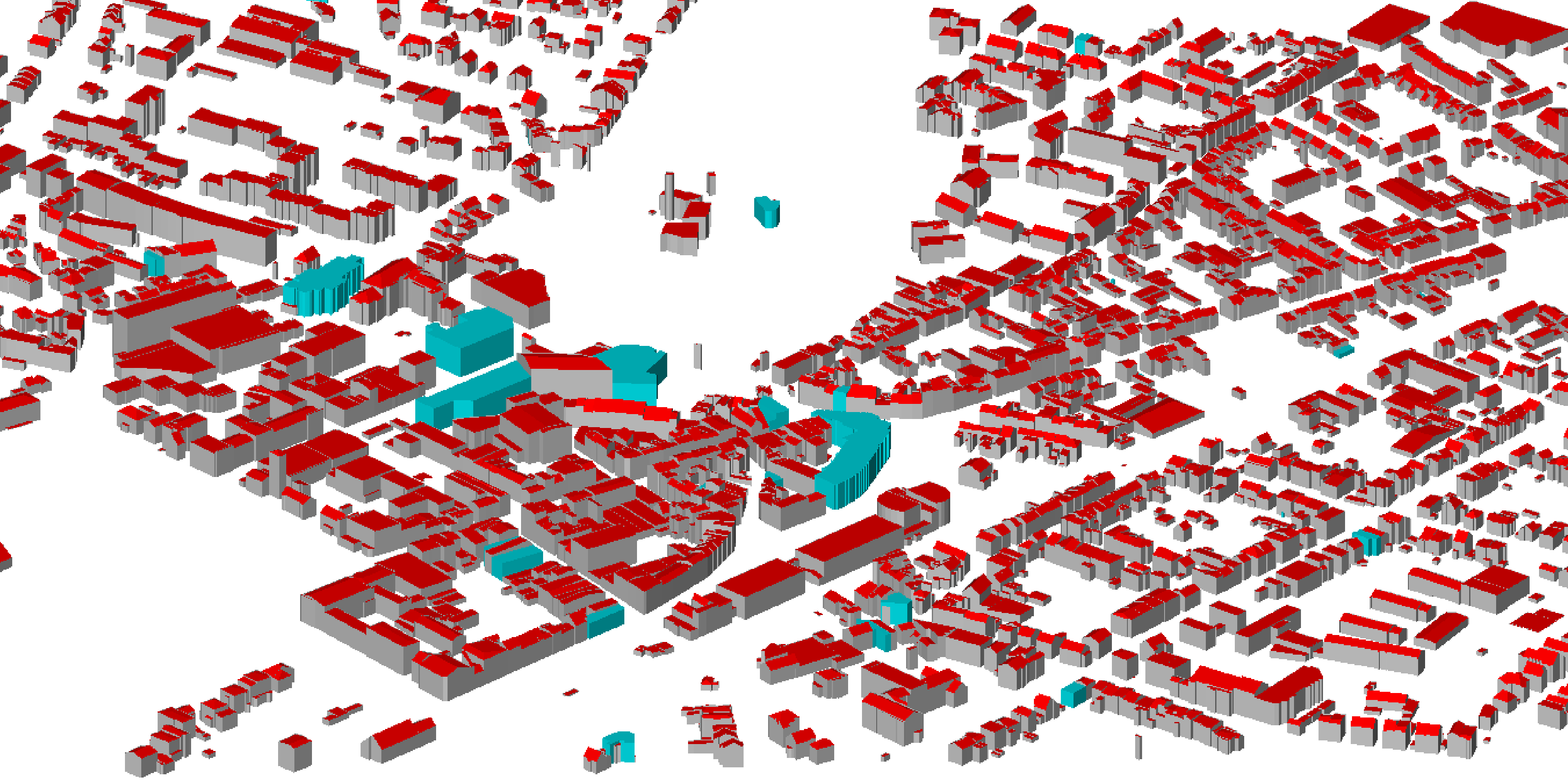


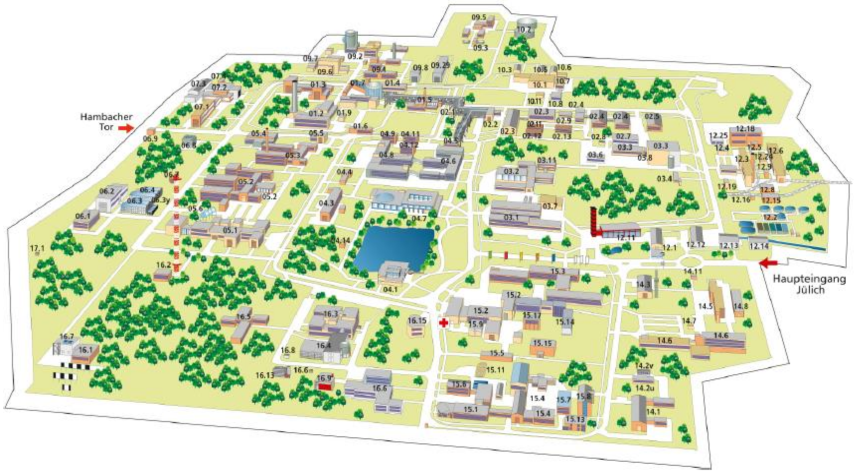
# Teaser

Tool for Energy Analysis and Simulation for Efficient Retrofit

Moritz Lauster

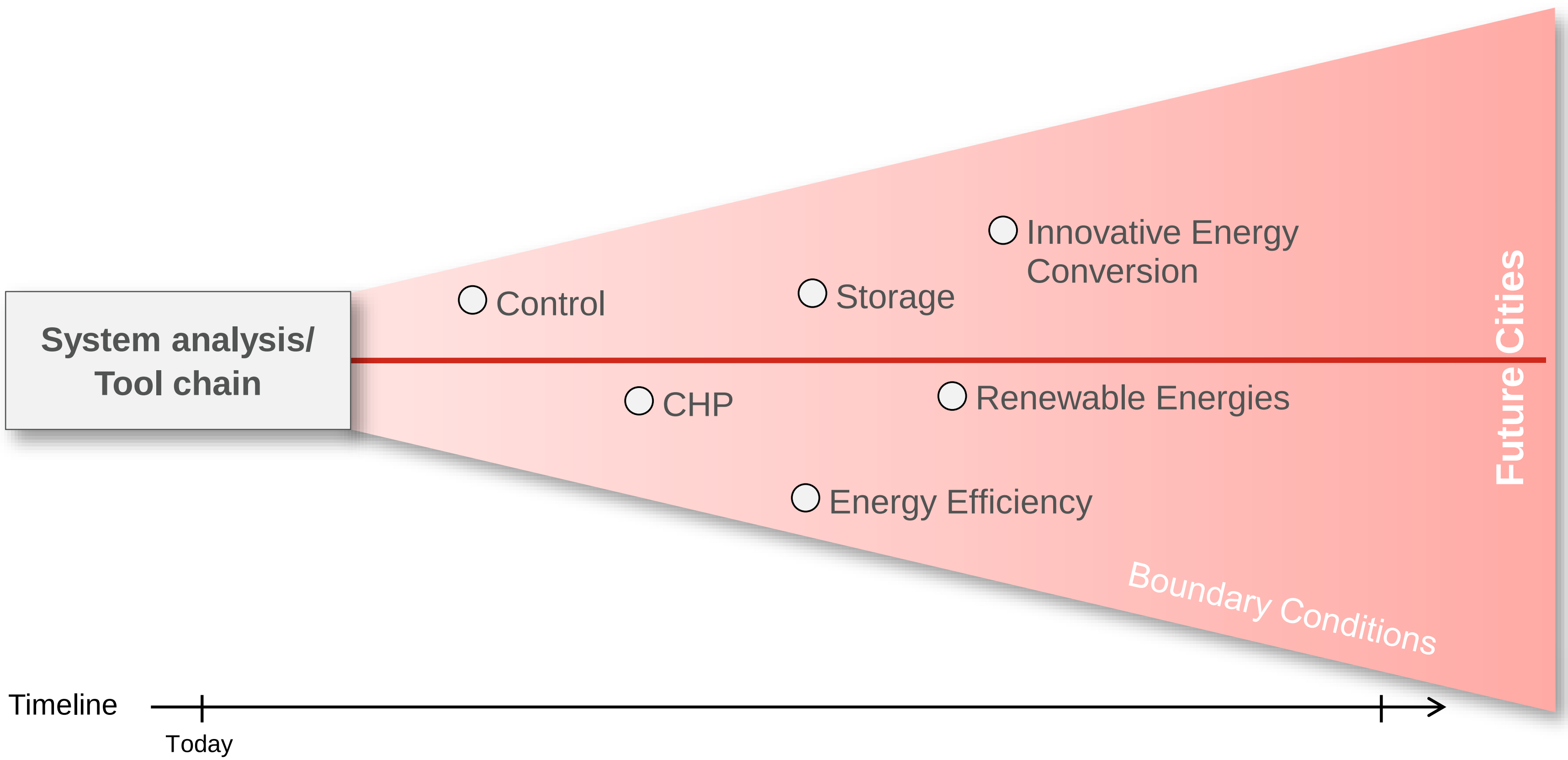
EBC | Institute for Energy Efficient Buildings and Indoor Climate | E.ON Energy Research Center | RWTH AACHEN UNIVERSITY

# Introduction




| Campus | Forschungszentrum Jülich | Melaten (RWTH Aachen) |
|---|---|---|
| Area | 2,2 km² | 1,25 km² |
| # Buildings | ~ 200 | ~ 50 |
| Thermal Grid | > 40 km | > 10 km |
| Heating | CHP | Gas boilers |
| Cooling | Compression Chillers | Absorption Chillers |

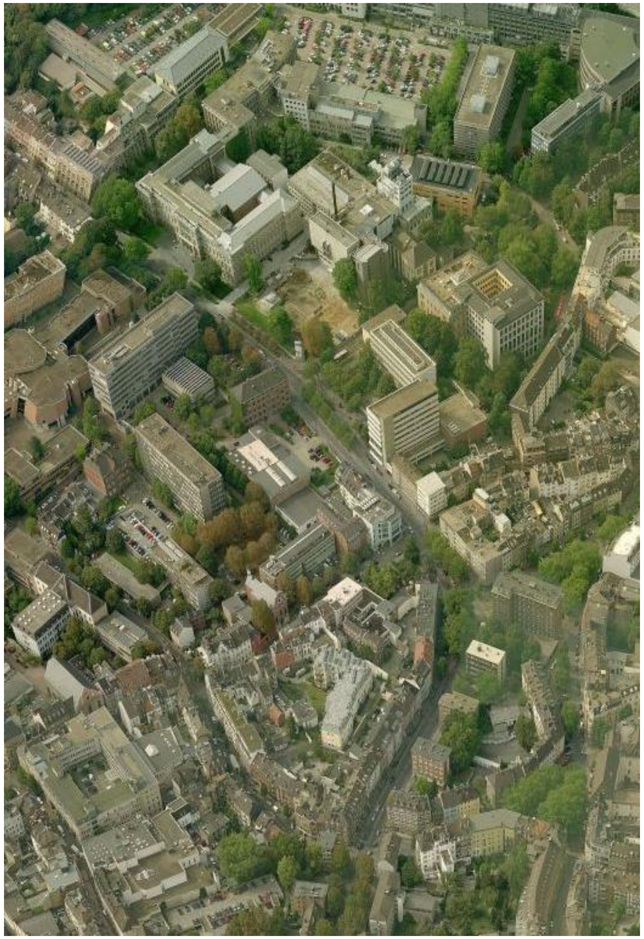
# Roadmaps to the City of the Future



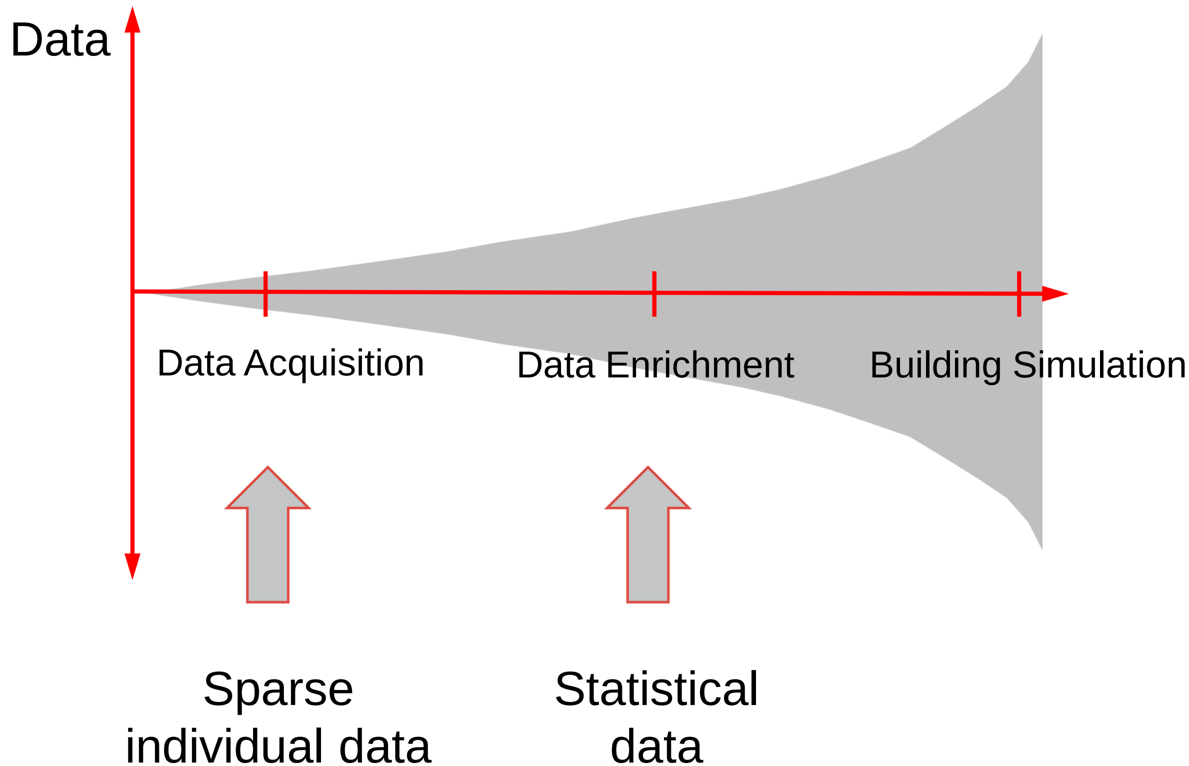
# Motivation

- Data acquisition and modelling on urban scale:
  - Time consuming
  - Sparse information, not sufficient for dynamic BPS
  - ➢ TEASER

- Dynamic Urban Building Energy Modeling (UBEM)
  - Common BPS tools are designed for in-depth analysis of single buildings
  - Full power of these tools cannot be utilized due to data issues
  - Full power of these tools is not necessary due to shifted focus on integral analysis of an entire district
  - Computational overhead of these tools is not justified by means of accuracy of level of detail on urban scale.
  - ➢ Reduced Order Model



Data acquisition on district scale often provides too sparse data for dynamic BPS




- One workflow from building to urban scale simulations

# What you should know and be able to do after this workshop

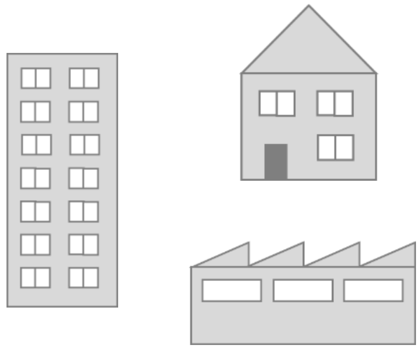
- Understand the impacts of using statistical enriched data sets
- Get an overview of the structure of TEASER and it's GUI
- Using TEASER's functionalities to create
  - Your own individual building
  - A building based on an archetype

- Understand the basics, advantages and disadvantages of ROM
- Export ROM's from TEASER and geht them running in Dymola

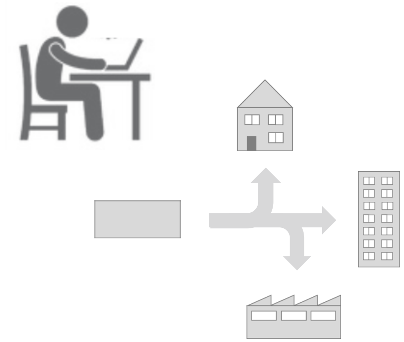
- Get an expression of possible workflows for Urban Building Energy Modeling using
  - Python
  - TEASER
  - Annex60 Lib

- Get yourself comfortable by using Annex60 building and HVAC models

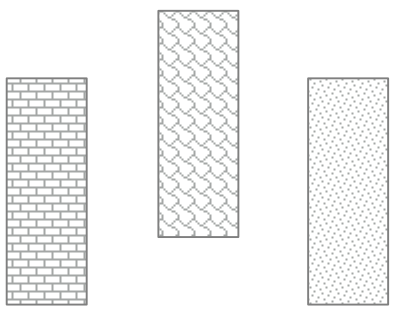
# Data Enrichment using Archetypes in TEASER



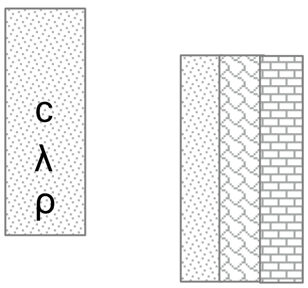
Type of Building



Boundary Conditions,
General Approach

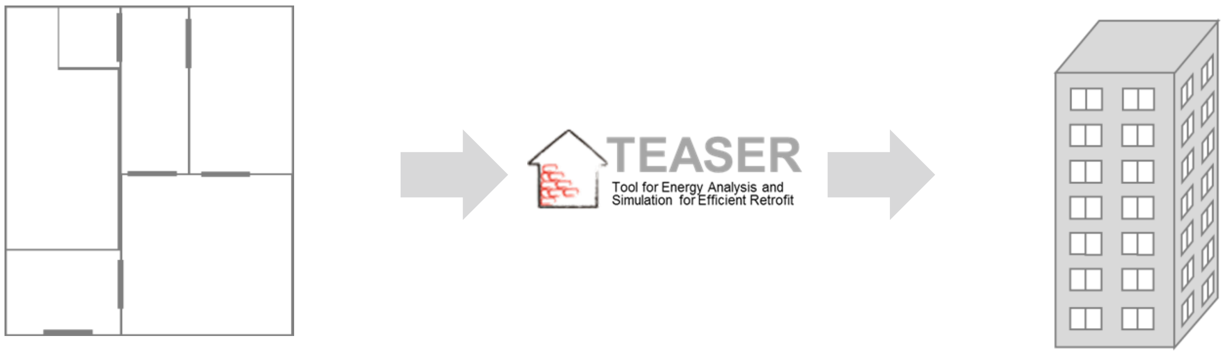


Year of Construction



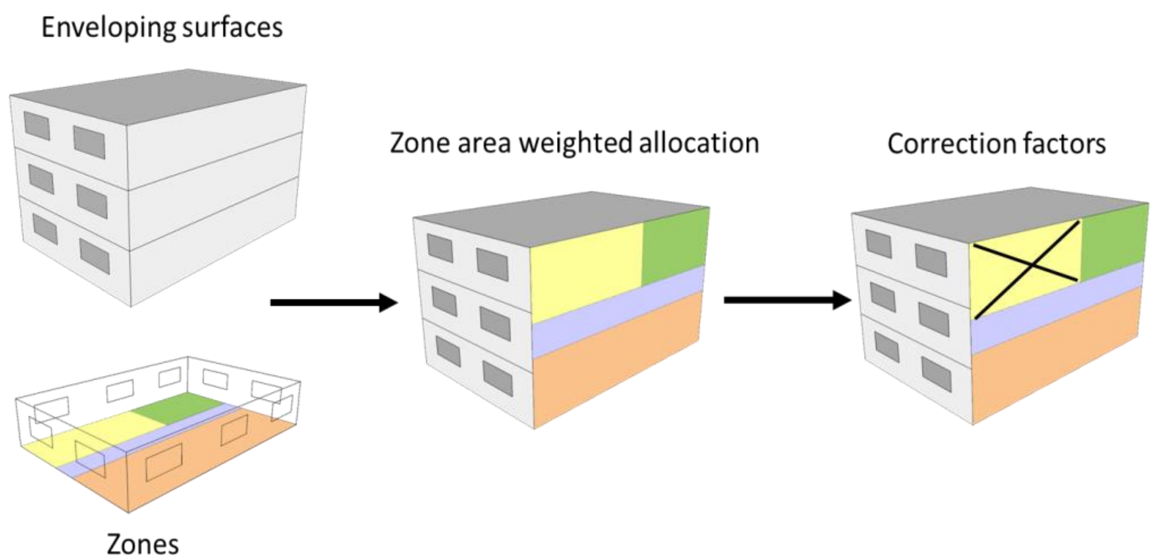

Materials,
Constructions

# Data Enrichment using Archetypes in TEASER



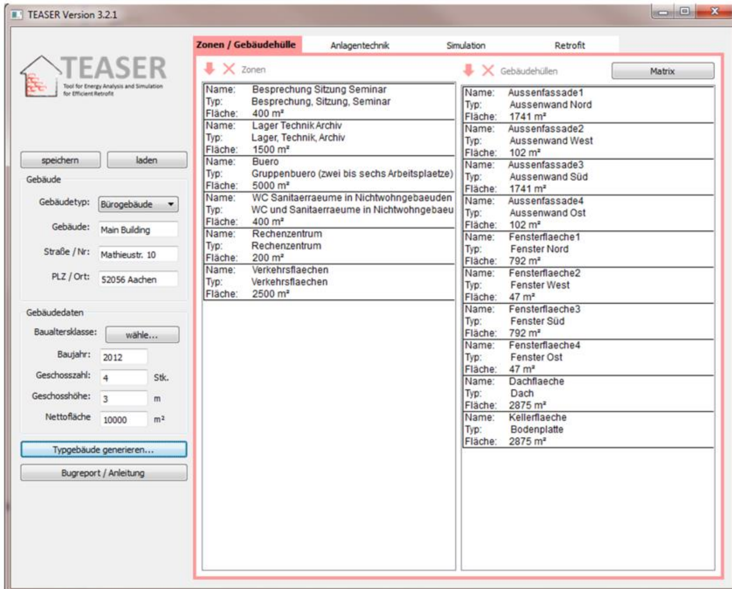

Geometry

Cubature



# TEASER – Application View

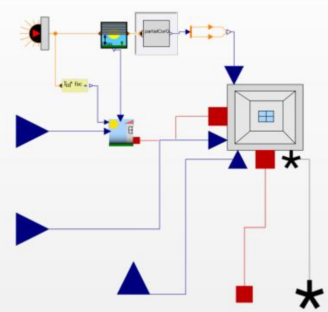
TEASER
Tool for Energy Analysis and Simulation for Efficient Retrofit




**Internal Database**

Statistical Data from German Building Stock

**Building Model**



Minimum Data Set:

- Year of Construction
- Floor Area
- Usage Type
- Building height

Optional Data :

- Wall properties
- Window properties
- Zoning
- ...



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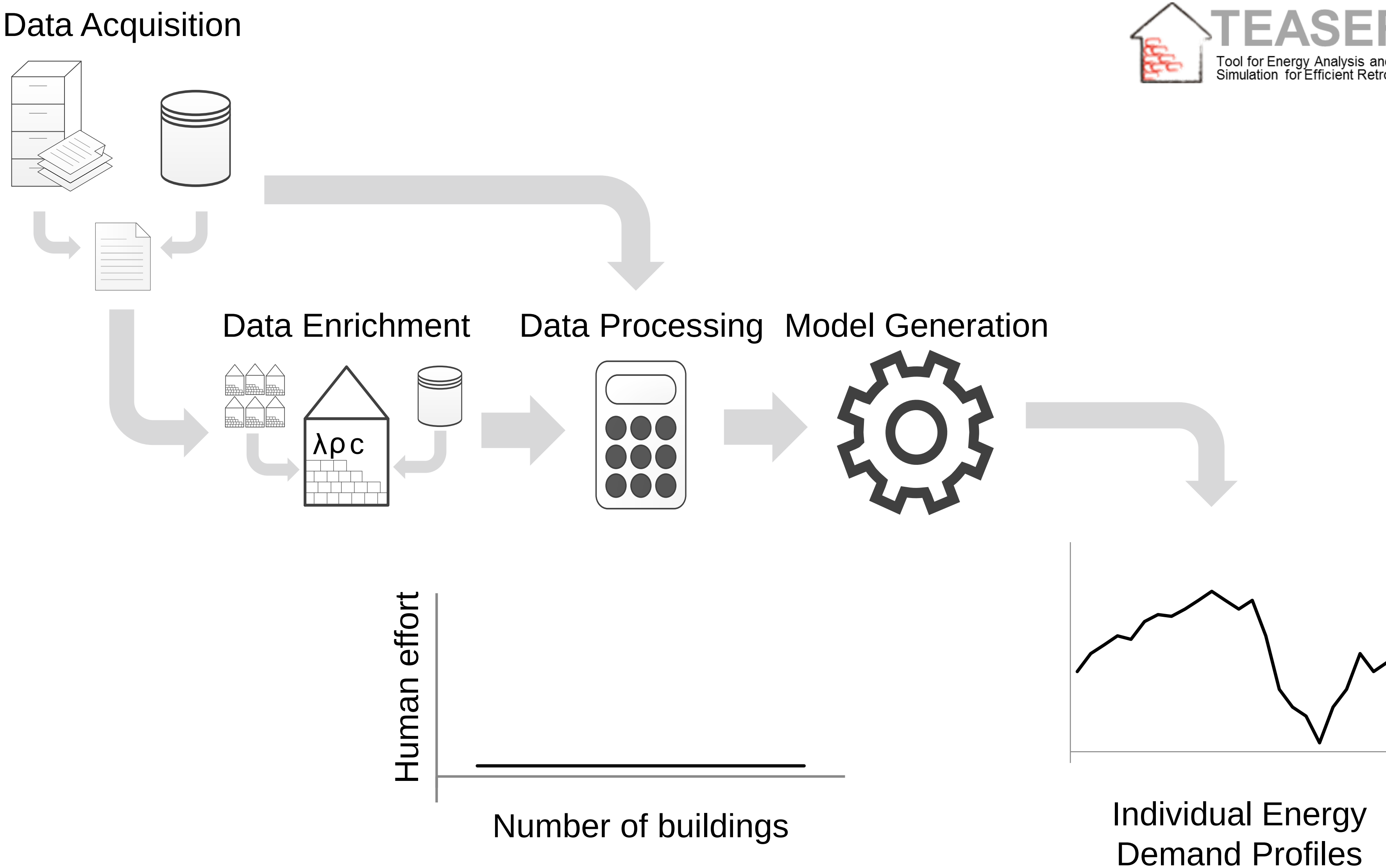
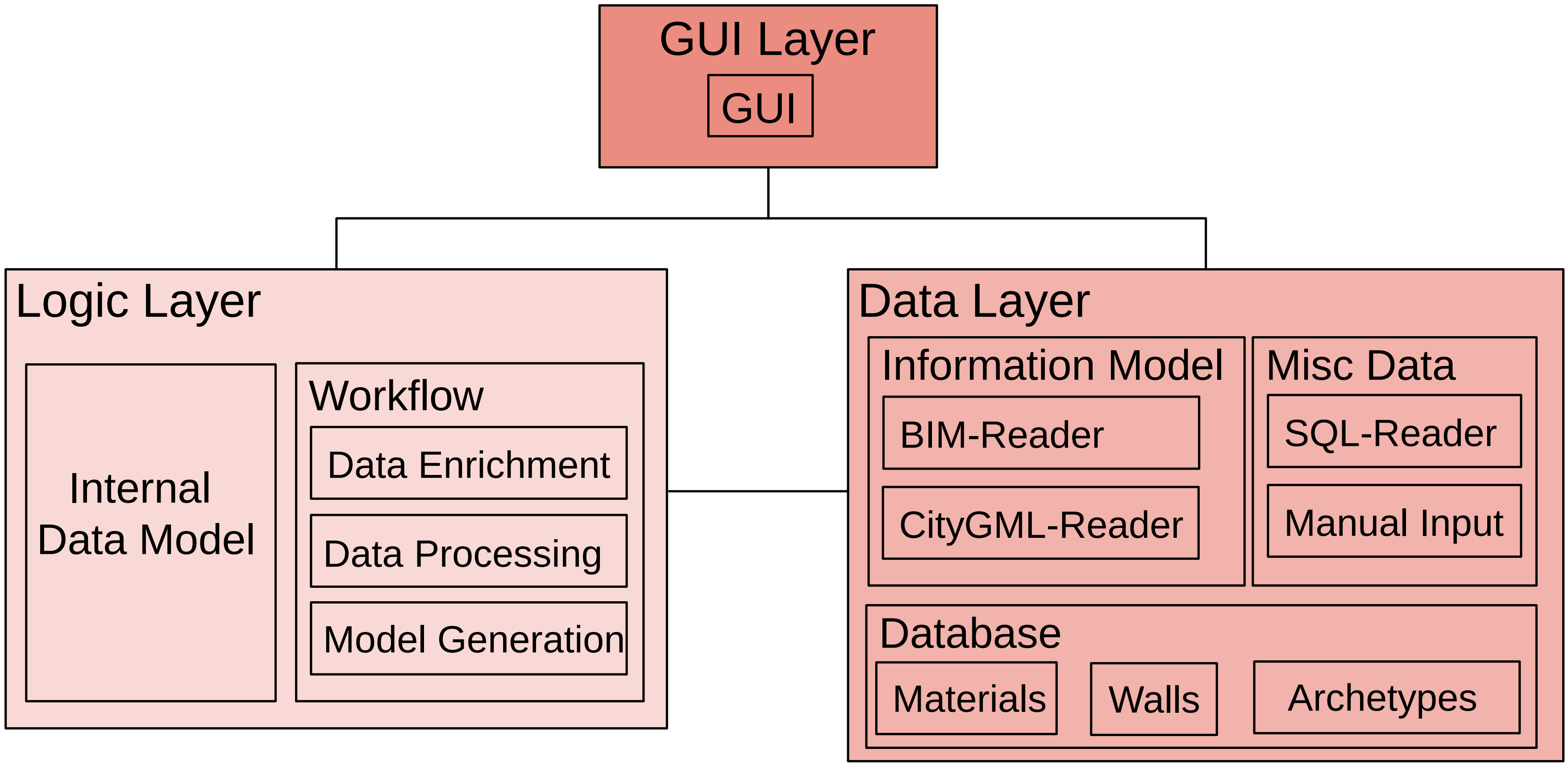
# TEASER – Workflow View
## Workflow Automation for Urban Building Energy Modelling

TEASER
Tool for Energy Analysis and Simulation for Efficient Retrofit



# TEASER – Structural View



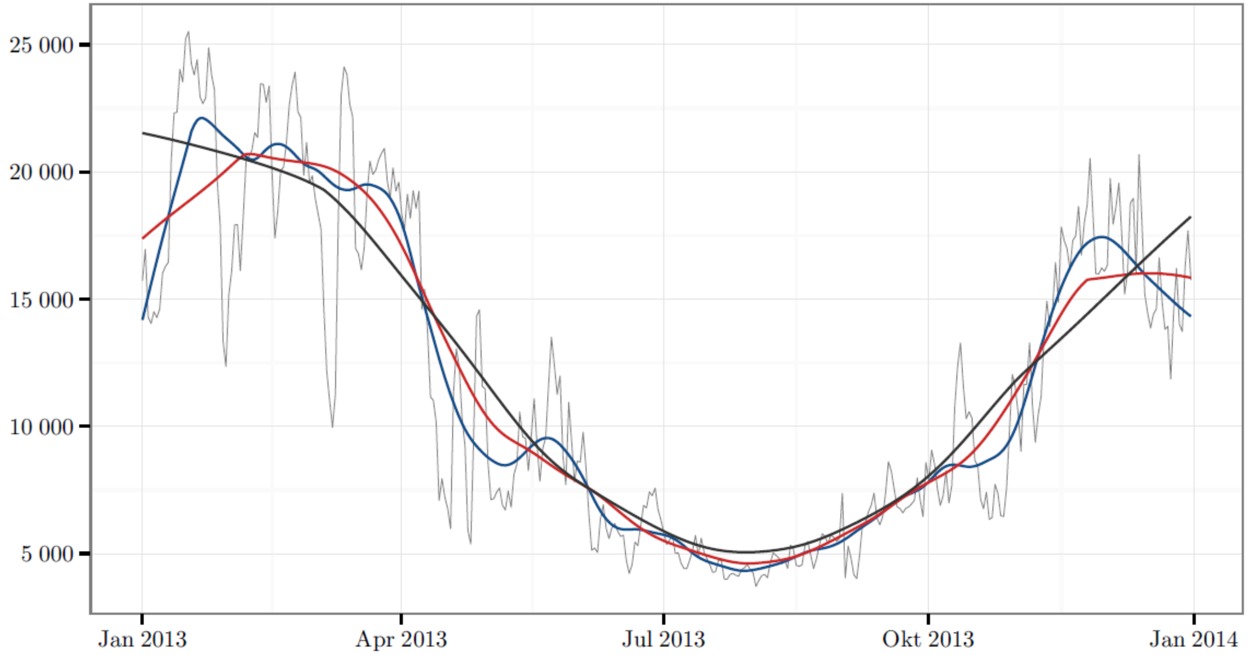
# Python

- Short history:
  - Developed 1991 by Guido van Rossum
  - Name inspired by Monty Python
- Properties:
  - Open-source
  - General-purpose
  - Readability
  - Scripting
    - Simple syntax
    - Simple semantics
    - Implicit variable declaration
    - Dynamic types
  - Procedural and Object-Oriented
  - Numerous packages available on the internet

# Reduced Order Modeling

Reducing the system's complexity through focussing on predominant time constants

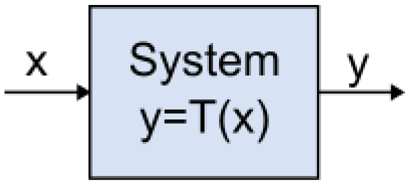
- Detailed analysis of the use case's
  - Which time constants are of interest?
  - Which interactions need to be modelled?




➢ Reduced order modeling using grey box modeling approaches from control theory

# Control Theory

- Interdisciplinary approach, often used in electrical and control engineering. Concerns the mathematical description of physical systems on an abstract level.
  - Input, Output
  - System (model)
  - Transfer function (mathematical model)






- Example:
  1. First order differential equation (e.g. energy storage)
  2. One-directional excitation
  - Always an exponential behavior:

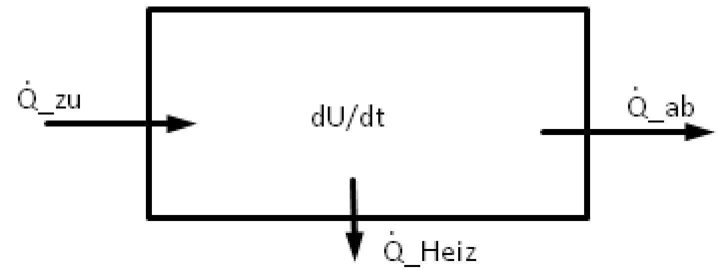
$$y(t) = y(t \rightarrow \infty) + [y(t_0) - y(t \rightarrow \infty)]e^{-\frac{t}{\tau}}$$

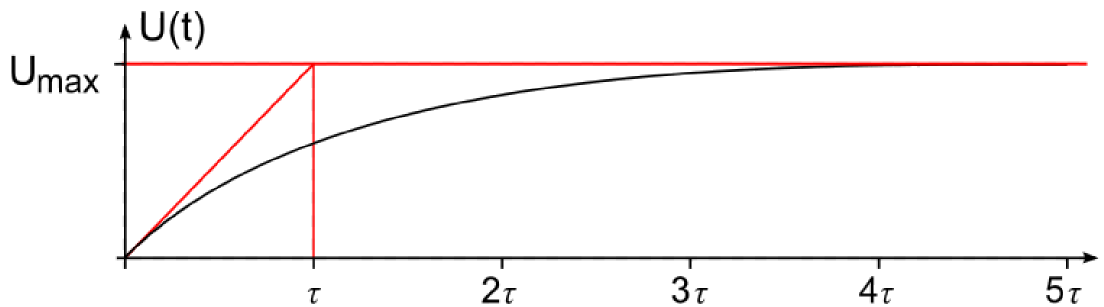
  - $\tau$: Time constant

Quelle: De Doncker, „Grundgebiete der Elektrotechnik II“

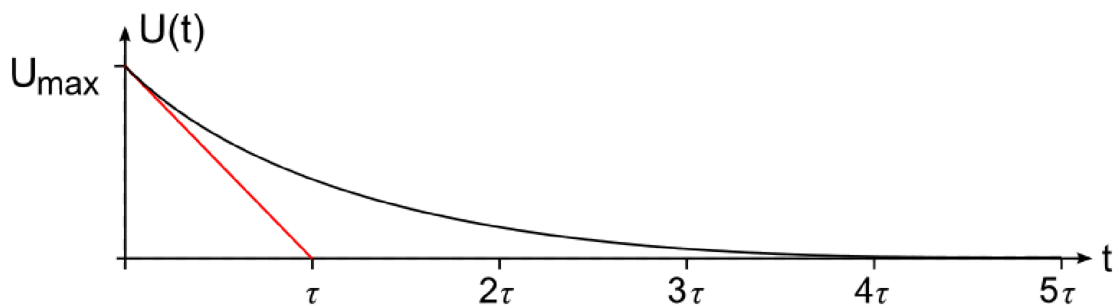
# Example

- Charging a storage (convective):
  - $mc\frac{dT}{dt} = \dot{m}c(T_{in} - T)$
  - $\frac{1}{T_{in}-T}dT = \frac{\dot{m}c}{mc}dt$
  - $T - T_0 = (T_{in} - T_0)(1 - e^{-\frac{\dot{m}c}{mc}t})$
  - $\tau = RC, R = \frac{1}{\dot{m}c}$ $and$ $C = mc$




- Decharging a storage (conductive):
  - $mc\frac{dT}{dt} = -kA(T - T_u)$
  - $T - T_u = (T_0 - Tu)e^{-\frac{kA}{mc}t}$
  - $R = \frac{1}{kA}$ $and$ $C = mc$





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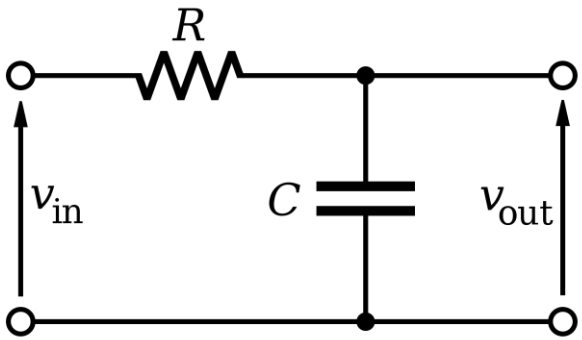
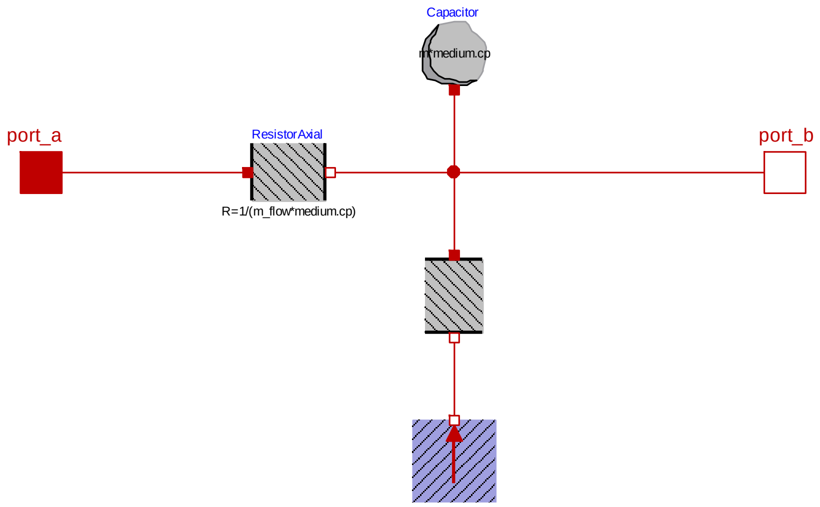
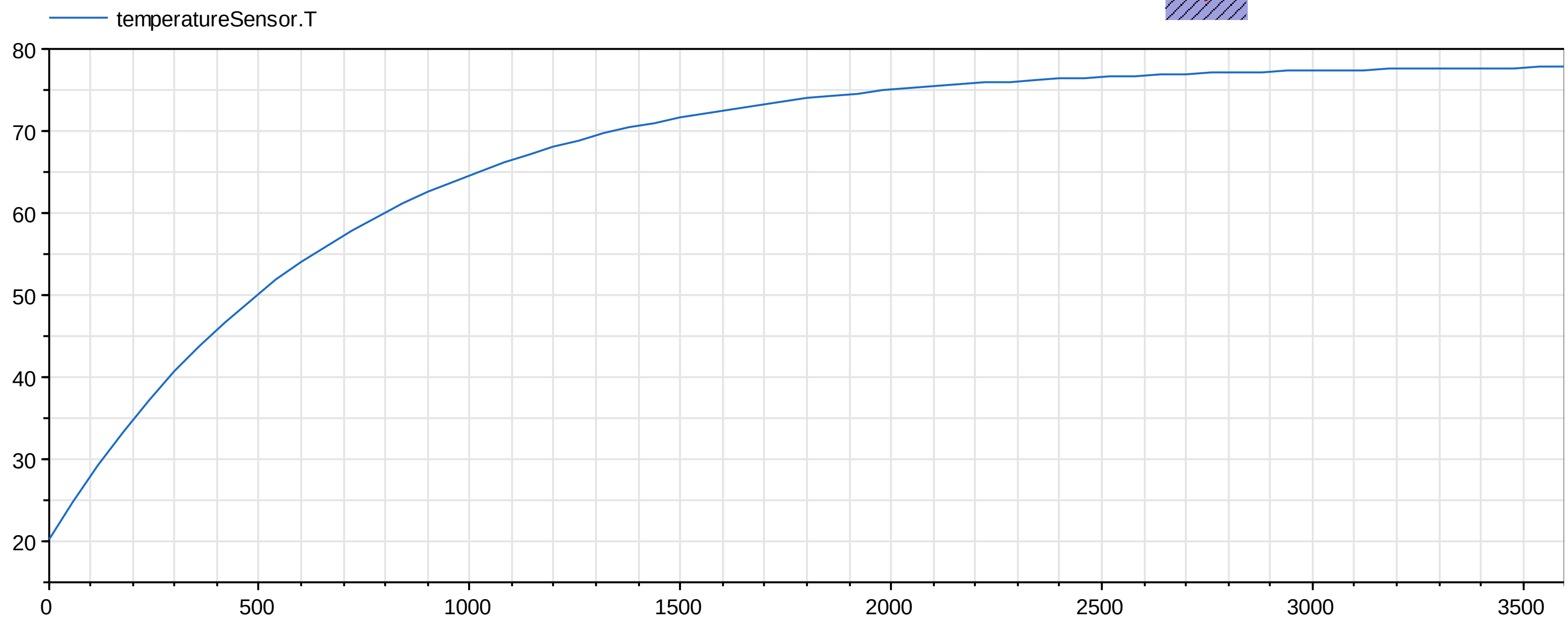
# Example


R
$v_{in}$
C
$v_{out}$


Capacitor
m*medium.cp
port_a
ResistorAxial
port_b
R=1/(m_flow*medium.cp)


temperatureSensor.T
80
70
60
50
40
30
20
0
500
1000
1500
2000
2500
3000
3500

# Thermal Network Models

$$\frac{\partial\vartheta(t,x)}{\partial t} = \frac{\lambda}{c*\rho} * \frac{\partial^2\vartheta(t,x)}{\partial x^2}$$

Discretization (Beuken-Model)

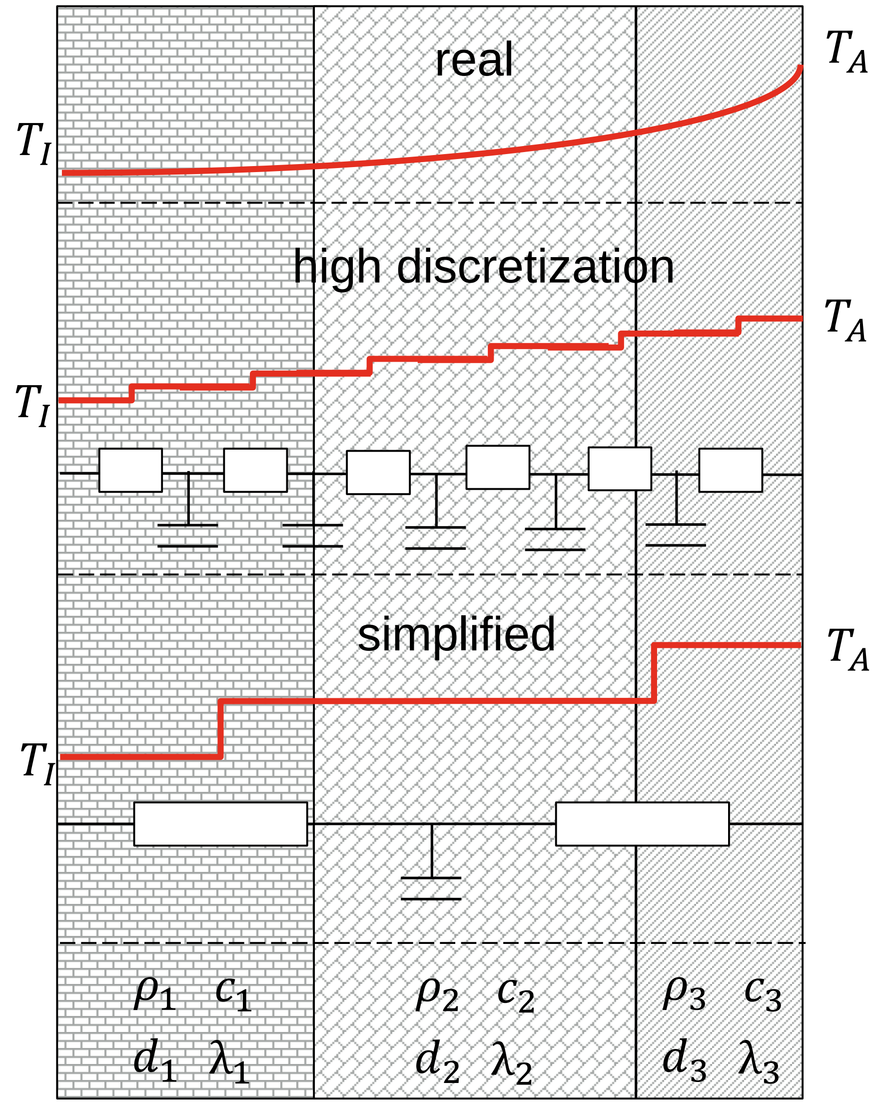
$$R = \frac{s}{\lambda}, C = c*\rho*s$$

Number of R‘s and C‘s determines spatial and physical resolution

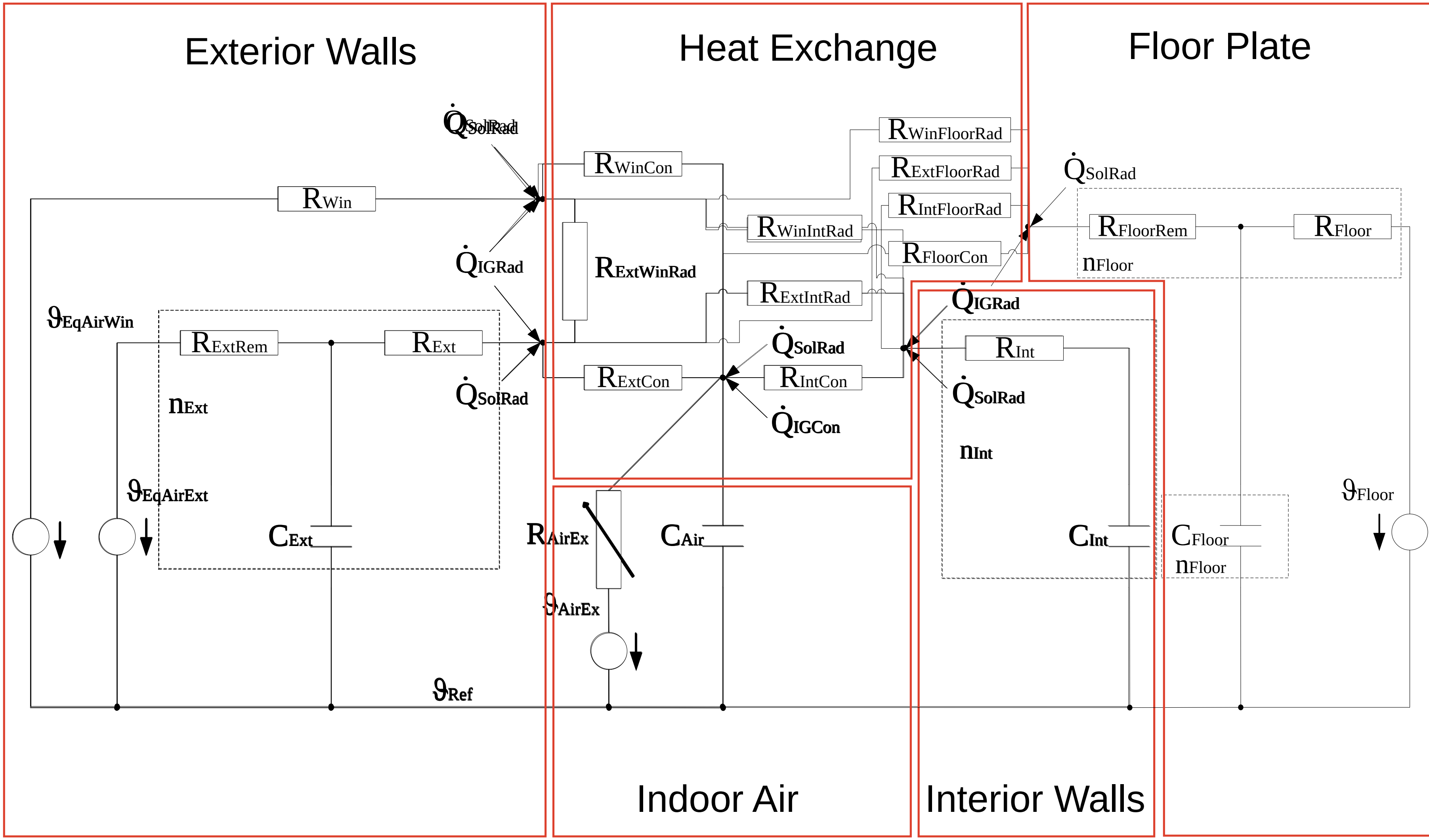
$$N_{RC} = N_{Zones} * N_{Walls} * N_{RCperWall}$$

Design decisions:

- Linearized indoor radiative heat exchange
- No view-factors
- Internal gains are considered as ideal point sources

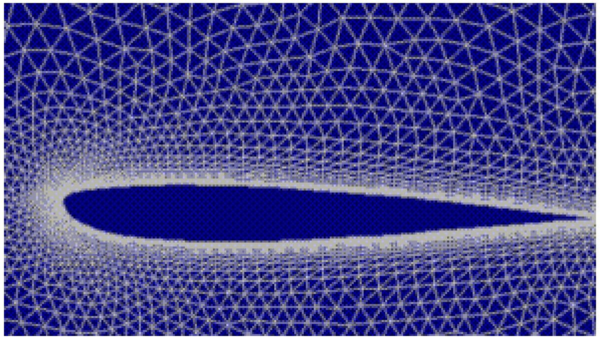


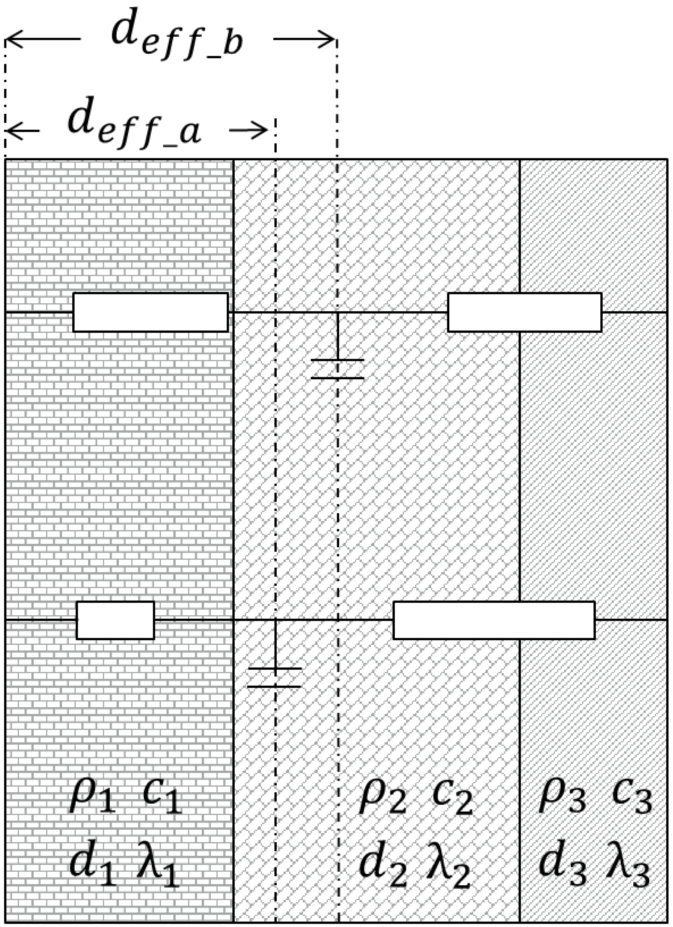
# Reduced Order Model



# Effective Thermal Mass

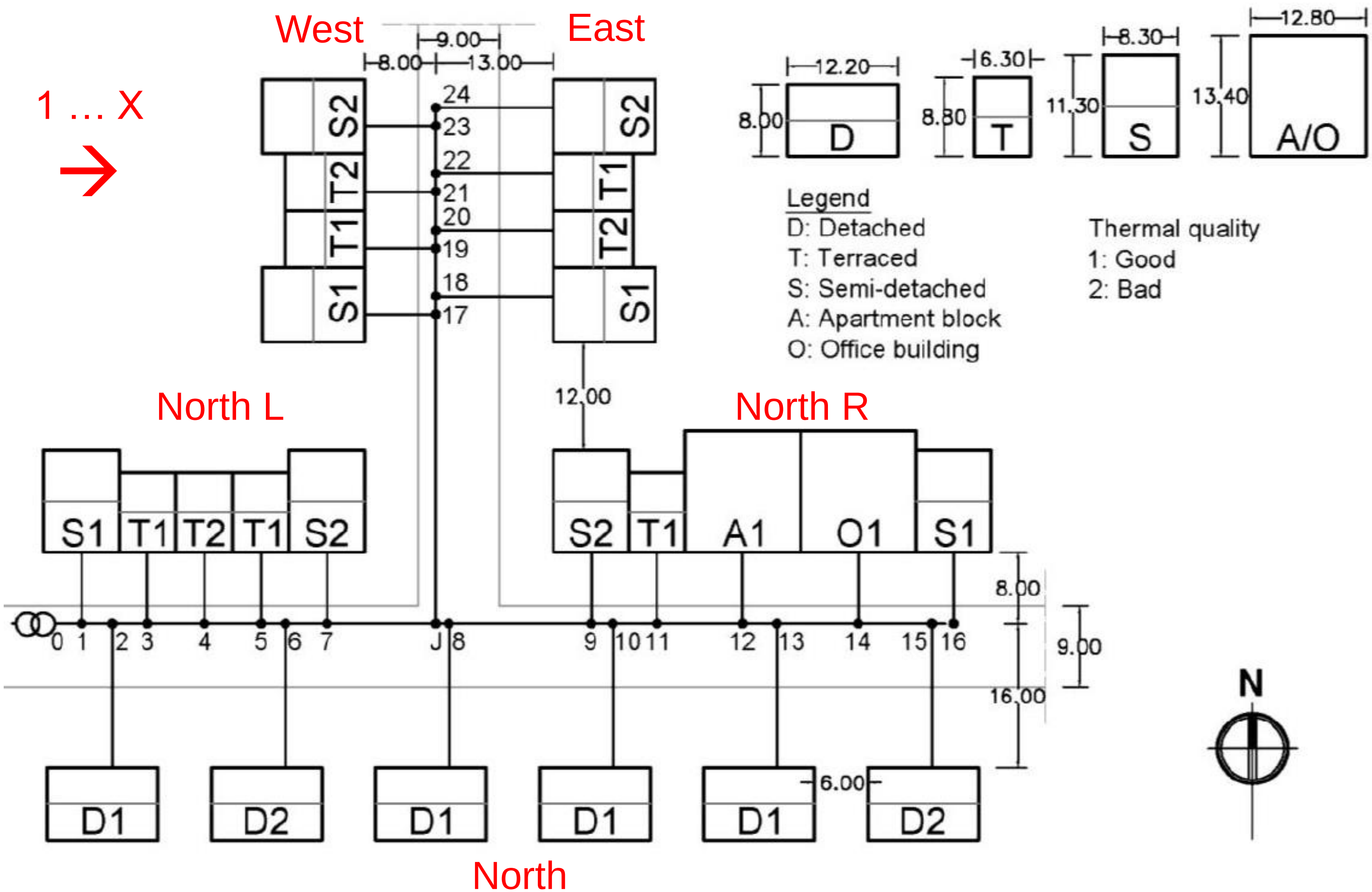
- Similar to a non-symmetrical discretization in CFD or FEM problems.





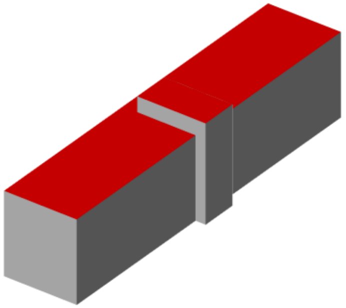

- $R, C = f(d_{eff})$
- $d_{eff} = f(\rho_n, c_n, \lambda_n, d_n, T)$
- $T$ depends on the system's typical fluctuations in time
- Recommendations
  - ISO 13790 = 1 Day
  - VDI 6007 = 5/7 Days

# First Exercise
# Use Case: Annex60 DESTEST



# Information Modelling on Urban Scale

- CityGML - City Geography Markup Language (XML-based format)
  - Open Geospatial Consortium Standard
  - Common information model for representation of 3D urban objects
    - Geometry (Level of Detail)
    - Semantics
    - Topology
  - Does not contain energy-related objects or attributes



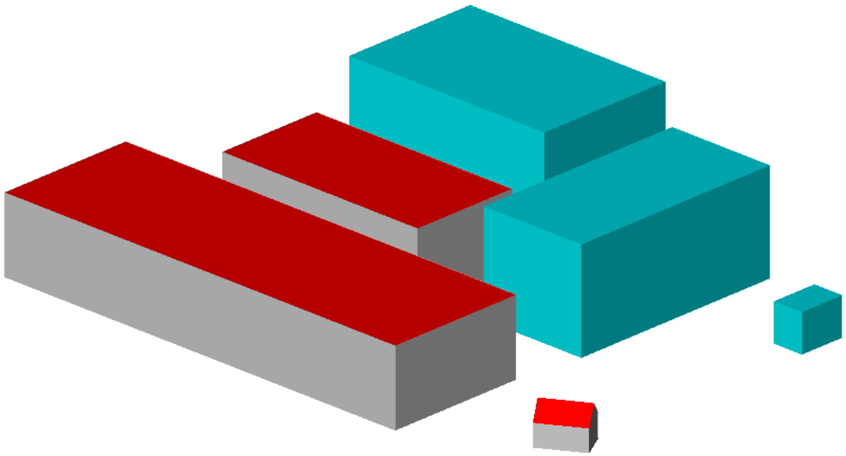
- CityGML – **A**pplication **D**omain **E**xtension
  - Extension of CityGML information model for specific domains
    - Extension of CityGML classes
    - Definition of new classes
  - EnergyADE (in Development)
  - Enables exchange of semantic and topological data for advanced energy applications (e.g. dynamic BPS)
  - Participative development in an international expert group from 13 organisations

# Use Case

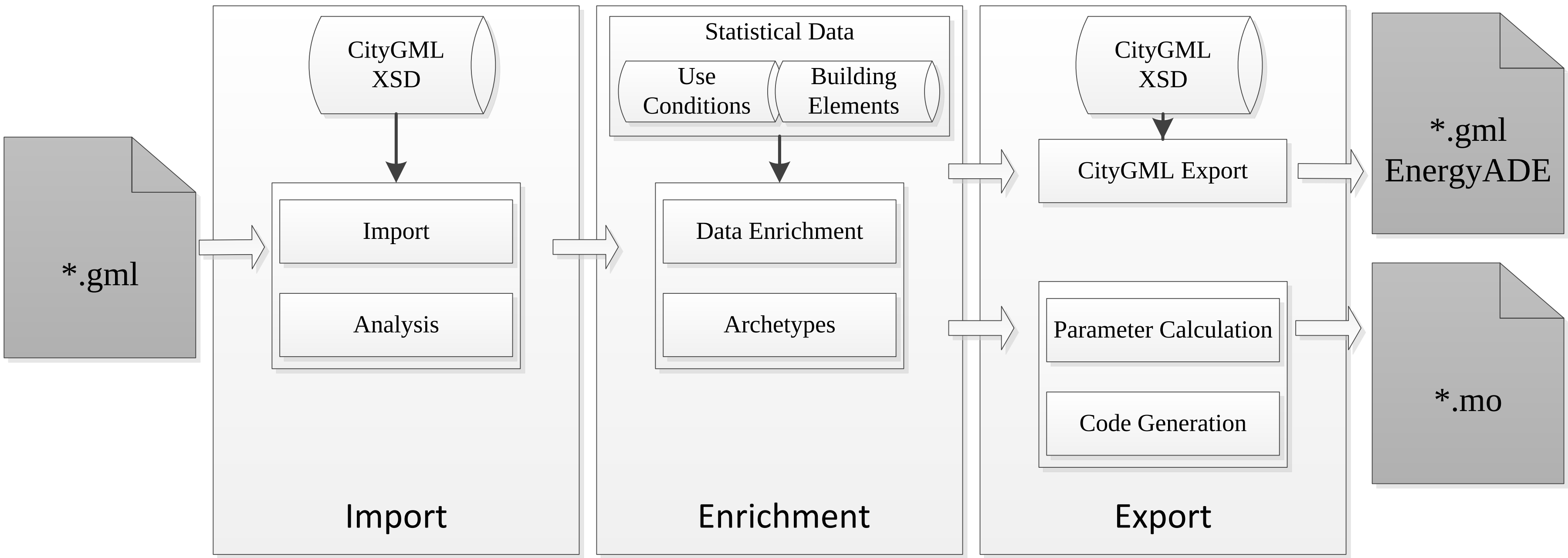
- Six buildings
  - Level of Detail 1
    - Generic surfaces
    - Extruded footprints
  - Level of Detail 2
    - Type of surfaces
    - Root structures

- Knowledge of existing CityGML attributes
  - Function
  - Year of construction
  - Number of storeys
  - Height of storeys

- Intended for workflow demonstration and export with EnergyADE



# Workflow for CityGML Import and Export



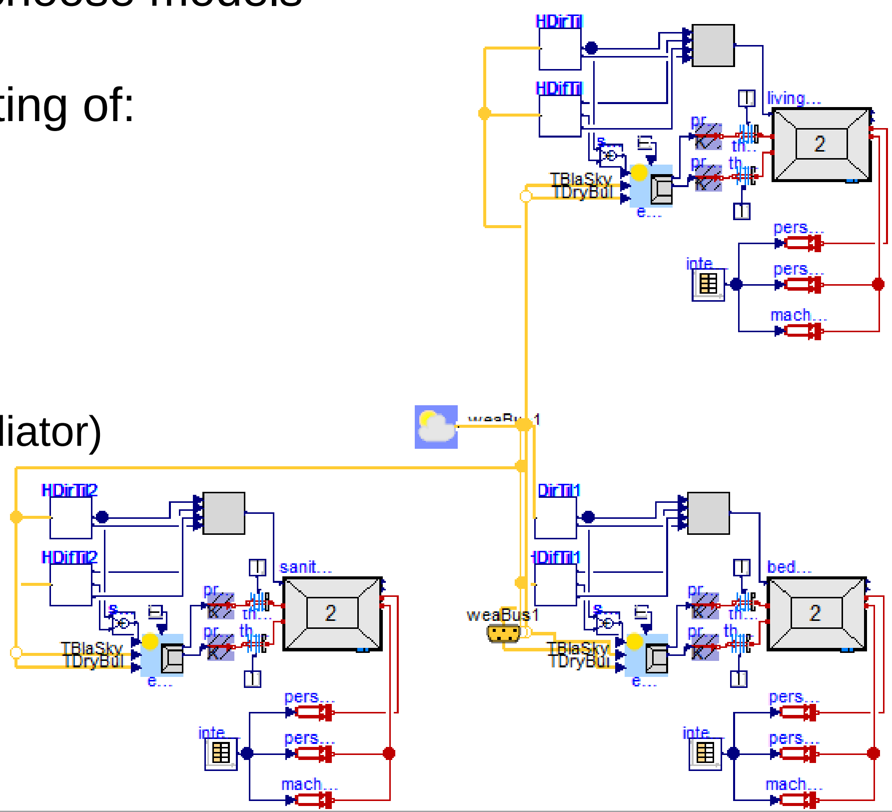
# Building and HVAC Exercise

Task: Set up a three-zone building and connect it to a heating system to compute the annual heating load

Use 2016-10-24-gensim\tuesday\BuildingAndHVAC\Models\A1_North_Template

First think about the general design, then choose models

1. Create a simple heating system consisting of:
    1. Ideal heater/boiler
    2. Integrator to get annual heat load
    3. Radiators (one per room)
    4. Valves with PI-controllers per room
    5. Pump
    6. Ideal pipes (no heat losses, two per radiator)



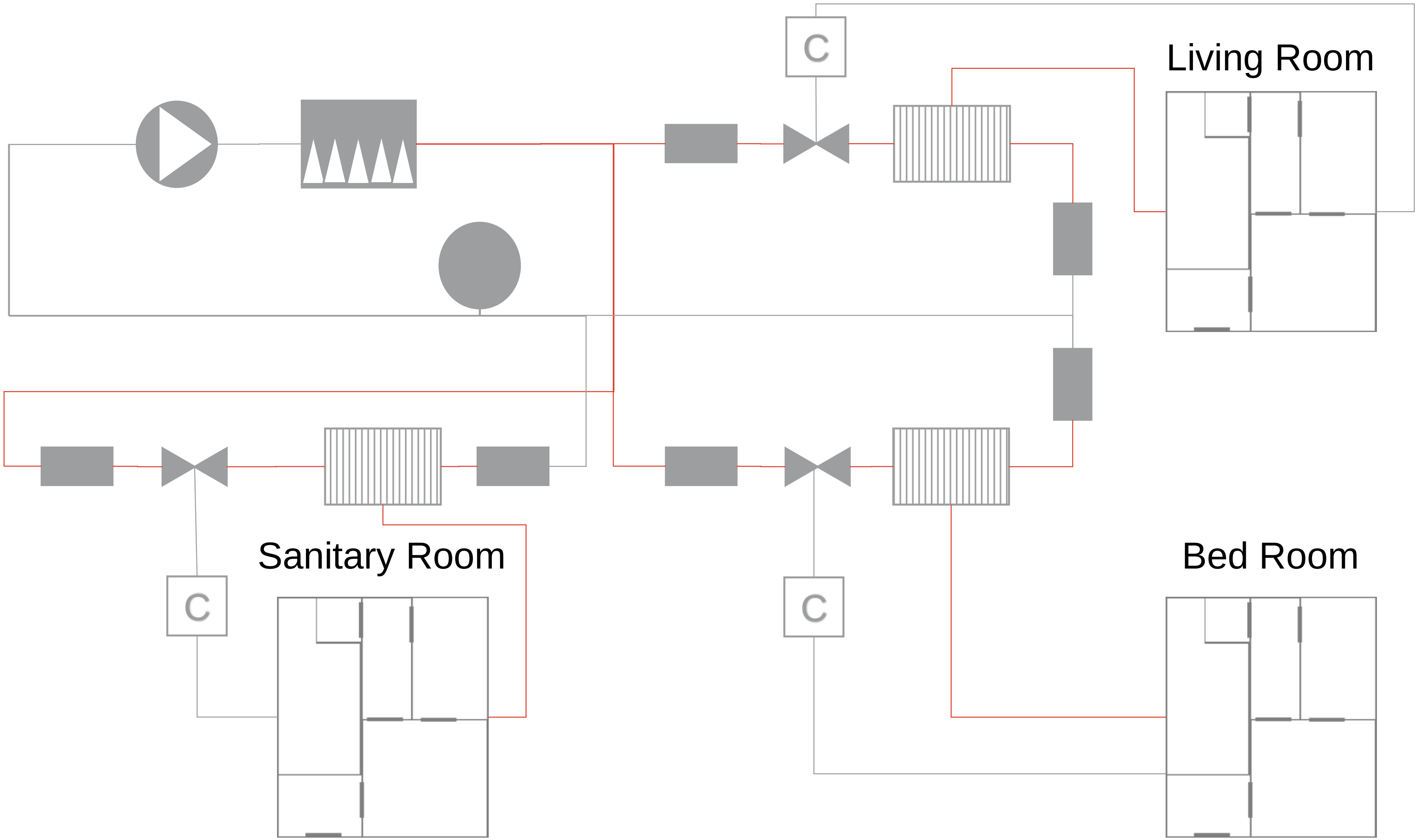

2. Change the control strategy to include night setback

3. Change the control strategy to be occupancy-dependent

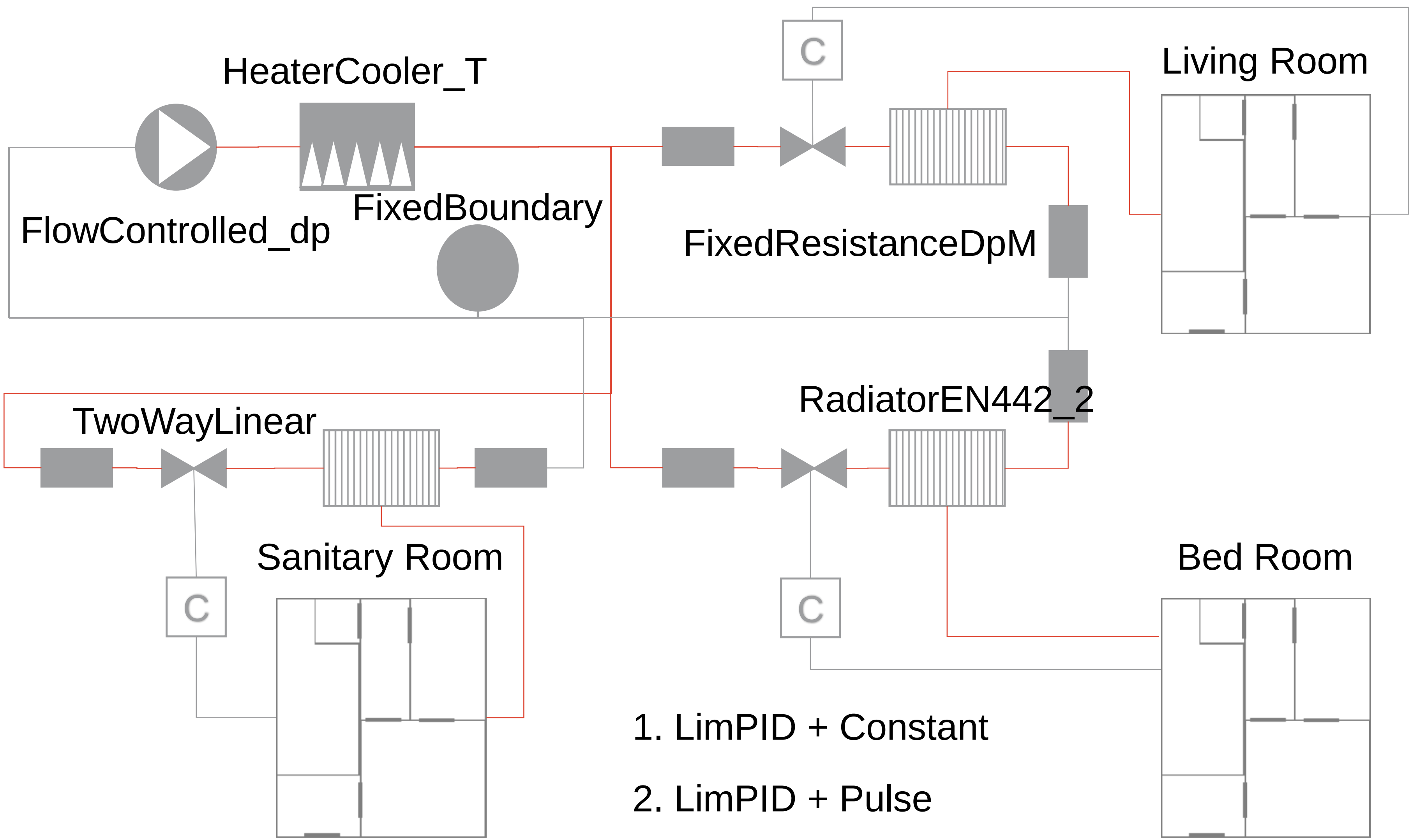
# Parameter Settings

- Medium:
  - Simple water, e.g. Modelica.Media.Water.ConstantPropertyLiquidWater
  - Pressure drops: 100 Pa
- Radiators:
  - Nominal flow temperature: 65 °C
  - Nominal return temperature: 50 °C
- Heat loads
  - Living room: 92028 W
  - Bed room: 70870 W
  - Sanitary room: 13040 W
  - Set temperatures: 20 °C
- Volume flows:
  - Living room circuit: 1.4 kg/s
  - Bed room circuit: 1.12 kg/s
  - Sanitary room circuit: 0.2 kg/s
- Night setback: 15 °C, 10 PM - 6 AM, Occupancy: 15 °C if nobody in the room

# Schema



# Models




1. LimPID + Constant
2. LimPID + Pulse
3. LimPID + Switch + 2*Constant

**Want to check your model?**

Here are some exemplary implementations:

**2016-10-24-gensim\tuesday\BuildingAndHVAC\Models**

# Setting up the Pulse

**Component**

Name: y

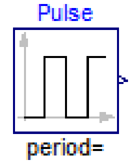
Comment: Input signal

**Model**

Path: Modelica.Blocks.Sources.Pulse

Comment: Generate pulse signal of type Real

**Icon**




**Parameters**

| | | | | |
|---|---|---|---|---|
| amplitude | 5 | | Amplitude of pulse | Minimum temperature + Amplitude = Max. temperature |
| width | 67 | | Width of pulse in % of period | Length of max. temperature (16 hours/ 24 hours) |
| period | 86400 | s | Time for one period | Repeating time (24 hours) |
| nperiod | -1 | | Number of periods (< 0 means infinite number of periods) | |
| offset | 273.15 + 15 | | Offset of output signals | Minimum temperature |
| startTime | 21600 | s | Output = offset for time < startTime | Start of the first max. temperature (6 AM) |

# Results

- Area: 581 m²
- kWh = Joule/(3600*1000)
  - Use Integrator to get the annual heat load in Joule
  - Set gain of integrator to 1/(3600*1000) to get kWh

- A1_NorthBoiler:
  - Annual heat load: 34158.4 kWh
  - Annual heat load per sqm: 58.8 kWh/m2a
- A1_NightSetback:
  - Annual heat load: 33692.5 kWh
  - Annual heat load per sqm: 58 kWh/m2a
- A1_Occupancy:
  - Annual heat load: 32289.5 kWh
  - Annual heat load per sqm: 55.6 kWh/m2a

https://github.com/RWTH-EBC/TEASER

https://github.com/RWTH-EBC/AixLib

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