Energy renovation of historic buildings using LCC optimization

By: PhD student Vlatko Milić

The Division of Energy Systems, Linköping University, Sweden

LINKÖPING UNIVERSITY

Agenda

- About me
- Background
- Objective
- Methodology
- Results
- Conclusion

About me

- Master’s degree in Mechanical Engineering
- PhD student from autumn 2016
- Potential and policies for energy efficiency in Swedish buildings built before 1945 (Stage II) – Energy systems analysis
  - Main project: Save and Preserve
  - Financier: The Swedish Energy Agency
  - Objective: Develop energy efficient solutions in historic valuable buildings

Background

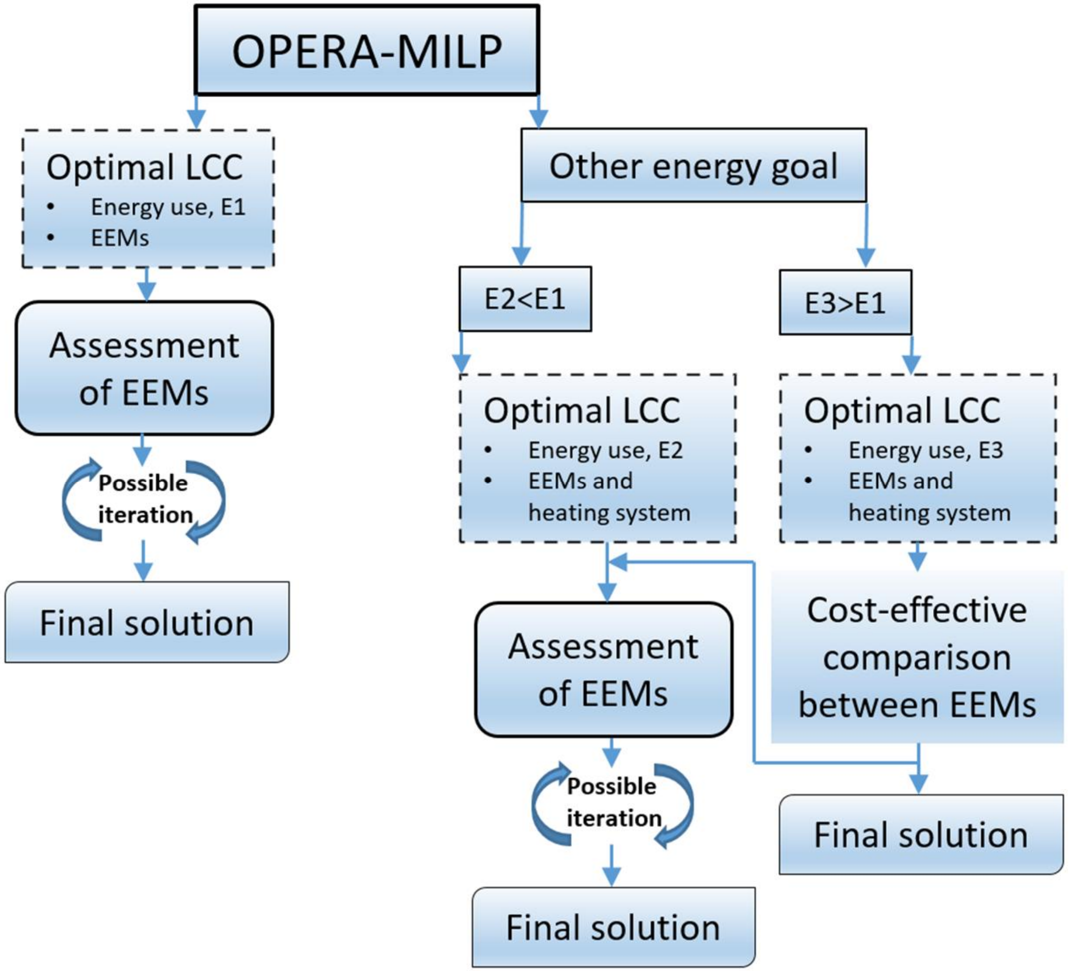
- Historic buildings
  - Focus on buildings built before 1945
  - 1/3 of the Swedish buildings
  - Large energy efficiency potential

- Essential to minimize life cycle costs (LCC) in historic building undergoing energy renovation
  - Optimization needed
  - Enables economic viability

Background

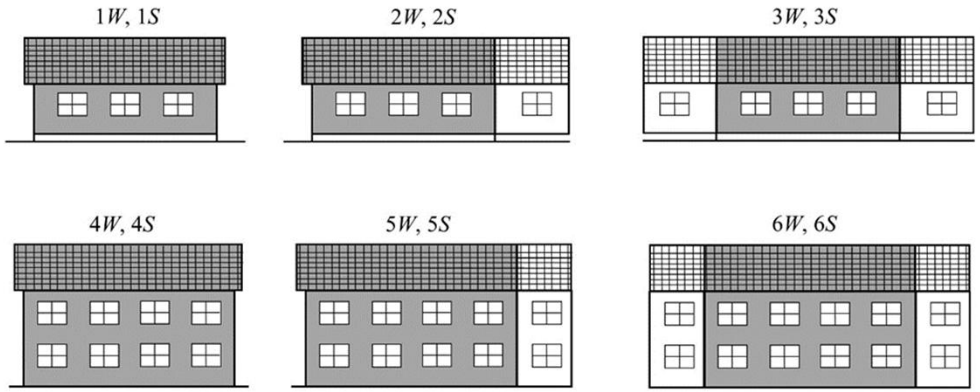
- OPtimal Energy Retrofit Advisory-Mixed Integer Linear Program (OPERA-MILP)
  - In-house LCC optimization software
  - Various energy efficiency measures (EEMs) and heating systems incorporated
    - EEMs: inside and outside insulation of the external wall, roof insulation, floor insulation, weather-stripping and window replacement
    - Heating systems: groundwater heat pump, wood boiler, district heating and electric radiator
  - Energy balance calculated with a time resolution of 12 time steps
    - Reduce computational effort during optimization
    - Included heat losses: transmission, ventilation and infiltration (also hot water)
    - Included free energy: solar gains and internal heat generation from e.g. occupants

OPERA-MILP- optimization procedures



Background

- World Heritage Town of Visby
  - Categorization of the historic building stock (Berg, 2015)
  - 920 buildings divided into 12 building types
  - Different building construction properties, layouts etc.



Objective

Provide cost-optimal energy renovation strategies for various historic residential building types in Visby, Sweden, using the in-house LCC optimization software, OPERA-MILP

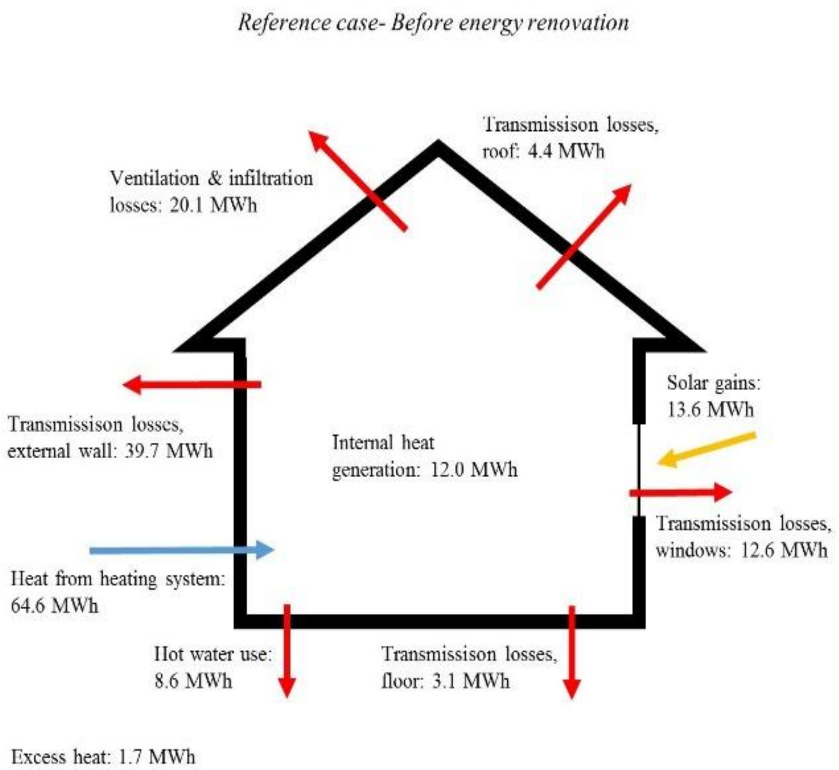
Methodology

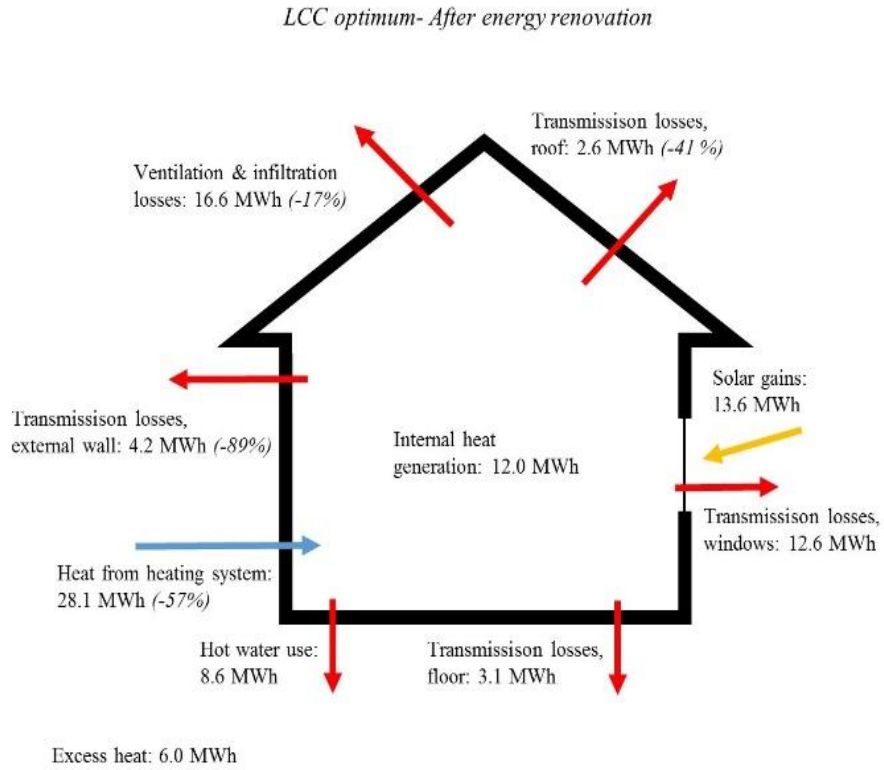
1. The buildings are modelled and simulated in OPERA-MILP
   - Initial energy use
   - Initial LCC
2. LCC optimization performed based on the implemented energy renovation measures in OPERA-MILP
   - Cost-optimal energy renovation strategy
   - Lowest possible LCC
   - Corresponding building energy use

Results

- Heating systems
  - District heating cost-optimal for small-family houses and wood boiler for apartment buildings
  - The implementation of a cost-optimal heating system varies depending on factors such as energy cost
- EEMs
  - Characterized by targeting parts of the building envelope with high transmission losses, e.g. inside insulation of the external walls in stone buildings
- Important to note: Simultaneous optimization of the heating system and EEMs

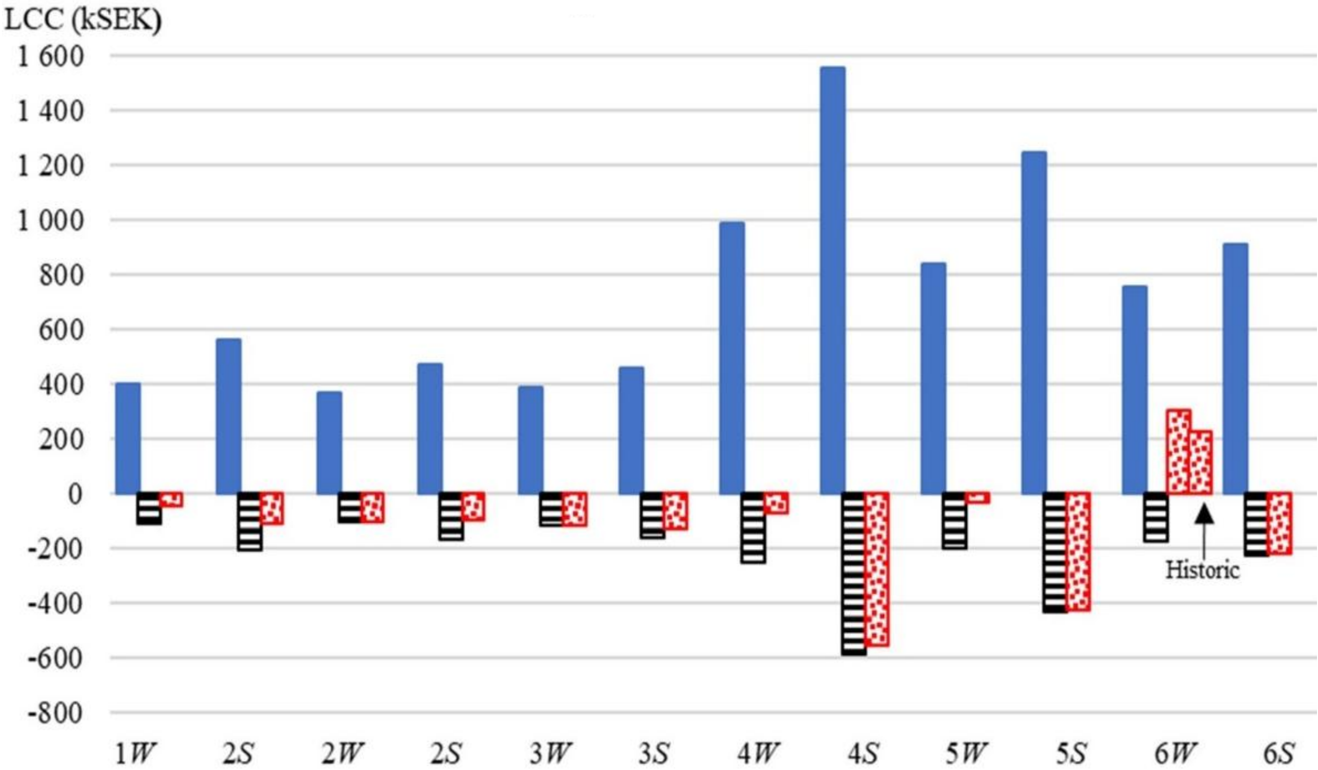
Results- Impact from cost-optimal energy renovation, building 5*S*





Results- Profitability

Blue bars = original LCC
Black striped bars = change in LCC at ***LCC optimum*** compared to the reference case
Red spotted bars = change in LCC at ***50% decrease in energy* use** compared to the reference case



Conclusion

The results show that energy renovations with economic viability are possible to perform in historic buildings by using LCC optimization

Thank you for your attention!

Questions?

vlatko.milic@liu.se

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