State-of-the art District Energy Simulation

prof.dr.ir.-arch. Dirk Saelens
KU Leuven / EnergyVille

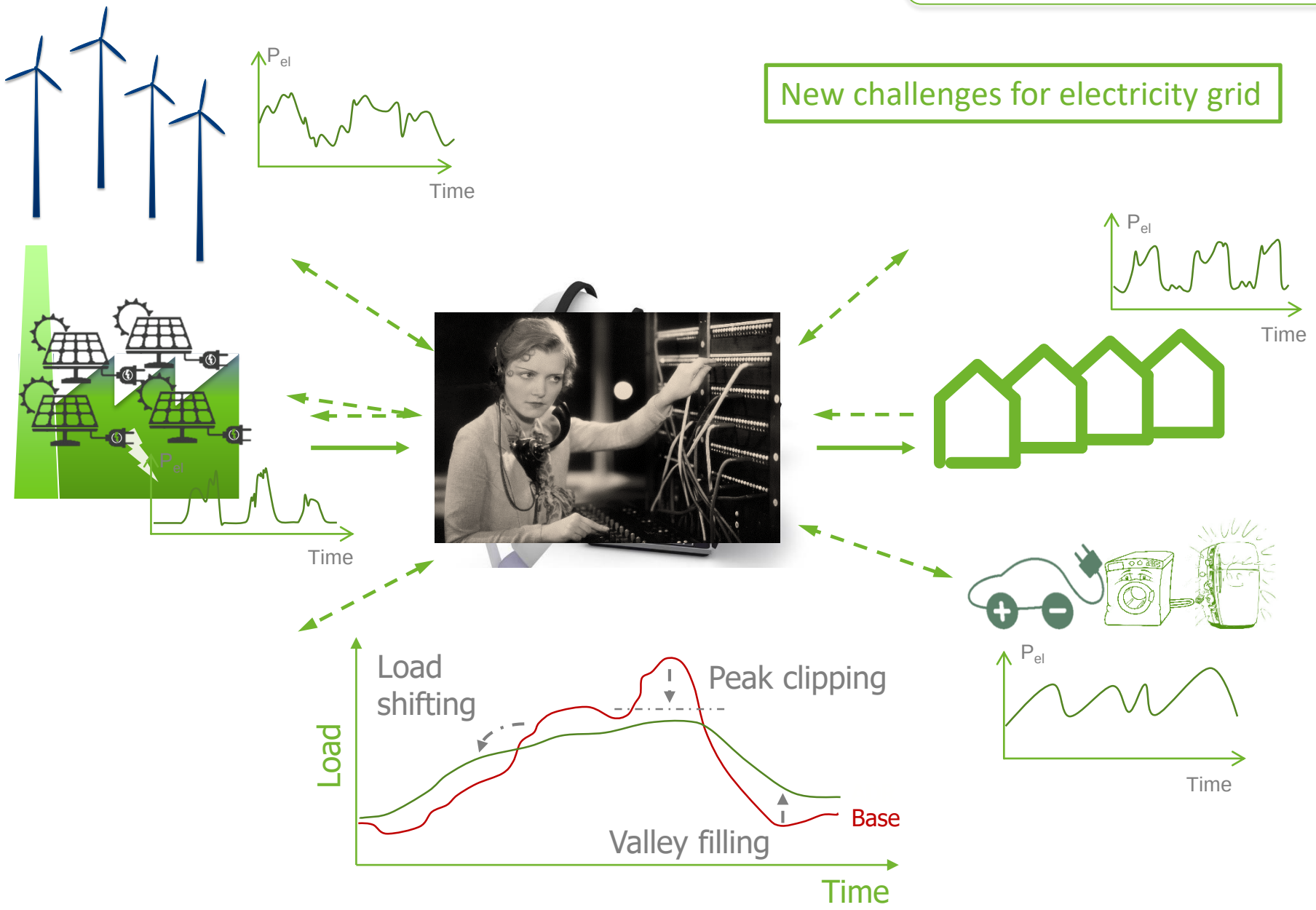
Kwaliteitsborging Simulaties van Gebouwen en Installaties voor Ontwerp en Onderhoud

28 mei 2018

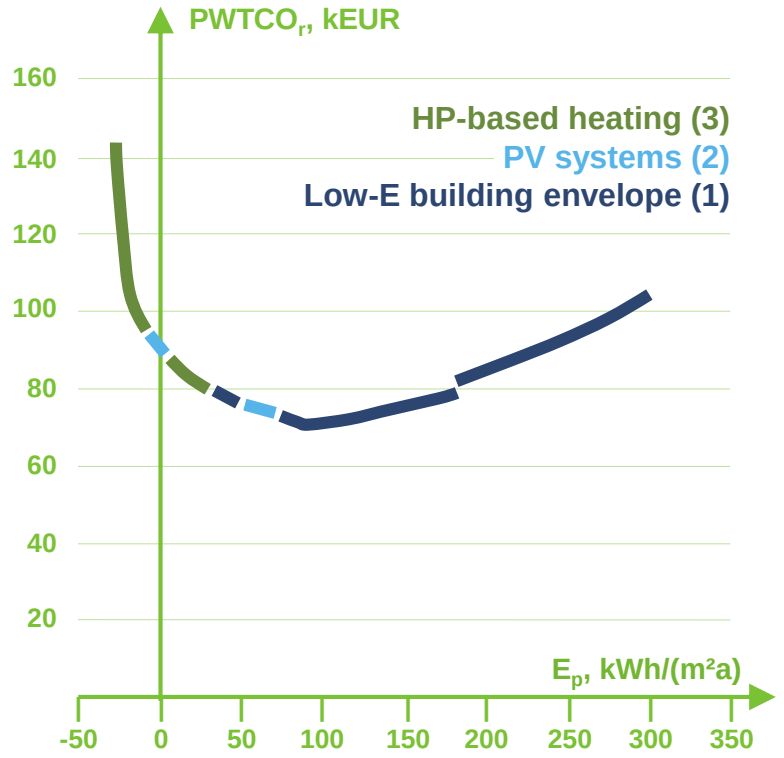
Saxion Hogeschool, Handelskade 75, 7417 DH, Deventer, NL

Introduction

New challenges for electricity grid

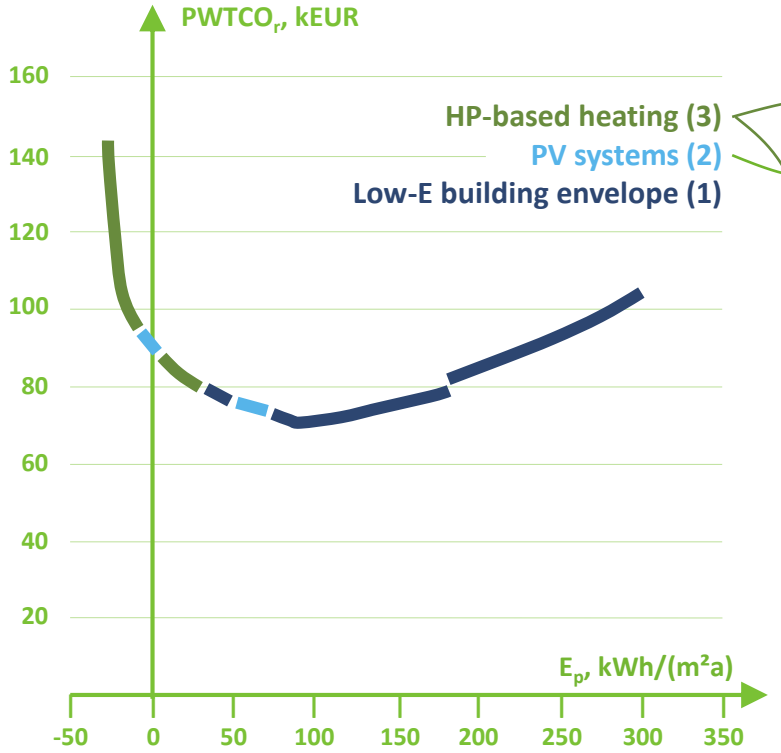


Challenges for buildings?



Source: J. Van der Veken *et al.* (2013). *Studie naar kostenoptimale niveaus van de minimumeisen inzake energieprestaties van gerenoveerde bestaande residentiële gebouwen.*

Challenges for buildings?



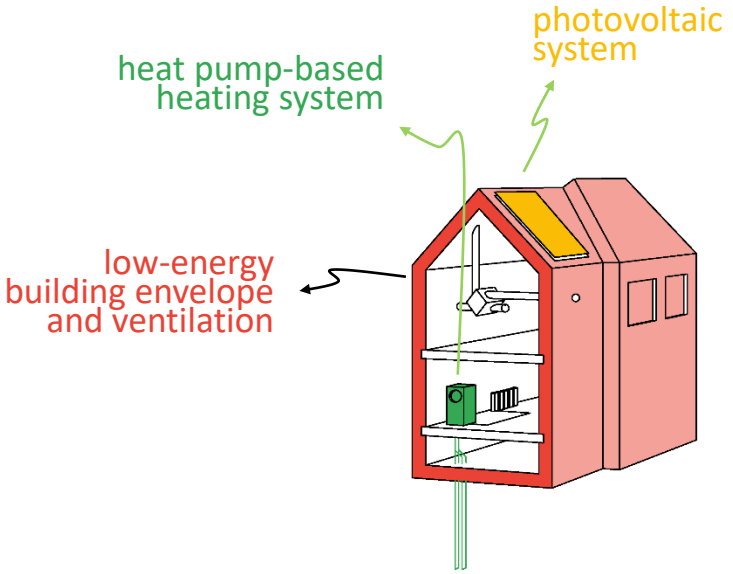
On the one hand,
Extra load for distribution network,
possibly resulting severe voltage drops
or overloading

On the other hand,
High thermal inertia, thus
significant amount of flexible consumption
if heating power can be controlled

Source: J. Van der Veken *et al.* (2013). *Studie naar kostenoptimale niveaus van de minimumeisen inzake energieprestaties van gerenoveerde bestaande residentiële gebouwen.*

From individual assessment …

Overview drawing of the researched context, i.e. residential heat pump-based low-energy dwellings in the low-voltage distribution grid.



From individual assessment …

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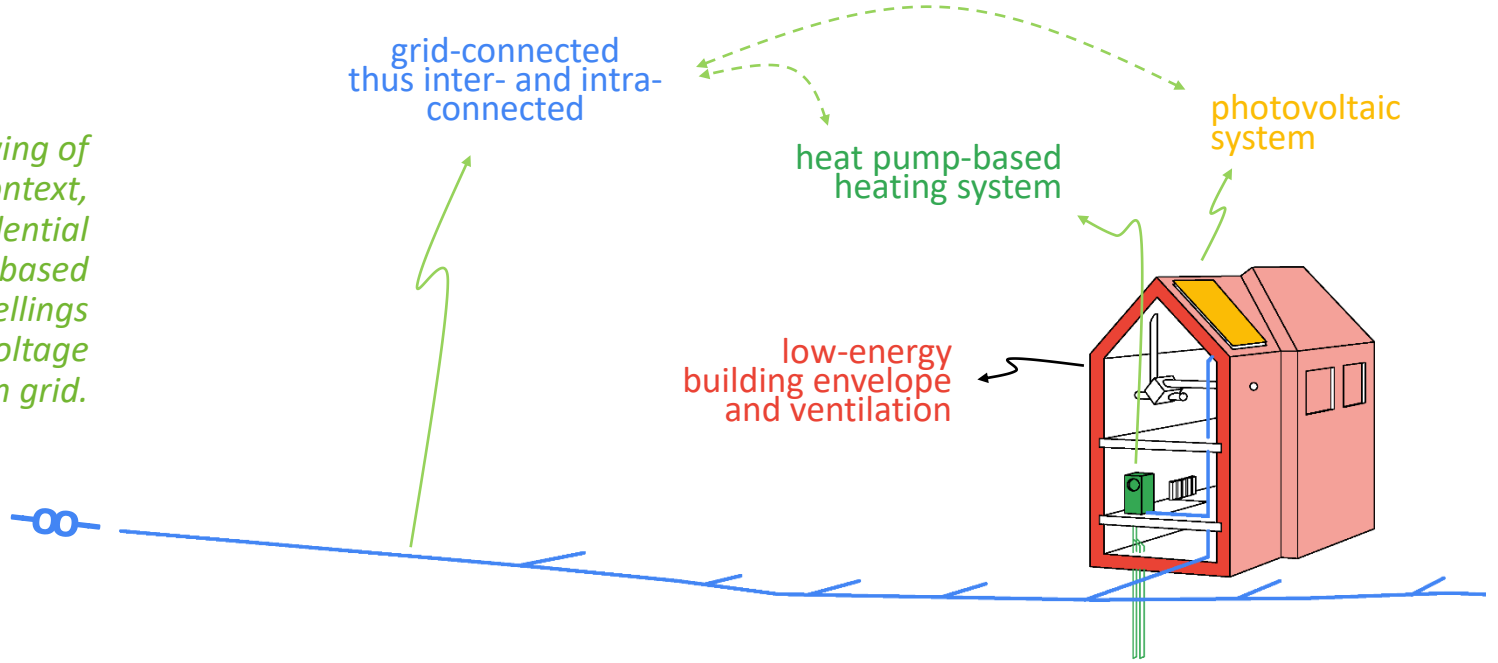
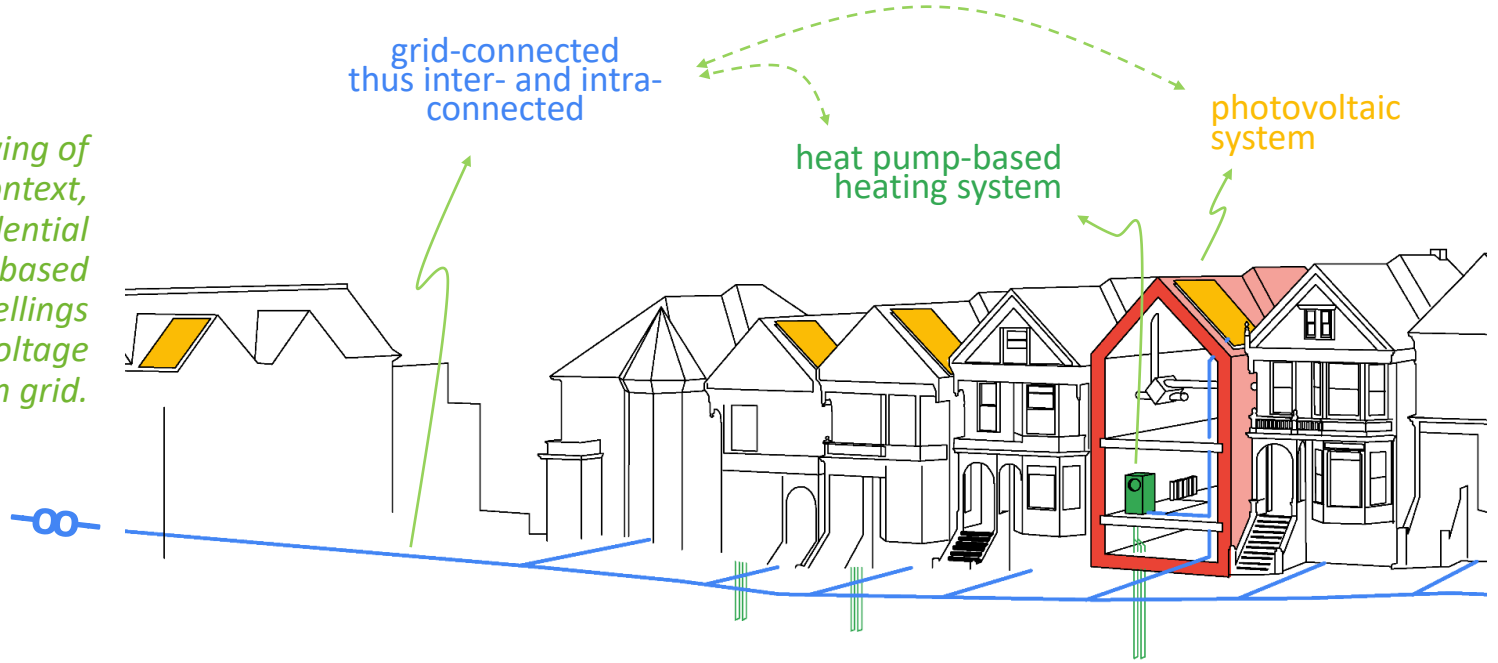


… towards a system approach

Overview drawing of the researched context, i.e. residential heat pump-based low-energy dwellings in the low-voltage distribution grid.



New **challenges** for building simulation

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

On externalities of heat-pump based low-energy dwellings at the low-voltage distribution grid, R. Baetens, 2015

New simulation environments emerge

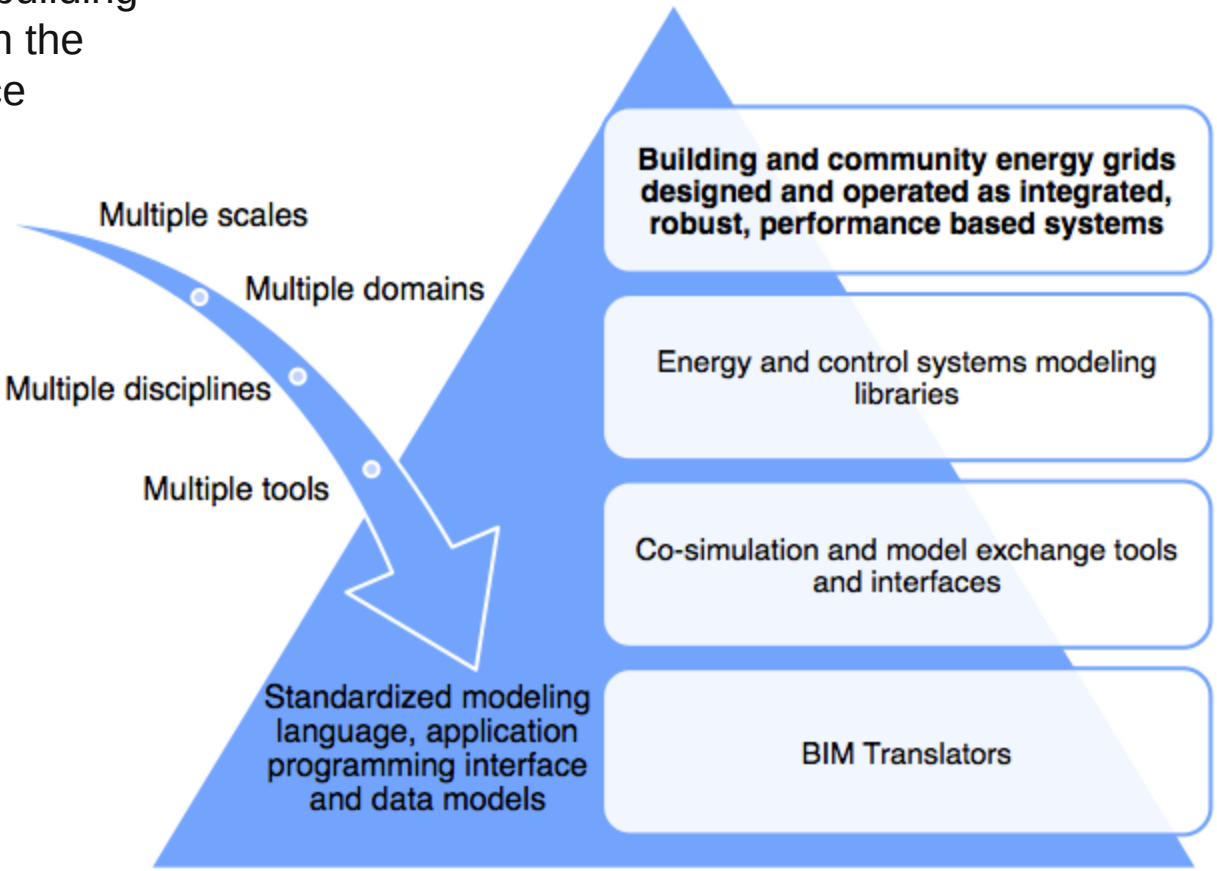
EBC
Energy in Buildings and Communities Programme

IEA EBC Annex 60:
"New generation computational tools for building and community energy systems based on the Modelica and Functional Mockup Interface standards"

BIM/GIS and Modelica Framework for building and community energy system design and operation

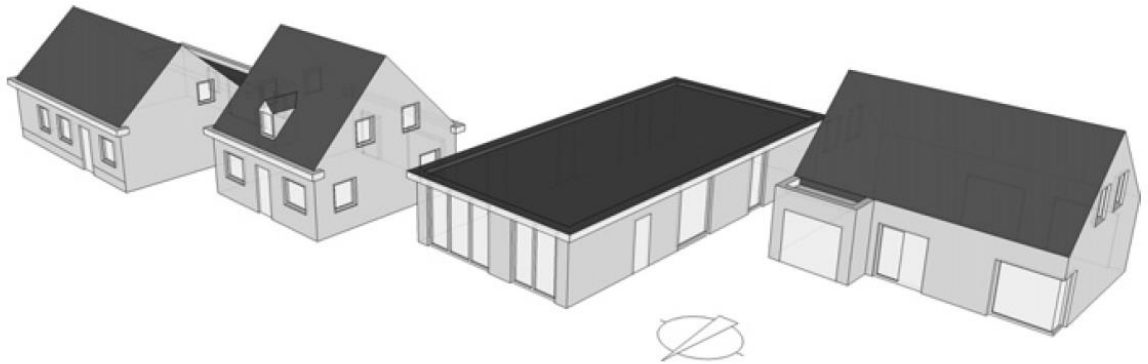
IBPSA Project 1
International Building Performance Simulation Association

IBPSA



Smart grids: assessment of effects of nZEB level

- Modeling of electricity use:
  - Heating with a heat pump
  - Stochastic use of appliances
- ZEB definition:
  total energy use is covered with the production of electricity from roof integrated PV

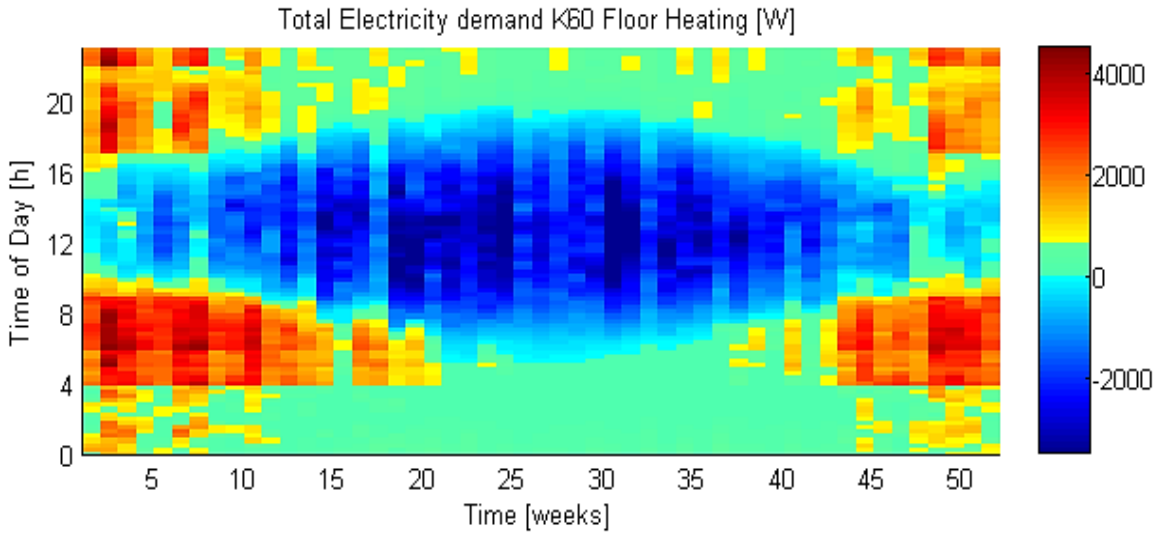


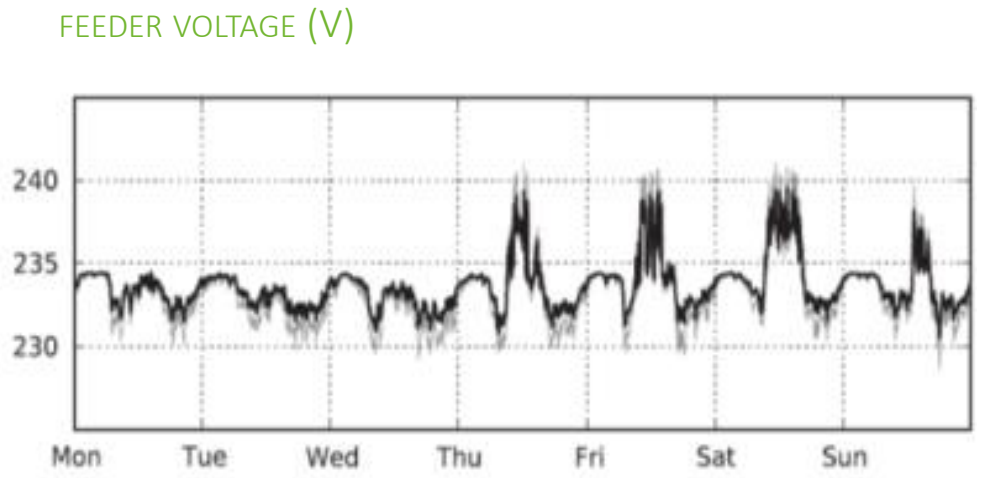
	Typ.1	Typ.2	Typ.3	Typ.4
Heated area, m^2	127	98	149	123
Window-floor ratio	0.12	0.19	0.16	0.13
Compactness, m	1.23	1.10	0.87	1.18
Infiltration rate n, h^{-1}	0.03	0.03	0.03	0.03
U_{av}, W/m^2 K	0.145	0.174	0.159	0.158
HRV efficiency	0.84	0.84	0.84	0.84
Design heat load, W/m^2	20.5	28.0	21.6	25.9

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.

Smart grids: assessment of effects of nZEB level

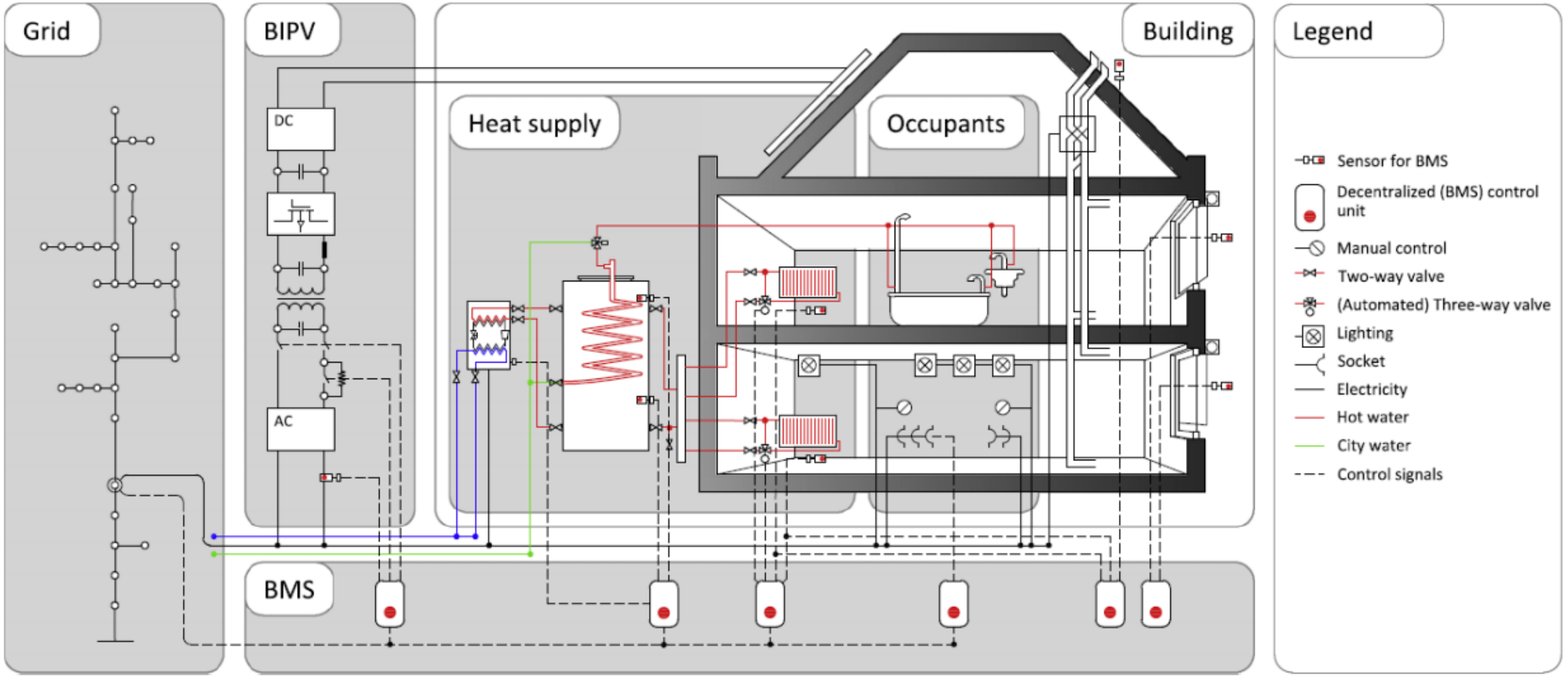
- Modelica environment to assess PV integration in districts
- Solar paradox: mismatch between supply and demand
- Virtual storage in the grid





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

Baetens, R., Saelens, D. (2013). Multi-criteria grid impact evaluation of heat pump and photovoltaic based zero-energy dwellings. Proceedings of Building Simulation 2013. International Conference of the International Buildings Performance Simulation Association. Chambéry, France, 25-28 August 2013



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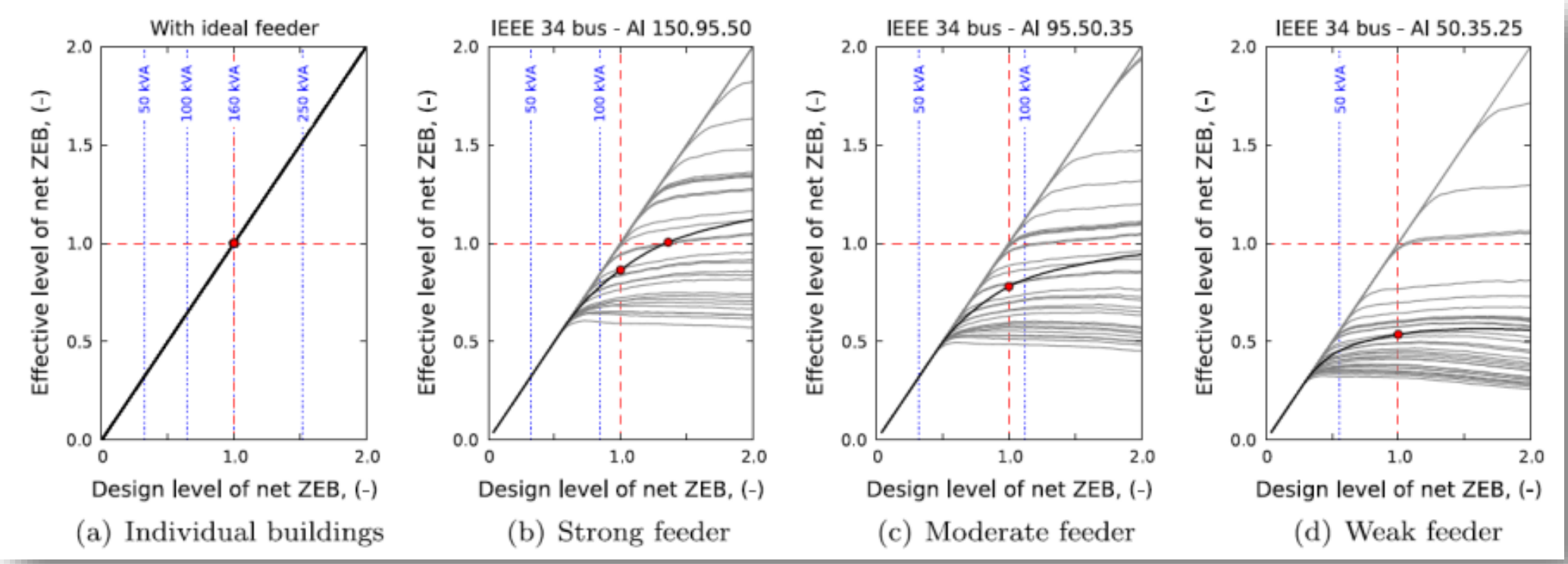
Open-source library: github.com/open-ideas

Smart grids: assessment of effects of nZEB level

- Modelica environment to assess PV integration in districts
- Effective nZEB-level compared against design ZEB level on individual building level (grey) and aggregated neighborhood level (black).



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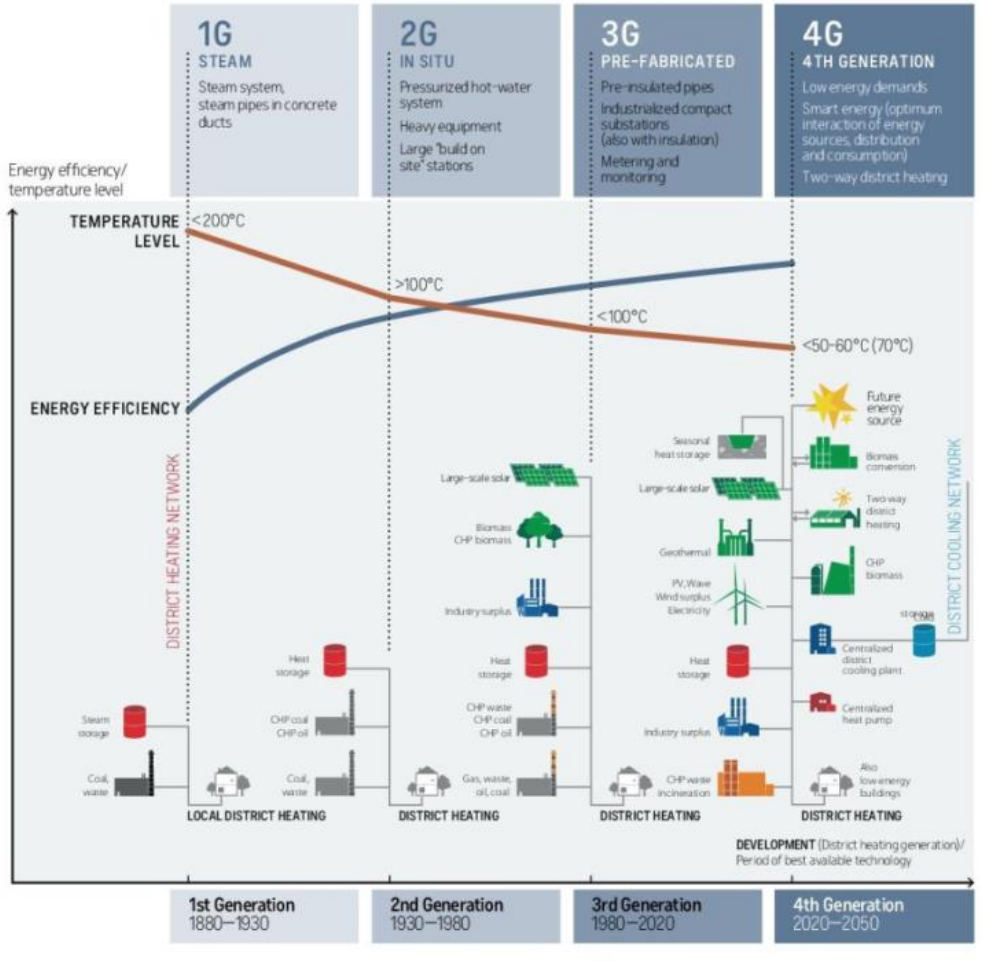
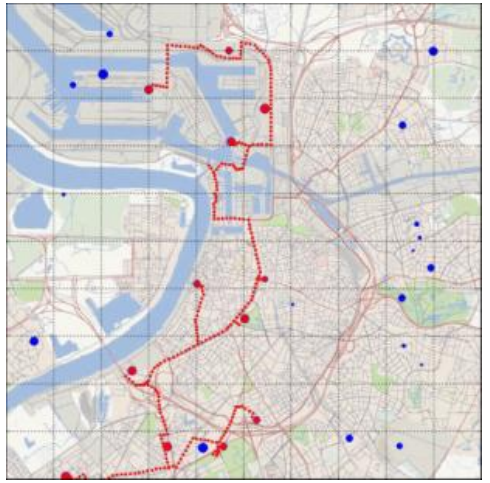
Thermal connections: district heating and cooling networks





E.g. Optimal trajectory definition

Defines the ideal heat net cluster for a set of potential heat consumers and producers

Henrik Lund, Sven Werner, Robin Wiltshire, Svend Svendsen, Jan Eric Thorsen, Frede Hvelplund, Brian Vad Mathiesen, 4th Generation District Heating (4GDH): Integrating smart thermal grids into future sustainable energy systems, In Energy, Volume 68, 2014, Pages 1-11,

EFRO-SALK GeoWatt Project

“Towards a Sustainable Energy Supply in Cities”

Research topics related to DHC

- Building models
- Optimal design
- Thermal network control
- Flexibility
- Geothermal energy
- Fault detection

Common case

- City of Genk (B)

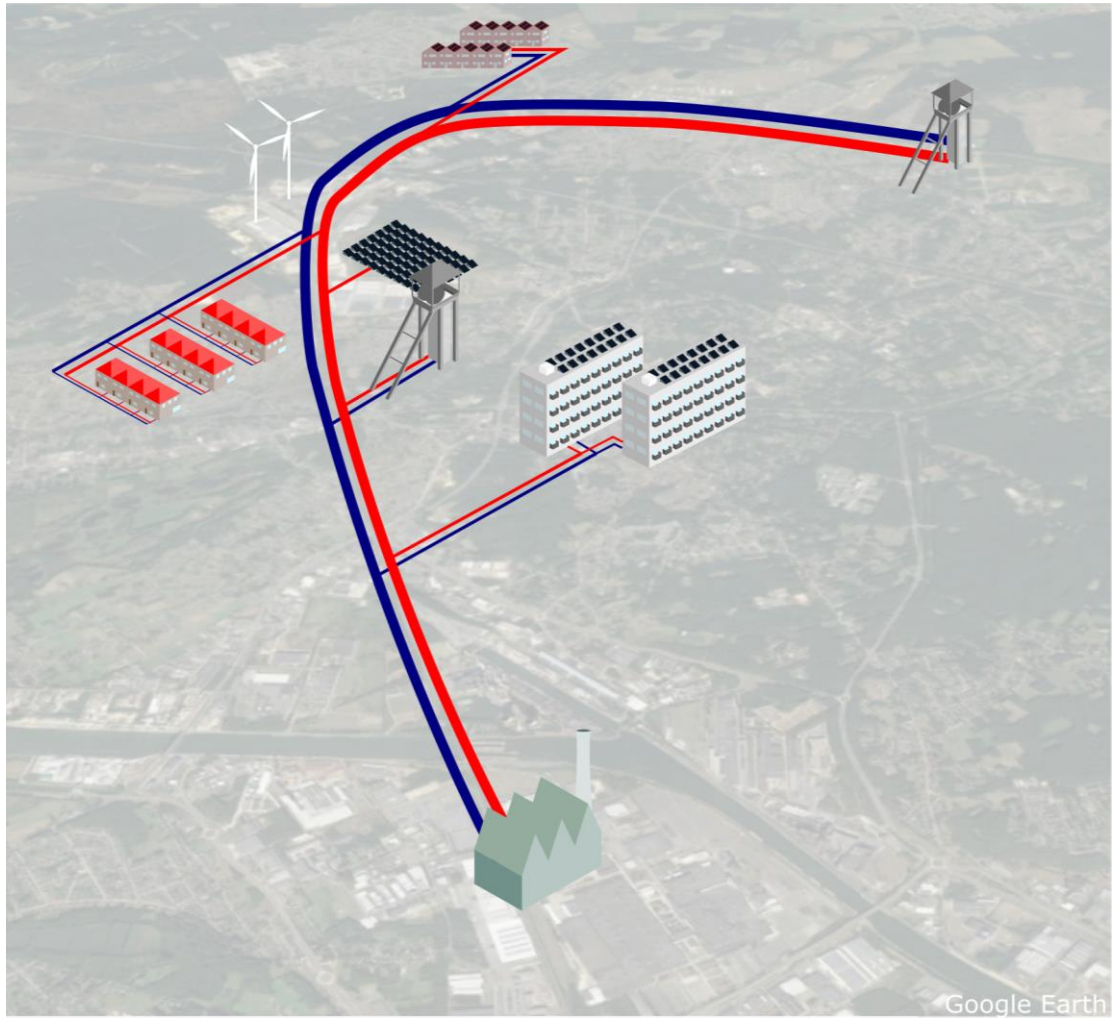
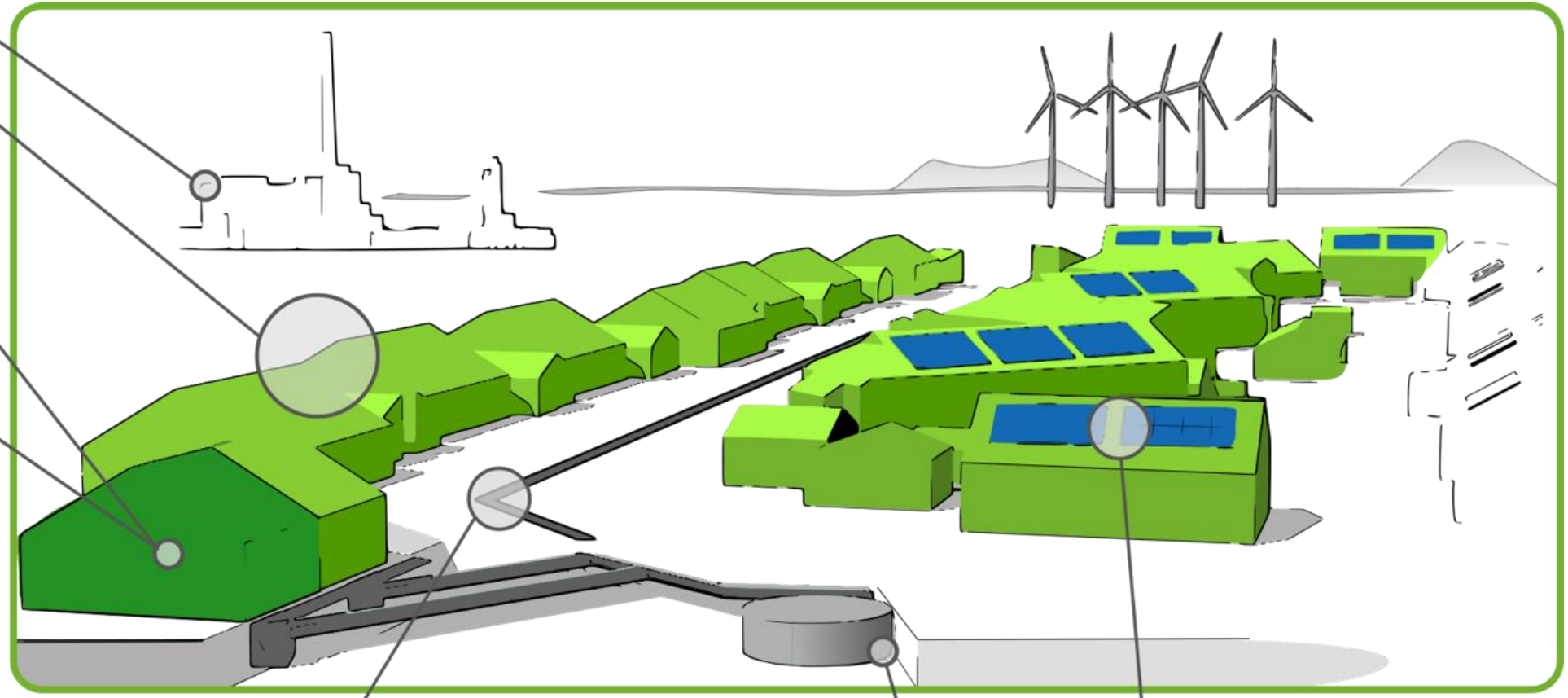


Illustration by Annelies Vandermeulen (KUL / EnergyVille)

District Energy System assessment



Geothermal exploration

Geo. Information (GIS)
Building Information (BIM)
Data enrichment
TEASER, AFC2Modelica

Stochastic occupancy
StROBe

Dynamic simulation
IDEAS
IDEAS2FMI
Modelica-IBPSA

Metamodel
Python

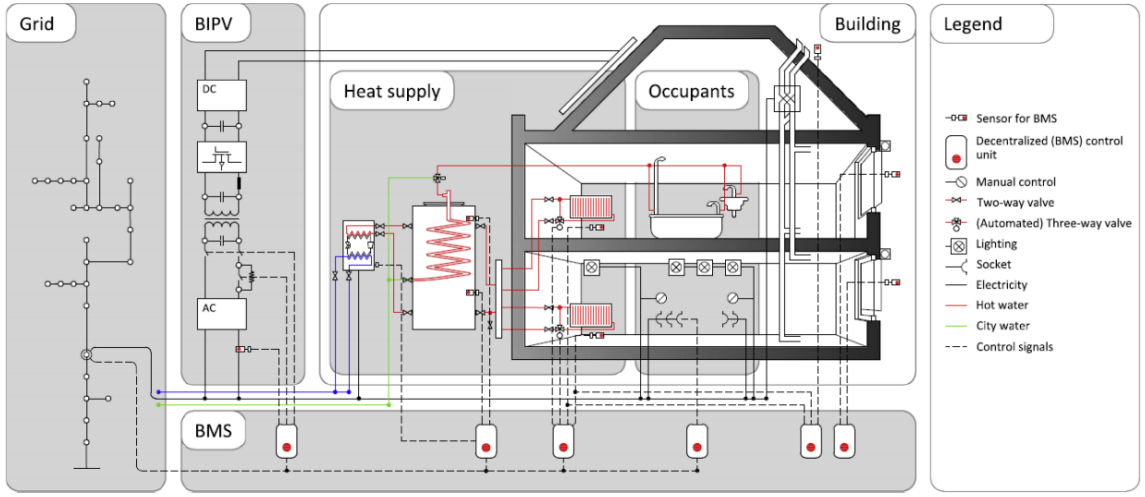
Network routing
Modesto
Modelicax

Storage optimisation
Modesto

Building Integrated Photovoltaics (BIPV)
IDEAS

Model to assess DES

Integrated
District
Energy
Assessment
Simulation



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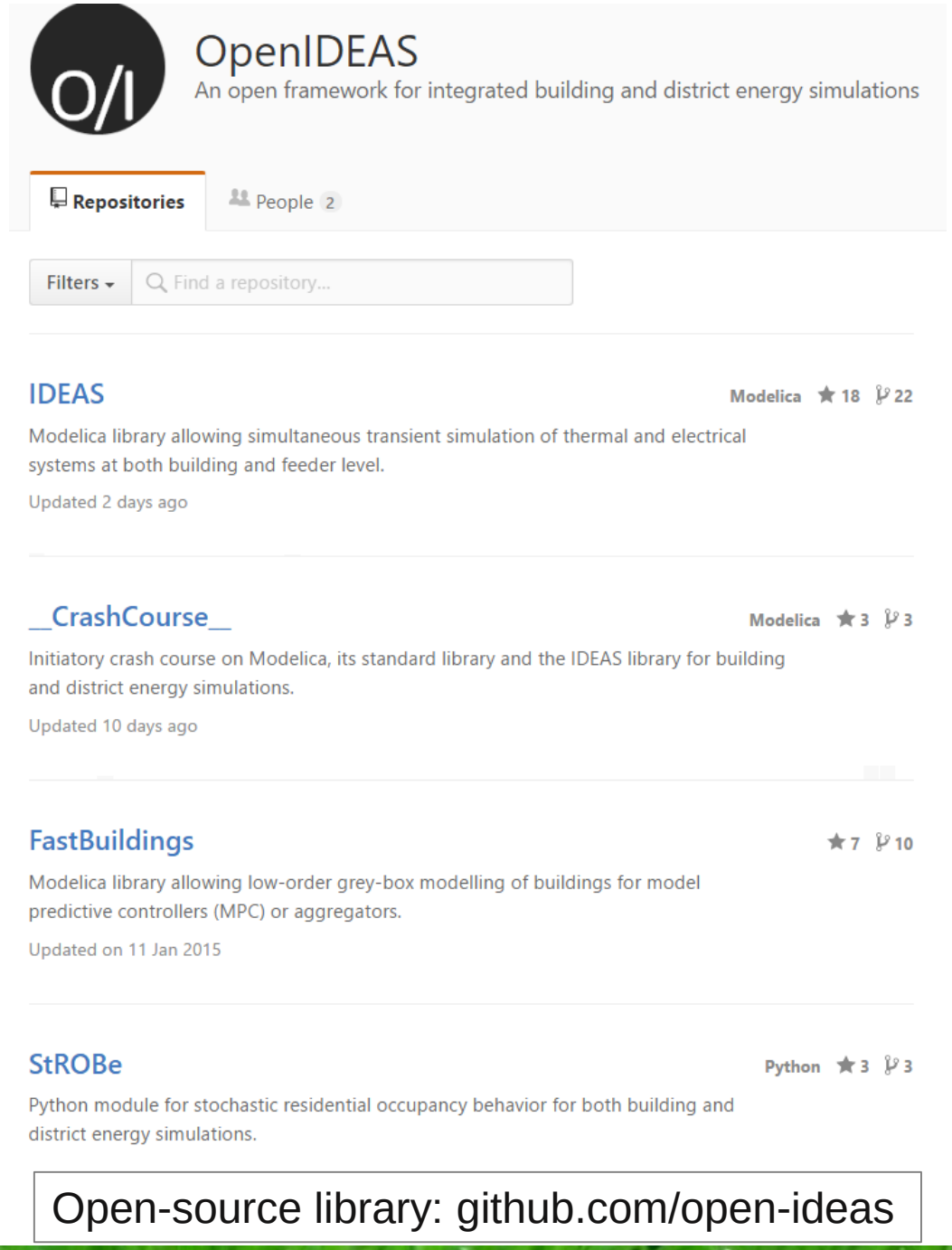


Open-source library: github.com/open-ideas

IDEAS.mo – Integrated District Energy Assessment Simulation

Buildings.mo	Thermal.mo	Electric.mo	Occupants.mo
Components Window.mo Zone.mo SlabOnground.mo OuterWall.mo … GreyboxModels TiTeThTsAe.mo … Data Validation BESTEST.mo Examples	Components Production Boiler.mo HP_AirWater.mo … Emission Storage Distribution DHW Ventilation GroundTubes Control HeatingSys VentilationSys Data Validation Examples	Distribution Grid.mo Components Examples Photovoltaic PvSystem.mo Components Examples Battery ElectricVehicle.mo Connections Data Validation Examples	Components Fanger.mo Standards ISO13790.mo Extern SingleZone.mo MultiZone.mo Examples StROBe.py

Open-source library: github.com/open-ideas

Buildings as an input for DES assessment

- Automation of the workflow is crucial! BIM2SIM

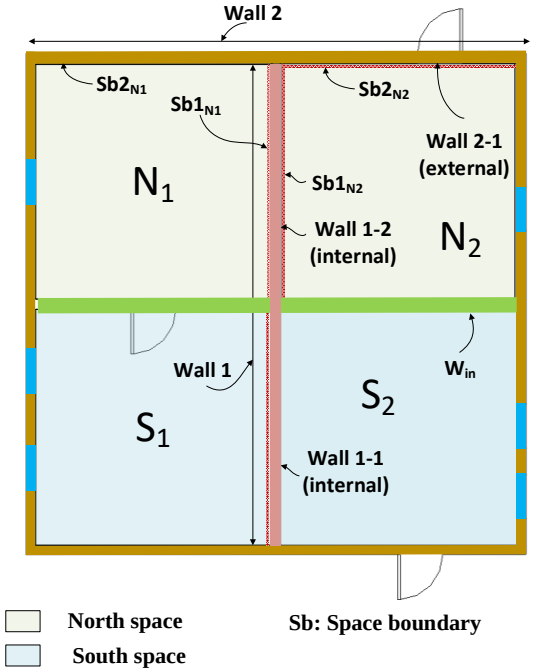
BIM software and formats

MODELICA

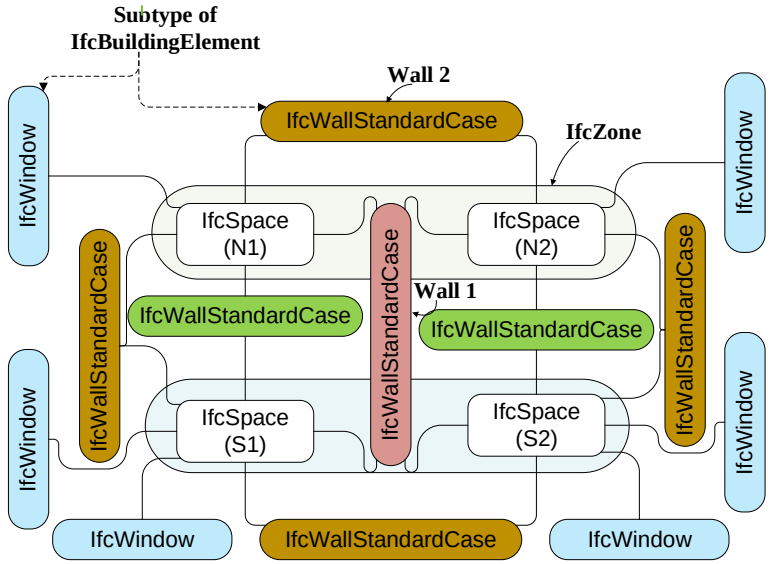
IES

EnergyPlus

Building energy simulation tools



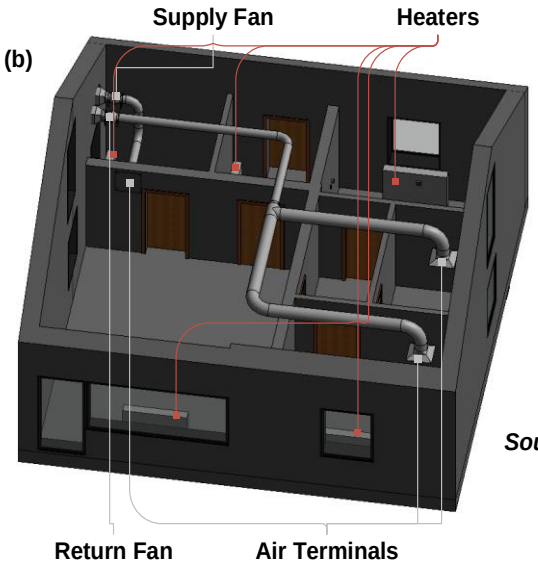
Four spaces, two zones example case

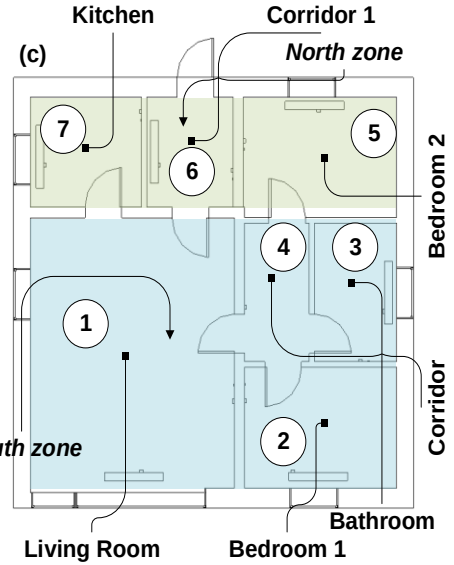


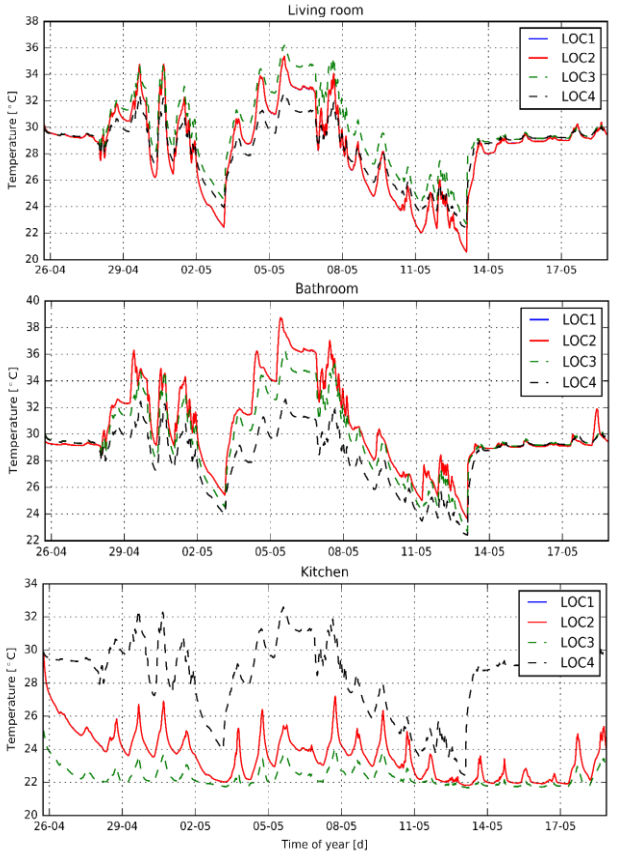
IFC structure of the example model

Buildings as an input for DES assessment

Automation of the workflow is crucial! BIM2SIM



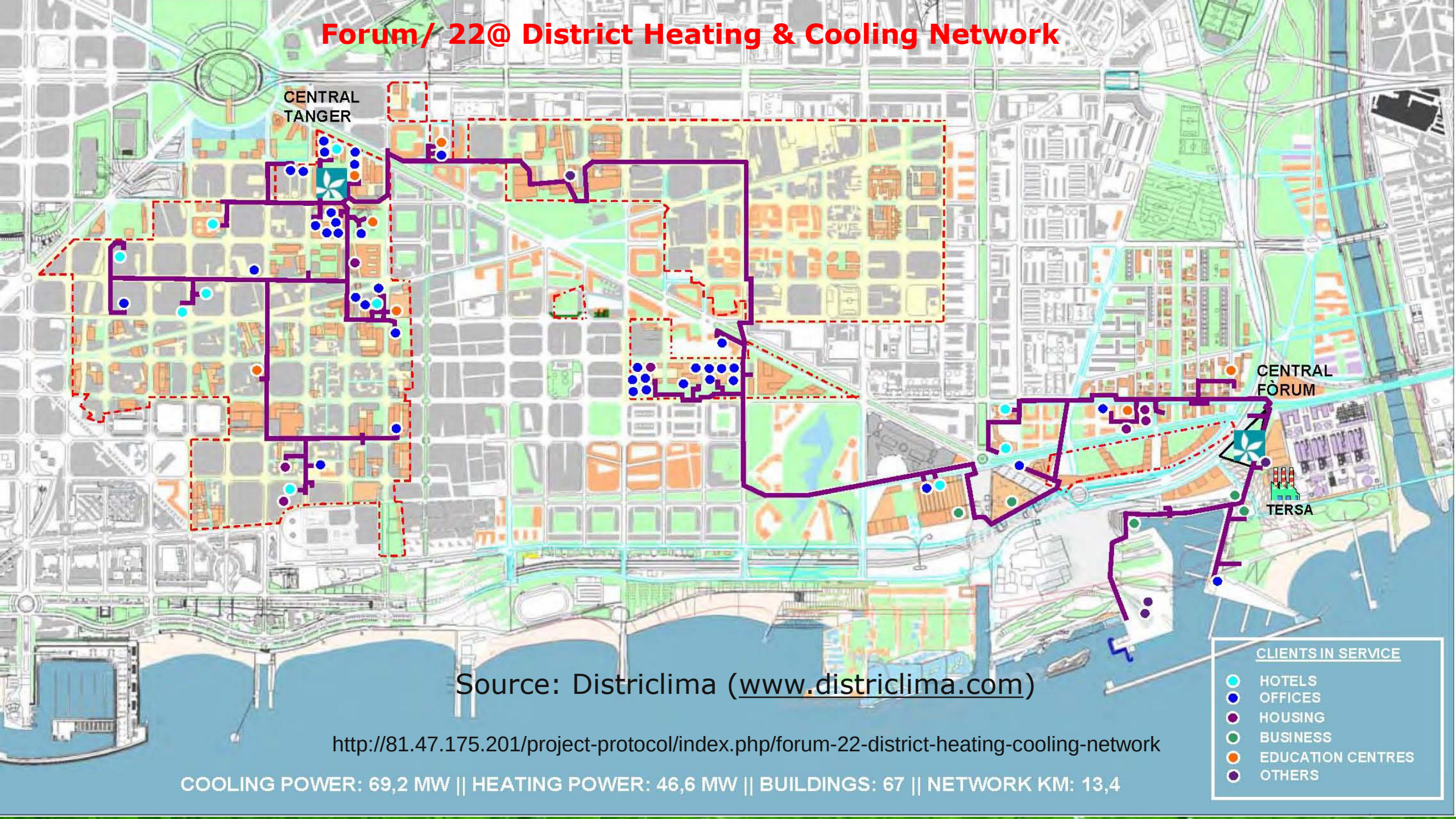




Andriamamonjy R., Saelens D., Klein R. (2018). An automated IFC-based workflow for building energy performance simulation with Modelica. *Automation in Construction, 91*, 166-181.

Reynders G., Andriamamonjy R., Klein R., Saelens D. (2017). Towards an IFC-Modelica Tool Facilitating Model Complexity Selection for Building Energy Simulation. 15th International conference of the international building physics association: Building Simulation 2017. Building Simulation. California, USA, 7-9 August 2017 (art.nr. 2621).

Forum/ 22@ District Heating & Cooling Network



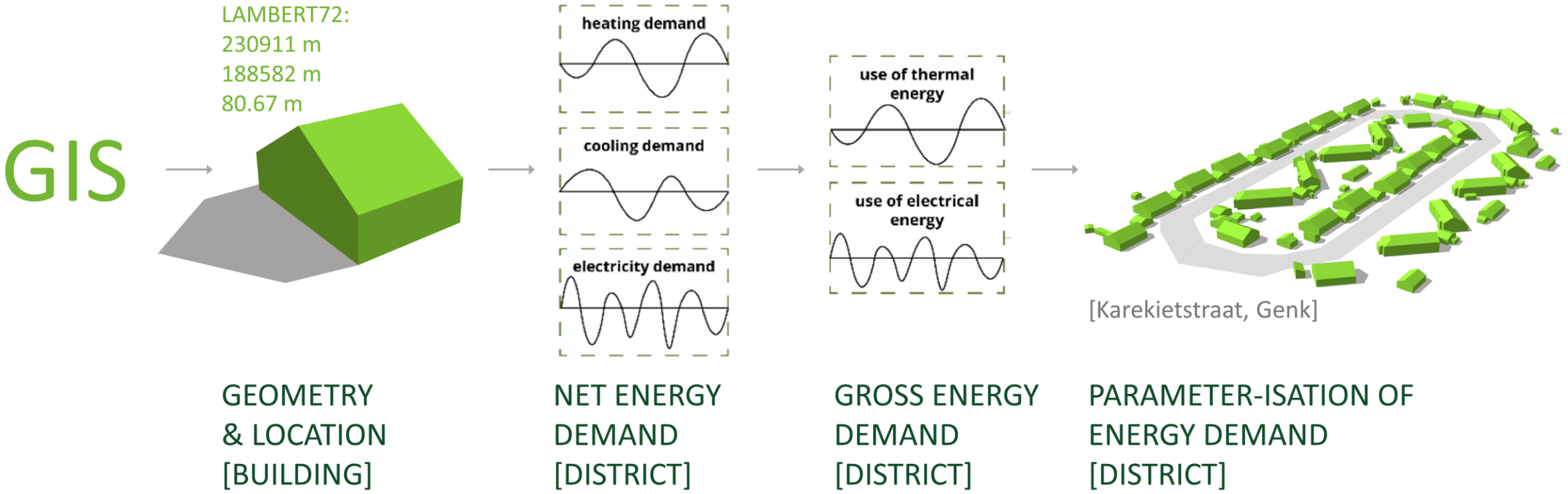
Source: Districlima (www.districlima.com)

http://81.47.175.201/project-protocol/index.php/forum-22-district-heating-cooling-network

COOLING POWER: 69,2 MW || HEATING POWER: 46,6 MW || BUILDINGS: 67 || NETWORK KM: 13,4

Buildings as an input for DES assessment

- Automation of the workflow is crucial! From building to city level: GIS



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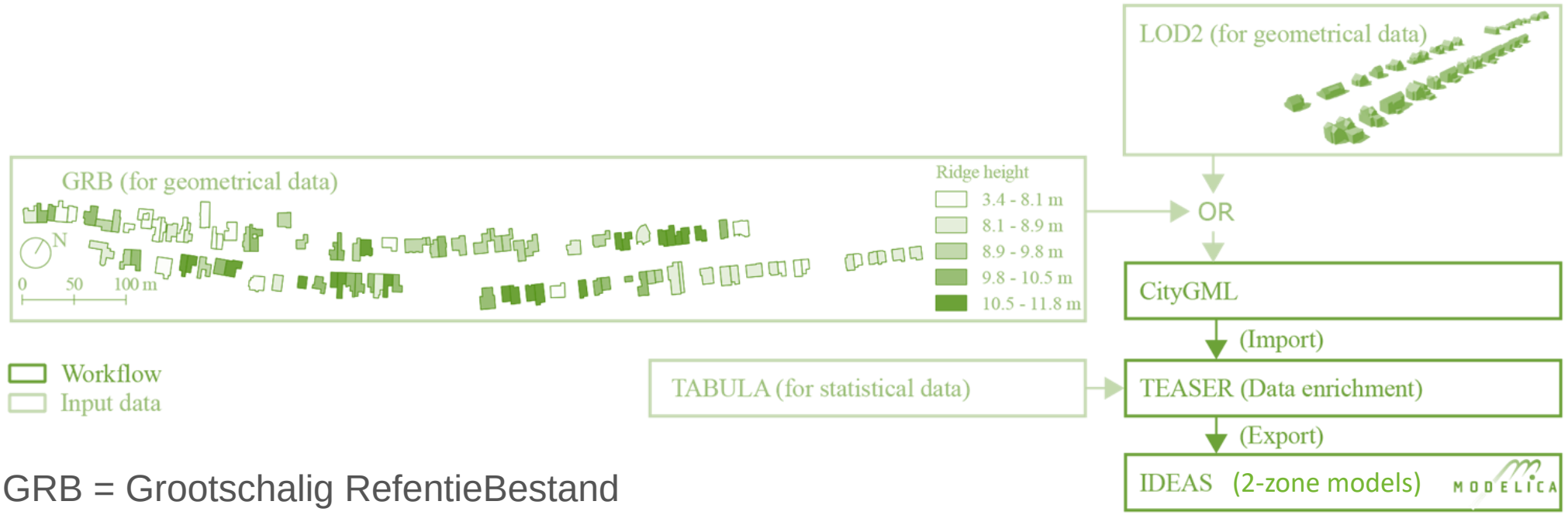
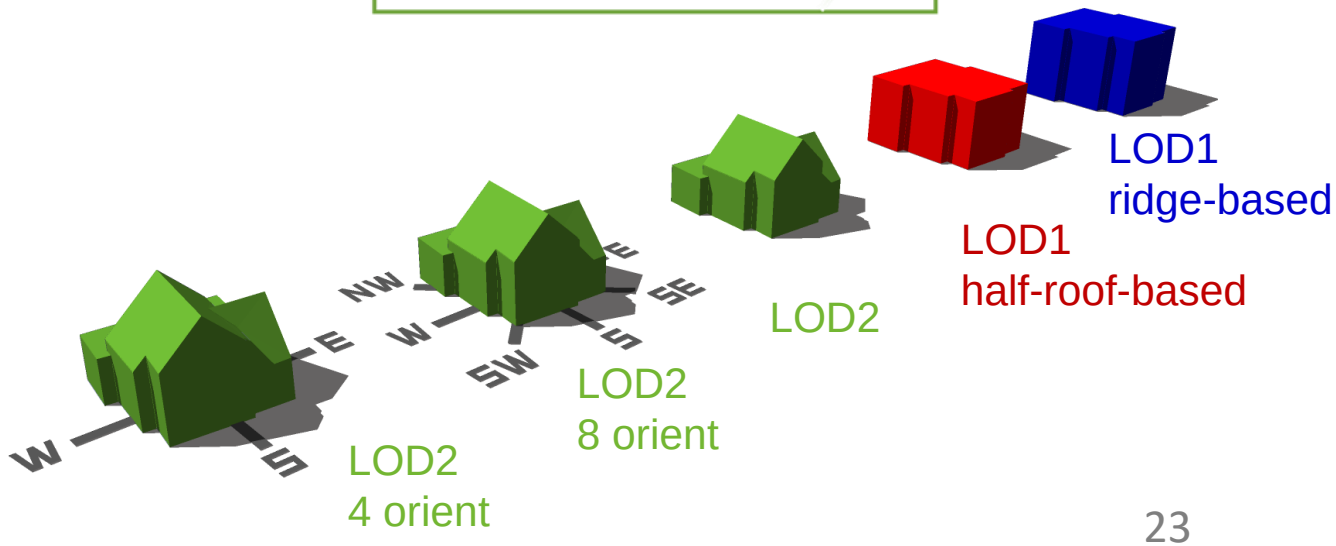
Describing the building stock



GRB = Grootschalig RefentieBestand

Topographic Reference for Flanders



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Describing the building stock

City of Genk

Wrap up – District Energy Simulations

- The assessment of future energy requirements need new simulation tools
  - An integrated approach covering different disciplines and scales is essential
  - Within different fields and international research programs new simulation environments and tools are being developed
  - These cover both electrical and thermal energy
  - Energy performance regulations to be revisited?
- Tools need many data: automated workflows to define the necessary input data and boundary condition have to be developed using standards such as BIM and GIS
- Challenge: How to evaluate and validate these developments?

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