Including uncertainty in building energy performance calculation methods

Staf Roels
Hans Janssen, Liesje Van Gelder, Liesbeth Staepels

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Quality of Methods for Measuring Ventilation and Air Infiltration in Buildings
Brussels, March 18-19 2014

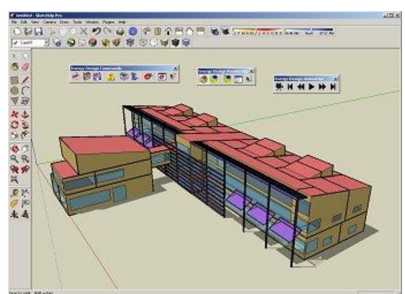
Problem statement

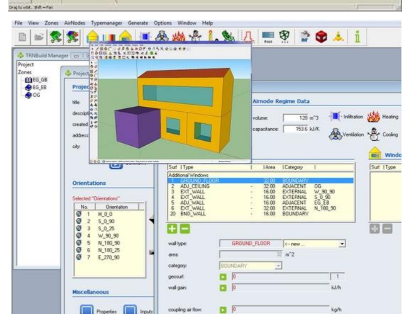
TRNSYS 17

seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND
Dwelling Energy Assessment Procedure (DEAP)

EnergyPlus

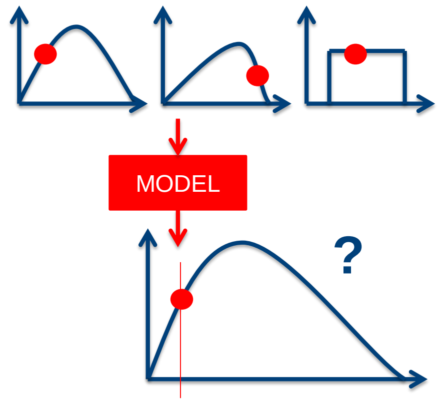
MODELICA





Buildings are exposed to several uncertain boundary conditions

- user
- climate
- workmanship
- ...



→ Performances are not deterministic

Including uncertainty in building energy performance calculation methods

- Measurement campaign
- Probabilistic design method
- Example: design of low energy dwelling
- Conclusions

Measurement campaign

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IWT Tetra-project BEP2020

- Monitoring of 70 dwellings in Flanders

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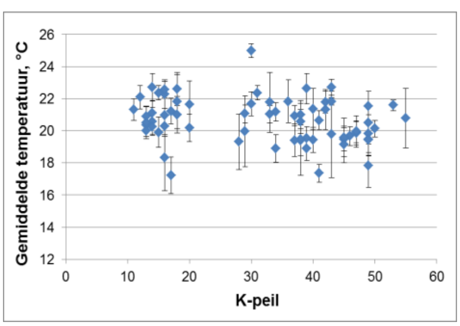
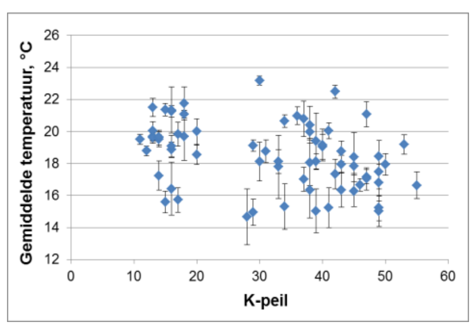
IWT Tetra-project BEP2020

- Monitoring of 70 dwellings in Flanders
  - 44 detached, 24 semi-detached, 2 terraced
  - 43 massive constructions, 27 lightweight
  - 14 natural ventilation system, 14 mechanical exhaust, 42 mechanical ventilation with heat recovery
  - Condensing boilers, heat pumps, local electrical resistances, …
- Measurement of global energy use (2012) + detailed monitoring of indoor temperature, CO_2 and RH

- Mean indoor temperature in winter

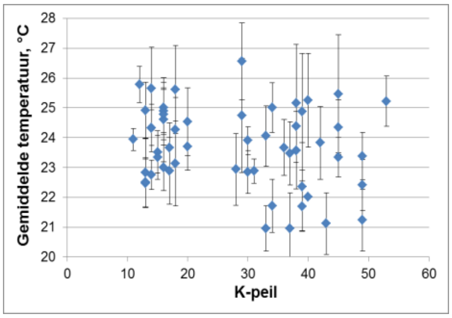


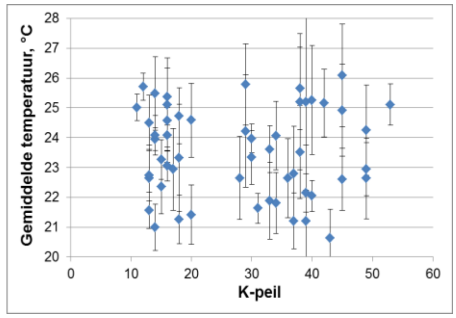
Living room



Master bedroom

- Mean indoor temperature in summer





Living room

Master bedroom

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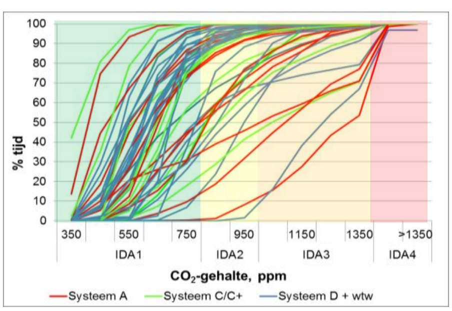
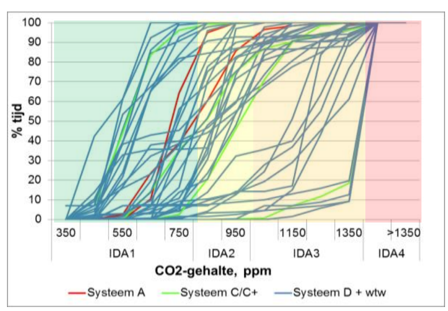
- Indoor Air Quality based on CO_2-concentration

	$c_{CO2,i}$ - $c_{CO2,e}$ (ppm)	$c_{CO2,i}$ (ppm)	
IDA1	≤ 400	≤ 750	Hoge binnenluchtkwaliteit
IDA2	400 – 600	≤ 950	Goede binnenluchtkwaliteit
IDA3	600 – 1000	≤ 1350	Matige binnenluchtkwaliteit
IDA4	≥ 1000	≥ 1350	Lage binnenluchtkwaliteit





Living room
(winter period)

Master bedroom
(winter period, at night)

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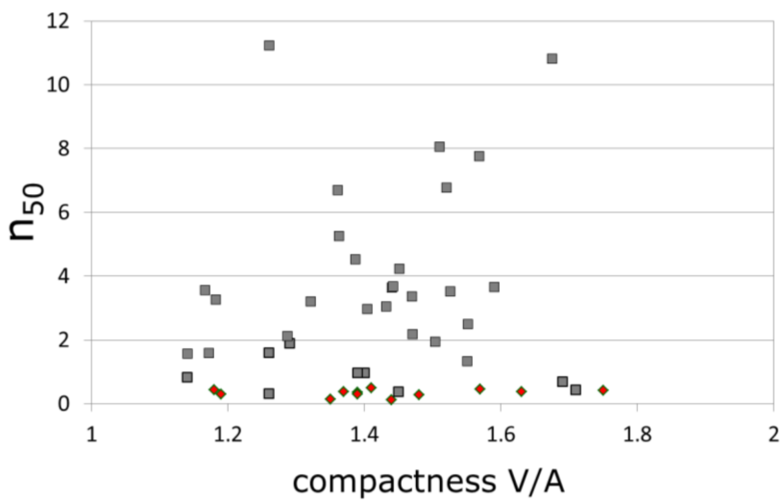
- Measured air tightness: n_{50}-value



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Conclusions measurement campaign:

- Significant variations in building quality: air tightness, insulation level,…
- Important impact of user behaviour: setpoint temperatures, ventilation behaviour,…

- Need for a probabilistic design method !!

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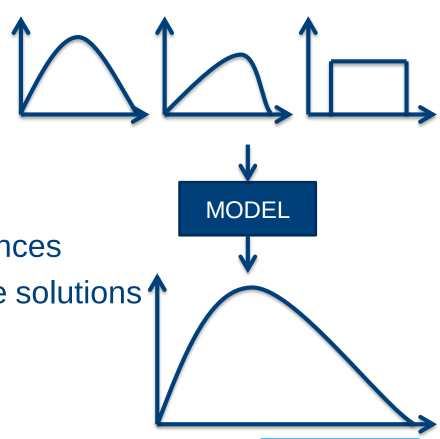
Probabilistic design

Probabilistic design

Take into account all uncertain boundary conditions

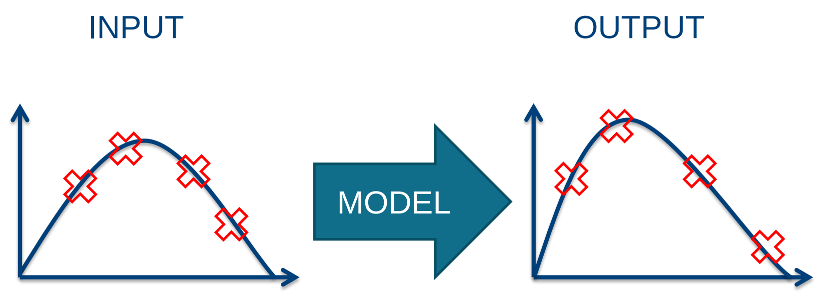
- user
- climate
- workmanship
- ...



→ Predict variation on performances

→ Check for robust and effective solutions

Monte-Carlo simulations



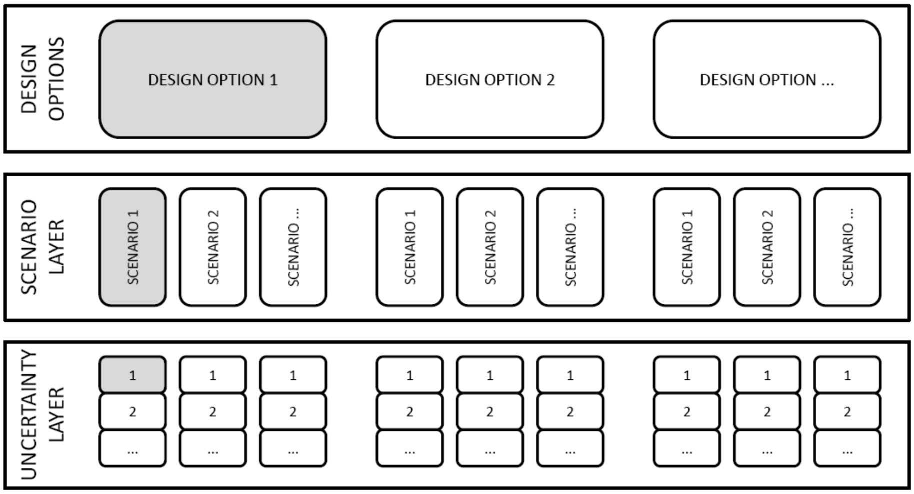
Improved sampling schemes to fasten convergence!

Multi-layer sampling scheme

Different kind of uncertainties:

- **Design parameters** → design options
  - n_{50}-value, U-value, ...
- Inherently **uncertain parameters**
  - workmanship, air change rate, ...
- **Scenario parameters**
  - energy price, user type, climate, ...

Multi-layer sampling scheme



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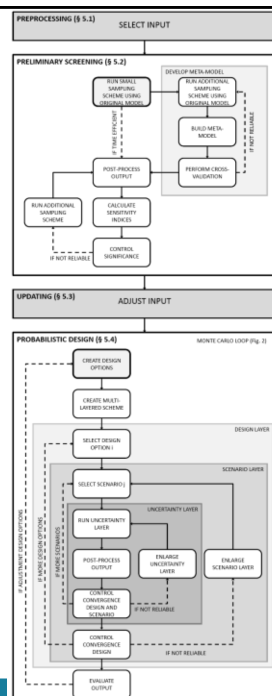
Overall methodology

1. Preprocessing
2. Preliminary screening
3. Updating
4. Probabilistic design



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Overall methodology

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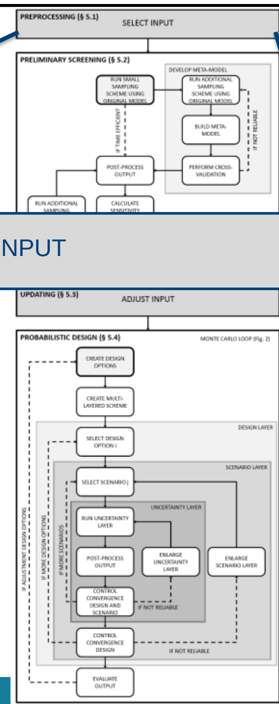

PREPROCESSING (§ 4.1) SELECT INPUT

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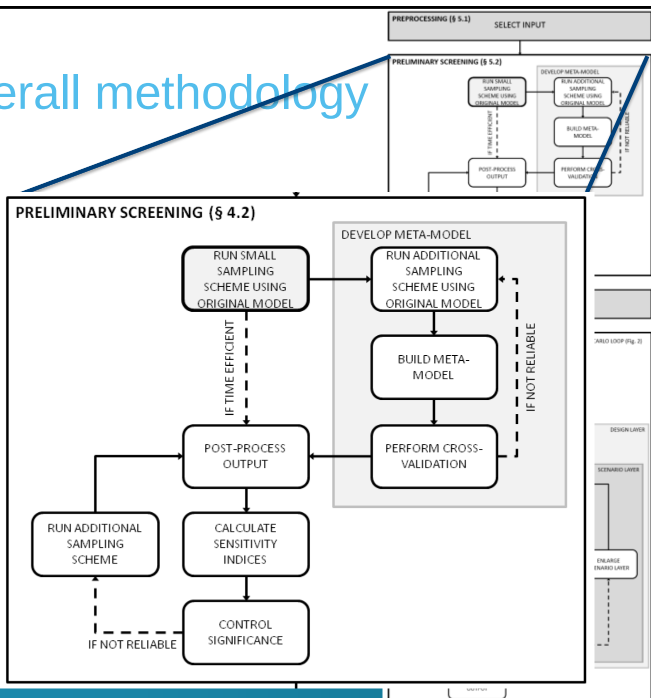
Overall methodology

1.
2.
3.
4.



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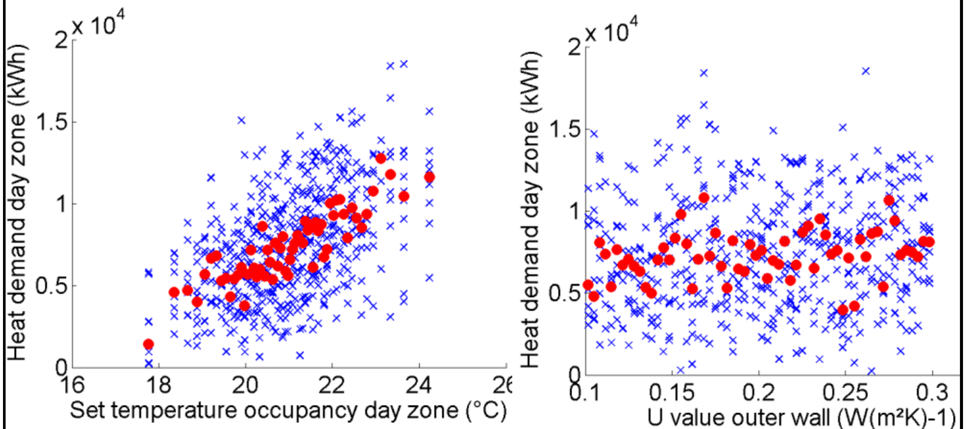
2. Preliminary screening: sensitivity analysis



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Overall methodology

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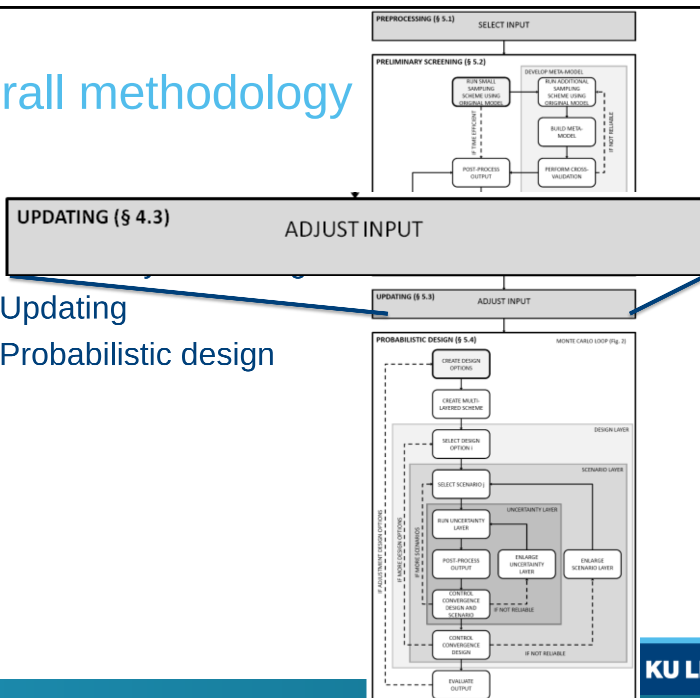

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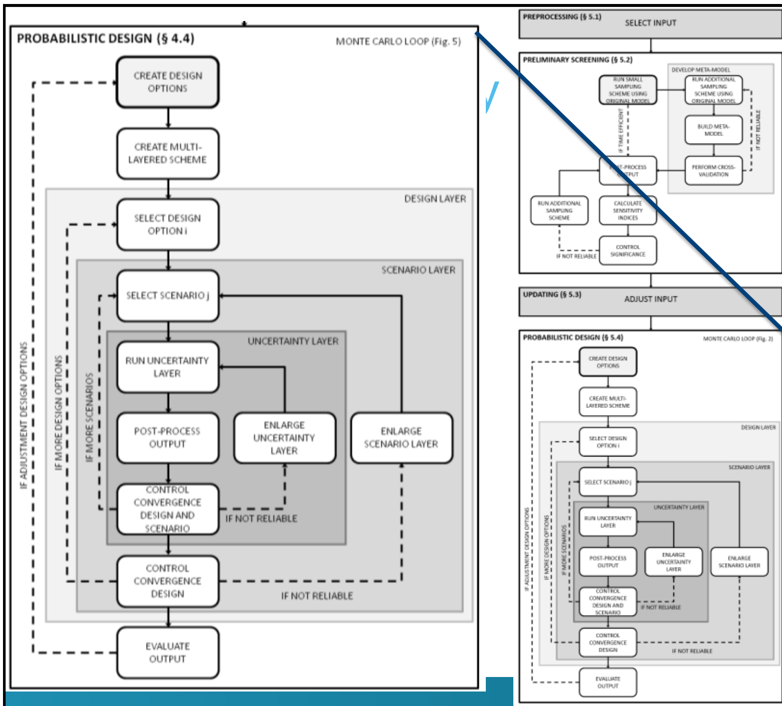
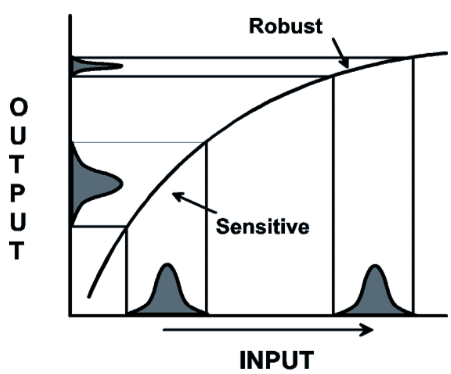


Output evaluation

Robust design: optimising mean performance, while minimising spread

Robust design can resist influence of uncontrollable factors



Output evaluation

- Effectiveness
  = improvement of median (compared to full uncertainty)

$$\varepsilon(x_n) = 1 - \frac{y_{50}(x_n) - y_{\min}}{y_{50} - y_{\min}}$$

- Robustness
  = improvement of performance spread

$$R_P(x_n) = 1 - \frac{y_{50+\mathrm{P}/2}(x_n) - y_{50\text{-}\mathrm{P}/2}(x_n)}{y_{50+\mathrm{P}/2} - y_{50\text{-}\mathrm{P}/2}}$$

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Example:
design of low energy dwelling

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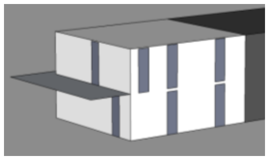
Example of probabilistic design

Design of low-energy dwelling

TETRA BEP2020



Design parameters

172.800 options:

- n_{50}
- ventilation system
- construction type
- U-values
- glazing type
- sunscreen
- sunscreen controle

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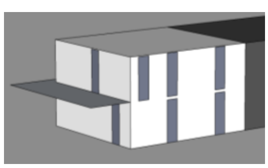
Example of probabilistic design

Design of low-energy dwelling



Inherently **uncertain parameters**

- actual air change rate
- workmanship heat recovery ventilation
- workmanship error n_{50}
- workmanship error U-values

→ 100 value combinations

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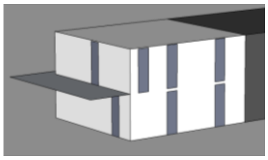
Example of probabilistic design

Design of low-energy dwelling



Scenario parameters

- 3 user types
  - saving
  - average
  - spending

- 3 energy price evolutions

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Example of probabilistic design

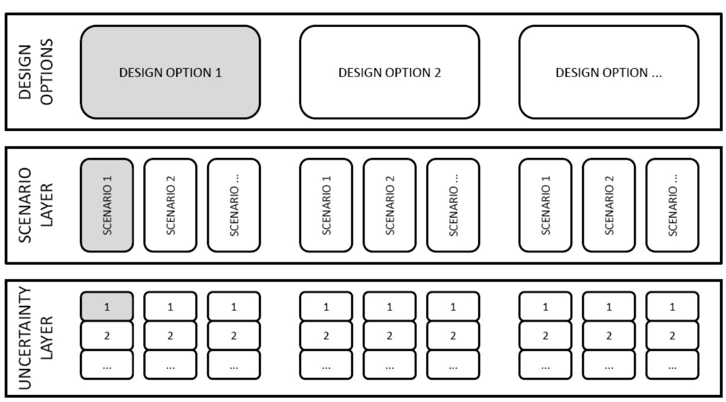
Design of low-energy dwelling

BES-model + cost calculation

172.800

3
(3)

100



= 51.840.000 simulation runs → meta-model!

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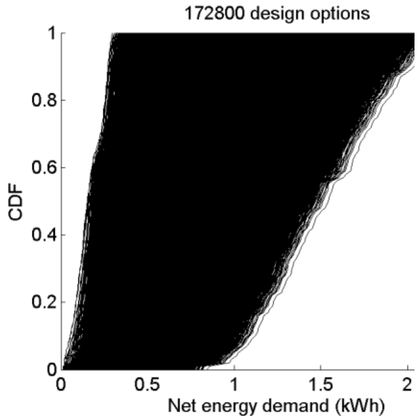
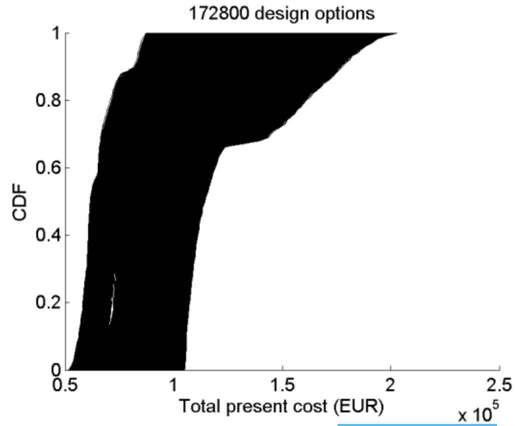
Obtained results

Design of low-energy dwelling





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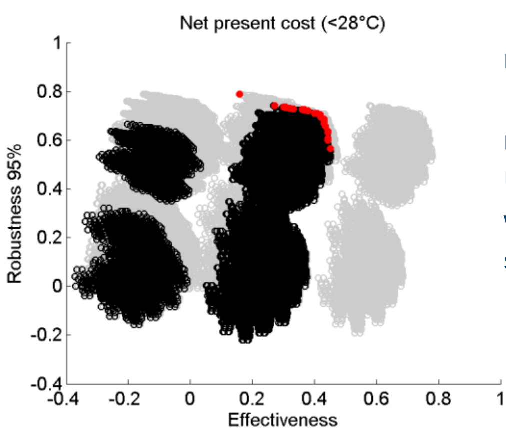
Obtained results

Design of low-energy dwelling



n_{50}: 0.6 – 1 /h

D+ 70-80% heat recovery

massive constructions

U-values: 0.1 – 0.3 W/m²K

window U 0.7 W/m²K - g 0.407

sunscreens

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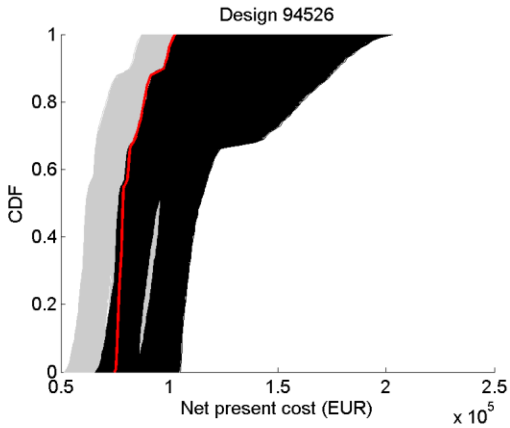
Obtained results

Design of low-energy dwelling



n_{50}: 1 /h
D+ 80% heat recovery
massive construction
U-values: 0.1 – 0.2 W/m²K
window U 0.7 W/m²K - g 0.407
sunscreens

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Conclusions

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Conclusions

- The measurement campaign illustrated the variation in boundary conditions due to user behaviour, workmanship,…
- Common building simulation models do not take this uncertainties into account, which might result in non-optimal designs
- A probabilistic design methodology was proposed to take reliable design decisions and to come up with effective and robust solutions

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Including uncertainty in building energy performance calculation methods

Thank you for your attention.
Questions?

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