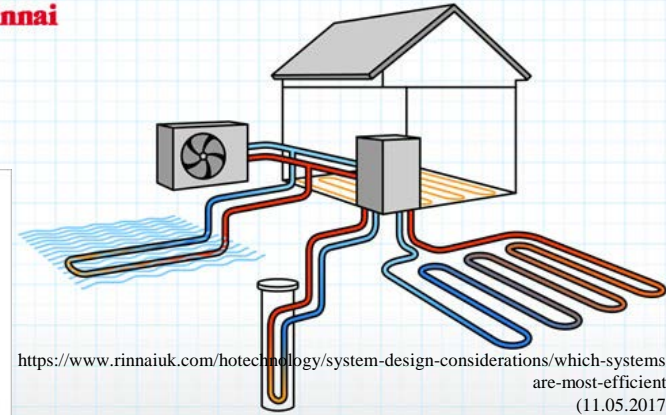


<http://www.polypacific.com.au/products/white-goods.html>  
(11.05.2017)



<http://www.re-solutions.co.uk/our-products-services/ventilation-heat-recovery/>  
(11.05.2015)

Rinnai



<https://www.rinnaiuk.com/hottechnology/system-design-considerations/which-systems-are-most-efficient/>  
(11.05.2017)



<https://eandt.theiet.org/content/articles/2015/11/smart-home-energy-system-enables-electric-car-solar-charging/>  
(11.05.2017)



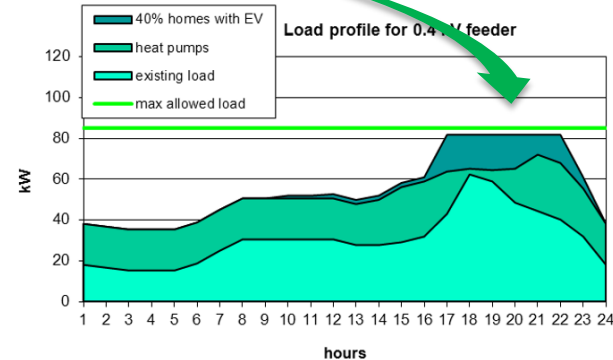
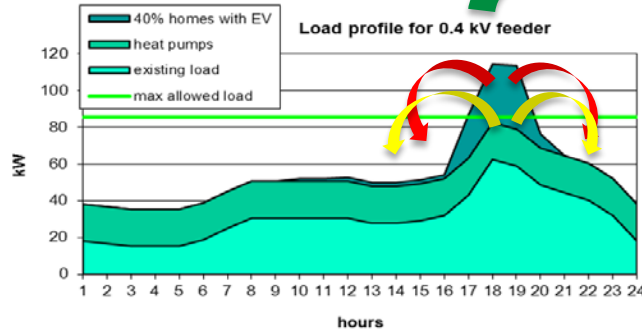
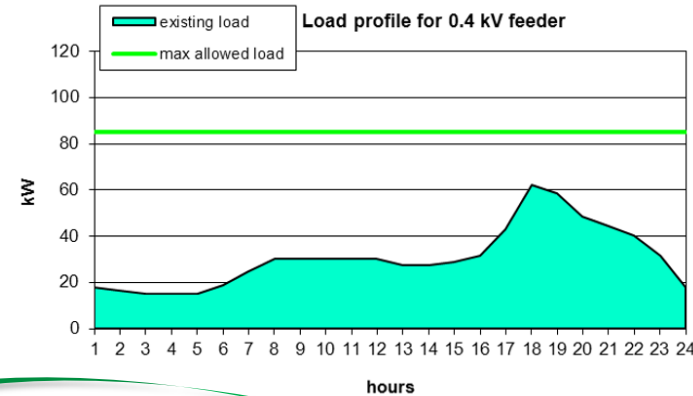
# Non-residential buildings

- Examples [2]:
  - Ventilation systems
  - Cooling systems
  - Pumps
  - Refrigeration systems
  - Waste heat for cascade systems



# Example of use of energy flexibility

- Example future scenario [2]:
  - Increased application of heat pumps in residential buildings
  - 40% of homes have electric vehicles



# Definition of energy flexibility in buildings <sup>Part I/II</sup>

- Energy flexibility of a building:
  - is the ability to manage its demand and generation according to local climate conditions, user needs and grid requirements
  - can be understood as the margin in which the building can be operated while respecting its functional requirements [3]
  - will allow for demand side management/load control and demand response based on the requirements of the surrounding grids



# Current knowledge

- **Currently:**
  - *No overview* or insight into how much energy flexibility different buildings may be able to offer to future energy systems
  - *Demonstration* of the energy flexibility that buildings can provide to the energy grids
  - *Identification of critical aspects and possible solutions* to manage energy flexibility

# IEA EBC Annex 67

## Energy Flexible Buildings

- **Time plan for Annex67:**
  - June 2014 – June 2015: Preparation phase: done
  - June 2015 – June 2018: Working phase: ongoing
  - June 2018 – June 2019: Reporting phase
- **Fifth working meeting:**
  - Graz, Austria. September 27-29, 2017
- **Website:**
  - [annex67.org](http://annex67.org)

# Work plan

- **Subtask A: Definitions and Context**
  - *Common terminology and definition* of Energy Flexibility in buildings
  - Methodology for characterization of Energy Flexibility in buildings
  - *User needs, motivation and barriers* for application of EF in building
  - Market analysis
- **Subtask B: Analysis, Development and Testing**
  - *Simulation of Energy Flexibility* in single buildings and clusters of buildings
  - *Control strategies and algorithms*
  - *Laboratory tests* of components, systems and control strategies
  - Example cases and design examples
- **Subtask C: Demonstration and User Perspectives**
  - Measurements in existing buildings
  - Demonstration of Energy Flexibility in real buildings and clusters
  - *User motivation* and acceptance

# Participating countries

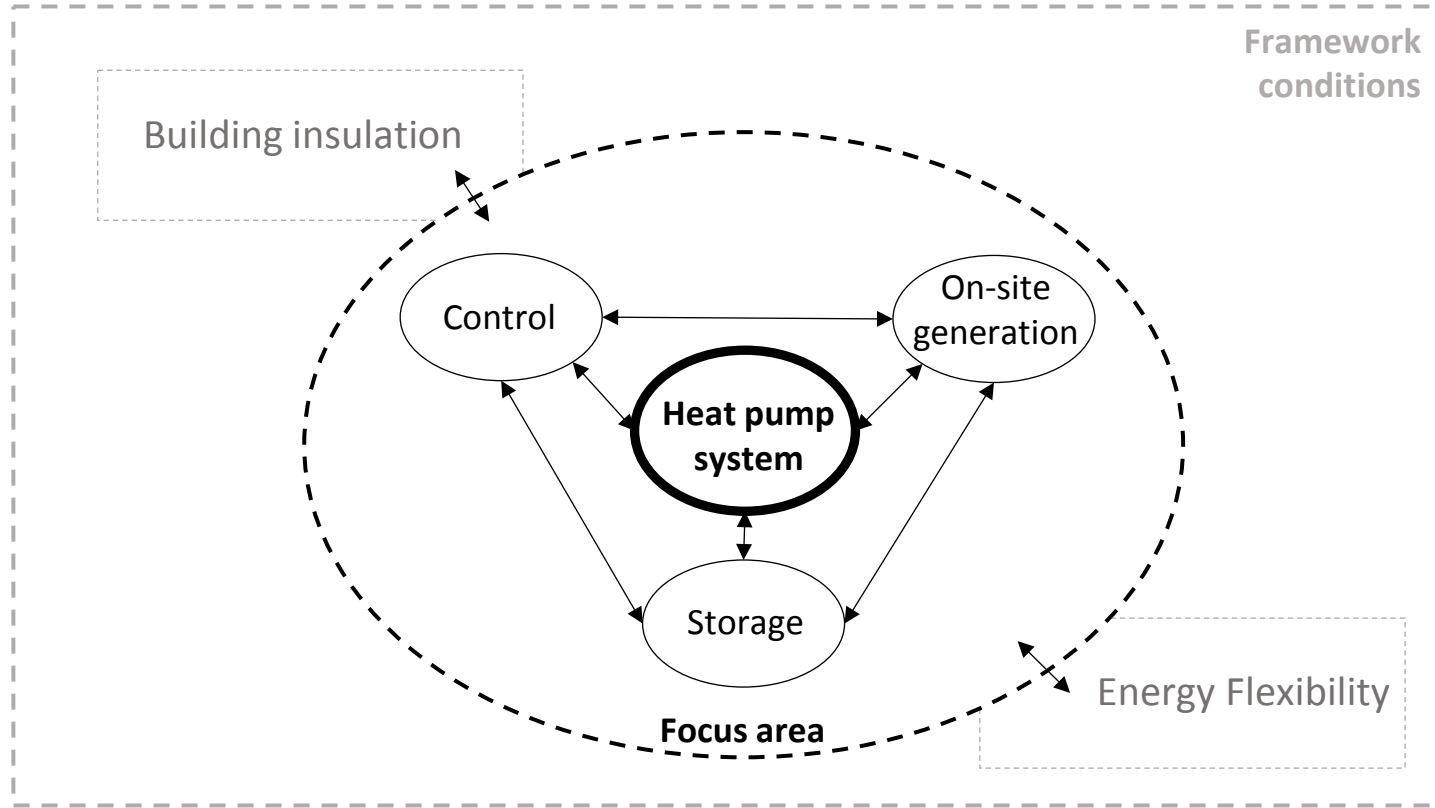


# Part II:

## Design and control of heat pump systems in energy flexible buildings in cold climate



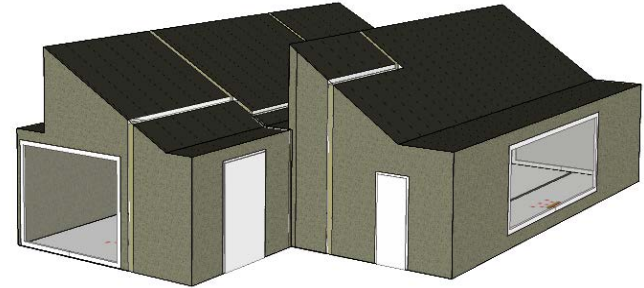
# Framework





# Methodology

- Using a detailed numerical model of the Living Laboratory in IDA ICE
- Model validation with data from experiments in the real building
- Design of heat pump systems
  - Using IDA ICE, GenOpt, MOBO
  - Sizing and system integration of the heat pump, thermal energy storage and on-site generation
- Developing control strategies for deploying energy flexibility
  - HPC2017 paper O.1.3.3: Investigation of Different Control Strategies for Heat Pump Systems in a Residential nZEB in the Nordic Climate



# Research questions

- How do different *design choices* influence the *performance of the heating system*?
- Which *control strategies* can be used to *deploy energy flexibility* in/of buildings?
  - Linked to design and sizing of the heating system and thermal storage
  - IBPSA Conference 2017 paper: Clauß, Finck, Vogler-Finck, Beagon, *Control strategies for building energy systems to unlock demand side flexibility – A review*, 2017, San Francisco, USA
- What are the inputs to the controller?
  - Price (spot price, balancing price, ...), weather, CO<sub>2</sub> intensity (average vs. marginal)
- Which *flexibility indicators* are most reasonable for application with regards to residential buildings?

# Thank you for your attention!

# References

- [1] D'Angiolella et al., “NZEB 2.0: interactive players in an evolving energy system”, REHVA Journal – May 2016, 2016
- [2] Jensen, “Energy Flexible Buildings IEA EBC Annex 67”, CLIMA 2016, 2016
- [3] Clauß et al., “Control strategies for building energy systems to unlock demand side flexibility – A review”, Proceedings of the Building Simulation Conference 2017, San Francisco, USA, 2017