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Towards zero-energy districts

opportunities for characterization in modeling and optimization

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EnergyVille

Building energy performance assessment based on optimized in-situ measurements
Workshop in preparation of new IEA EBC Annex project – Brussels April 18-19 2016

Content

1. Introduction: identifying opportunities
2. District Energy Simulations
3. Some potential applications
4. Wrap up

INTRODUCTION: IDENTIFYING OPPORTUNITIES

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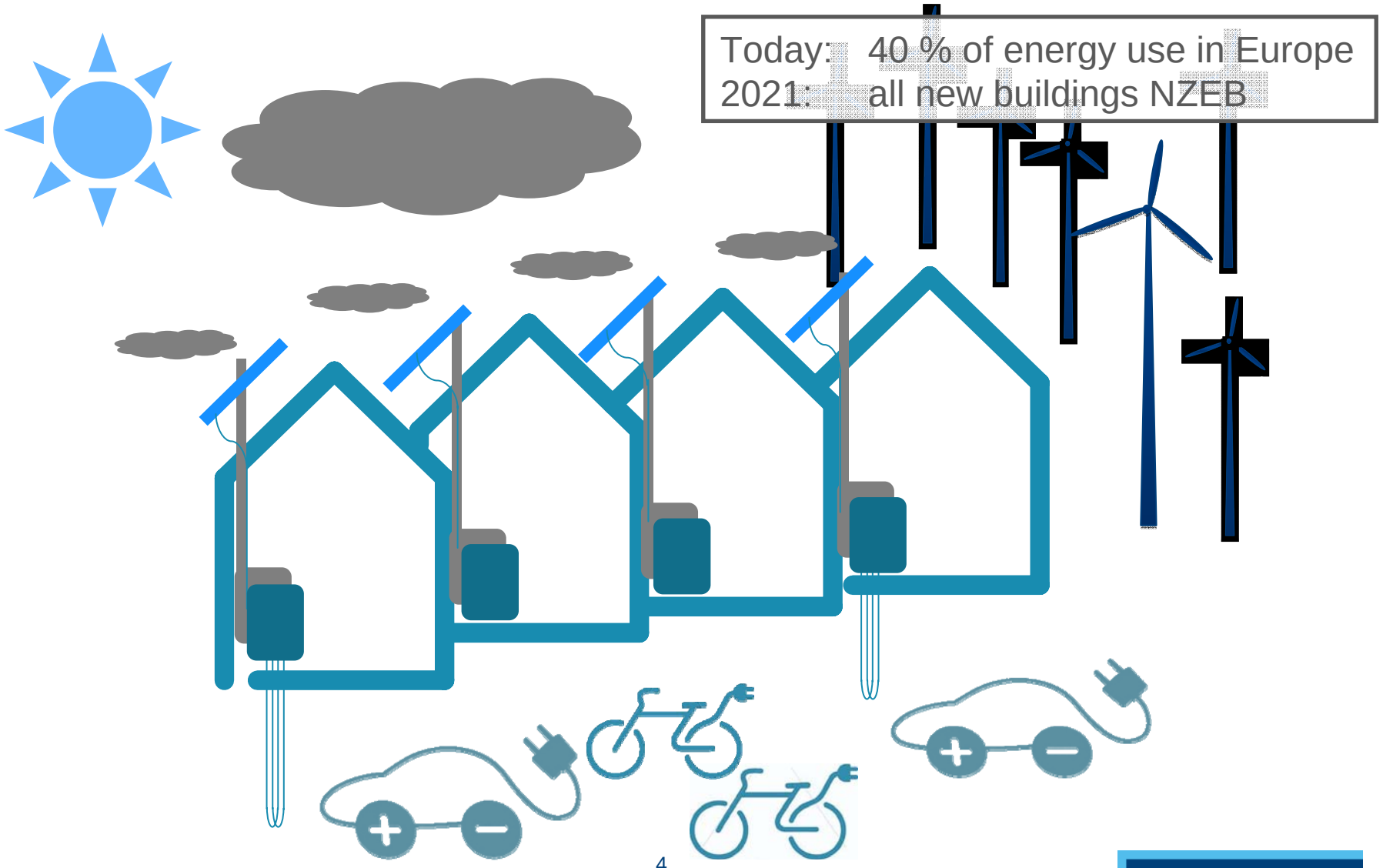
Opportunities in smart grids



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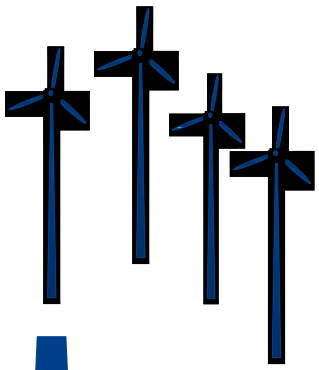
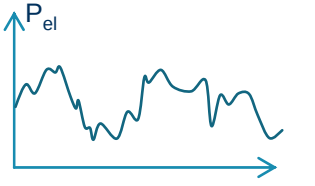
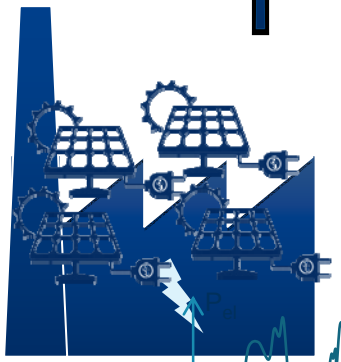
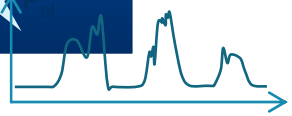
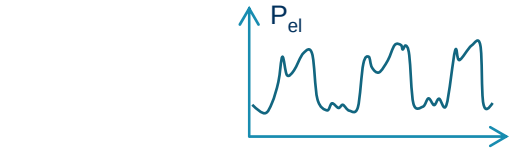
New challenges for electricity grid

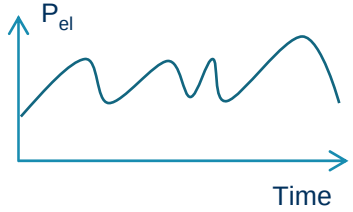


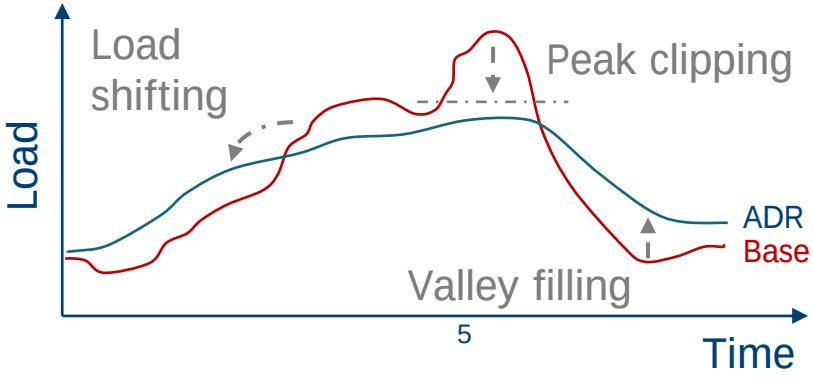












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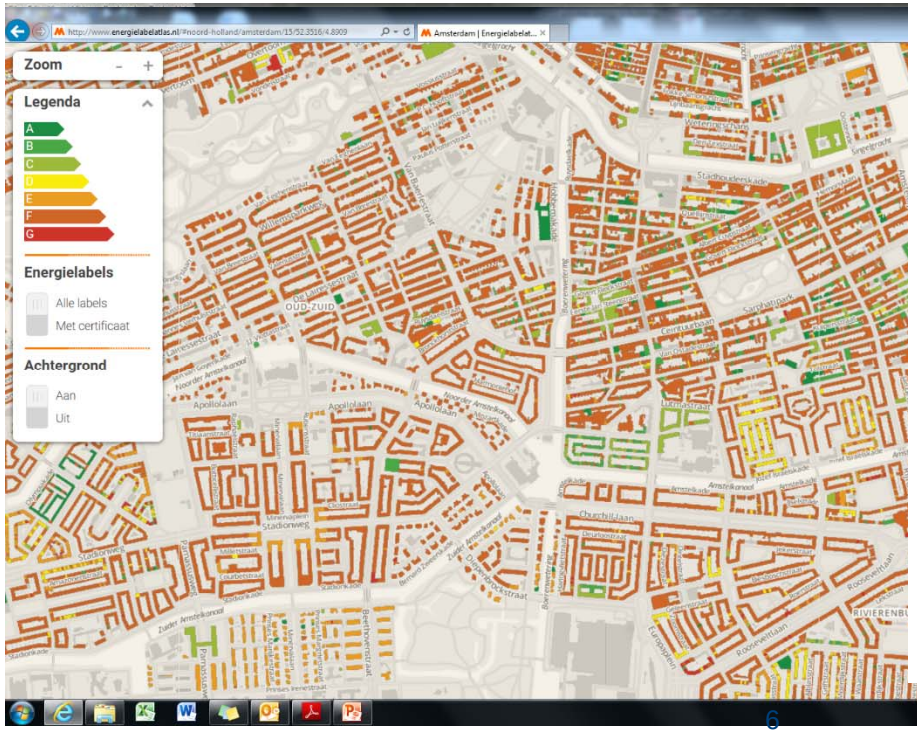
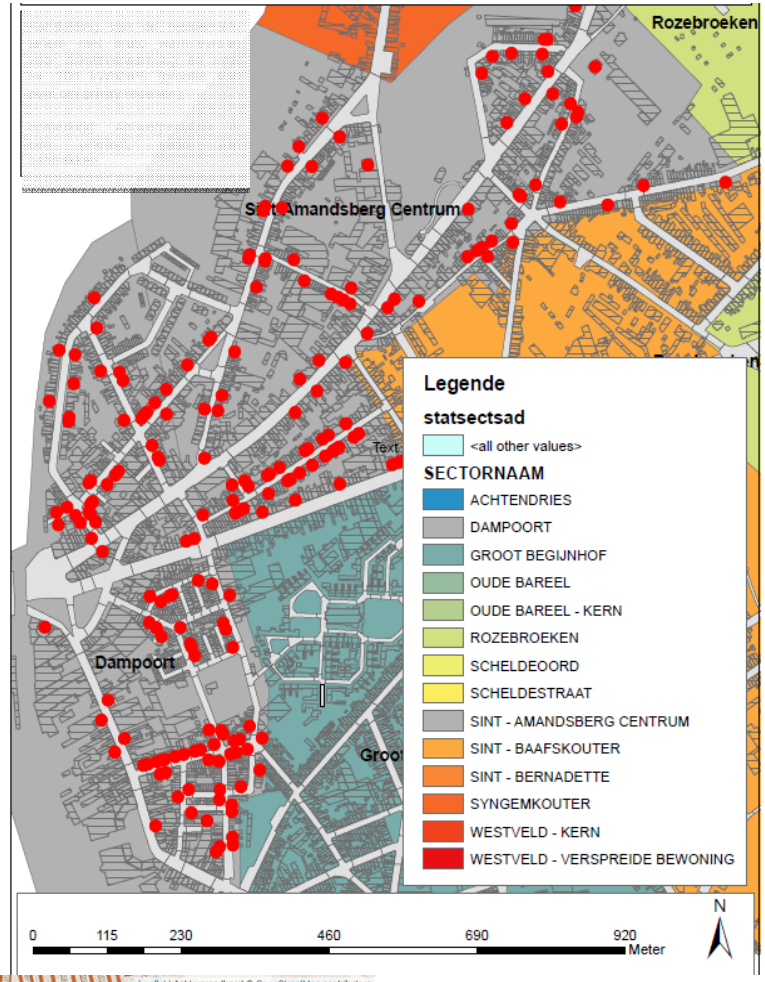
Opportunities in existing neighbourhoods

Assessing renovation potential

GIS-based data platforms on building sto renovation activities





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Opportunities in existing neighbourhoods

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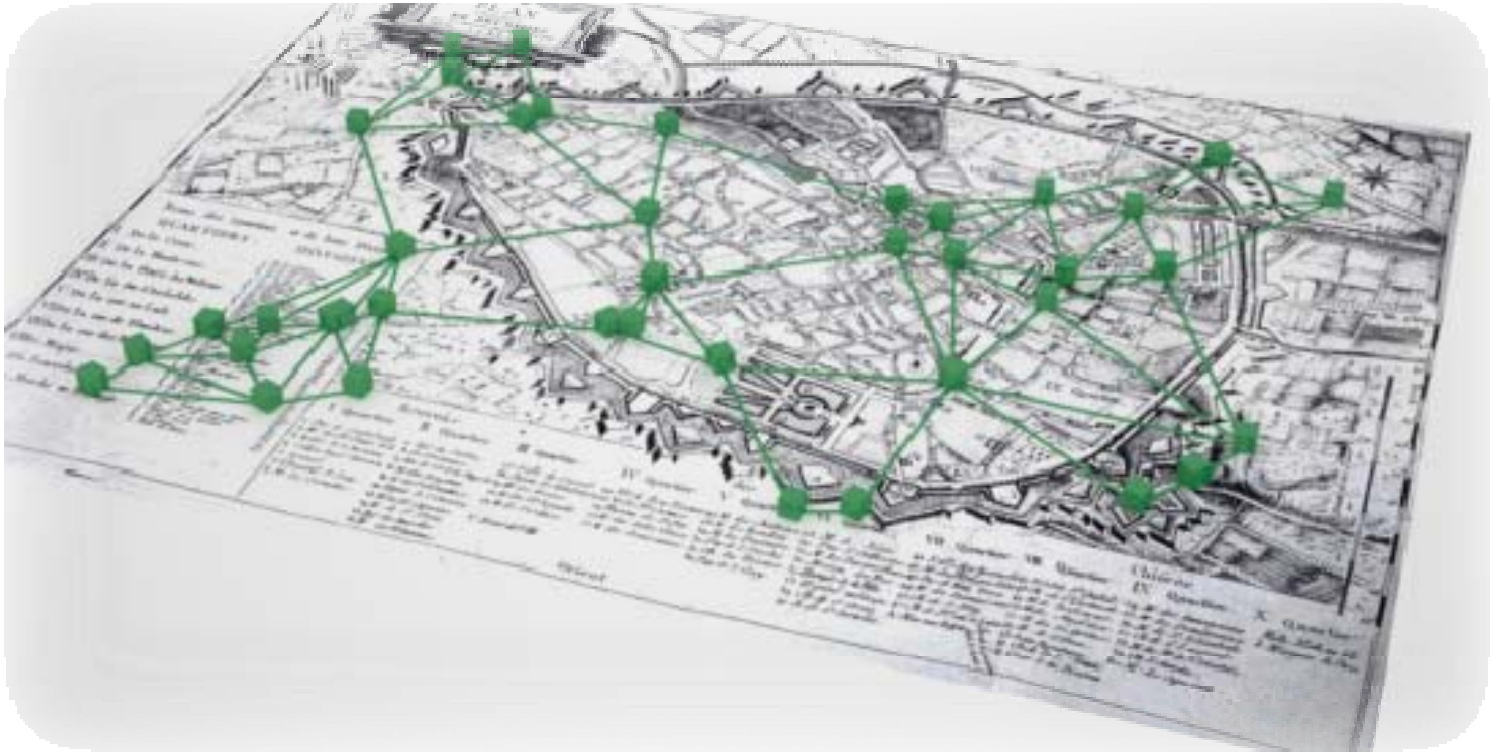
Opportunities in existing neighbourhoods

Assessing potential for thermal grids



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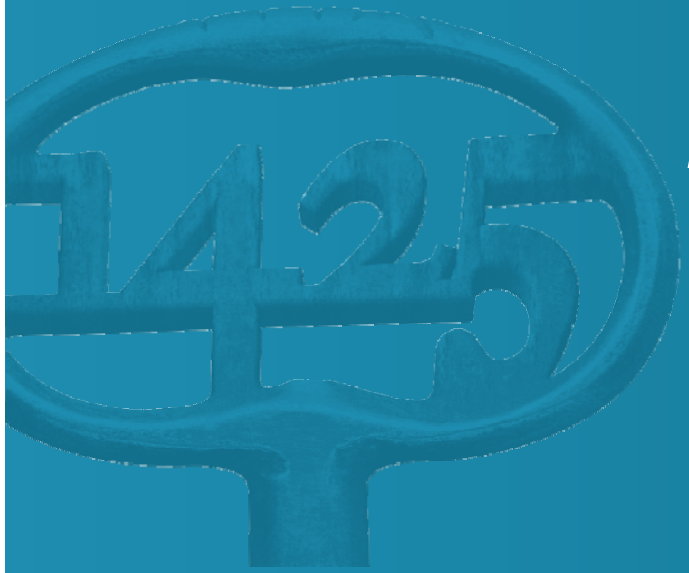
DISTRICT ENERGY SIMULATIONS

From building level to district level



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From building level …

Traditional Building Energy Simulation

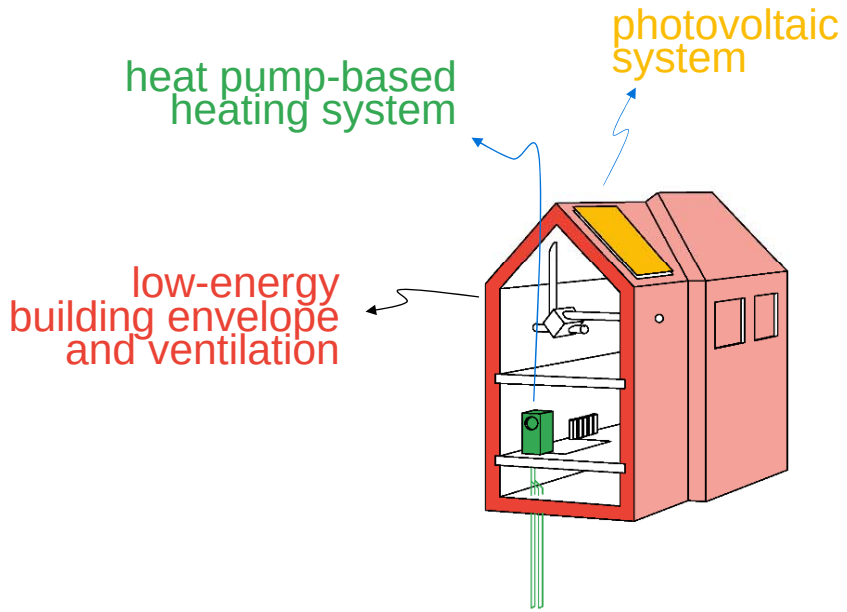
Detailed modelling of

- Envelope
- Systems
- Occupants

Evaluate

- Energy use
- Energy cost
- Comfort

} Building level



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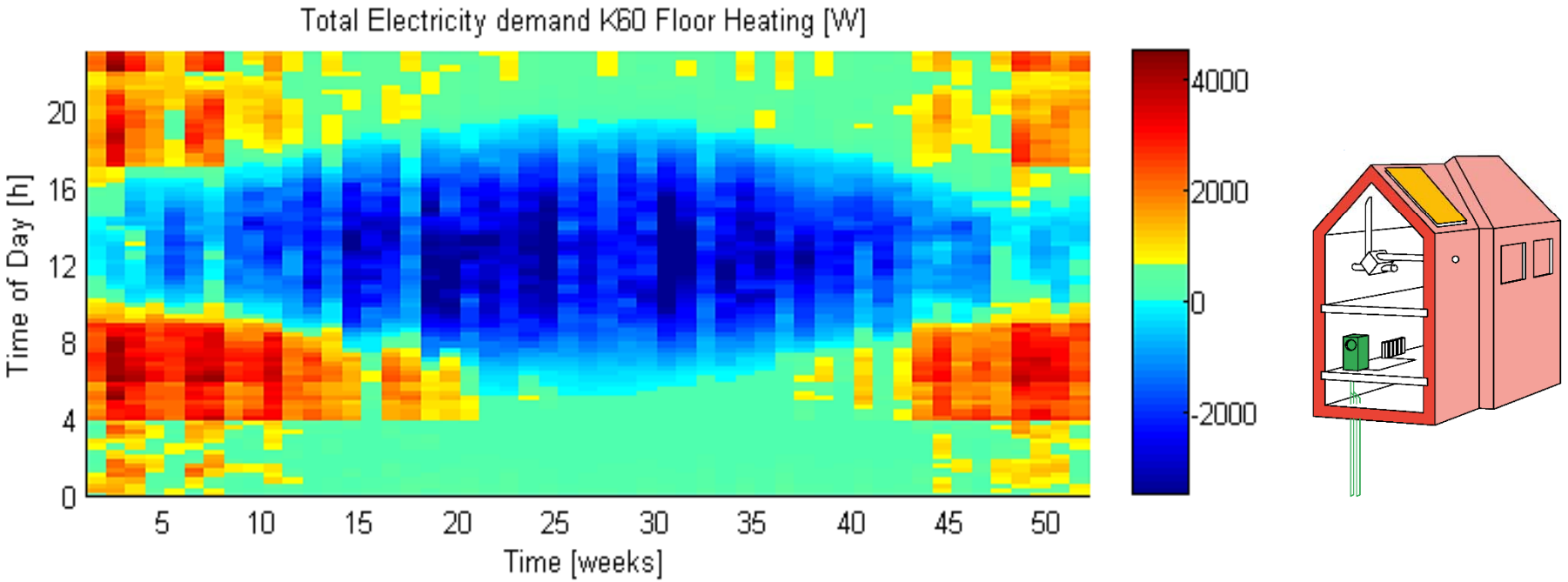
From building level …



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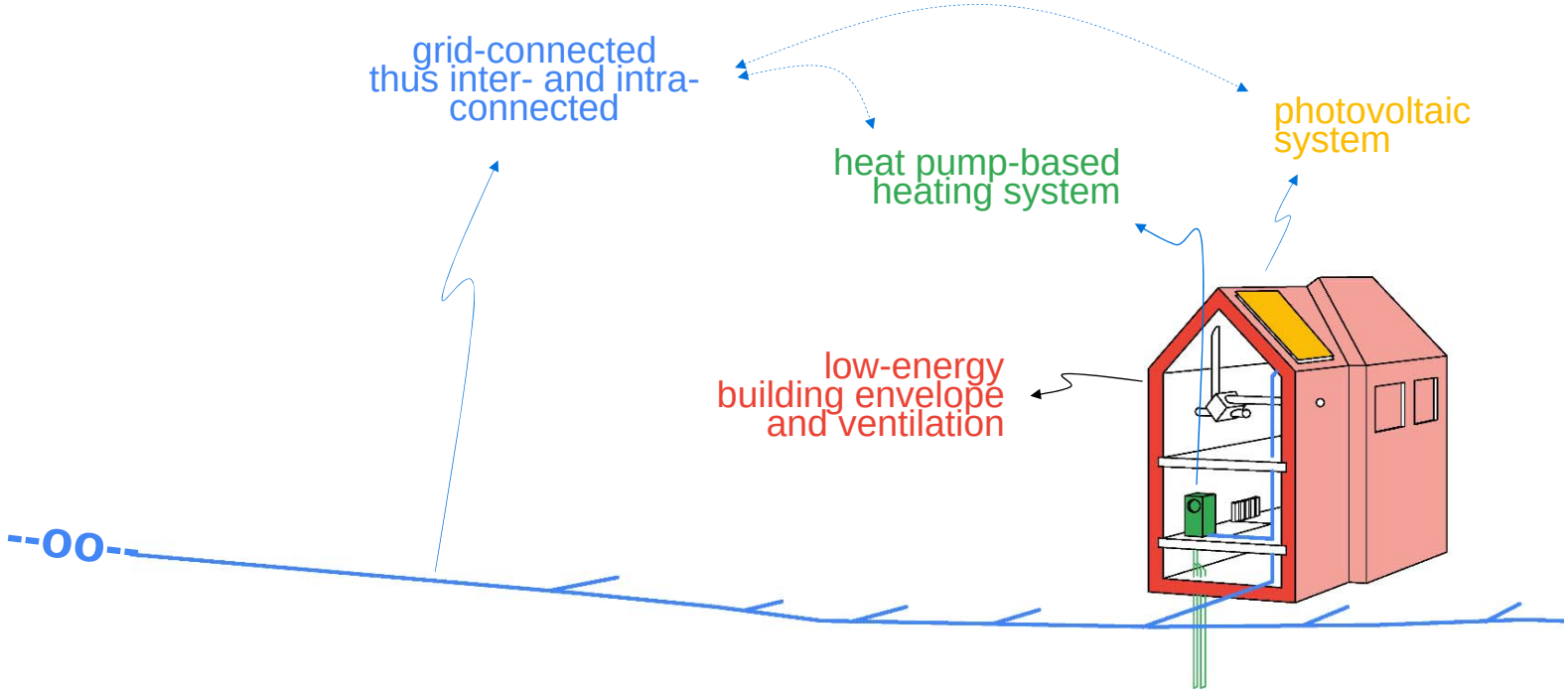
From building level …



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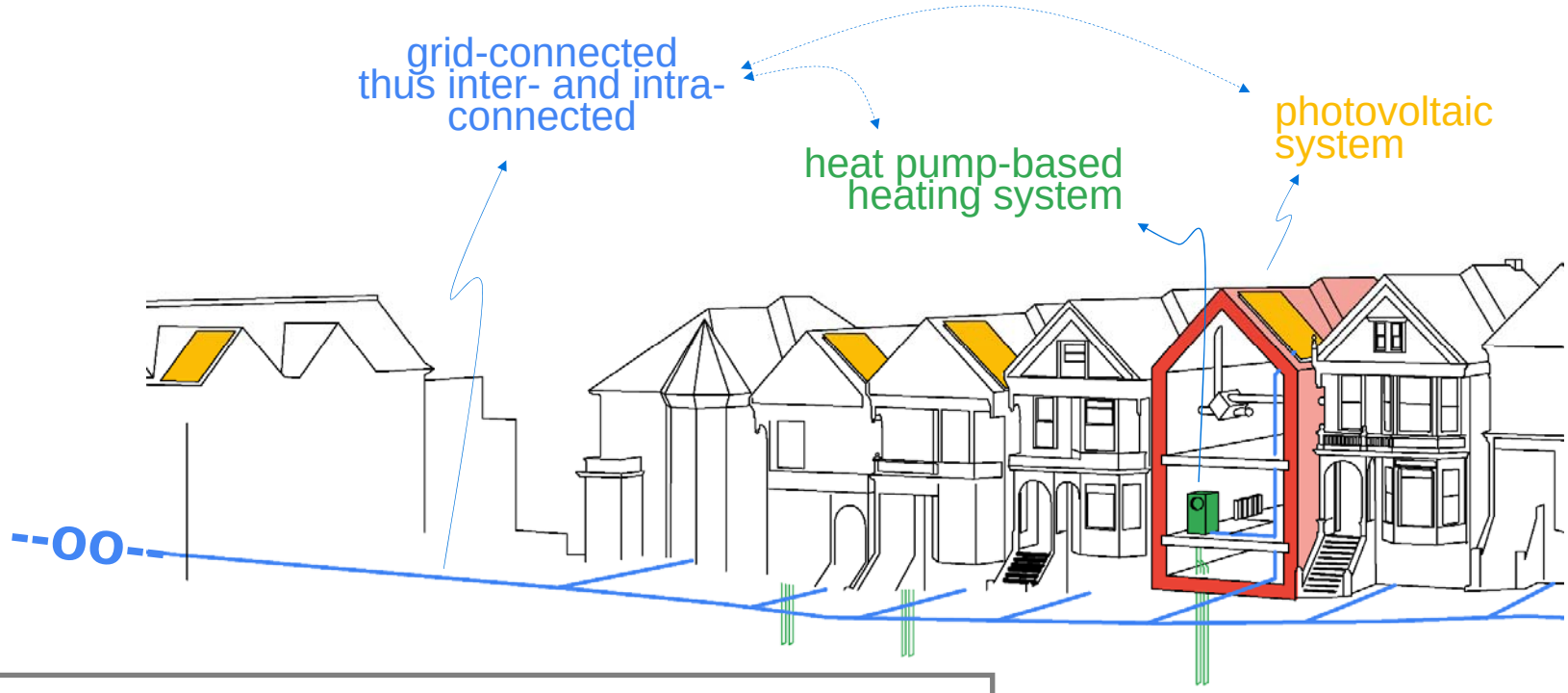
… to district level



New **challenges** for building simulation

- multi-domain modelling
- increase of dimensionality
- reduction of time-scale

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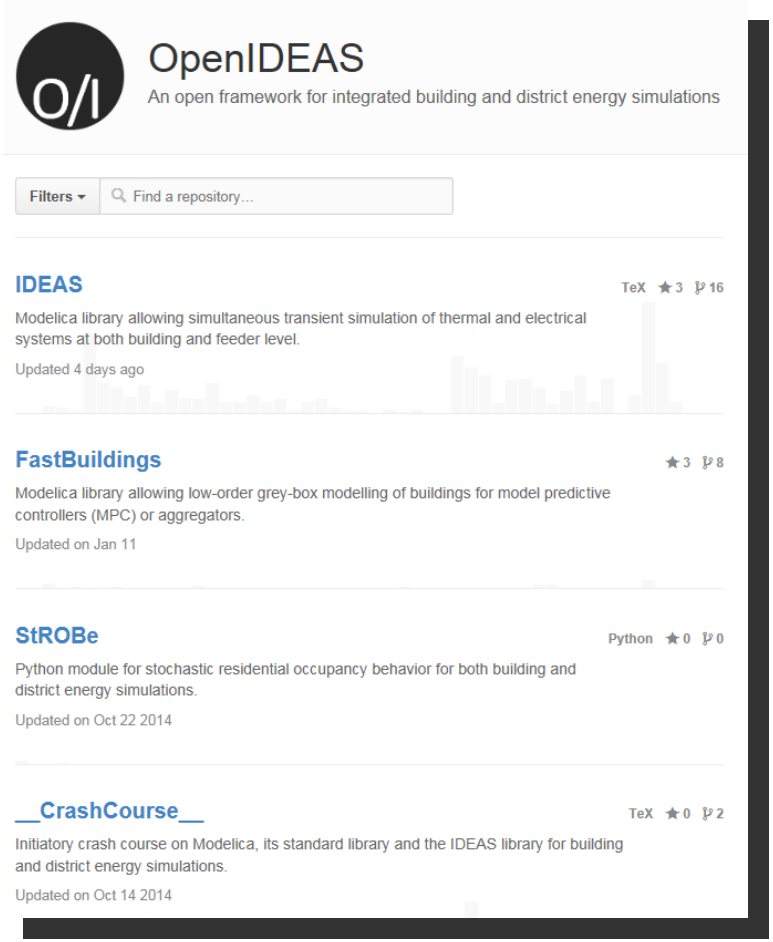
Integrated District Energy Assessment by Simulation

Modelica + Python simulation environment to assess the influence of integrating renewable energy sources

- Object oriented approach
- Equation based
- Use of dymola

Repository freely available at:
https://github.com/open-ideas



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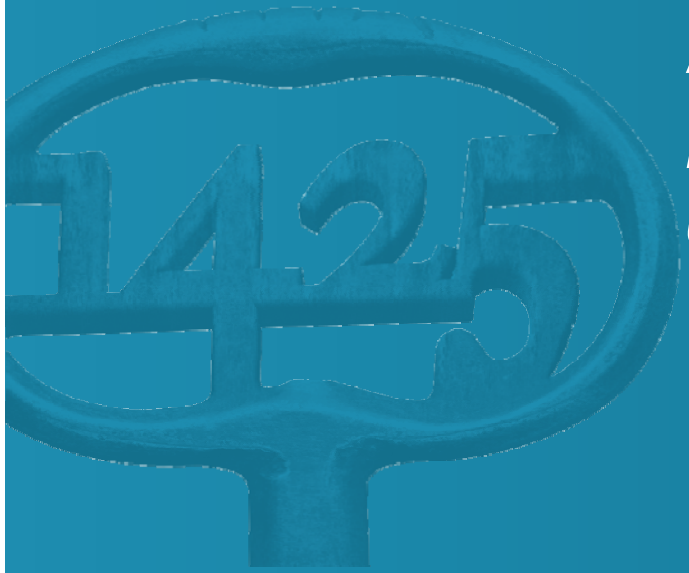
APPLICATION 1

impact of heat pump-based building design on distribution grid level



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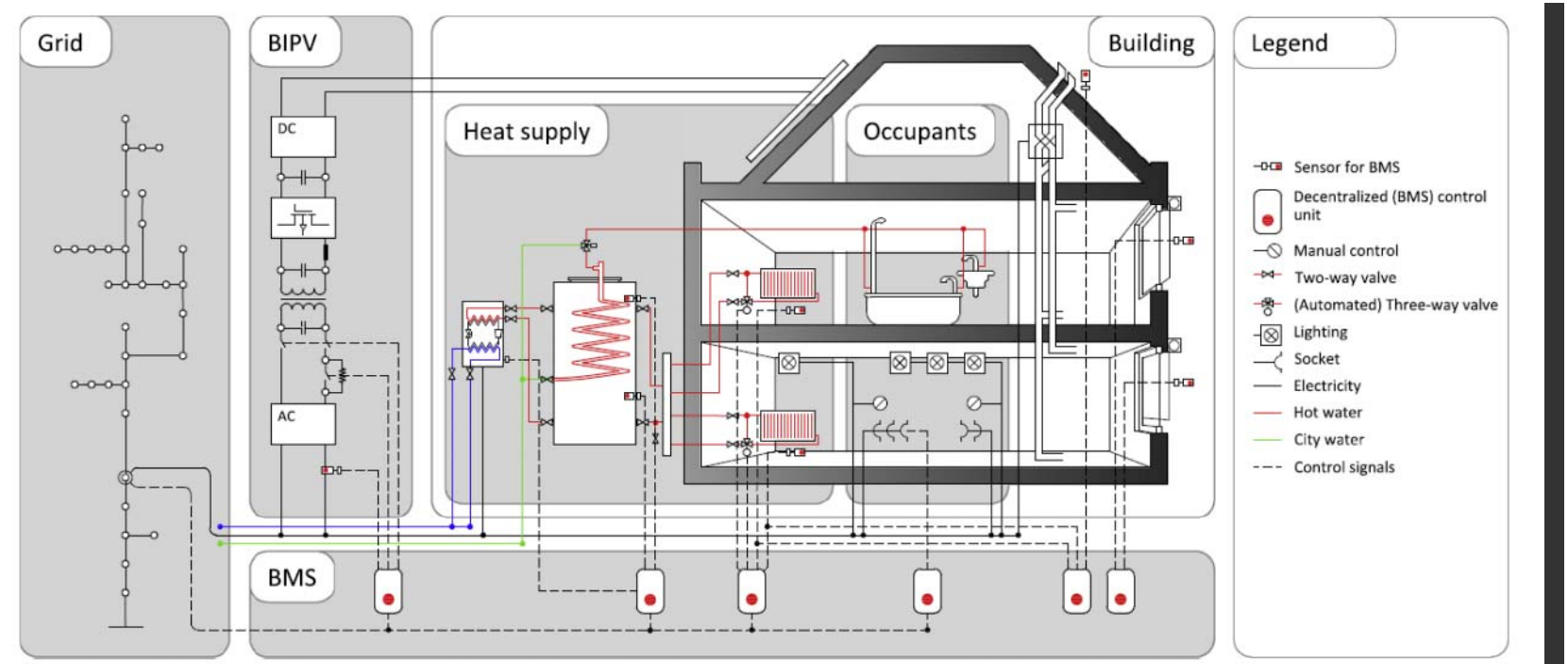
IDEAS.mo – Integrated District Energy Assessment Simulation



R. Baetens, R. De Coninck, J. Van Roy, B. Verbruggen, J. Driesen, L. Helsen, D. Saelens, Assessing electrical bottlenecks at feeder level for residential net zero-energy buildings by integrated system simulation, Applied Energy, Volume 96, August 2012, Pages 74-83, ISSN 0306-2619, 10.1016/j.apenergy.2011.12.098.

Baetens, R., De Coninck, R., et.al. (2012). Assessing electrical bottlenecks at feeder level for residential net zero-energy buildings by integrated system simulation. Applied Energy, 96, 74–83.

Effect on nZEB level

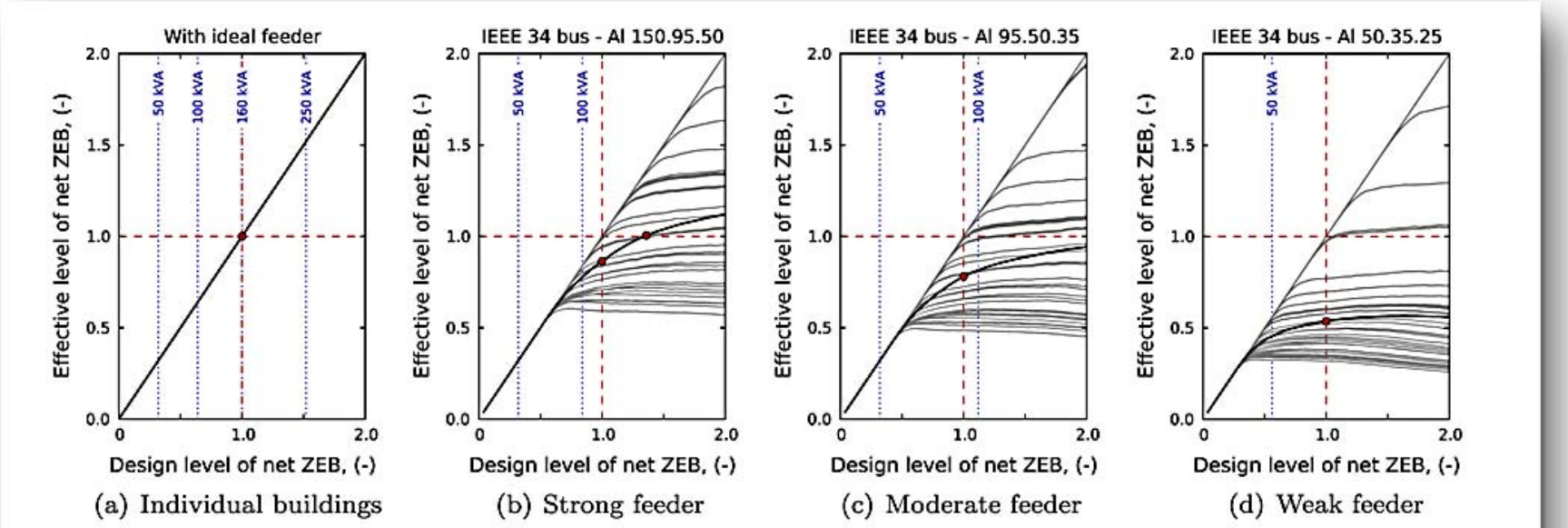
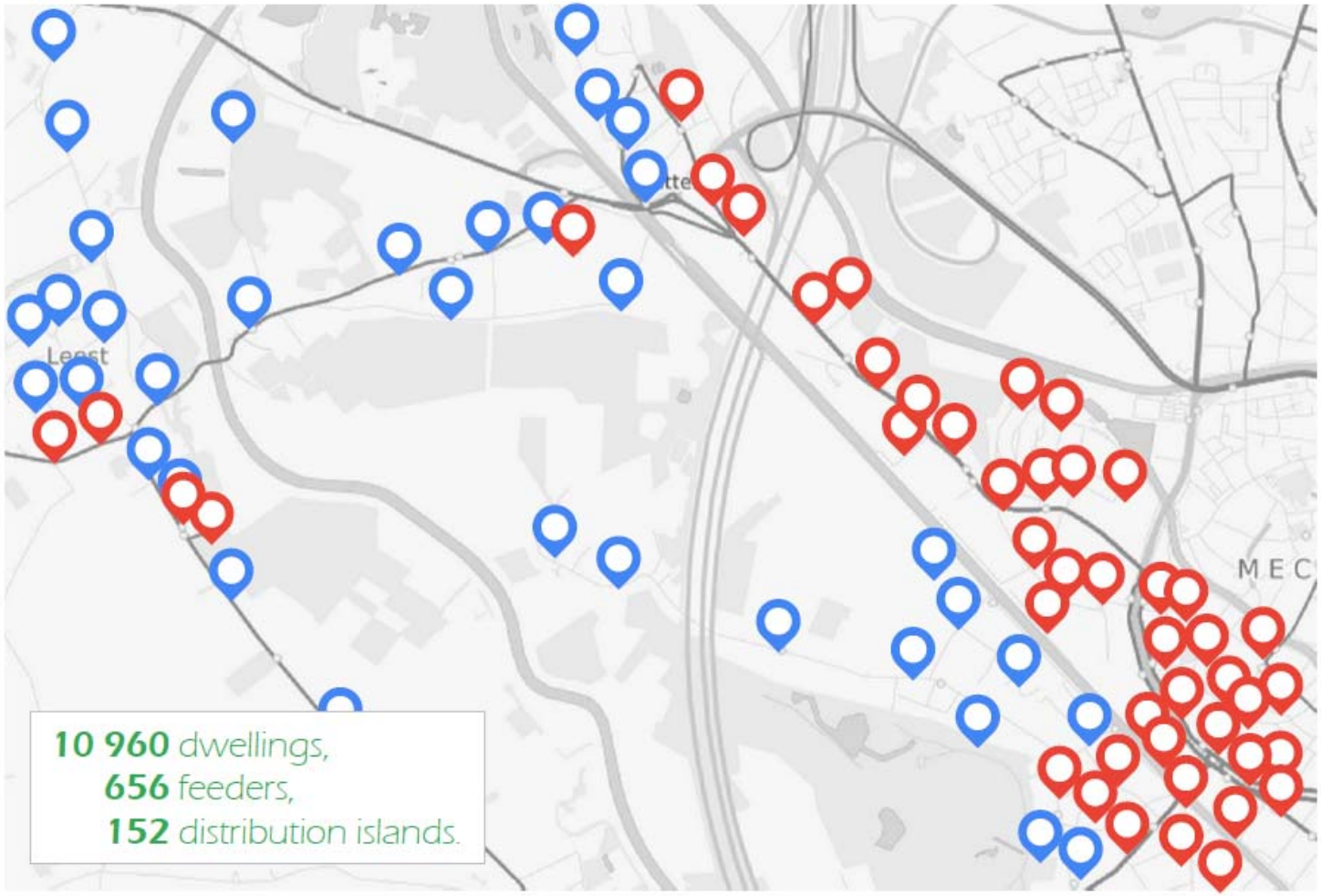


Fig. 7. Effective levels of net zero-energy plotted against the design level of net zero-energy at building (gray) and aggregated (black) level determined ideally at building level and after integrated district energy system simulation including feeder consequences for the considered feeder designs. Here, a depicted design level of net zero-energy of 1.0 denotes the exact dimensioning of the photovoltaic capacities as described whereas a design level of net zero-energy of e.g. 0.8 depicts an under-sizing by a fraction of 20% at annual basis of the provided local supply of renewable energies. The dotted lines indicate the required transformer capacity.

Baetens, R., De Coninck, R., et.al. (2012). Assessing electrical bottlenecks at feeder level for residential net zero-energy buildings by integrated system simulation. Applied Energy, 96, 74–83.

Example
Analysis of DES impact

Overview drawing of an example distribution of rural and urban low-voltage distribution islands.



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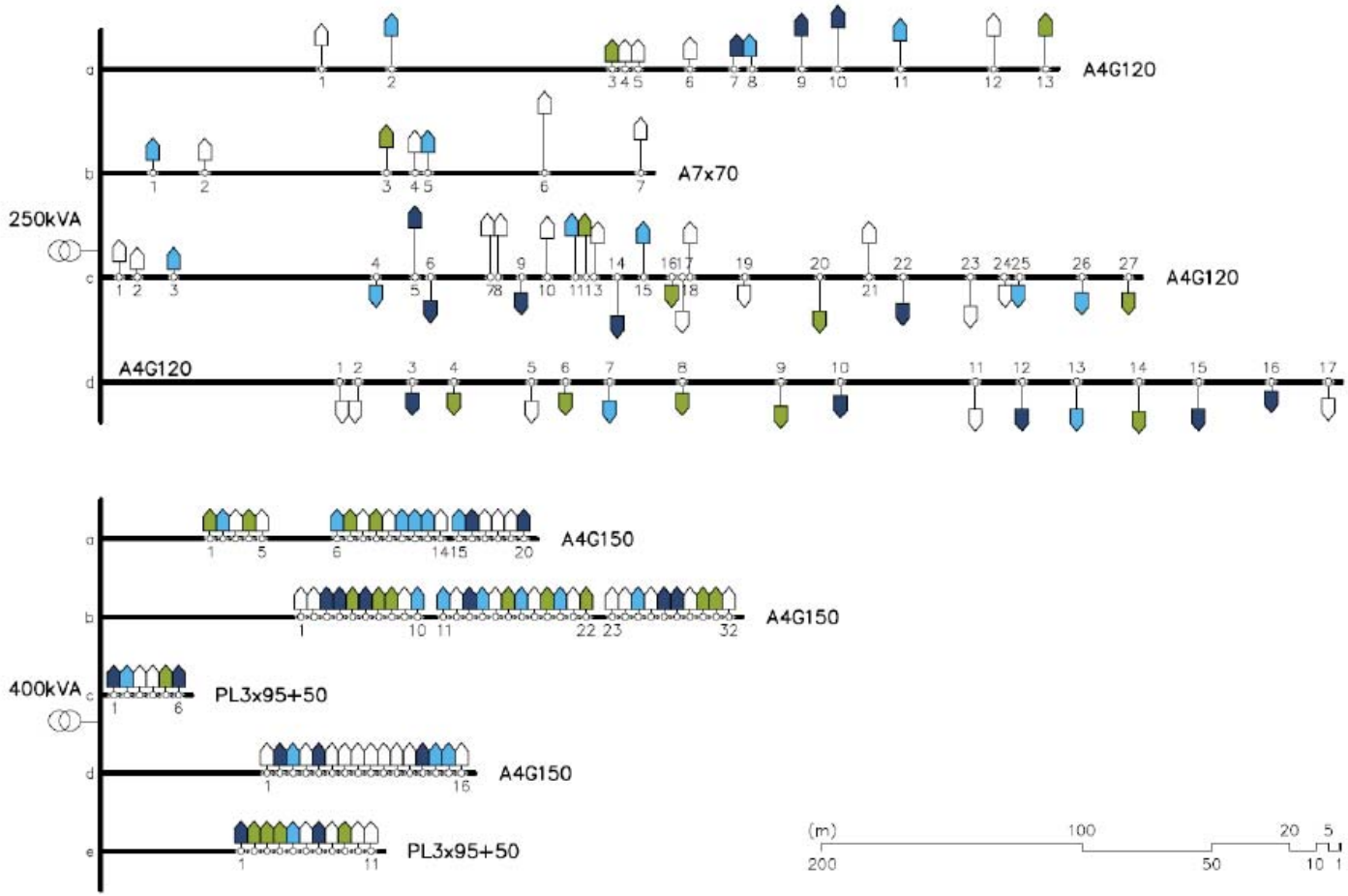
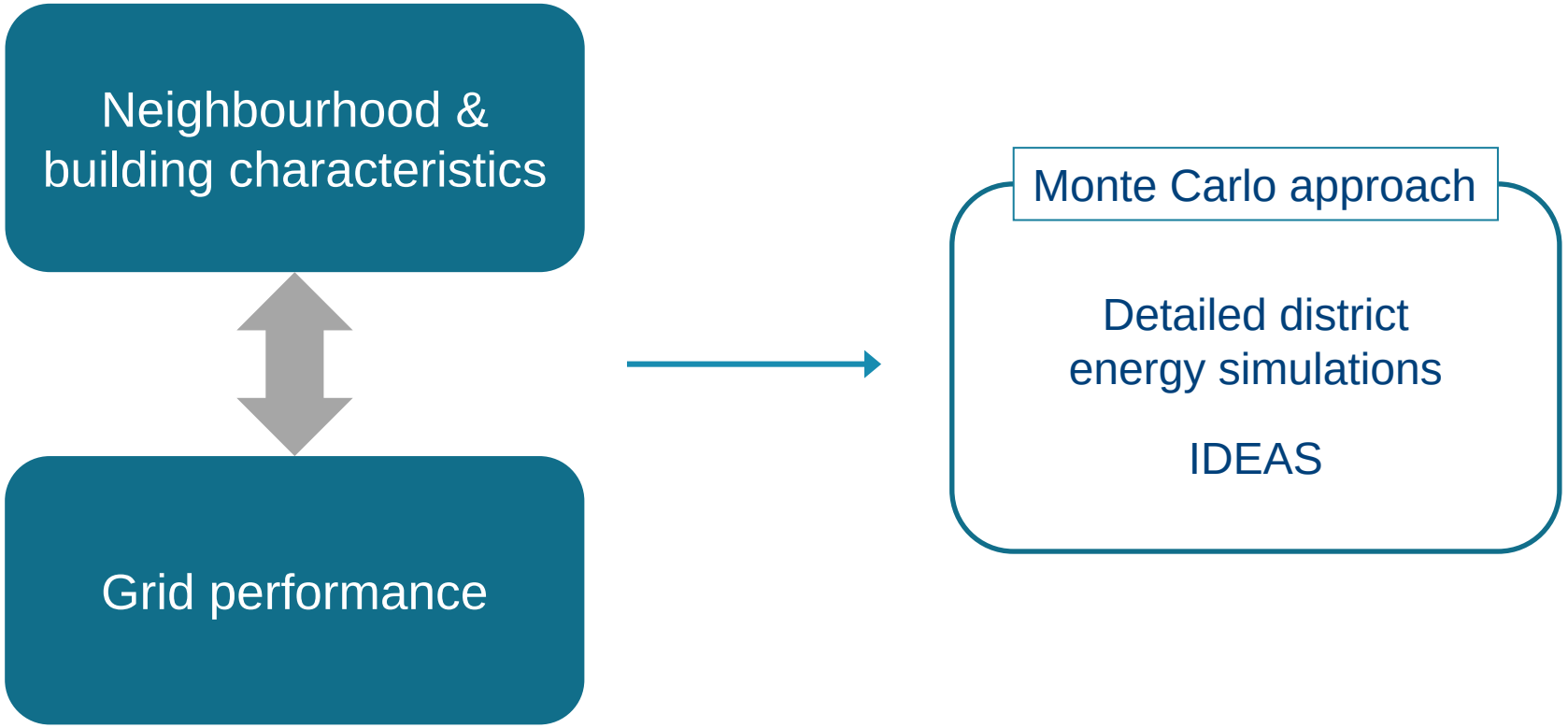
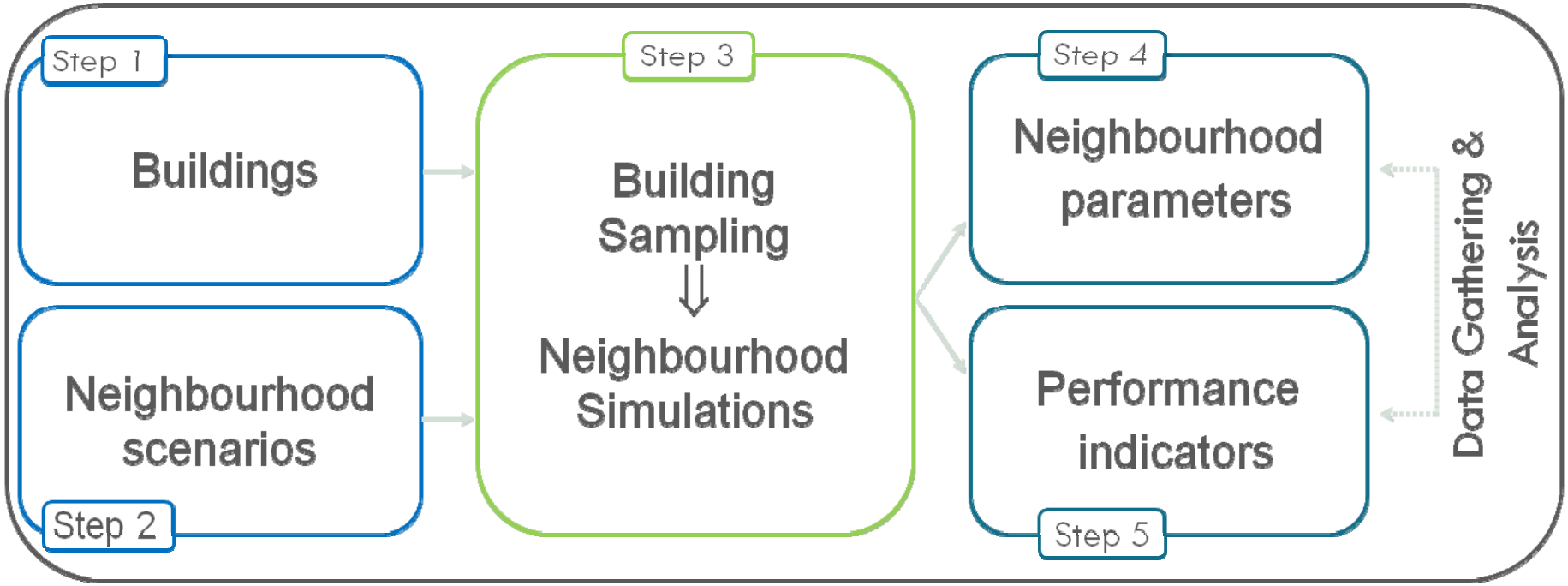
Example
Analysis of DES impact



Graphical representation of the reference rural and urban low-voltage distribution island connecting 64 and 85 dwellings respectively.


Neighbourhood & building characteristics
Grid performance
Monte Carlo approach
Detailed district energy simulations
IDEAS



Protopapadaki C., Baetens R. and Saelens D. (2015) Exploring the impact of heat pump-based dwelling design on the low-voltage distribution grid. Proceedings of Building Simulation 2015, Hyderabad, India.

(1200) Feeder simulations

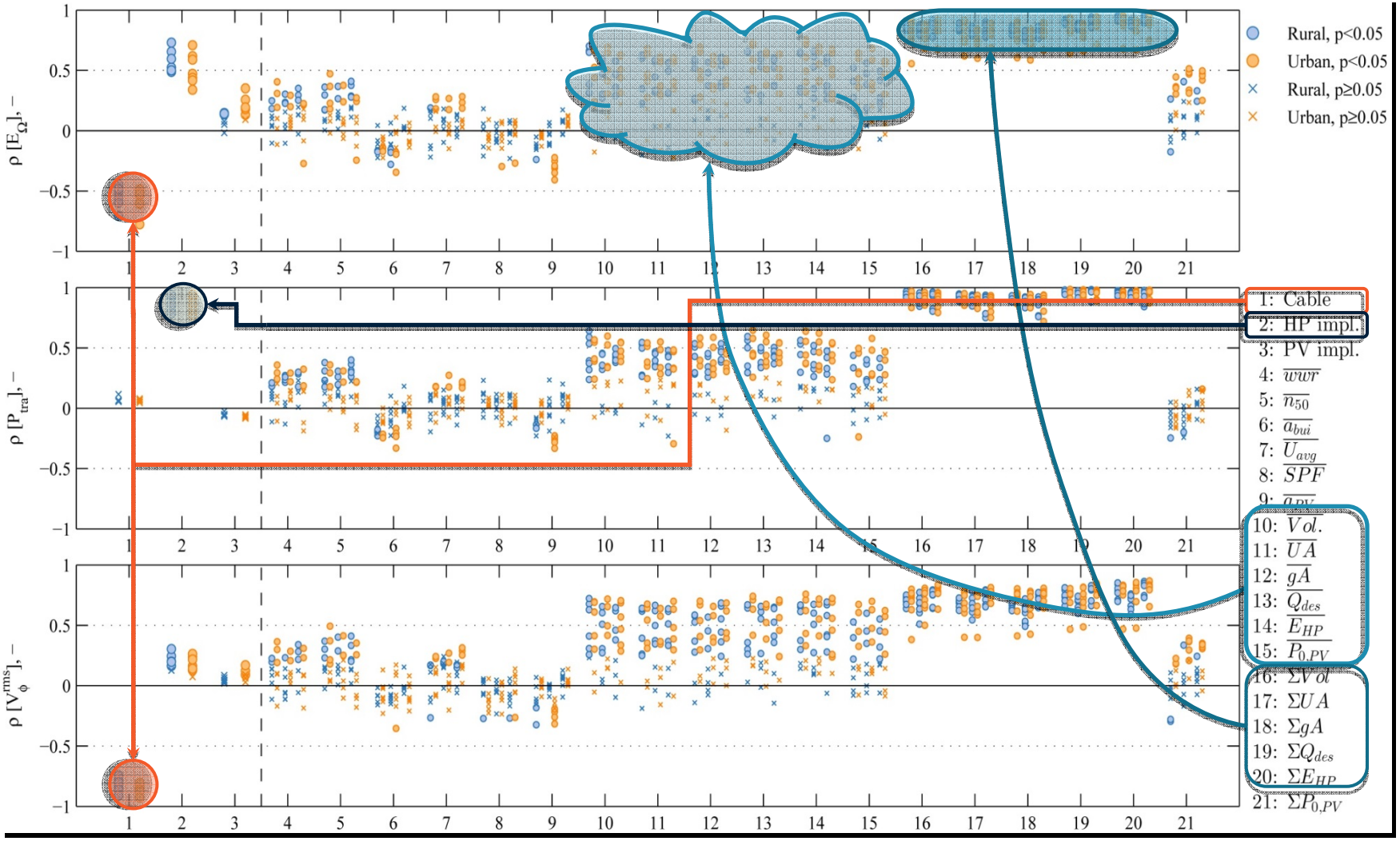
IDEAS district model

Simulation outputs
Electrical demand
Transformer load
Voltage profiles
PV curtailment
Grid losses

CORRELATIONS ?

Neighbourhood parameters
Cable type
HP impl. rate
PV impl. rate
HP el. Demand*
Q_{design}*
Volume*
UA-value*
gA-value*
avg U-value
wwr
n_{50}
Building ori.
SPF
PV capacity*
PV orientation

*also total values



Spearman's correlation coefficients of all neighbourhood parameters based on the simulation set, feeder configuration and cable type. Different color for different feeder (Rural, Urban). Three column sets represent the cable types (from left to right: cable section 70, 95 and 150 mm2). No disaggregation by cable type for the scenario parameters (1-3). Filled dots (•) denote p-values smaller than 0.05, while crosses ( ) denote values above 0.05.

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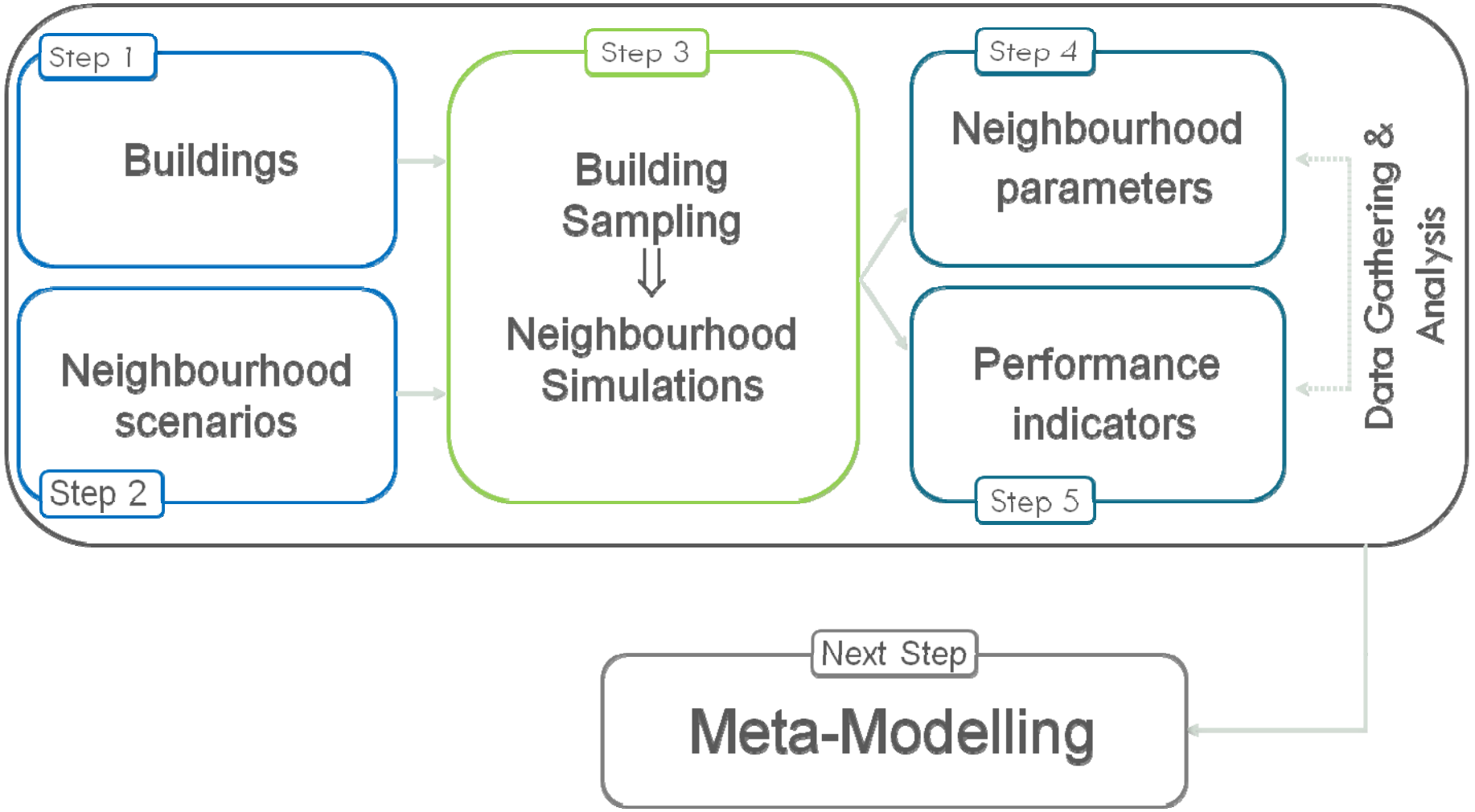
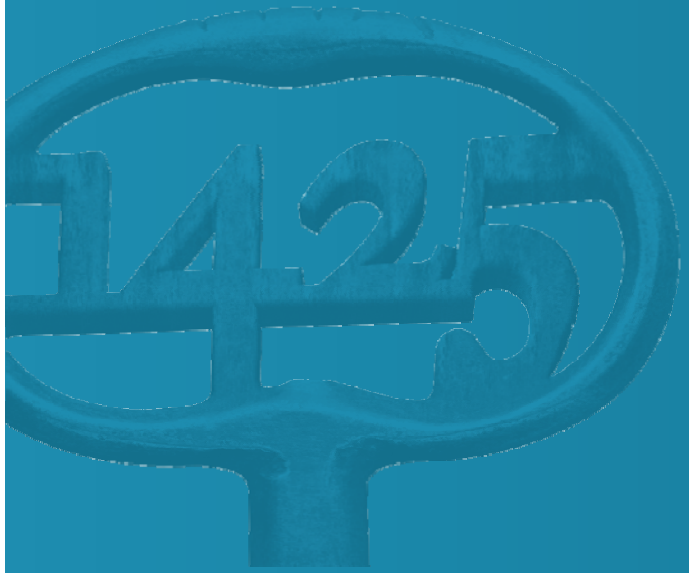

Step 1
Buildings
Neighbourhood scenarios
Step 2
Step 3
Building Sampling
⇓
Neighbourhood Simulations
Step 4
Neighbourhood parameters
Performance indicators
Step 5
Data Gathering & Analysis
Next Step
Meta-Modelling

APPLICATION 2

Buildings in an active demand response context: using structural thermal energy storage



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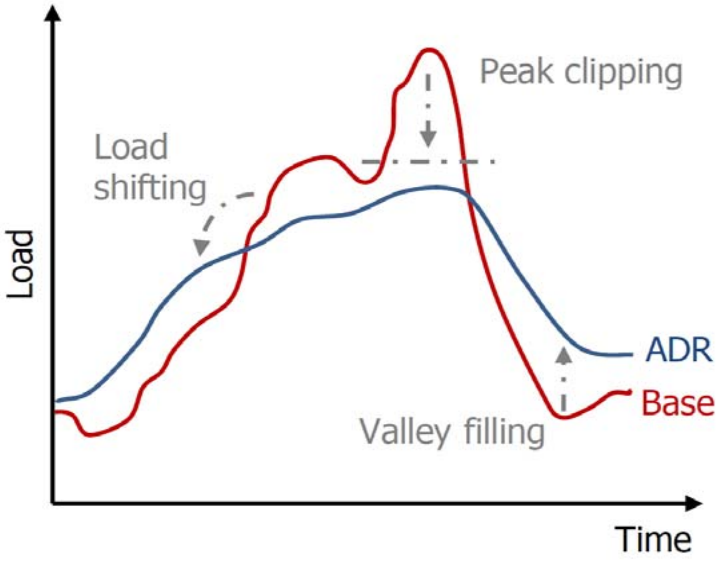
The need for flexibility

"How can building buildings influence the potential for active demand response using structural thermal storage?"



Reynders, G., Nuytten, T., Saelens, D. (2013). Potential of structural thermal mass for demand-side management in dwellings. Building and Environment, 64, 187-199.

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grid perspective

- Size (kWh)
- Power (kW)
- Availability (s)
- Investement cost (€ + kWh)
- Current state (-)

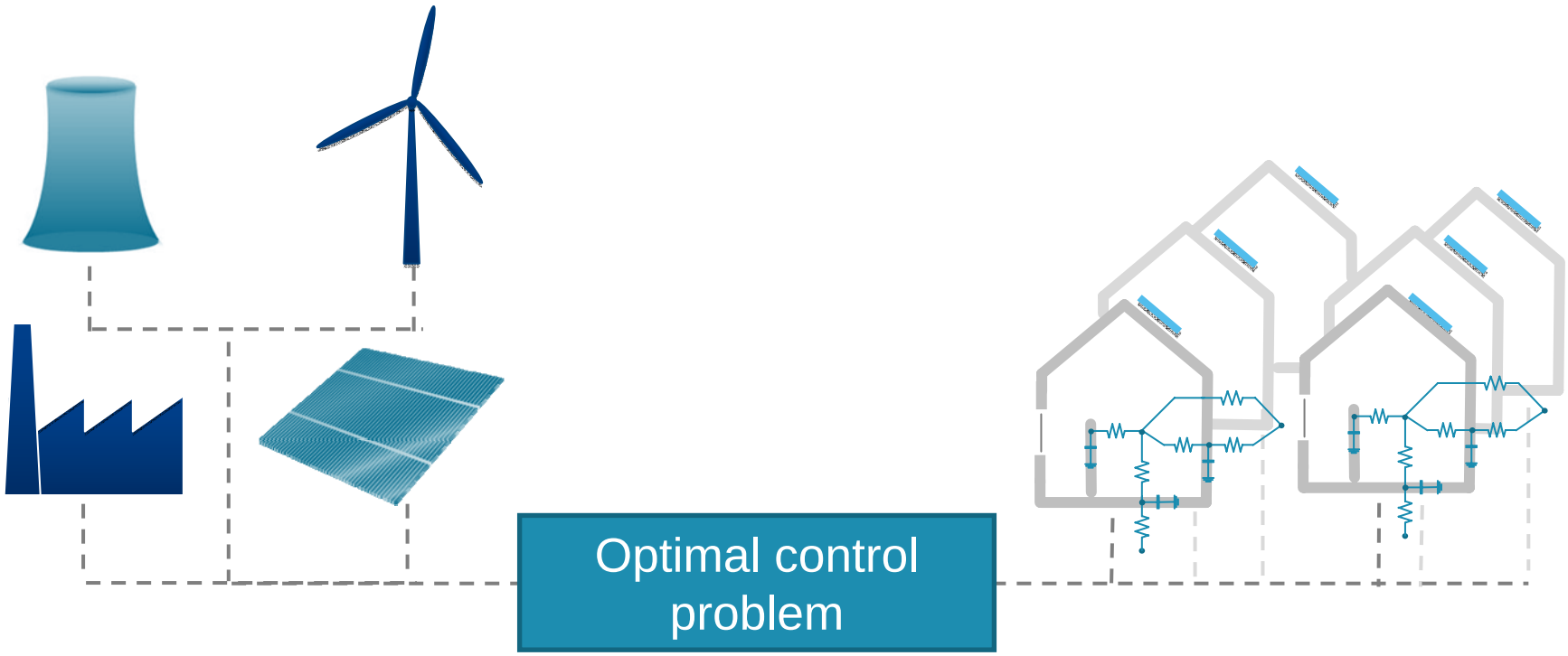
building perspective

- Comfort
- Cost / Profit (€)
- Energy use (€ + kWh)

4 Performance indicators

- Available capacity
- Storage Efficiency
- State of Charge
- Power shifting capability

ADR potential of Belgian residential stock



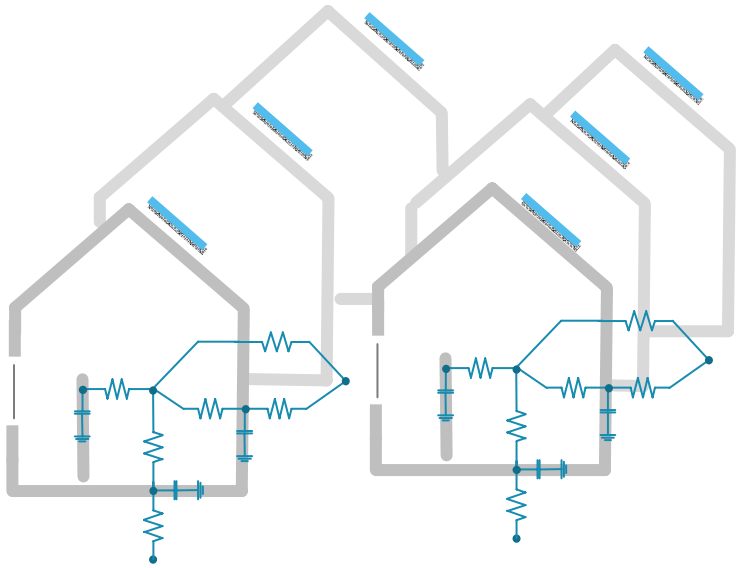
Patteeuw, D., Reynders, G., Bruninx, K., Protopapadaki, C., Delarue, E., D'haeseleer, W., Saelens, D., Helsen, L. (2015). CO2-abatement cost of residential heat pumps with Active Demand. Response: demand- and supply-side effects. Applied Energy, 156, 490-501.

ADR potential of Belgian residential stock

I. REDUCED-ORDER BUILDING STOCK MODEL

Main matrix of the Belgian housing typology

	Region	Construction Year Class	Single Family House - Detached	Single Family House – Semi detached	Single Family House - Terraced
1	national (Belgium)	... 1945	 BE.N.SFH.01.deta	 BE.N.TH.01.semi	 BE.N.TH.01.terr
6	national (Belgium)	1946 - 1970	 BE.N.SFH.02.deta	 BE.N.TH.02.semi	 BE.N.TH.02.terr
12	national (Belgium)	1971 - 1990	 BE.N.SFH.03.deta	 BE.N.TH.03.semi	 BE.N.TH.03.terr
18	national (Belgium)	1991 - 2005	 BE.N.SFH.04.deta	 BE.N.TH.04.semi	 BE.N.TH.04.terr
24	national (Belgium)	2006 ...	 BE.N.SFH.05.deta	 BE.N.TH.05.semi	 BE.N.TH.05.terr



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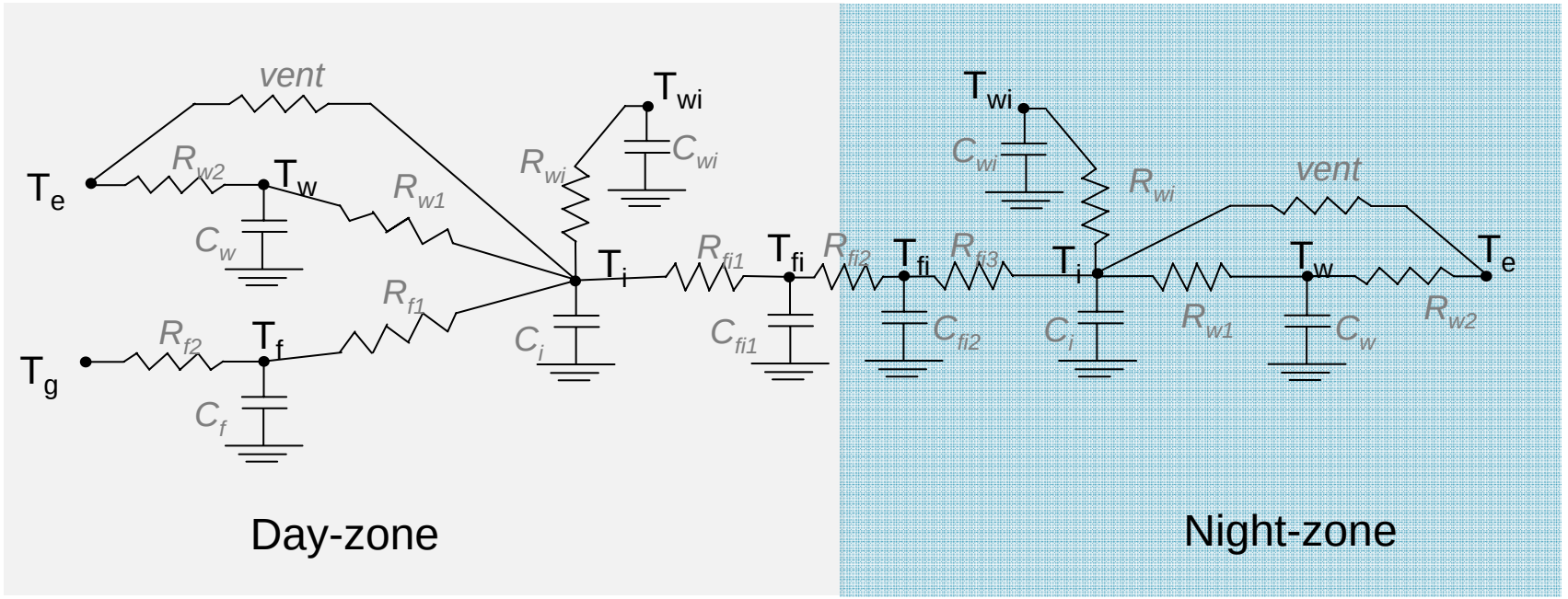
Reduced-order building stock model

MODEL STRUCTURE



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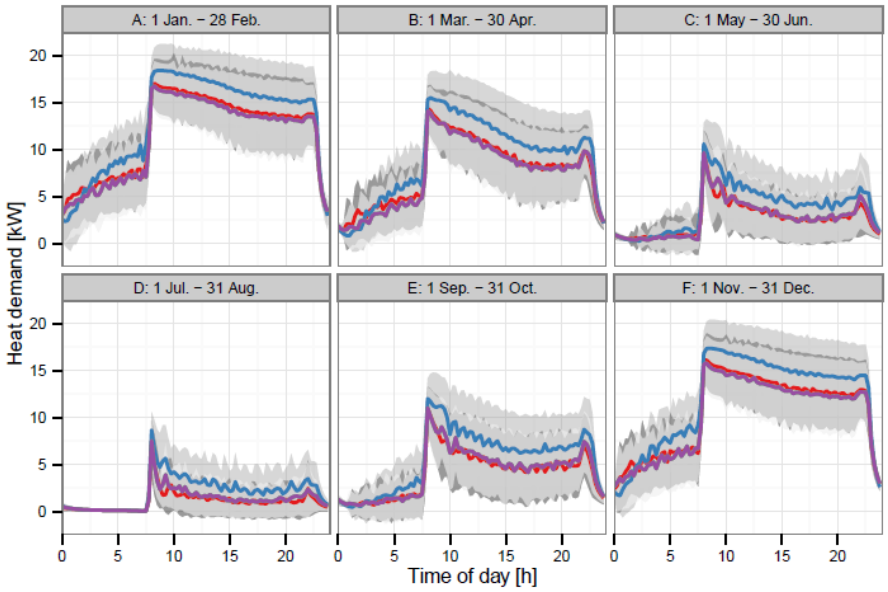
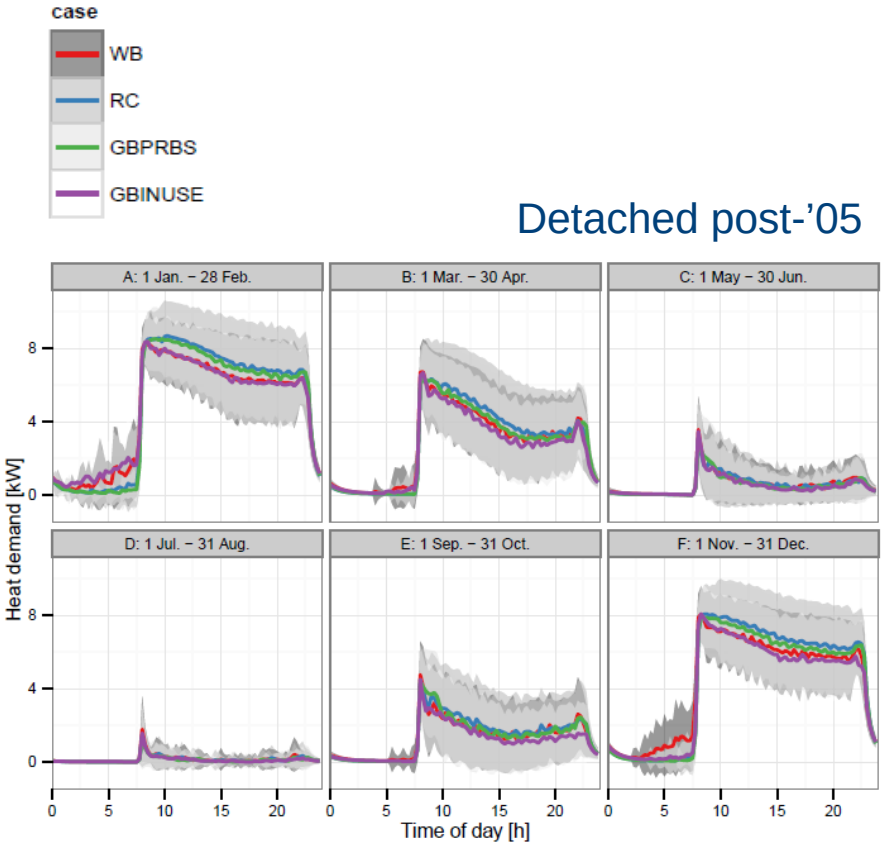
Reduced-order building stock model

VERIFICATION IDENTIFIED MODELS

Instantaneous heat demand profiles



Detached pre-'45



Detached post-'05

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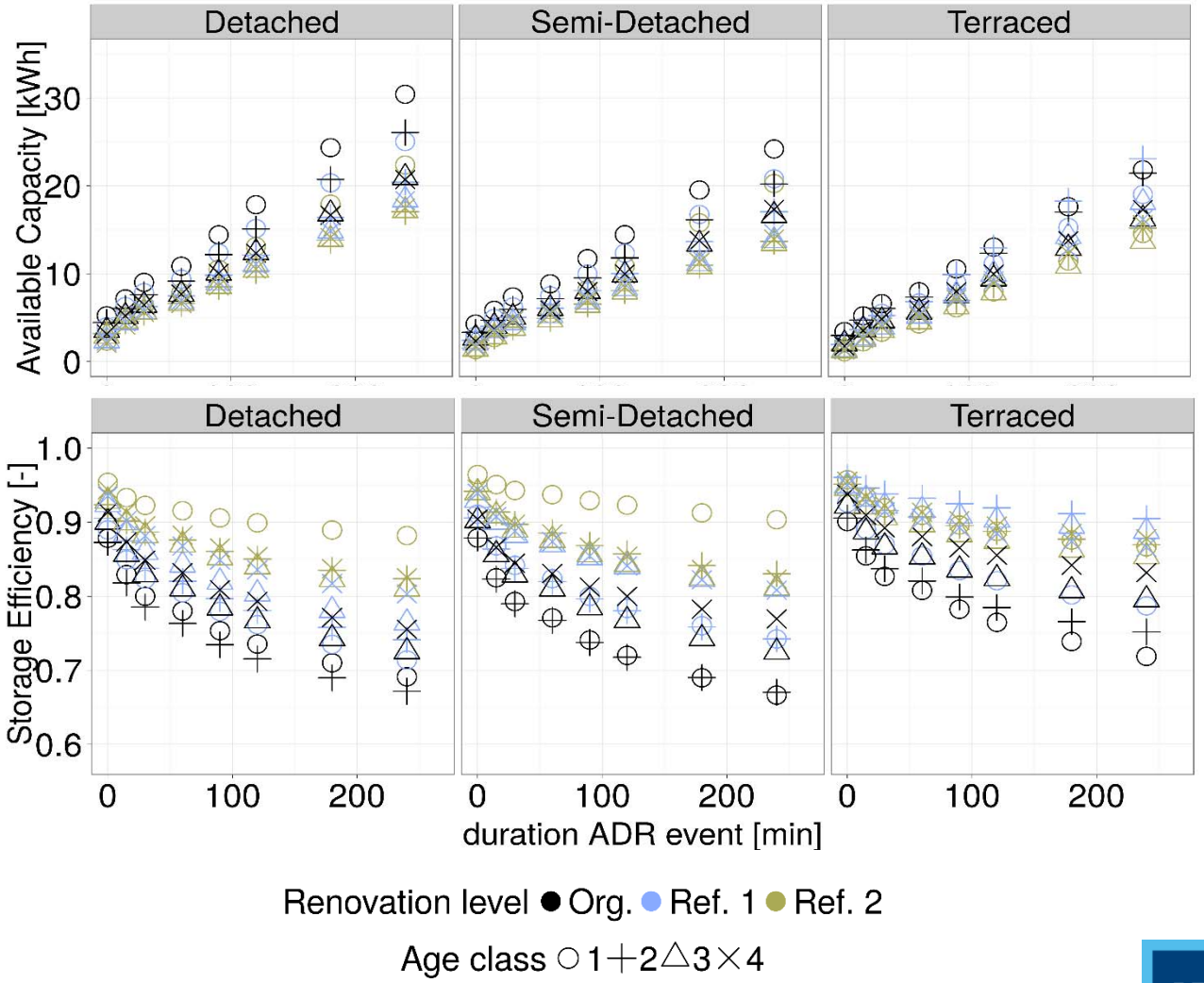
ADR potential of Belgian residential stock

ADR CHARACTERISTICS



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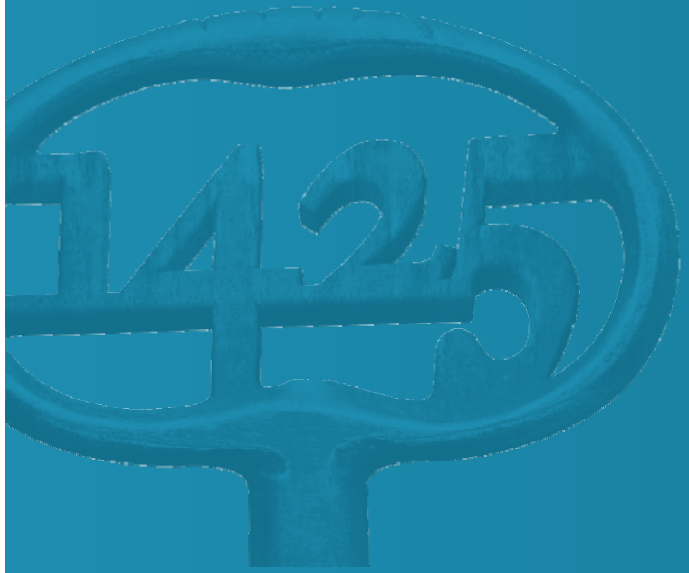
APPLICATION 3

Developing control strategies for smart energy networks



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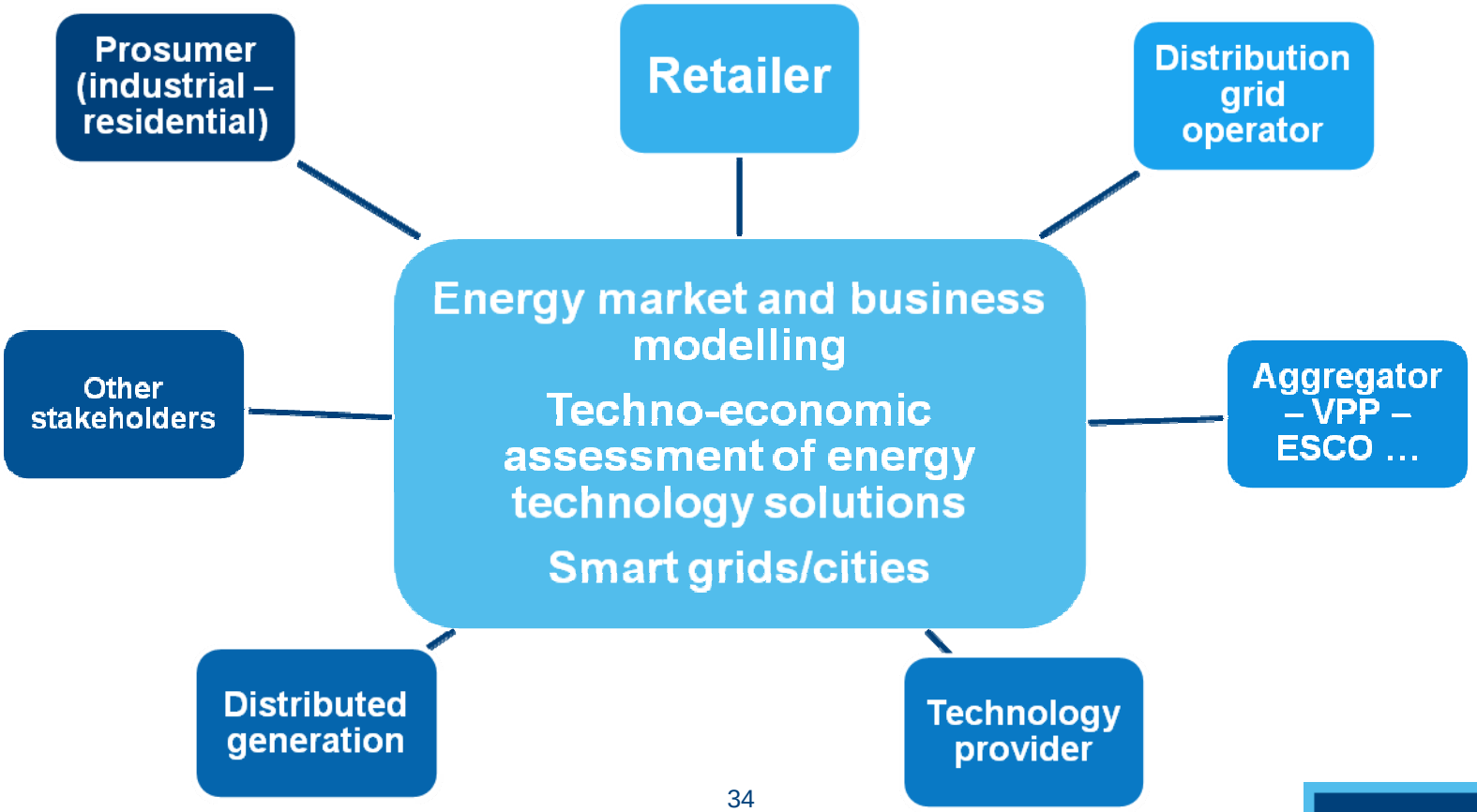
Interoperability for future electricity markets

European Energy Markets



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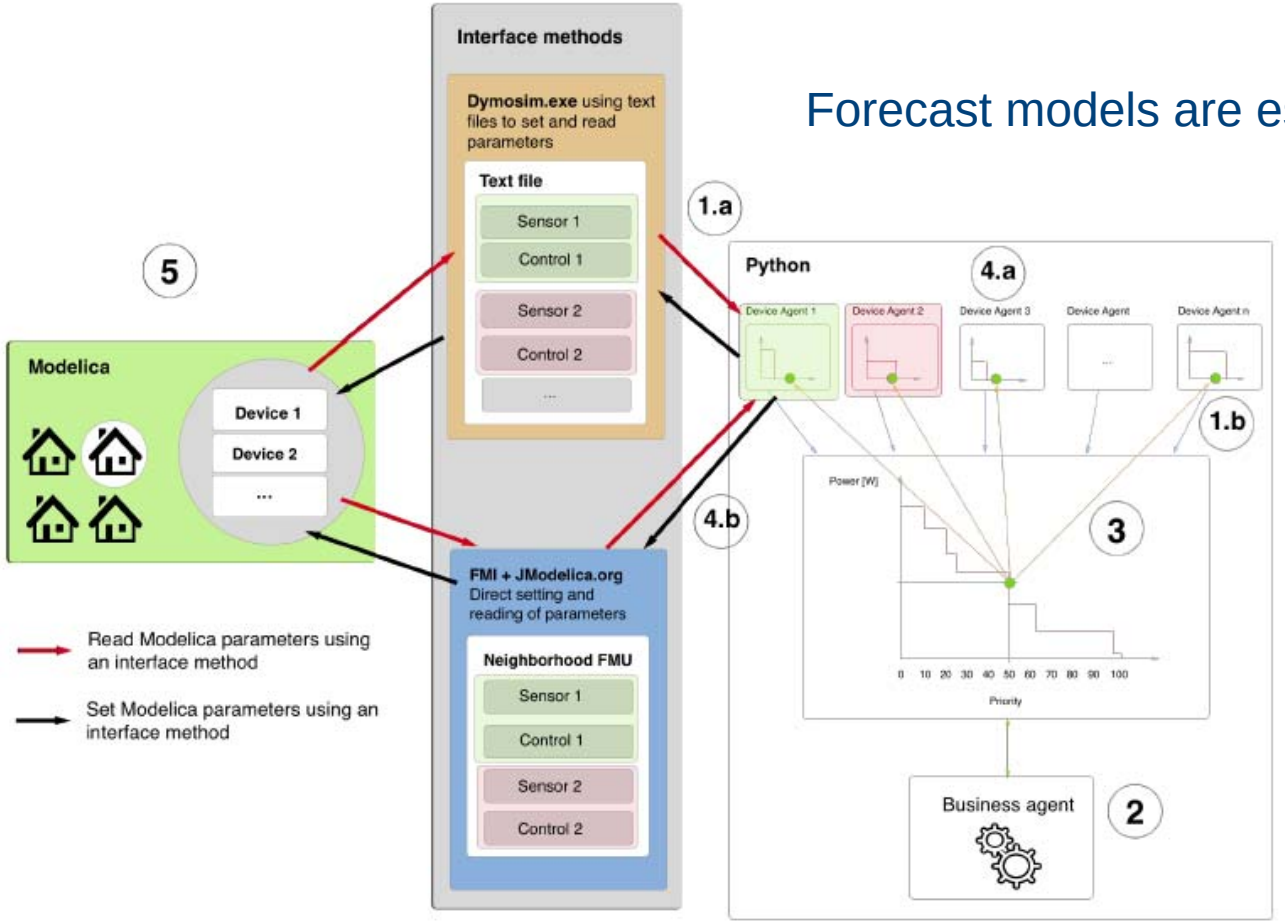
Example
Hierarchical control techniques using co-simulation



Forecast models are essential

Demand side management of the thermal flexibility in a residential neighborhood using a hierarchical market-based multi-agent system. A. Aertgeerts, 2013 (MSc thesis sup. D. Saelens & L. Helsen)

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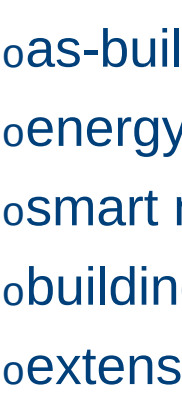
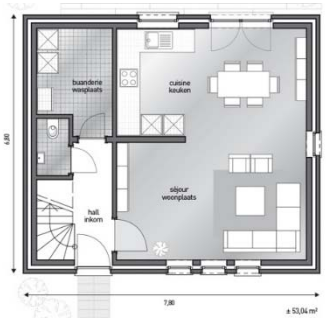
Example
Hierarchical control techniques using co-simulation

- Data for models in controllers to be derived from different kind of sources

  Characterization based on:

  - as-built data
  - energy invoice data
  - smart meter data
  - building automation systems
  - extensive measurement data





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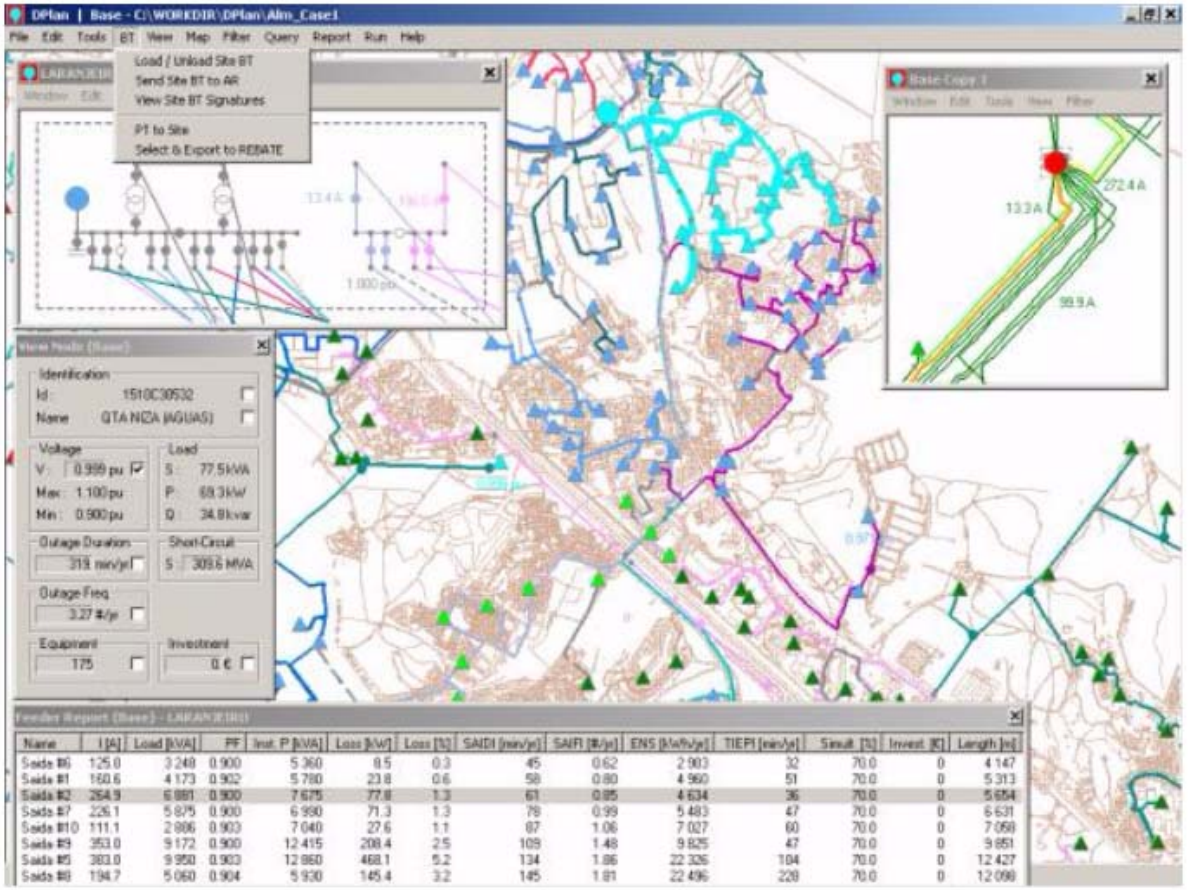
Example
Hierarchical control techniques using co-simulation

- Characterization of whole neighbourhoods + coupling to GIS



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WRAP UP

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Wrap up

Opportunities for characterization in Districts and Neighbourhoods

- District Energy System simulations
  - DES simulation developments are ready to use
  - Reduction of simulation time is possible with reduced order models
- Potential applications
  - Characterization used for identification of renovation opportunities
  - Characterization used for assessment of thermal networks
  - Characterization used as an input for developing models for control applications