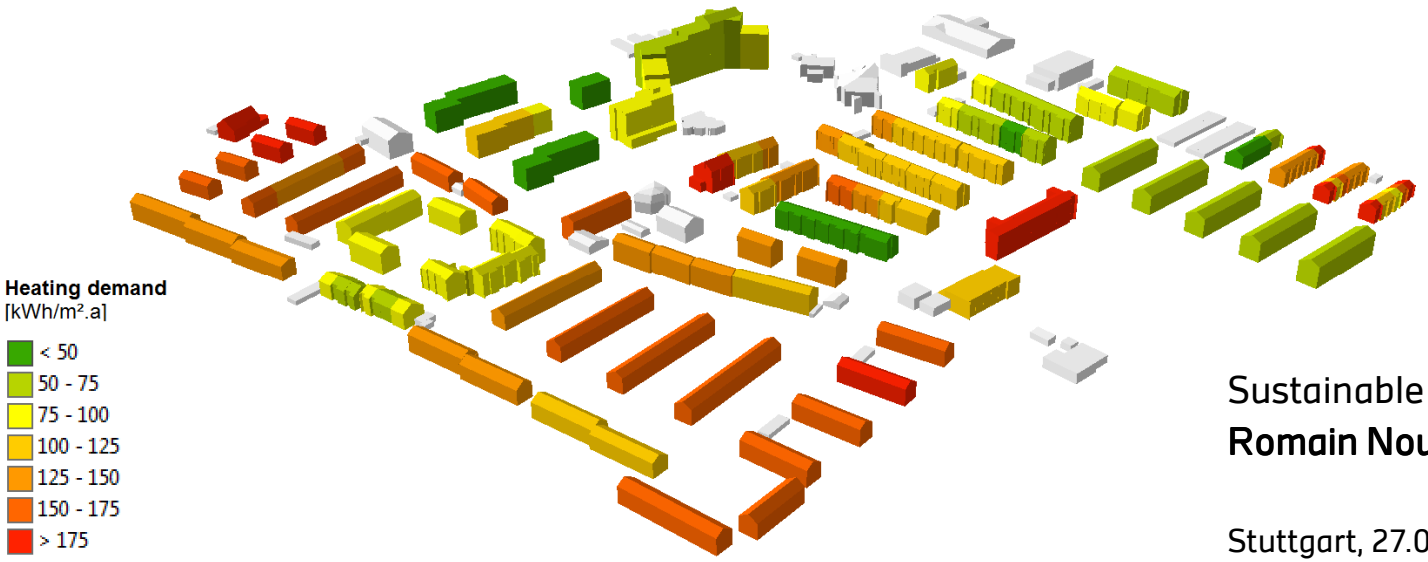
urban energy simulation models



Sustainable Energy Technics
Romain Nouvel, M. Sc.

Stuttgart, 27.05.2014

Purposes of urban energy simulation

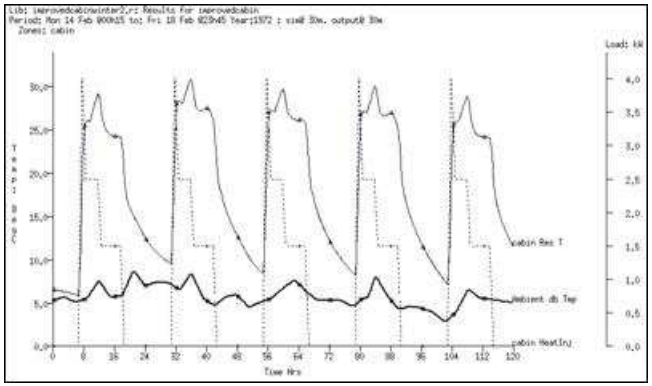
- Energy diagnosis of city building stocks
  - ➢ Evaluate building performance / energy standards
  - ➢ Define refurbishment priorities

Grünbühl - Ludwigsburg

- Understand energy consumptions / detect abnormalities and wastes
  - ➢ Compare simulated results with actual consumptions

- Size individual/centralised HVAC systems and energy infrastructures
  - ➢ Investigate load curves and peak loads

- Find solutions to soften the peak loads
  - ➢ Smart grids/cities, storage solutions…

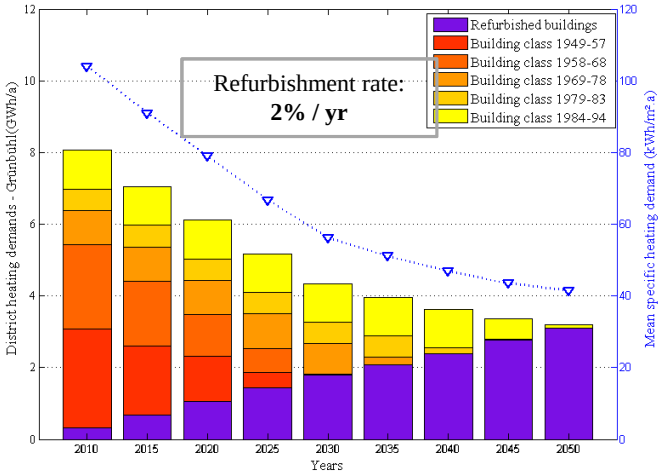


Purposes of urban energy simulation (2)

- Optimize/rank new urban planning projects
  - ➢ Integrate new buildings in building urban environment
  - ➢ Solar planning

Solar atlas, City Berlin

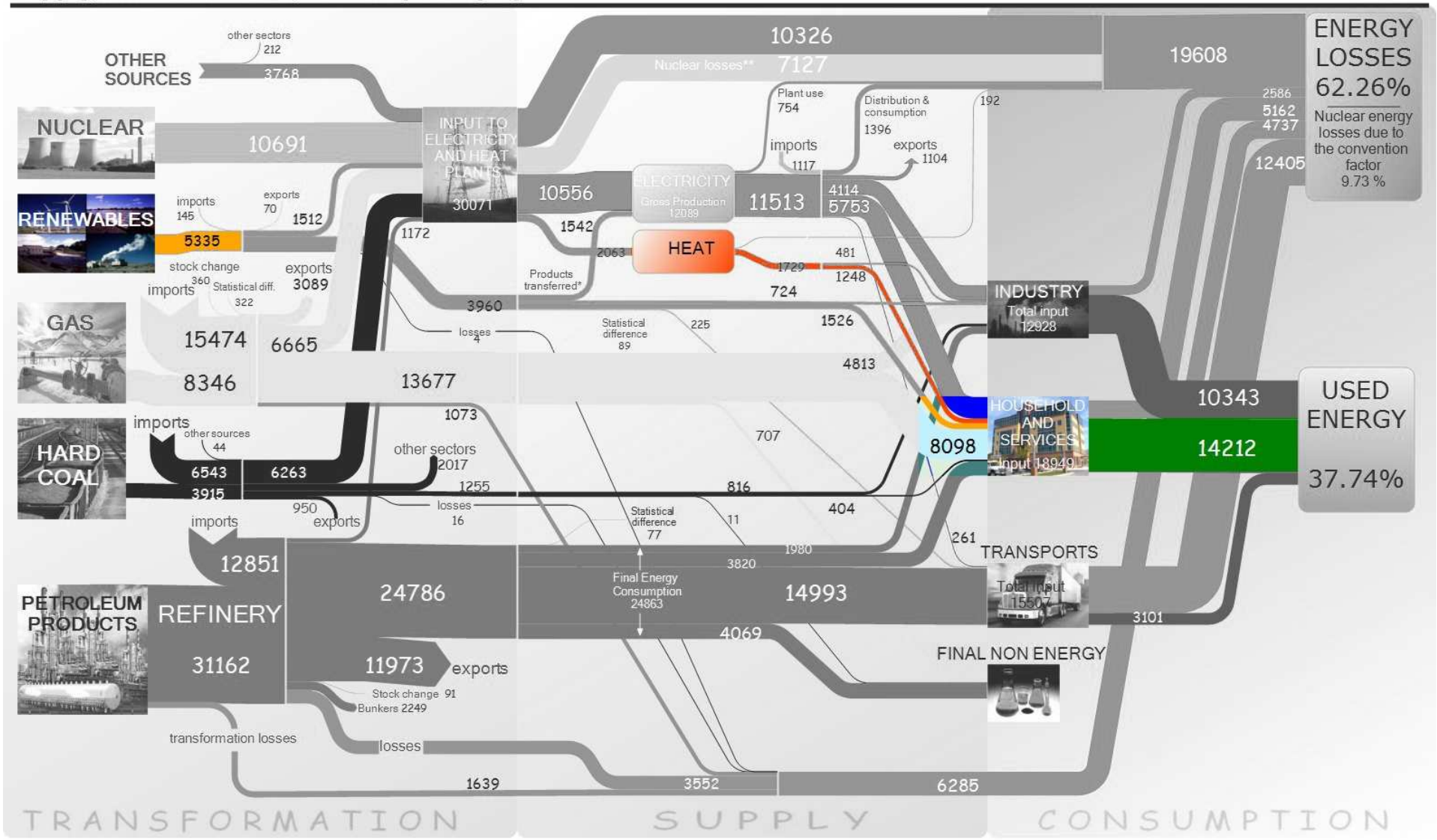
- Plan long-term low-carbon scenarios
  - ➢ Assess renewables and refurbishment potentials
  - ➢ Multi-criteria decision support



Time resolutions / purposes

Time resolutions	Purposes
Year	• Energy diagnosis of city building stocks • Optimize/rank new urban planning projects • Plan long-term low-carbon scenarios
Season / Month	• Understand energy consumptions / detect abnormalities and wastes
Hour	• Find solutions to soften the peak loads
Design winter / summer days	• Size individual/centralised HVAC systems

EU-27 streamlined energy flow trends - 2006
Supply, transformation, consumption (PJ)



* It refers to electricity produced from Hydro, Wind and Photovoltaic Power which is directly counted as gross electricity production. It has been added also the gross electricity generation from pumped storage plants.

** Losses occurred due to the convention factor for nuclear power. These are not properly losses.

LEGEND

Petroleum products | Hard coal | Natural Gas and Derivates (GAS) | Renewable energies (hydro, biomass, wind,PV, wood, wastes) | Nuclear | Electricity | Heat | Lignite & peat | Useful Energy | Losses

Energy Flows

Energy Demand

- Space Heating / Cooling
- Domestic Hot Water
- ~~Heat / cool process (industry)~~
- Ventilation
- Electricity for lighting
- Other electrical devices

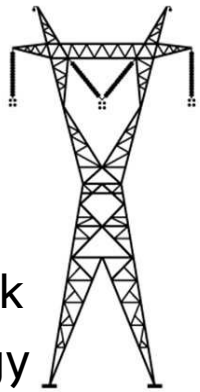
Building Energy

Energy Production

- Heat and cool
- Electricity
- Combined Heat and Electricity (CHP)

Energy Supply

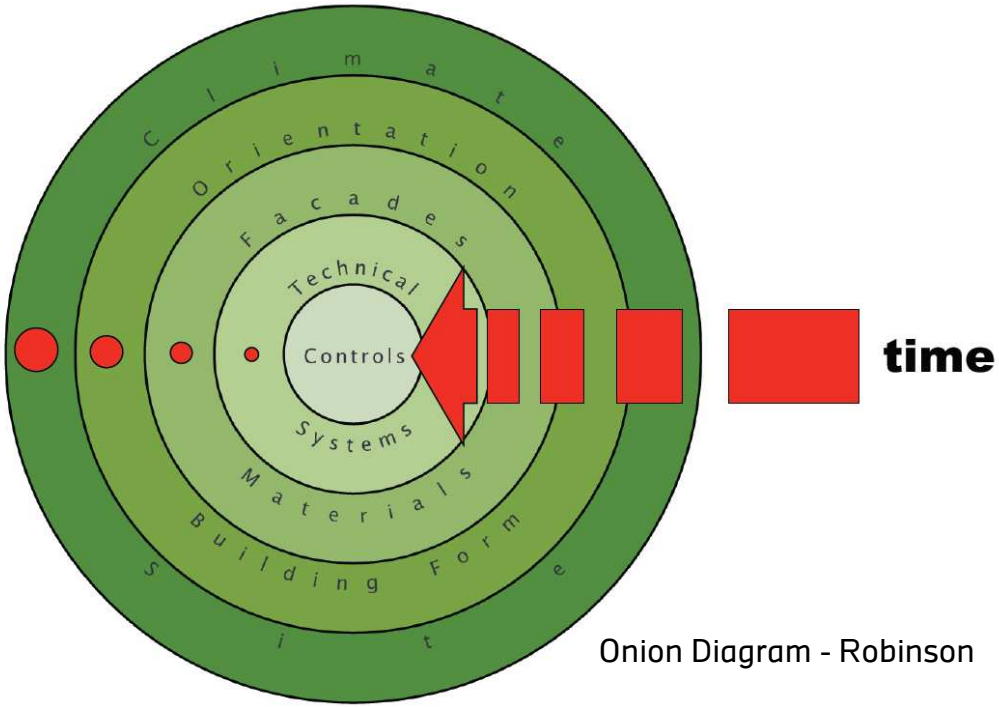
- Electricity network
- Fossil fuels
- District Heating Network
- Renewables/Free energy



Layers of Building Energy

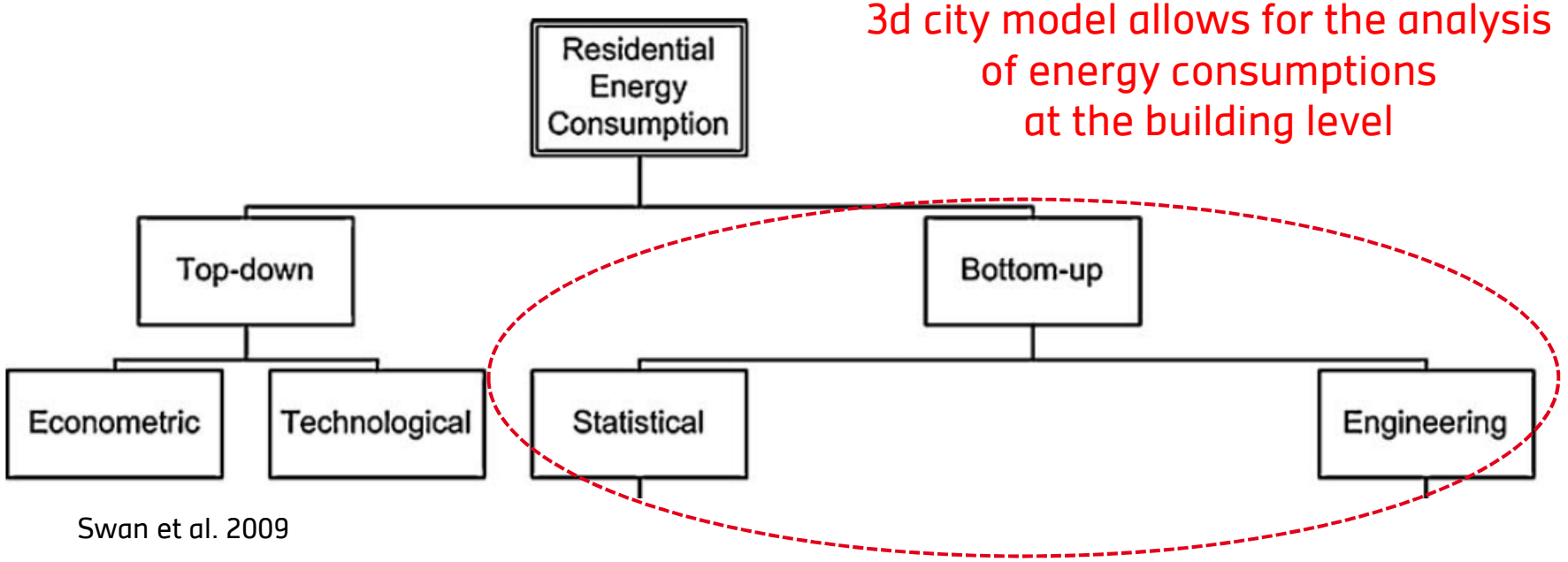
- Climates / Microclimates
- Building Form/Orientation
- Building physics
- HVAC systems
  - Individual systems inside building
  - urban energy infrastructures
- HVAC Controls
- Building usages and occupant profiles/behaviours

+ Economics? (Financial, O&M, and energy costs)



Onion Diagram - Robinson

Urban Energy Consumption – Modelling techniques



3d city model allows for the analysis of energy consumptions at the building level

Swan et al. 2009

Based on historical consumption data

Based on physical models

Urban Energy Consumption – Modelling techniques

DHW demand

Electricity demand

Statistical techniques :

+ capable to encompass occupant behaviour

+ include macroeconomic and socioeconomic effects in consumption equation

- require historic consumption data

- difficulty to simulate impact of new technologies

Engineering techniques:

+ don't require historic consumption data

+ may simulate new system/refurbishment technologies

- require many geometrical and parametric input building data

- Difficulty to encompass occupant behaviour

Heating/Cooling demand

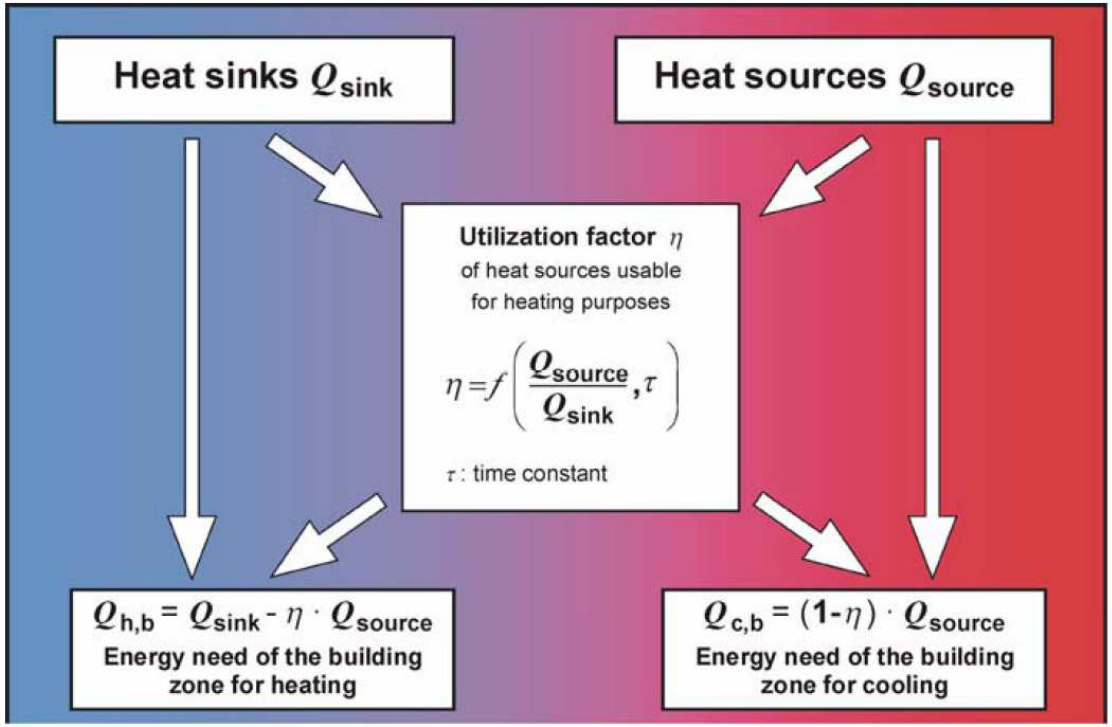
Electricity for lighting

Thermal building models for urban energy analysis

Statical building model:

Time resolution: year / month

- Yearly /Monthly energy balance (ISO 13790 / DIN 18599 / PHPP)
  - ➢ Used for the calculation of many national energy standards



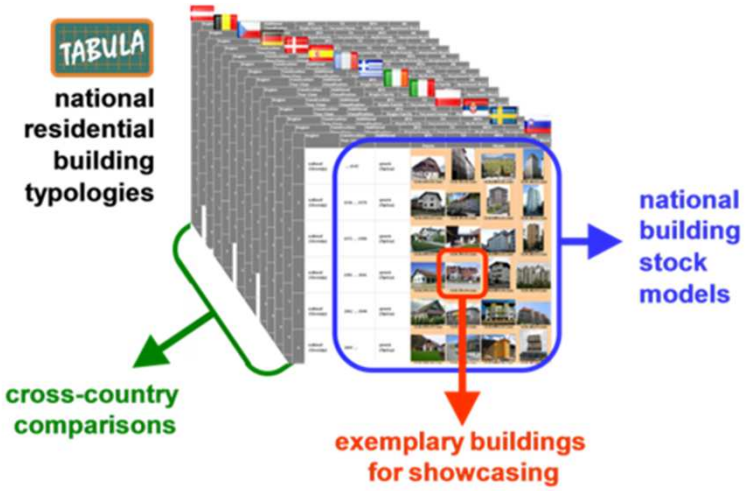
DIN 18599-2 (2011)

Thermal building models for urban energy analysis

Statical building model:
Required building data

- Building Geometry data (Thermal boundary area…)
  - ➢ Preprocessing of CityGML geometry

- Stationary building physics data (Uvalues…)
  - ➢ Many building libraries exist for residential (Tabula project, IWU Gebäudetypologie…)



- Building usage data (average internal gains, set-point temperatures…)
  - ➢ Standardised in many regulation texts

Thermal building models for urban energy analysis

Dynamical building model (transient heat transfer)

Time resolution: hour / sub-hour

- Explicit solution of the heat equation by finite difference or response function methods (EnergyPlus)
  - ➢ High data requirements (and associated uncertainties)
  - ➢ High modelling/computational time

- Model reduction techniques (Grey box methods)
  - ➢ Lack of generality (derived from specific cases)

- Model simplification techniques such as the resistance capacitance (RC) network (VDI 6007 / CitySim Solver)

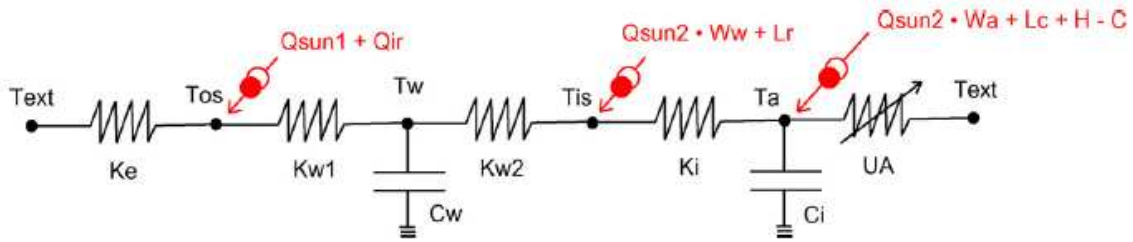
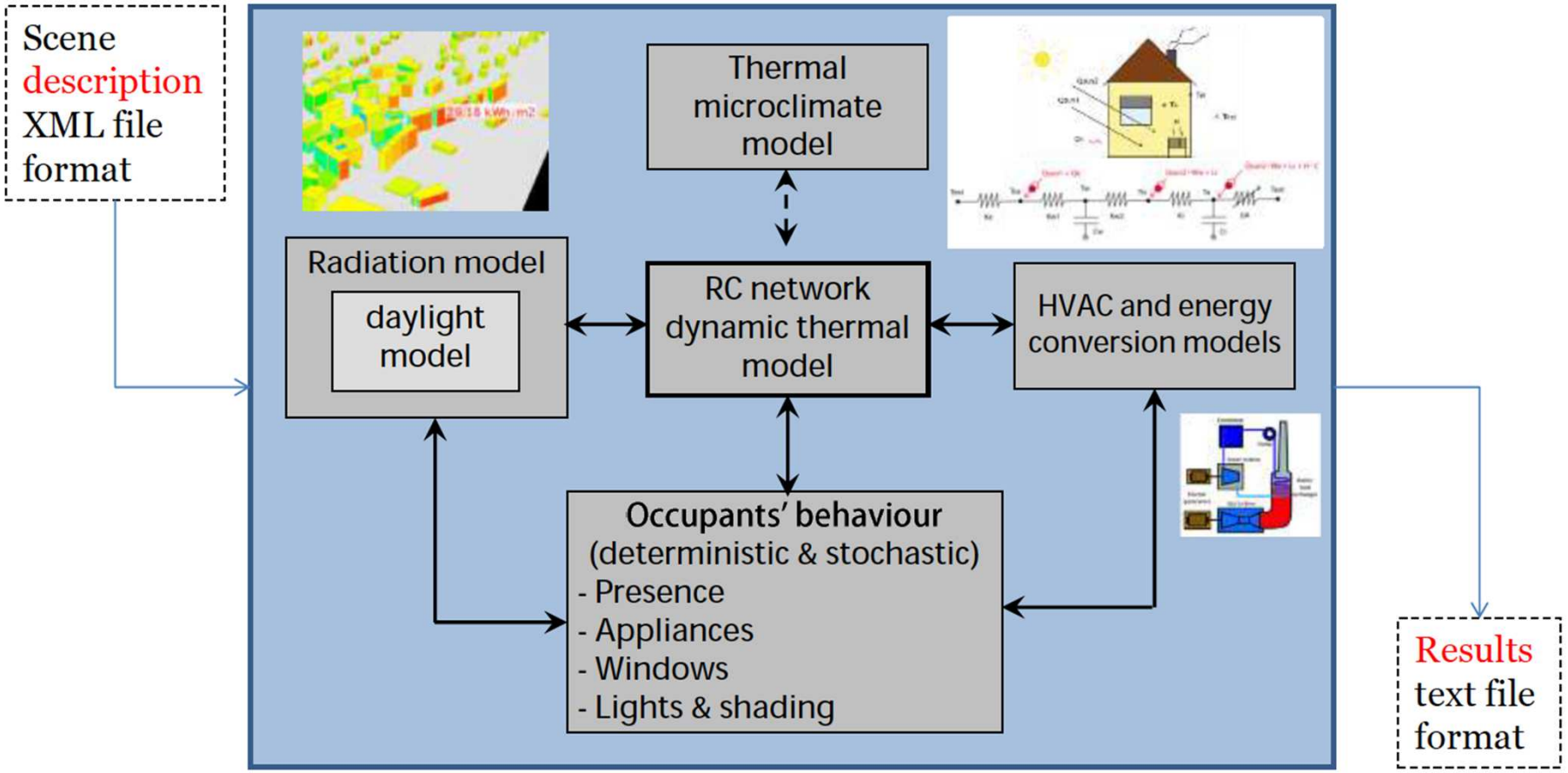


Fig. 1. The thermal model as an equivalent electric circuit.

Kämpf and Robinson (2007)

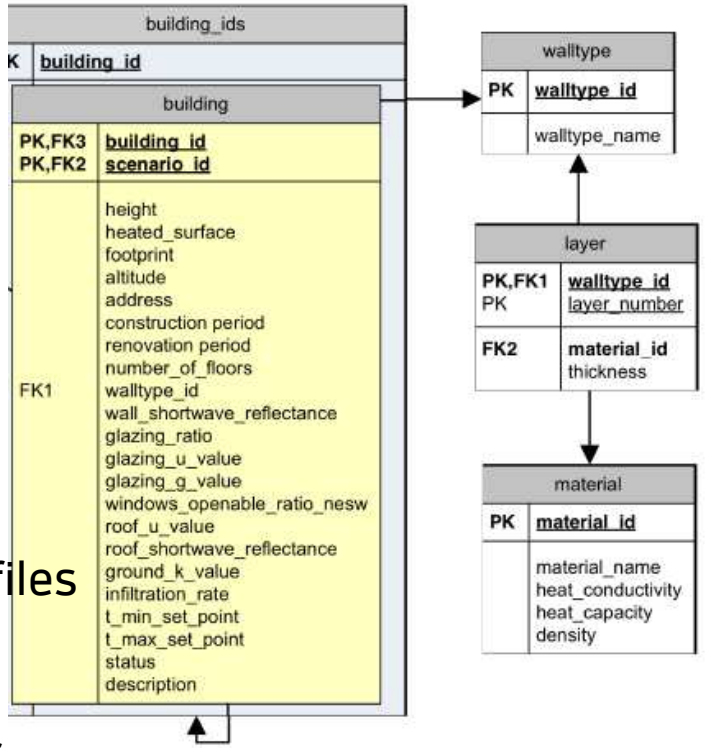
CitySim Solver – Simulation process



Results (hourly): irradiance on surfaces, buildings heating demand, fuel and electricity consumption, electricity production, surface temperature

CitySim Solver – Building data model

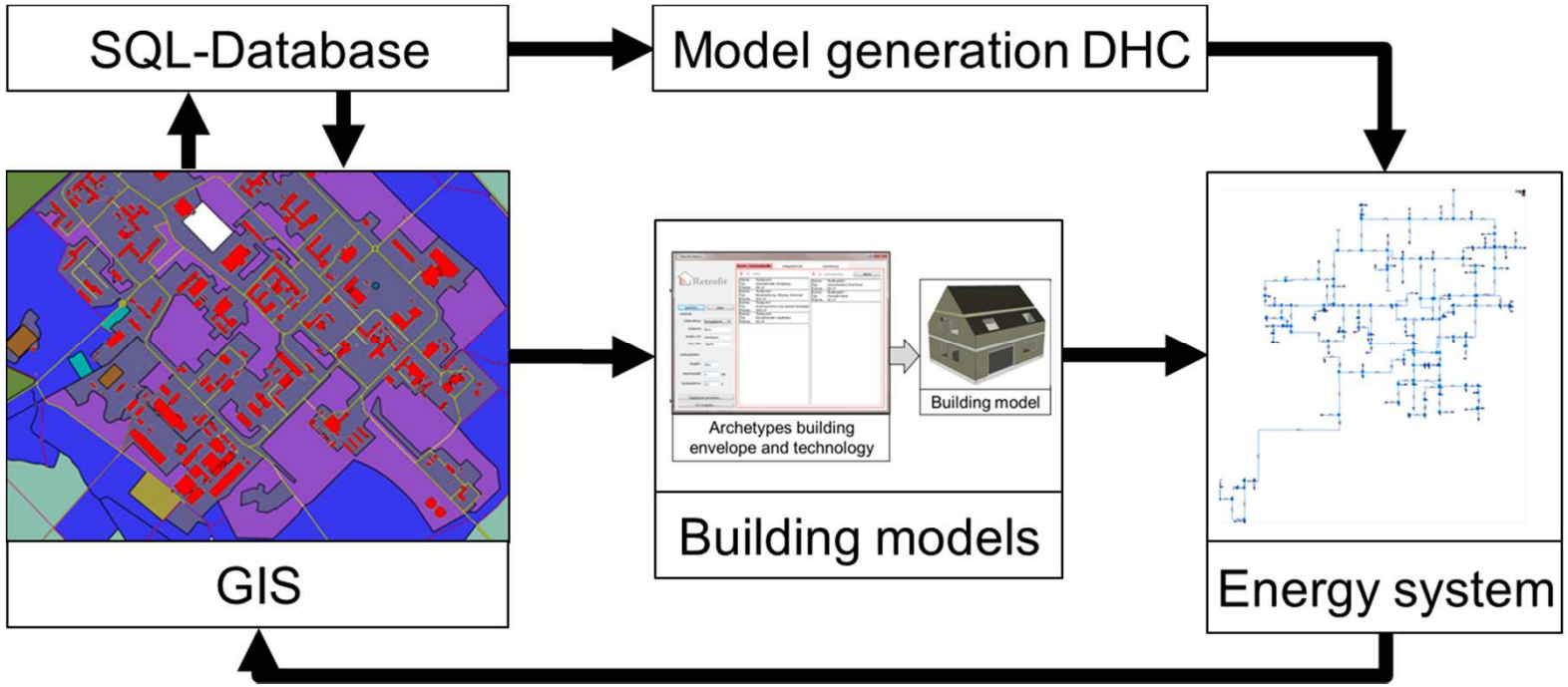
- Physical parameters
  - Resistance and capacity of wall layers…
- Time-depending building operation parameters
  - ventilation, temperature set points
- Time-depending internal heat gains
  - occupants' presence and electricity use profiles
- Occupants interactions with windows and blinds
  - stochastic models)
- Buildings energy conversion systems
  - Boiler, Solar panels, Heat pumps, etc.



AixLib LOM – Simulation process

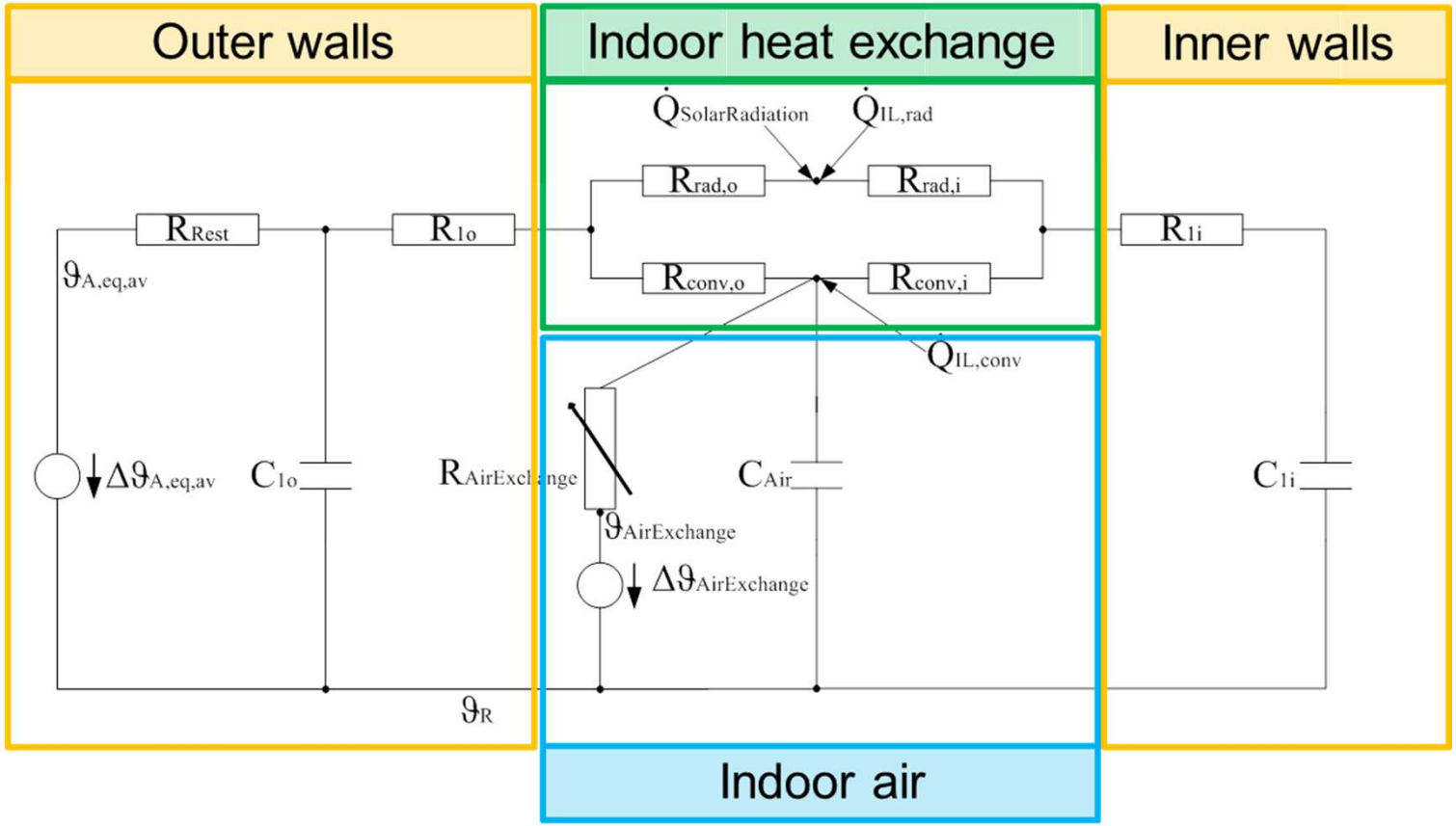
Simulation of District Heating System

- Location of nodes (from GIS)
- Length, diameter, isolation of pipes
- Power, volume flow, pressure drop of heat exchanger



AixLib LOM – Building model

3R2C-Model based on VDI 6007 ("AixLib LOM")

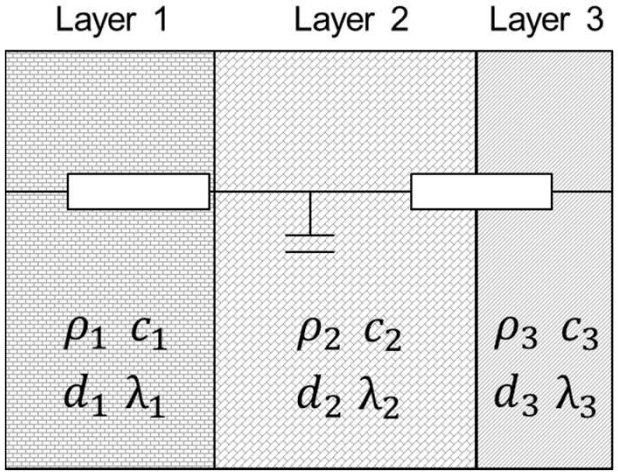


More Information: Lauster et al. Low order thermal network models for dynamic simulations of buildings on city district scale. Building and Environment 2014;73:223–31, http://dx.doi.org/10.1016/j.buildenv.2013.12.016.

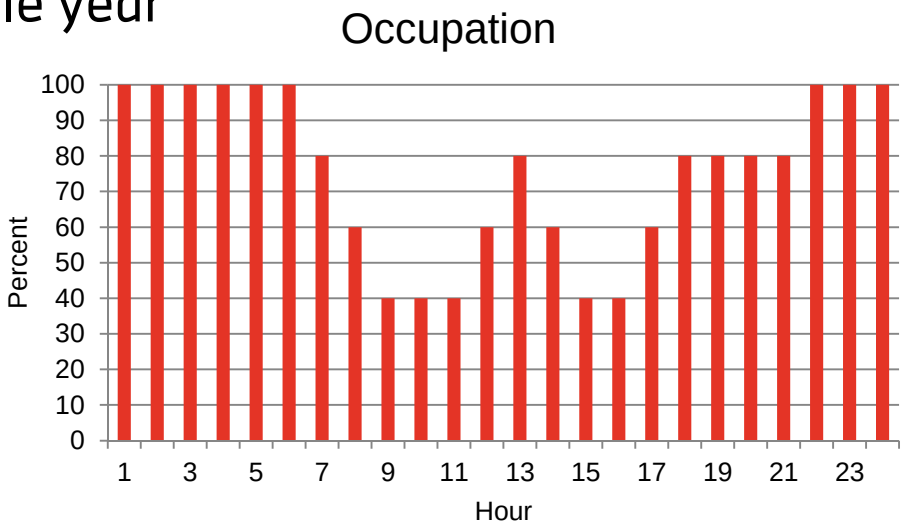
AixLib LOM – Building data model

Data requirement specific to dynamic simulation:

- Physical Parameters:
  - Heat capacity of thermal masses
  - Detailed wall construction (layers)



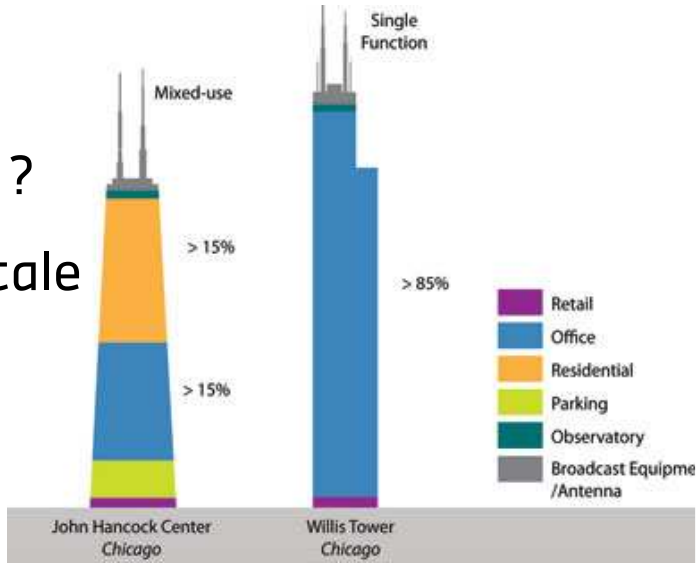
- Hourly schedules for the whole year
  - Persons
  - Machines
  - Light
  - Weather



Mono-zone or Multi-zones Building Model ?

For CityGML **LOD1-LOD3**: no interior building architecture

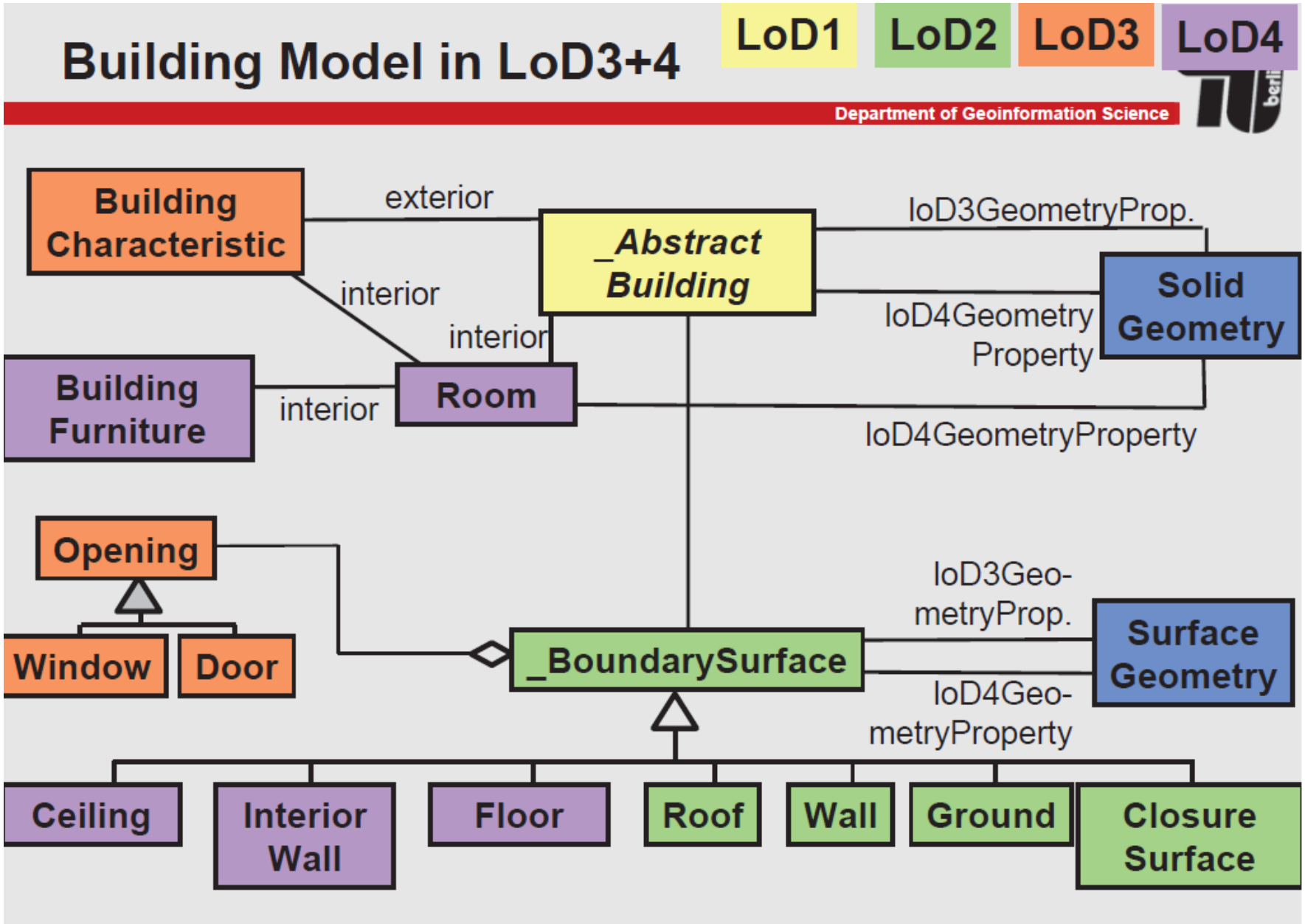
- case mono-usage building: no problem
- case multi-usage building
  - ➢ Abstract (non-geometrical) usage zones ?
  - ➢ Average usage parameters at building scale



For CityGML **LOD4**: interior building architecture

- mono-usage building and multi-usage buildings: no problem
- Usage zone linked with geometrical CityGML object „Room“

Geometrical Building Model



The End

Thanks for your attention