From building to district retrofit: contrasting the optimal strategies through a multi-objective approach

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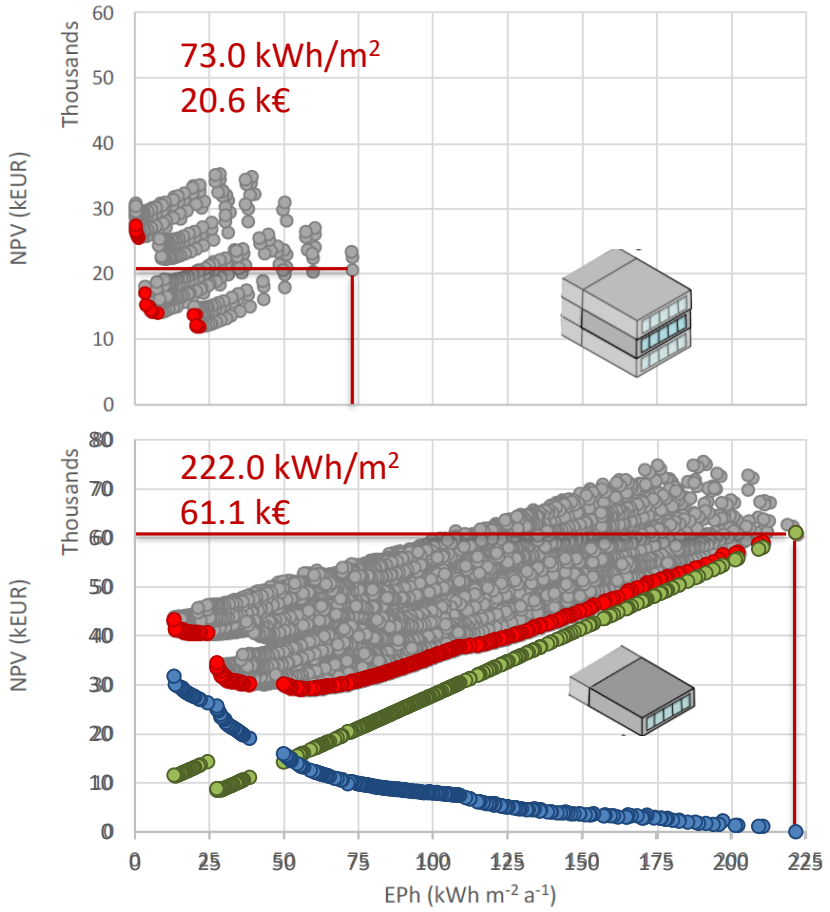
Outline

1. Introduction
2. Methods
   a. Building Archetypes and Stocks
   b. Energy Efficiency Measures
   c. Optimization Algorithm
3. Results
4. Conclusions

1. Introduction

Cost optimization

- EPBD reference approach to
  - define minimum energy performance requirements
  - major renovation of existing buildings
  - replacement or retrofit of building elements
- Reference target: individual buildings or dwellings
- Minimize the Net Present Value (NPV) for any given Energy Performance (EPh) and choose the solution with the minimum overall NPV



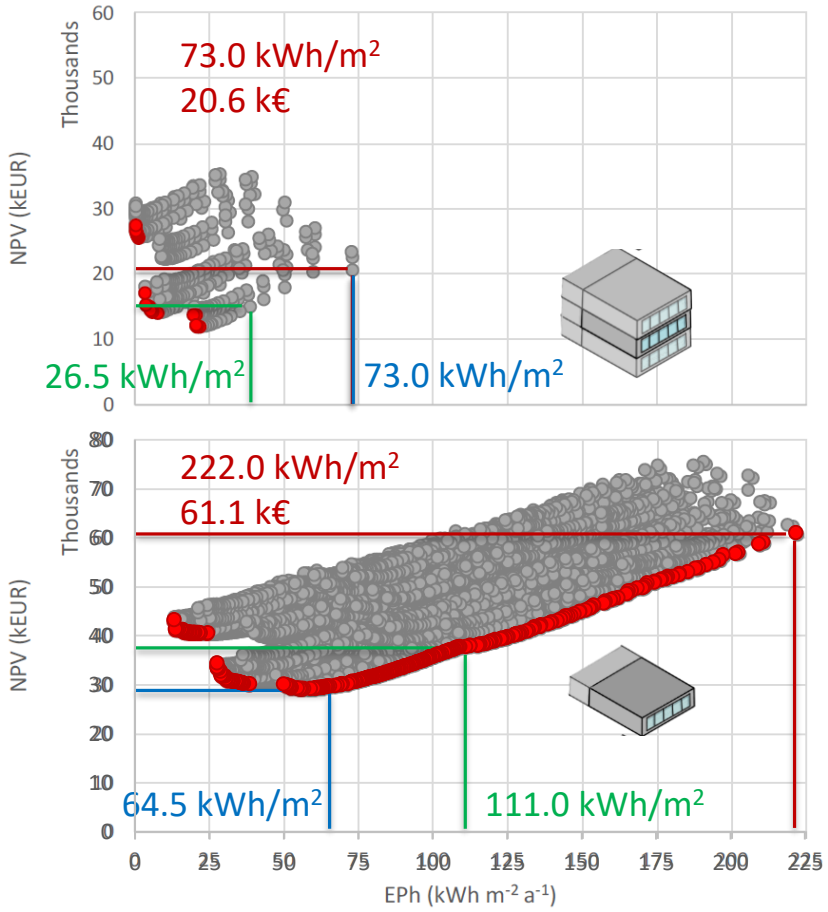
1. Introduction

Possible limitations:

- The owner may want to minimize the Investment Cost (IC) instead of NPV
- Public authority needs to achieve a specific EP reduction target
- PA sometimes invests directly with limited resources (subsidies or public buildings)

Research question:

- Assume a given savings target for the stock (ex. 50 %)
- Objective: optimizing each individual building (NPV) or miminize the IC at a stock level?



1. Introduction

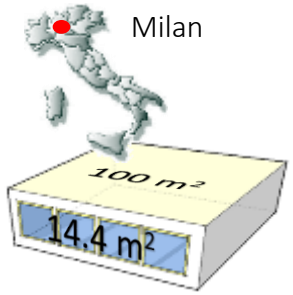
Aims

- Quantifying the advantages of optimizing the retrofit of the existing stock instead of each single building.

Contents

- Three reference building archetypes
- Different mixes to represent existing building stocks
- Four groups of Energy Efficiency Measures (EEMs):
  (i) opaque envelope, (ii) windows, (iii) heat generation system, and (iv) mechanical ventilation
- IC saving optimizing (i) the stock vs (ii) each single building
- EEMs in the optimal solutions
- Additional EPh savings when reinvesting IC savings

2. Methods: building archetypes and stocks



Opaque envelope
- Non-insulated
- Reference resistance
  $R = 0.97\ m^2\,kW^{-1}$

Transparent Envelope
- Single glass pane
  $U_{gl}=5.7\ W\ m^{-2}\ K^{-1}$
- Timber frame
  $U_{fr}=3.2\ W\ m^{-2}\ K^{-1}$
- South oriented

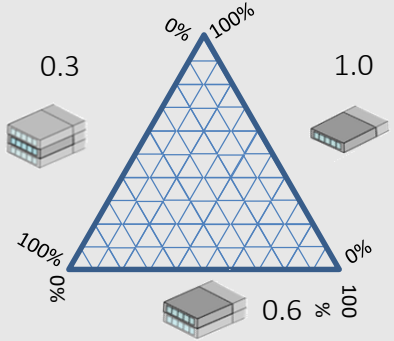
HVAC System

Generator:	Standard
Emission:	Radiators
Control system:	On-Off
Distribution:	Moderate insulation
Ventilation:	Natural

Compactness Ratio S/V Archetypes

1		0.3 (0.30)
2		0.6 (0.63)
3		1.0 (0.97)

66 Stock mixes



3 Saving targets

- 50 %
- (60 %)
- (70 %)

EP_h Primary energy for heating

2. Methods: energy efficiency measures

External insulation

Up to 20 cm (step 1cm)

- Wall
- Roof
- Floor

Heating system

Efficiency on LHV

- Modulating Boiler, η=96%
- Condensing Boiler, η=101%

Windows replacement

Improved Frame

- DH – Double, High SHGC
- DL – Double, Low SHGC
- TH – Triple, High SHGC
- TL – Triple, Low SHGC

Ventilation system

Introduction of mechanical ventilation with heat recovery

2. Methods: algorithms

Algorithm: multi-objective optimization through NSGA-II with customizations:

- Initial Sampling
- Data-set recordings
- Convergence criterion

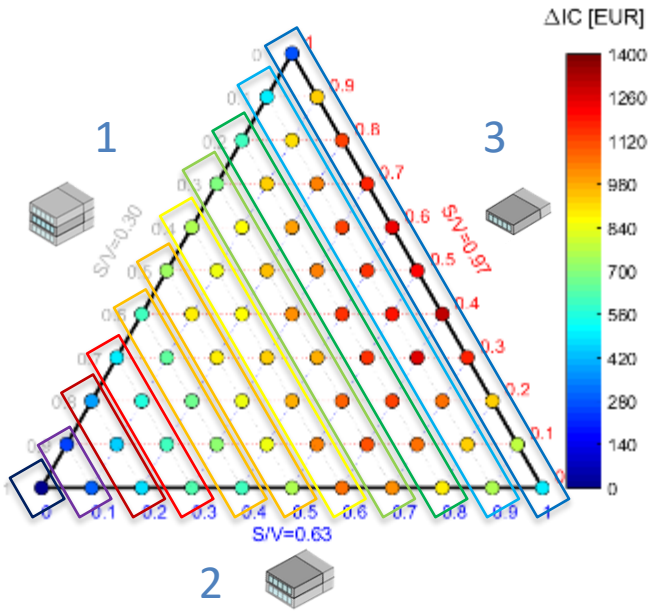
Energy Simulation:

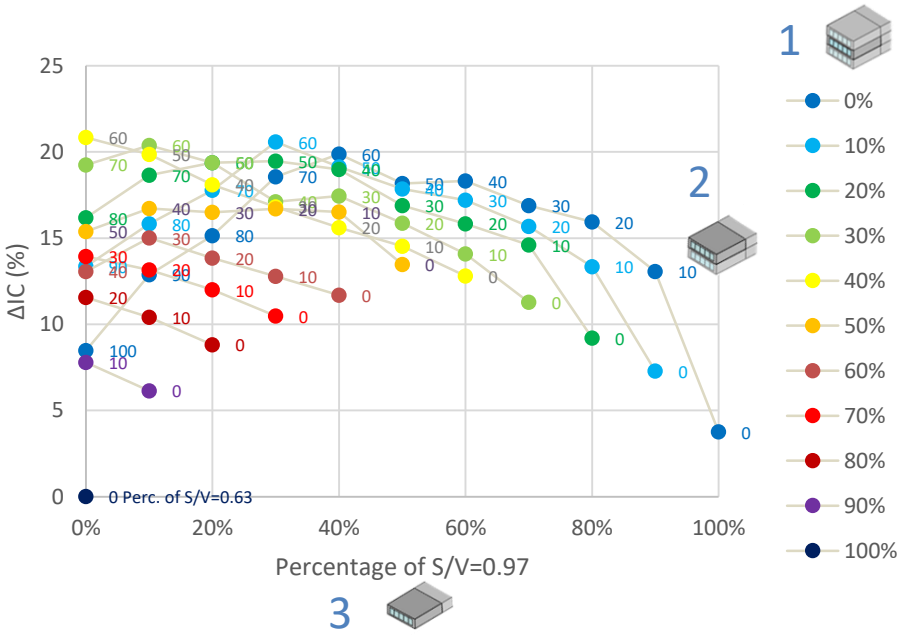
- TRNSYS hourly simulation
- Energy Performance index for heating (EP_h)

Economic evaluation:

- Cost-optimal approach according to EU 244/2012 and EN 15459
- NPV summing the discounted cash flows related to each intervention
- Including: initial investment, annual energy cost, maintenance cost, replacement cost, and residual value
- Lifespan of 30 years

3. Results: IC savings (all mixes) - target 50 %





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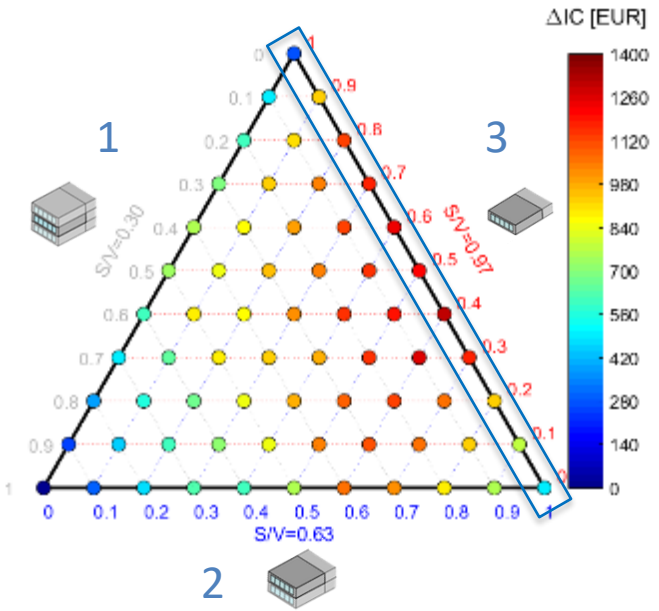
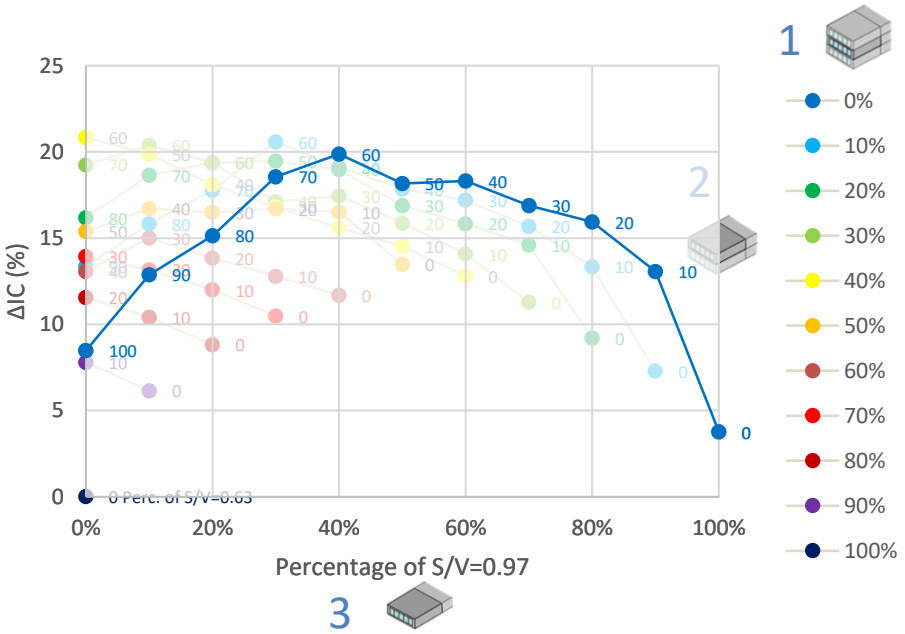
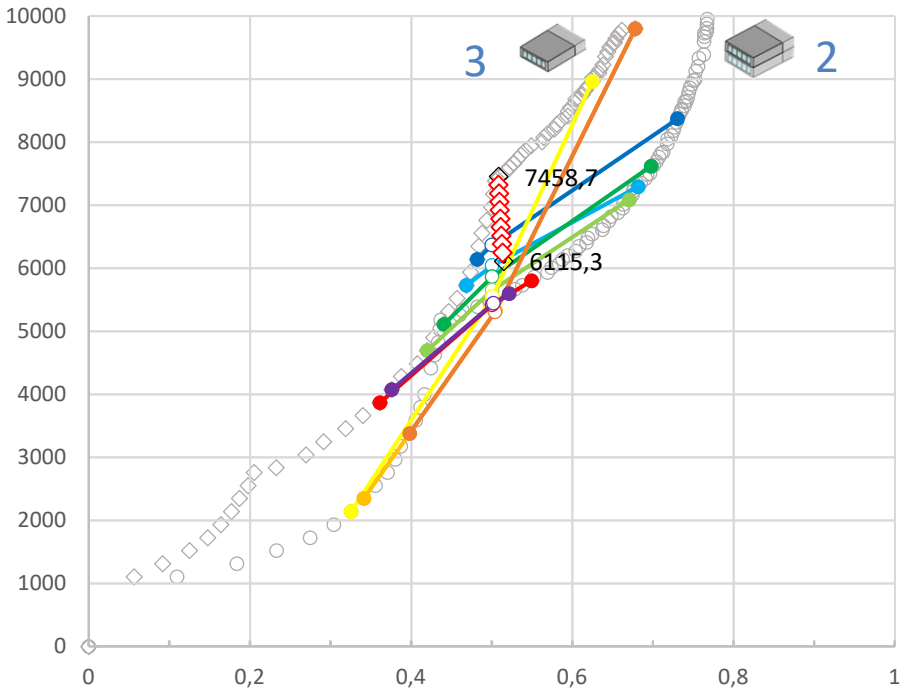
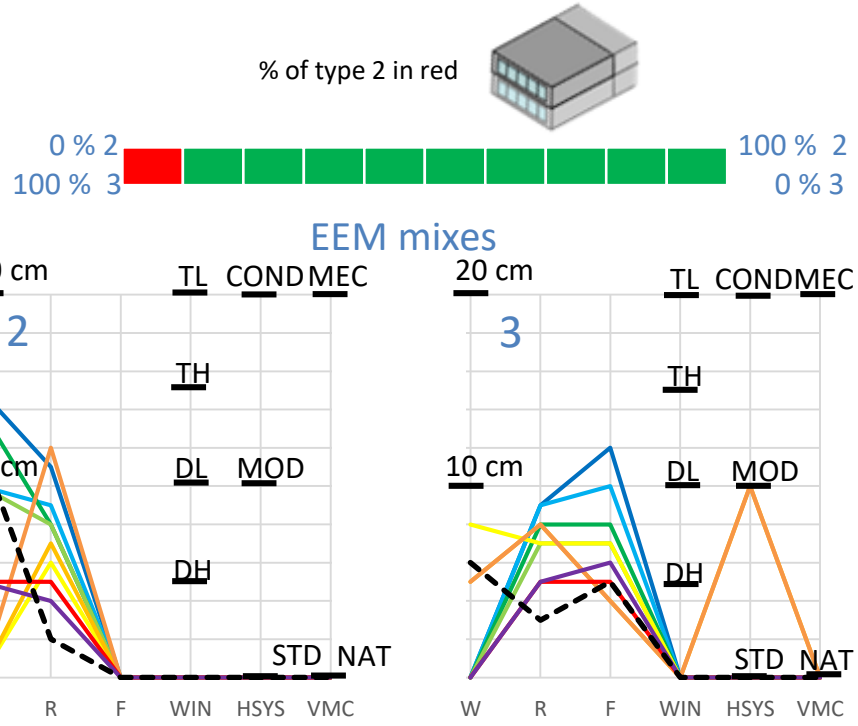




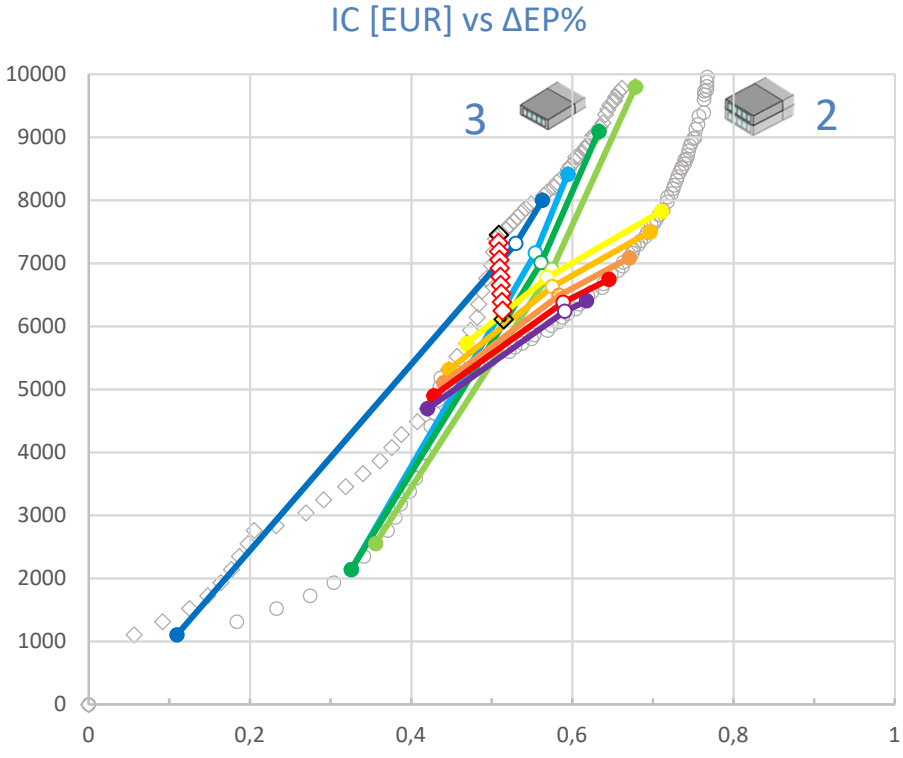
3. Results: type 2-3 mixes - target 50 %

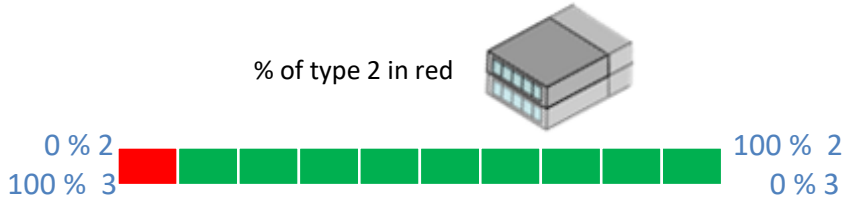
IC [EUR] vs ΔEP%

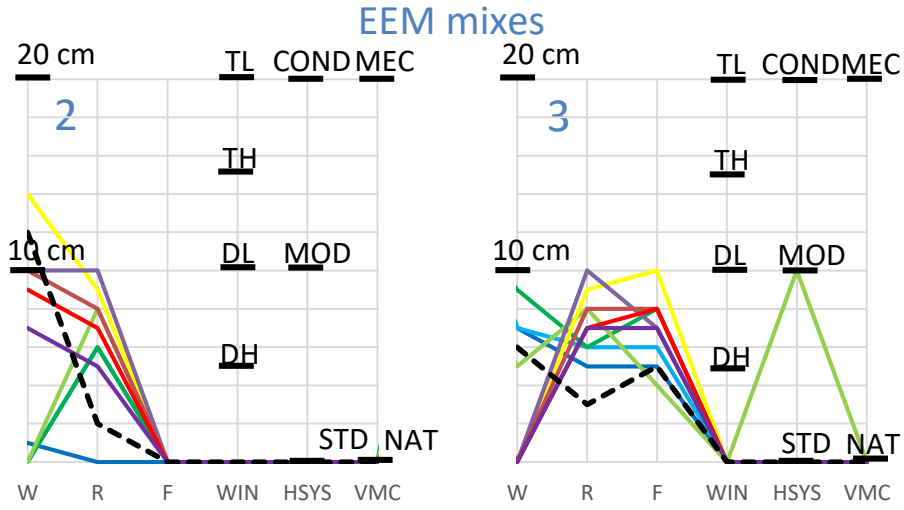




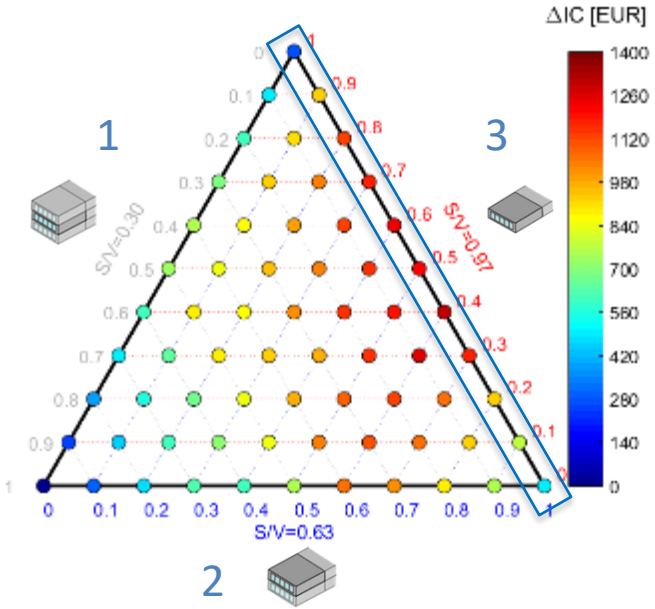
3. Results: type 2-3 mixes – same IC (50 %)

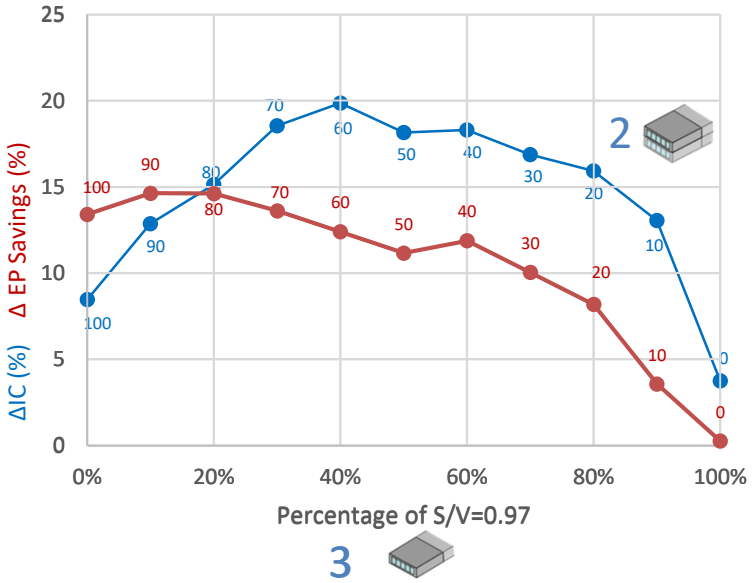






3. Results: extra EP savings (2 and 3) - target 50 %





Conclusions

- Significant savings in terms of IC or EP can be obtained when optimizing the stock instead of each single building
- Preliminary study:
  - Results change for higher savings targets – less compensation possible between different buildings
  - Do not account for minimum requisites
  - Higher targets: can be achieved through a multi-step approach (long term) which minimizes the initial IC and reinvests the savings in a period in further EEMs in a following period

Thank you

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