CityGML Energy ADE – 3D City Models for Energy Simulation on Urban Scale

Prof. Dr. Volker Coors
Tutorial: 3D GeoInfo 2015, Kuala Lumpur, Malaysia, 27.10.2015

2015: 150Years Education in Geodesy at HFT Stuttgart

HFT Stuttgart

Facts and Figures

- 3.900 students
- More than 125 professors
- More than 400 lecturers from industry and economy

- 14 Bachelor programmes
- 14 Master programmes, also part-time

- My research group on Geoinformatics
    - 10 Researcher
    - Focus on 3D Spatial Data Infrastructures and
    - Geovisulasation

Marie Curie Initial Training Network

Funding: €3.7M EU FP7-PEOPLE-2013-ITN
Duration: 48 months
Grant Agreement: No. 606851
Coordinator: HFT Stuttgart

GOAL: interdisciplinary PhD Program training young scientists in urban decision-making and operational optimisation software tools to minimise non-renewable energy use in cities

CINERGY

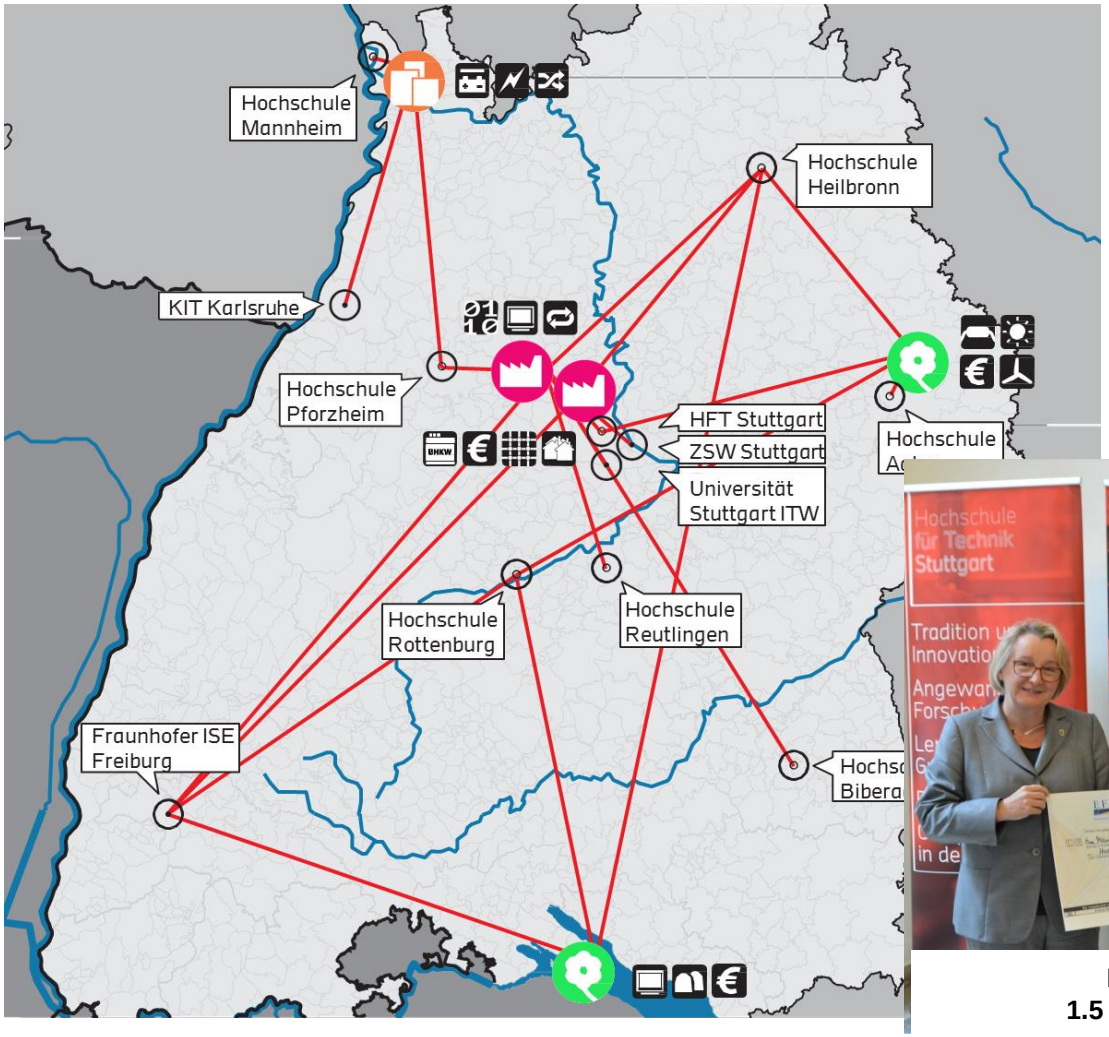
Fellows: 11 Early Stage Researchers representing 6 European countries, Russia, India and China

Co-funded by the Intelligent Energy Europe Programme of the European Union

Hochschule für Technik Stuttgart

ENsource (Coordinator)

Center for Applied Research on sustainable Urban Energy Systems



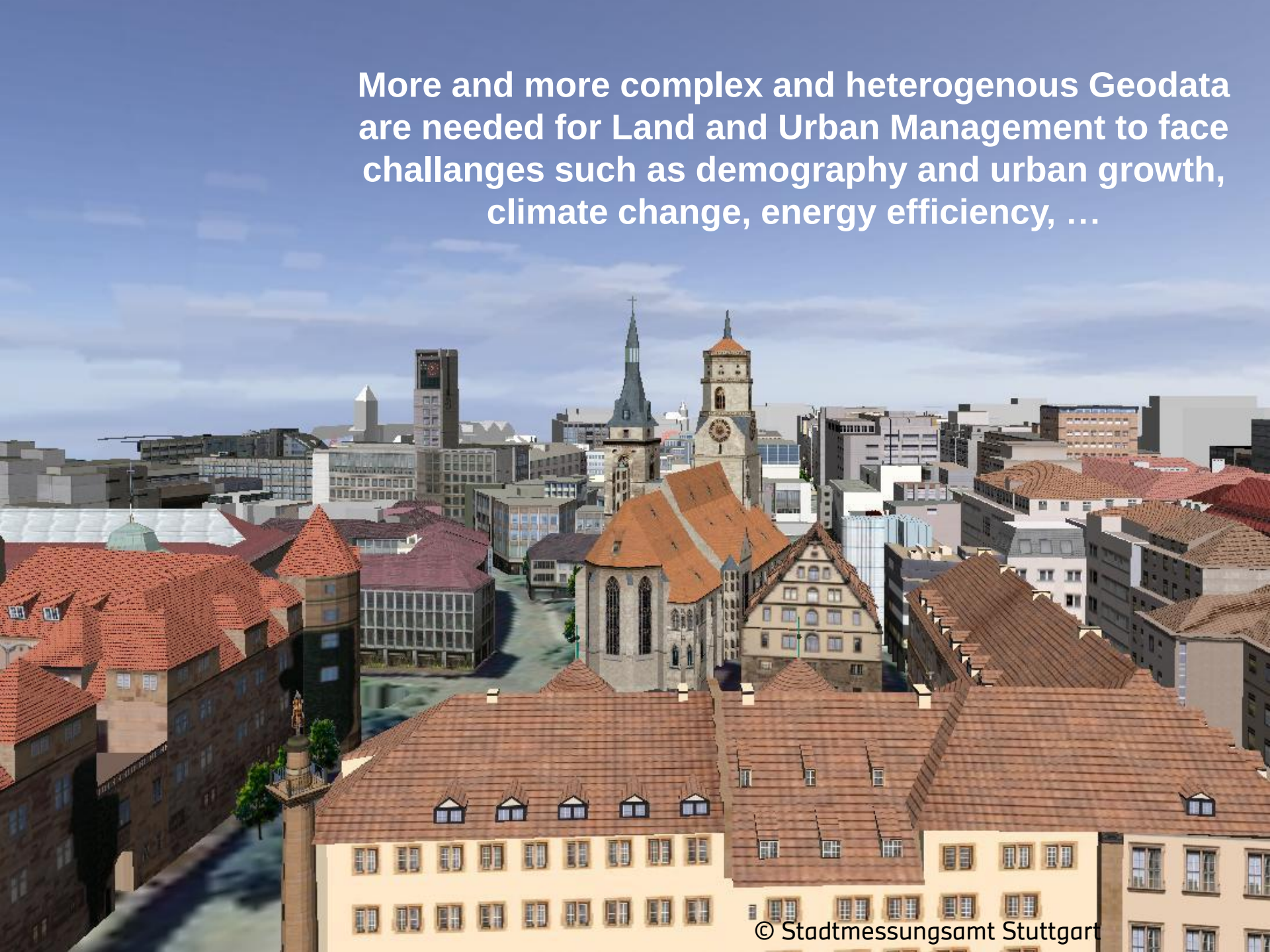
Minister Bauer gives grant to ENsource
1.5 Million Euro funding for 3 years (15.9.2015)

Future Cities

Quelle: ZEIT 02/2014

Paris 2050
© Vincent Callebaut

More and more complex and heterogenous Geodata are needed for Land and Urban Management to face challanges such as demography and urban growth, climate change, energy efficiency, …



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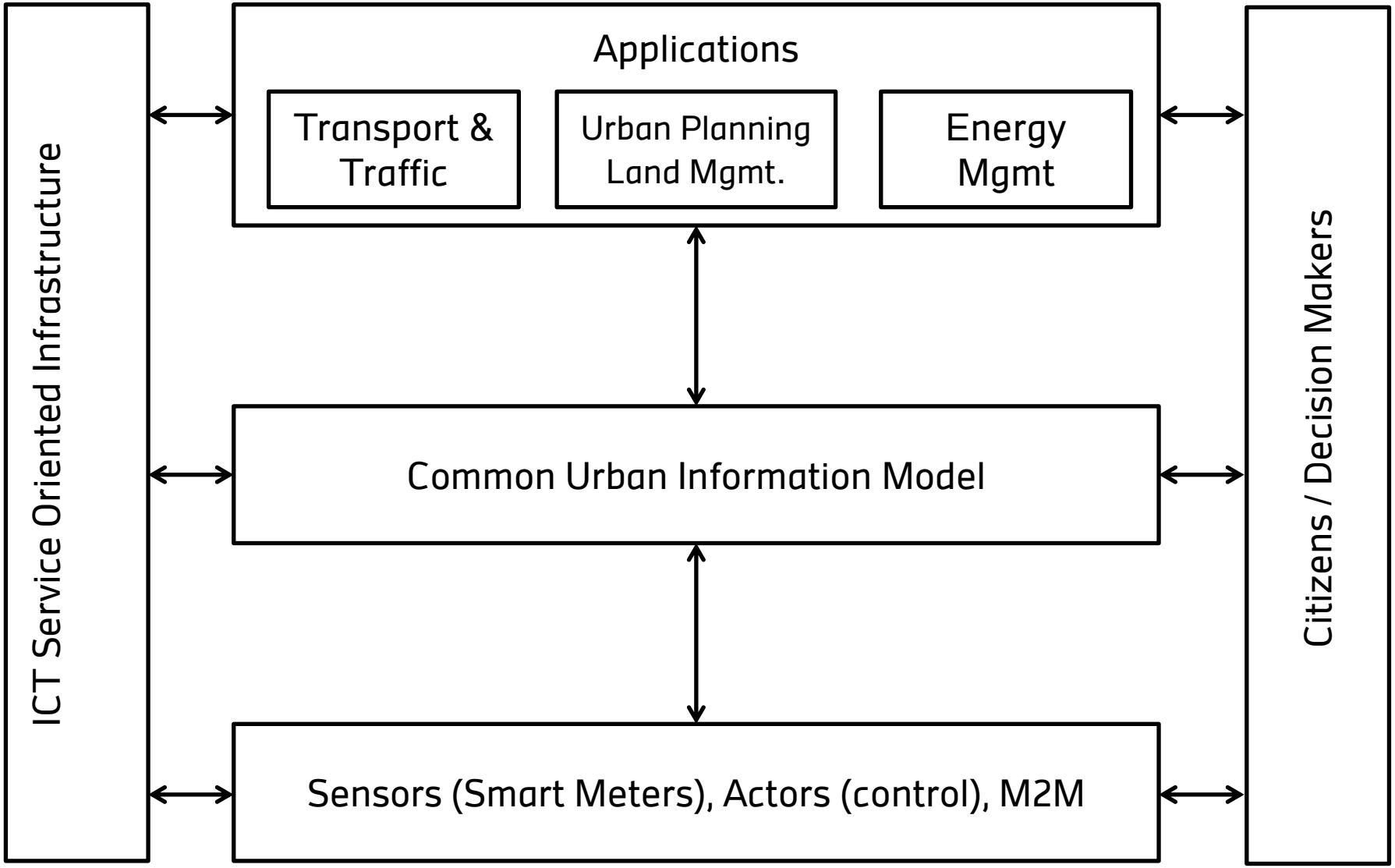
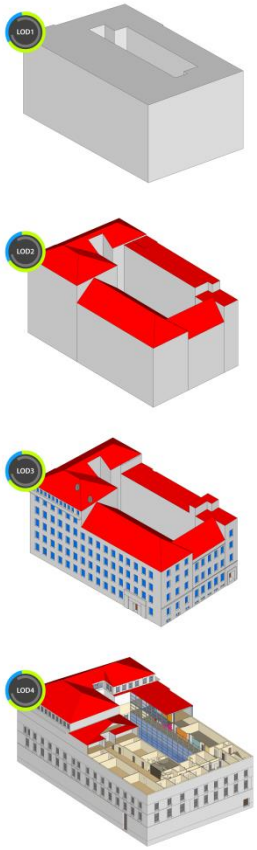
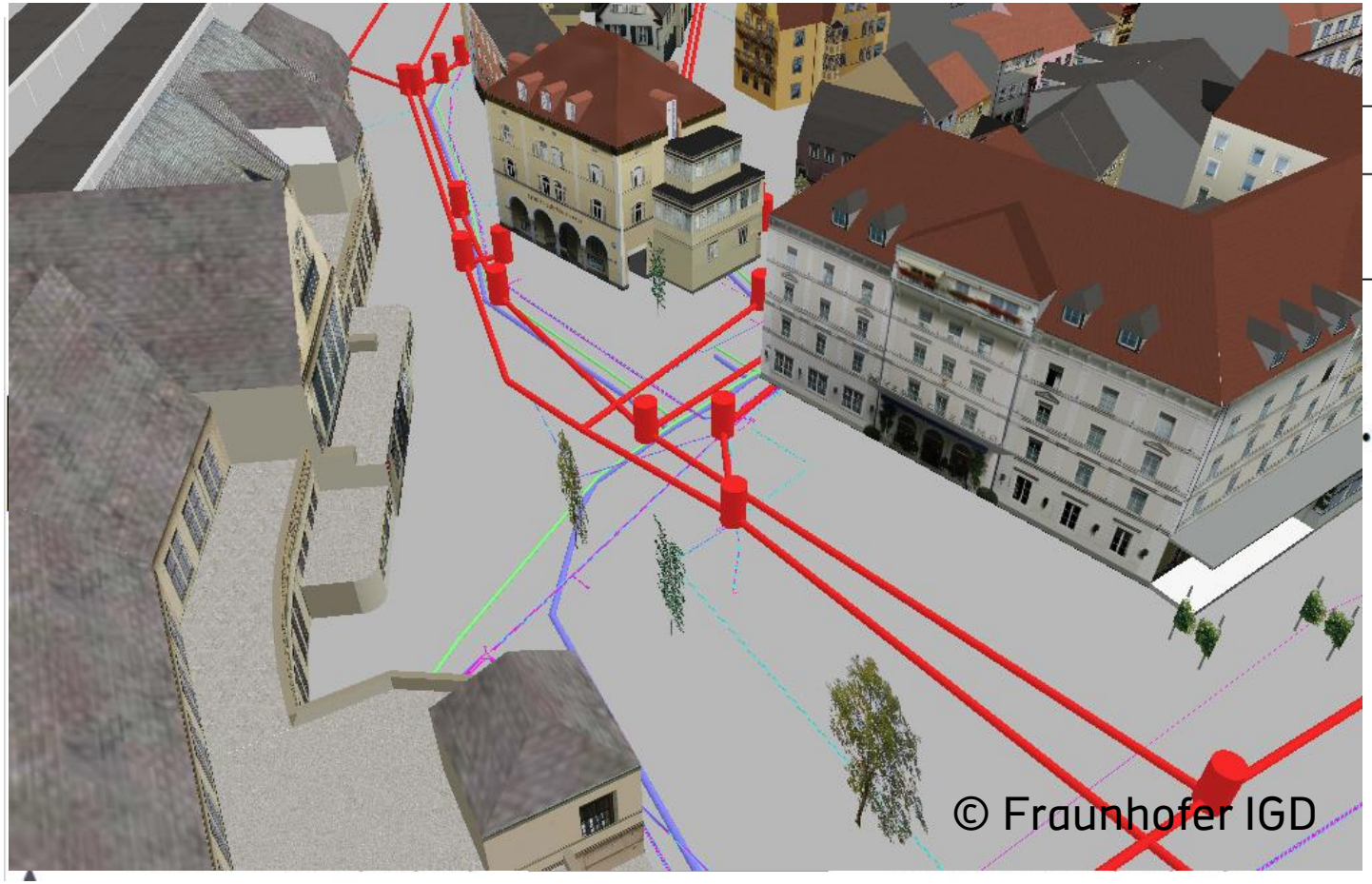
Our Contribution



CityGML





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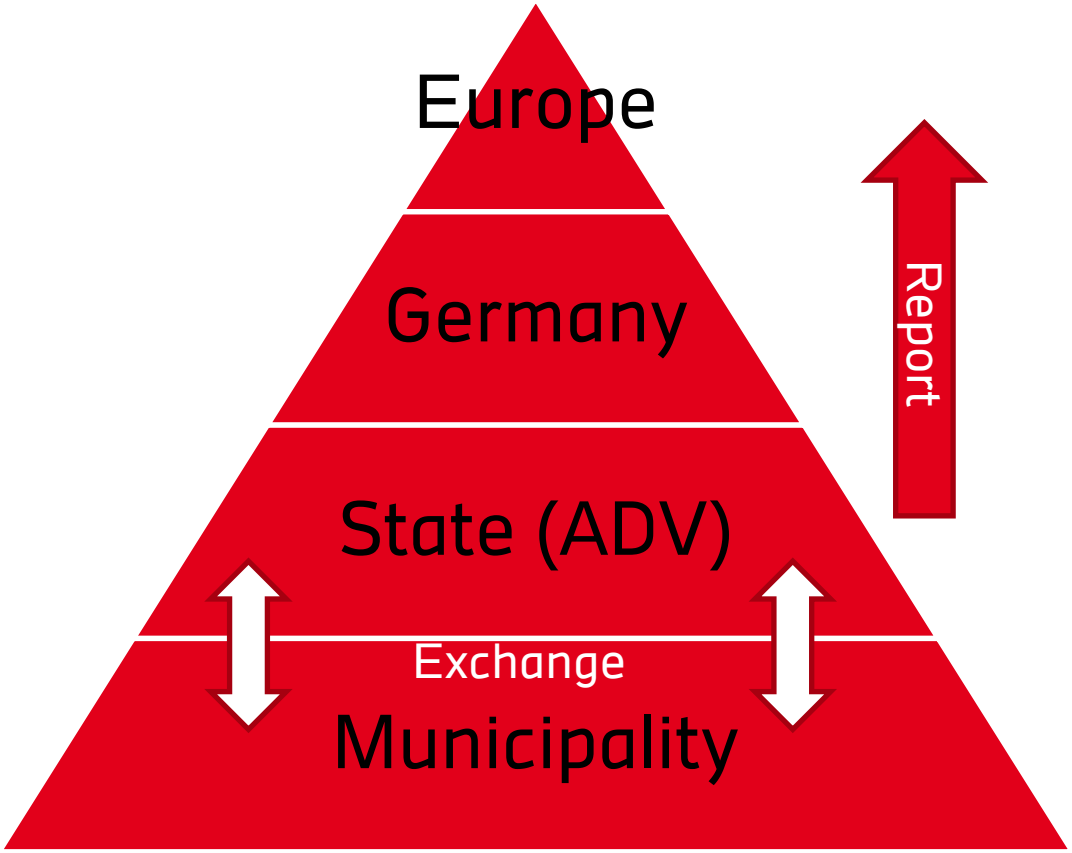
3D City Models



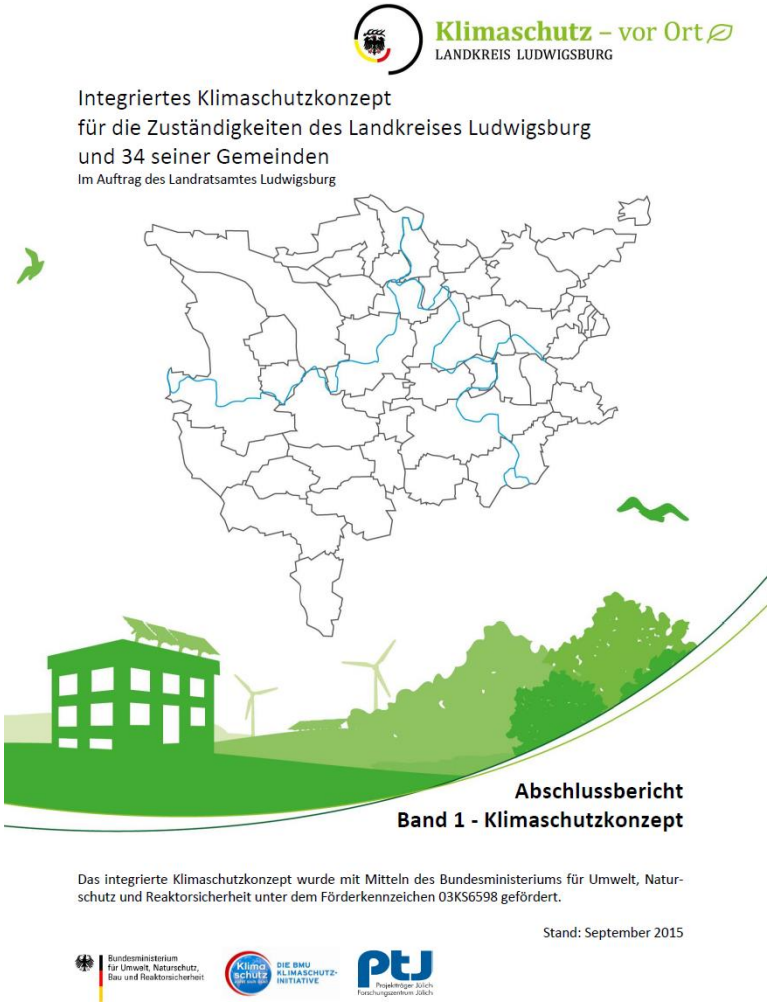
INSPIRE building model
(CityGML INSPIRE ADE)

CityGML ADV profile

CityGML ADV profile

CityGML
SIG3D Modelling Guide

Climate protection


Klimaschutz – vor Ort
LANDKREIS LUDWIGSBURG

Integriertes Klimaschutzkonzept
für die Zuständigkeiten des Landkreises Ludwigsburg
und 34 seiner Gemeinden
Im Auftrag des Landratsamtes Ludwigsburg

Abschlussbericht
Band 1 - Klimaschutzkonzept

Das integrierte Klimaschutzkonzept wurde mit Mitteln des Bundesministeriums für Umwelt, Naturschutz und Reaktorsicherheit unter dem Förderkennzeichen 03KS6598 gefördert.

Stand: September 2015

Our contribution:

- Heat demand simulation (monthly energy balance)
- PV potential simulation
- Refurbishment scenarii simulation

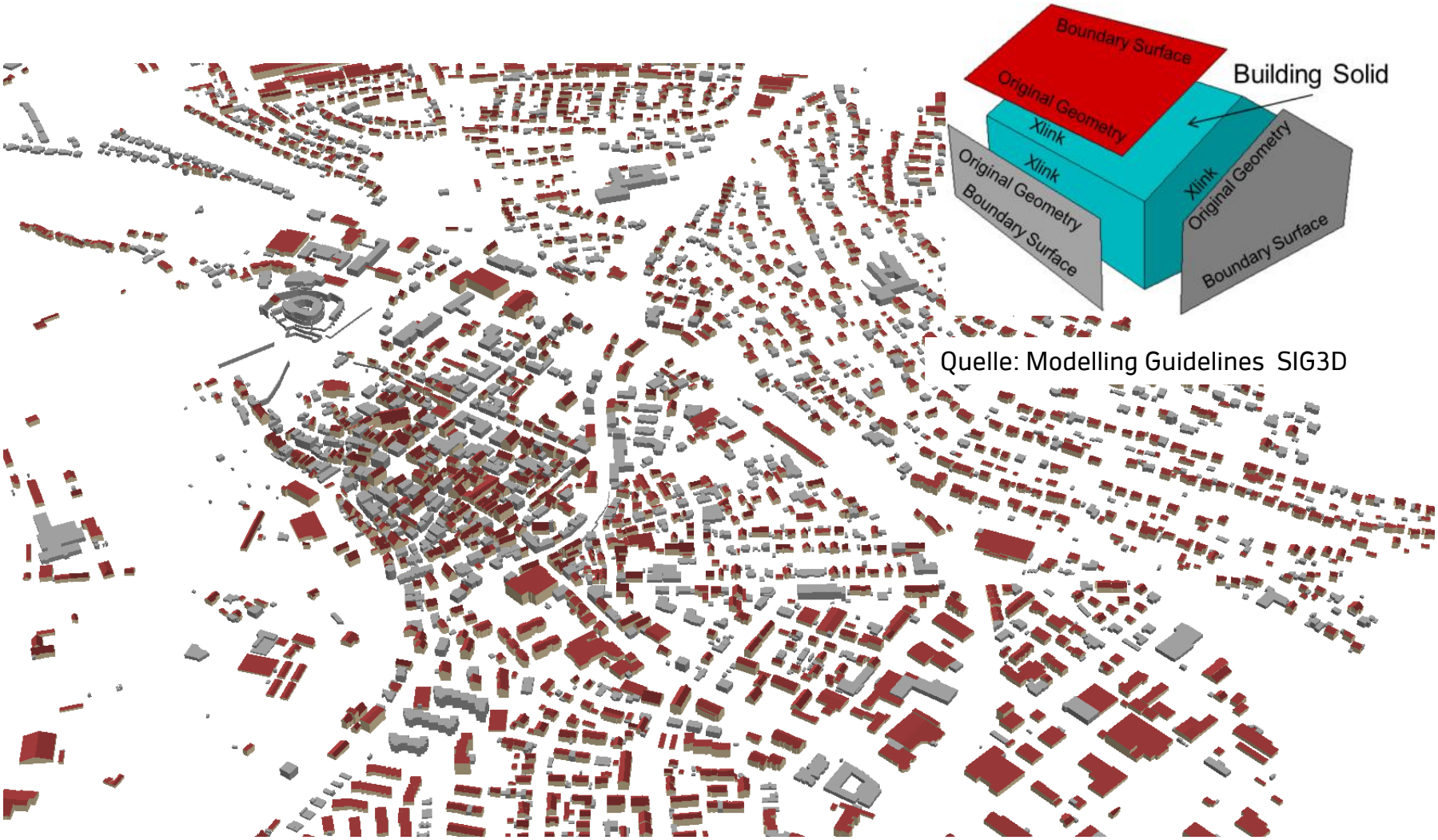
- Based on CityGML LOD2 building model

DREES & SOMMER

Hochschule für Technik Stuttgart

LEA LUDWIGSBURGER ENERGIEAGENTUR

ENERGETIKOM ENERGIEKOMPETENZ UND ÖKODESIGN E.V.

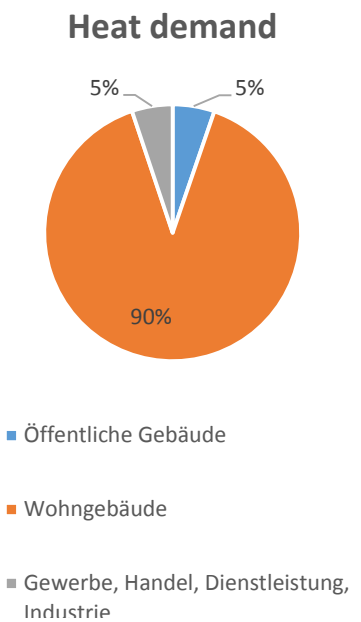


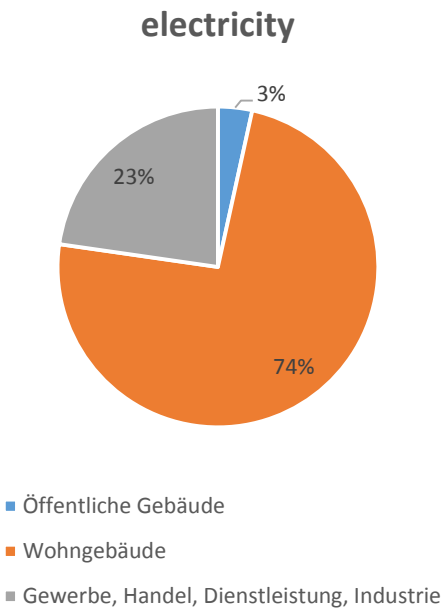
Quelle: Modelling Guidelines SIG3D

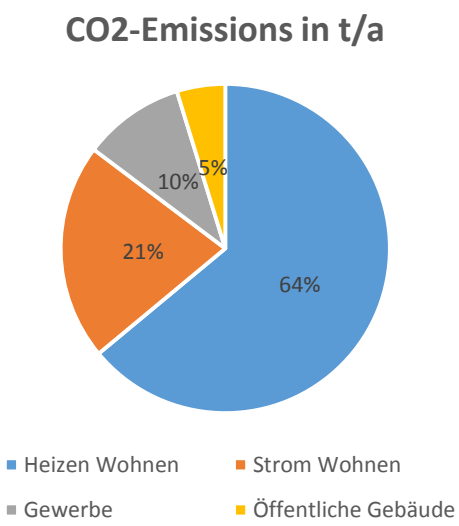
© Landesamt für Geoinformation und Landentwicklung BW

Results: Heat demand

Results (example)







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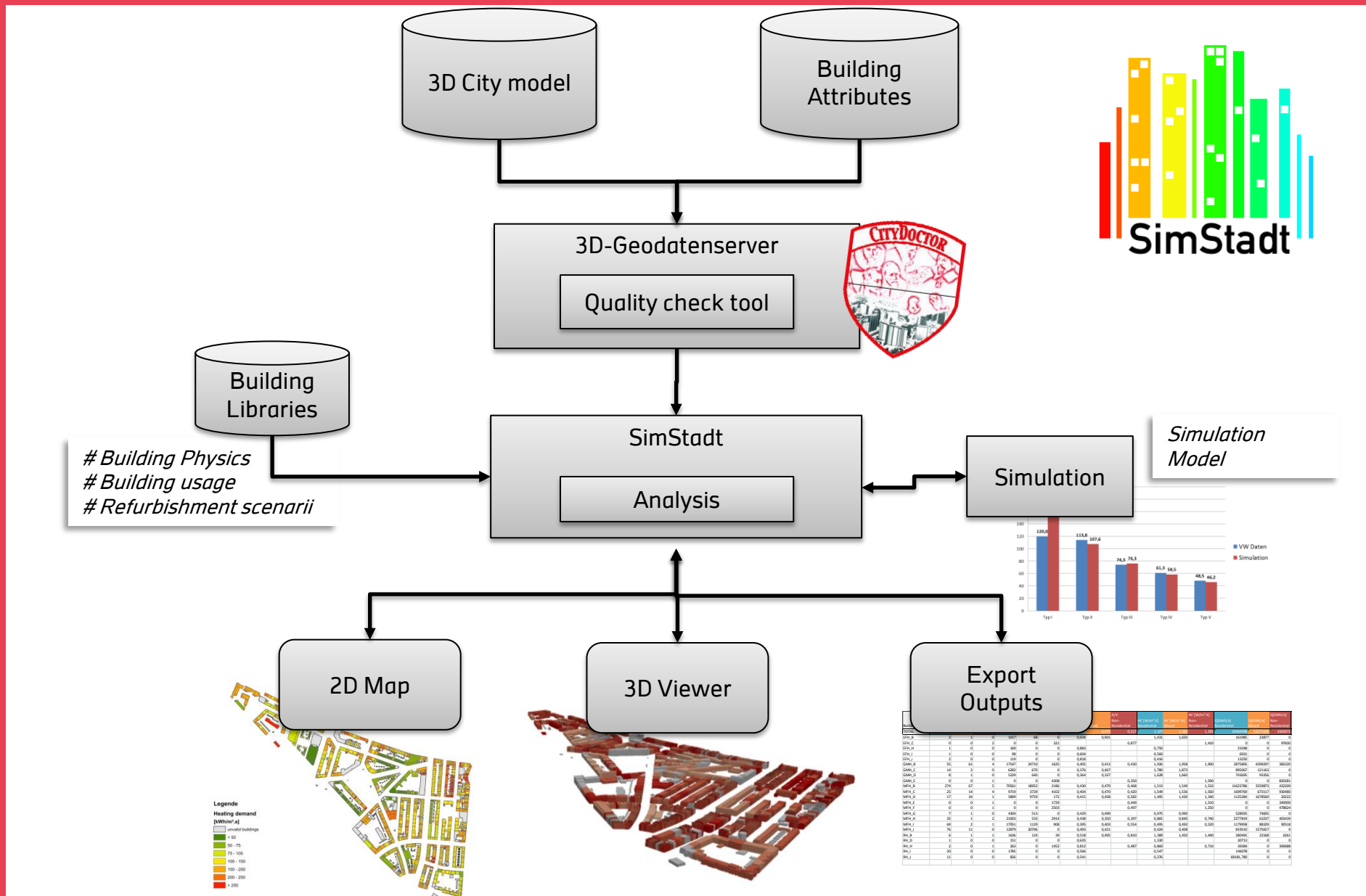
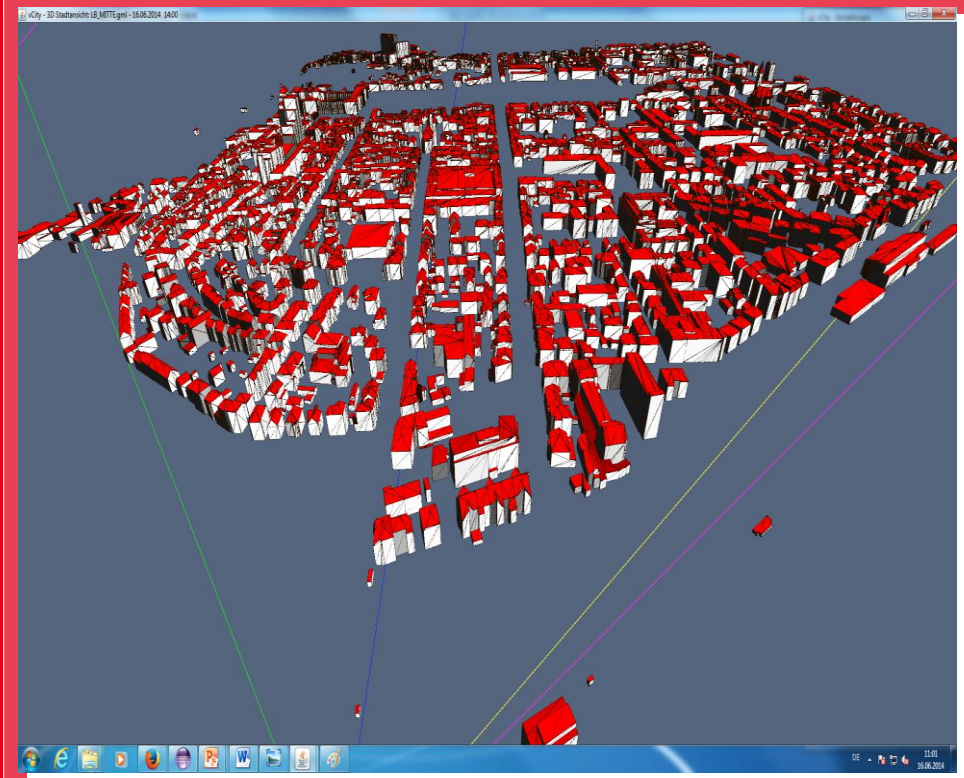
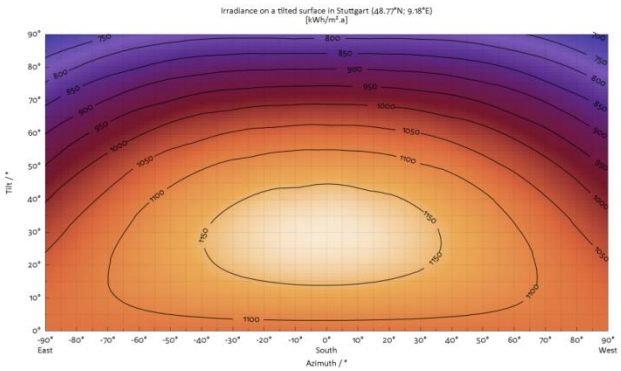
SimStadt: Urban Simulation Platform



PV / Solarthermal: Irradiance + Shadow





Shadow per Surface for an entire year

LoD2-Modell Ludwigsburg, 2200 Buidlings
Resolution 5 m², ~ 850 000 Triangles
10 Minutes computation time

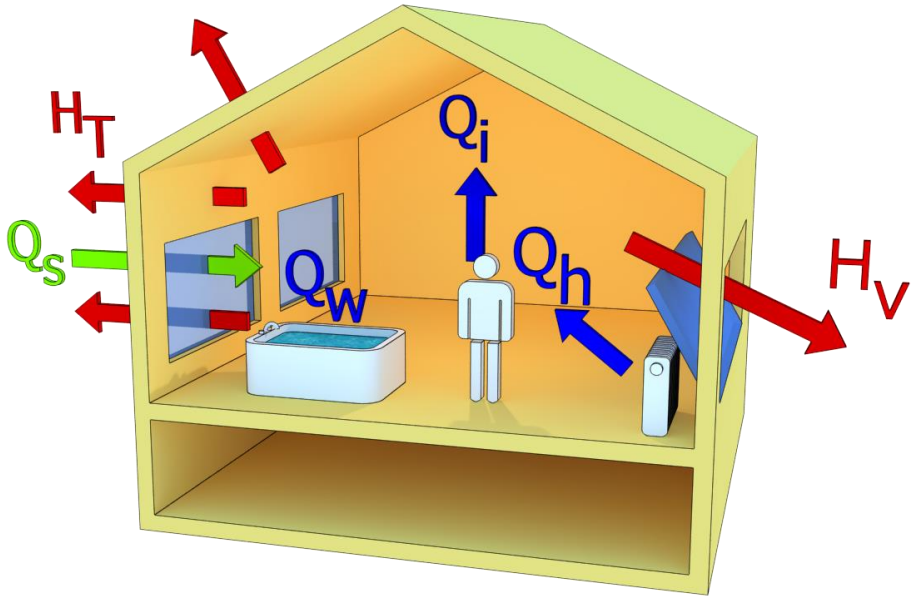
Resolution 0.75 m², ~ 5 300 000 Triangles
40 Minutes computation time

GPU NVIDA, 3072 CUDA Kernel 4 GB RAM

Heating demand: monthly energy balance

- Q_h heating demand
- Q_w hot water heating demand
- Q_s solar gains
- Q_i internal gains

- H_T transmission heat loss
- H_V ventilation losses



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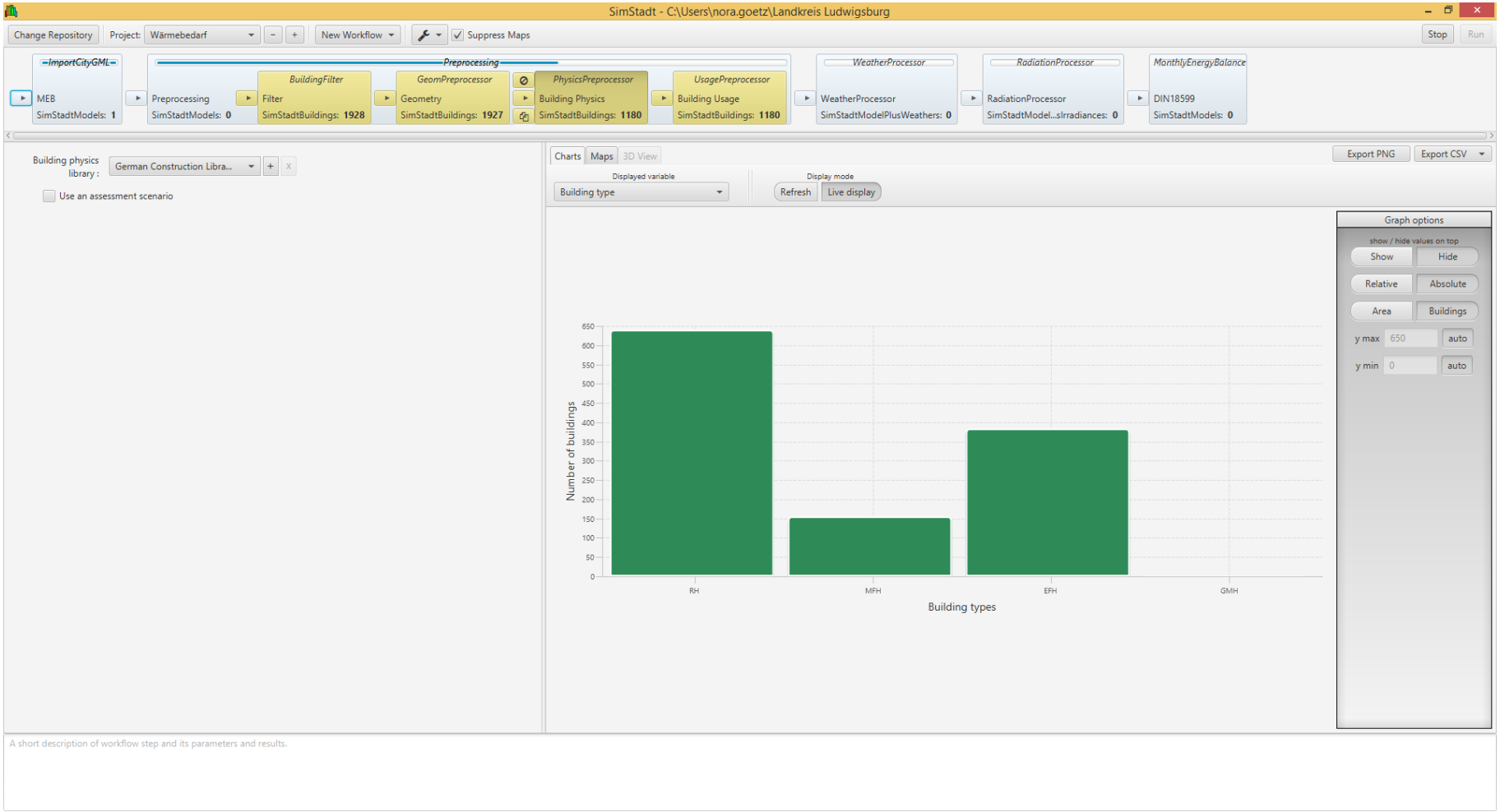
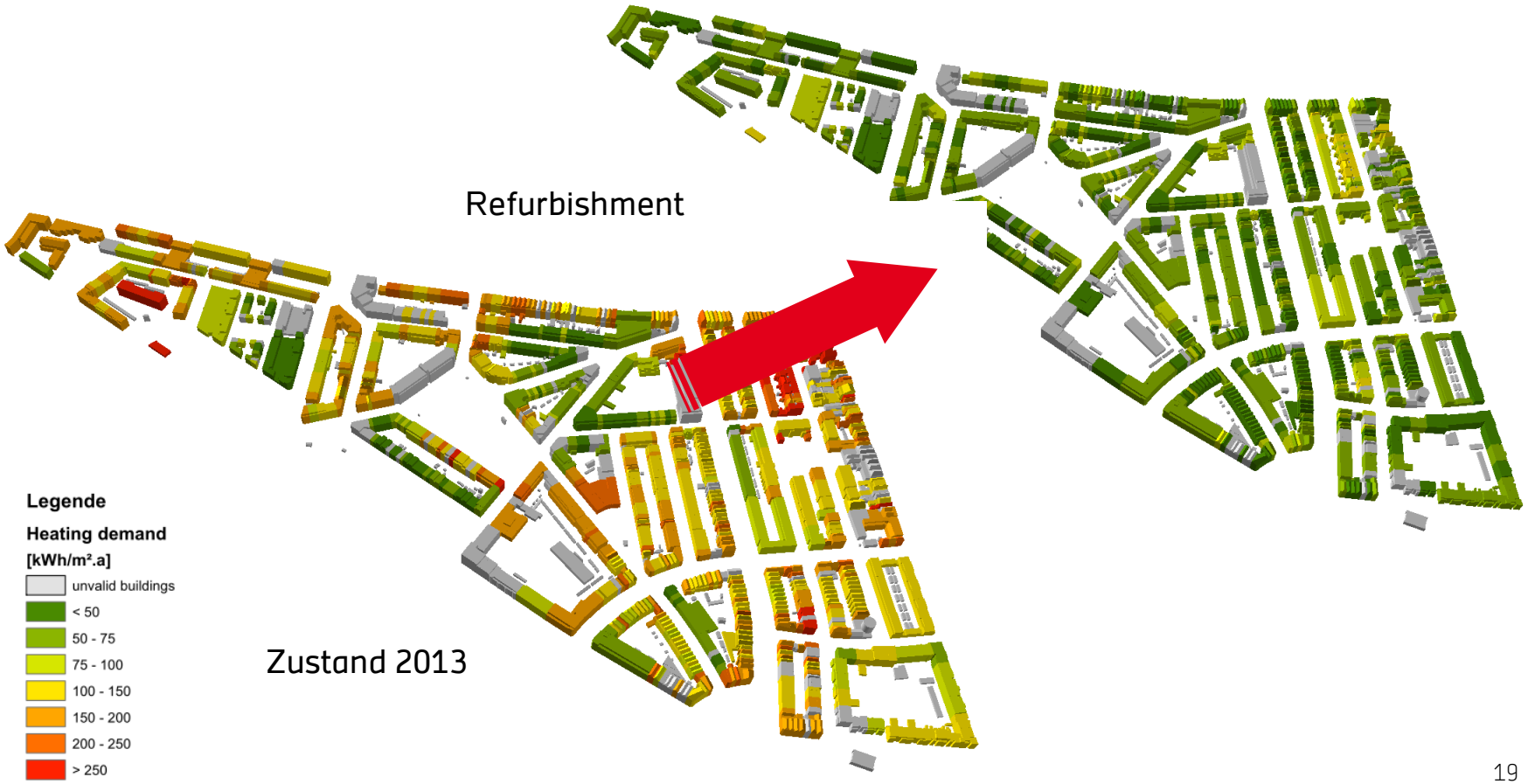
SimStadt: Heat Demand



Scenatio: Refurbishment

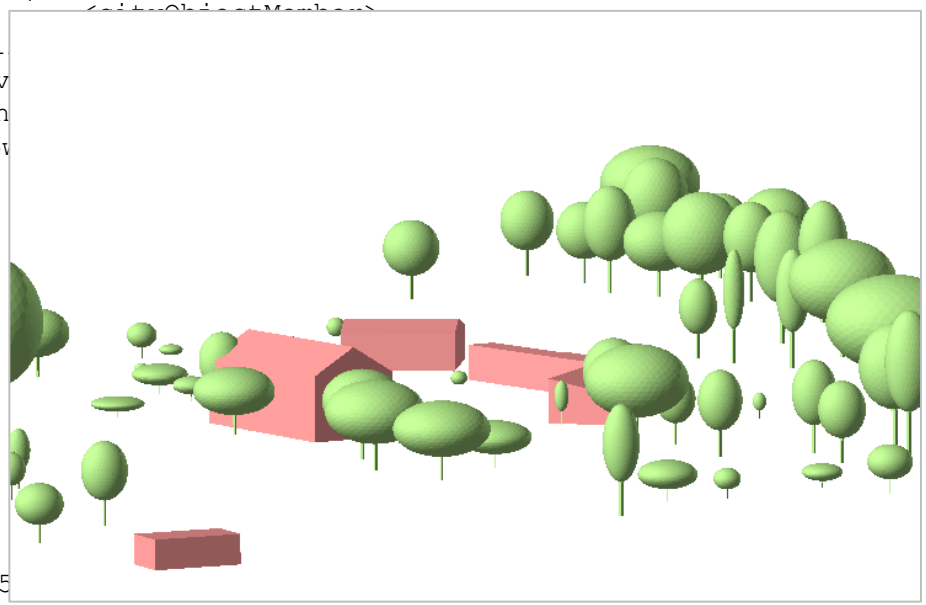


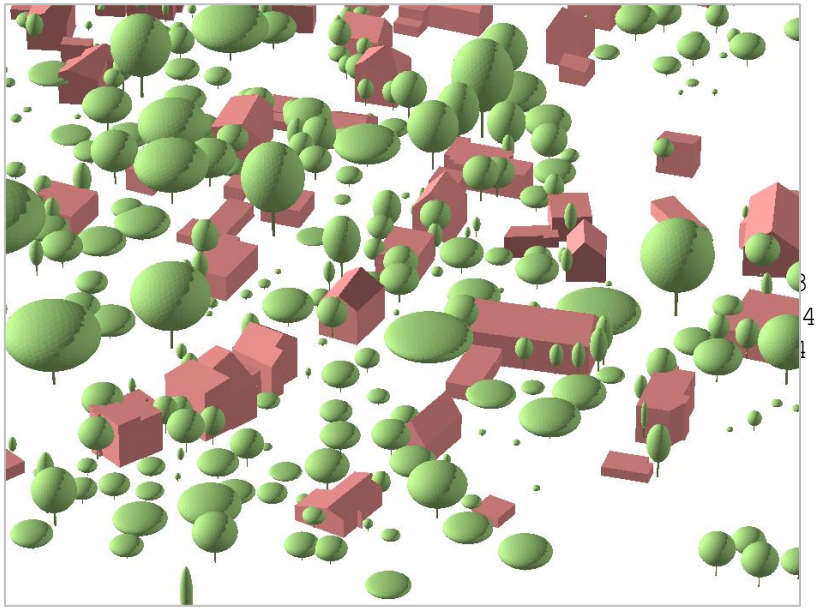
Vegetation

Geobasisdaten © Landesamt für Geoinformation und Landentwicklung Baden-Württemberg, www.lgl-bw.de

Quelle: BLP Agro Software GmbH

Verschattungsobjekte





```
<veg:Sol
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                                                         <gml:surfaceMember>
                                                       …
                                              </CityModel>
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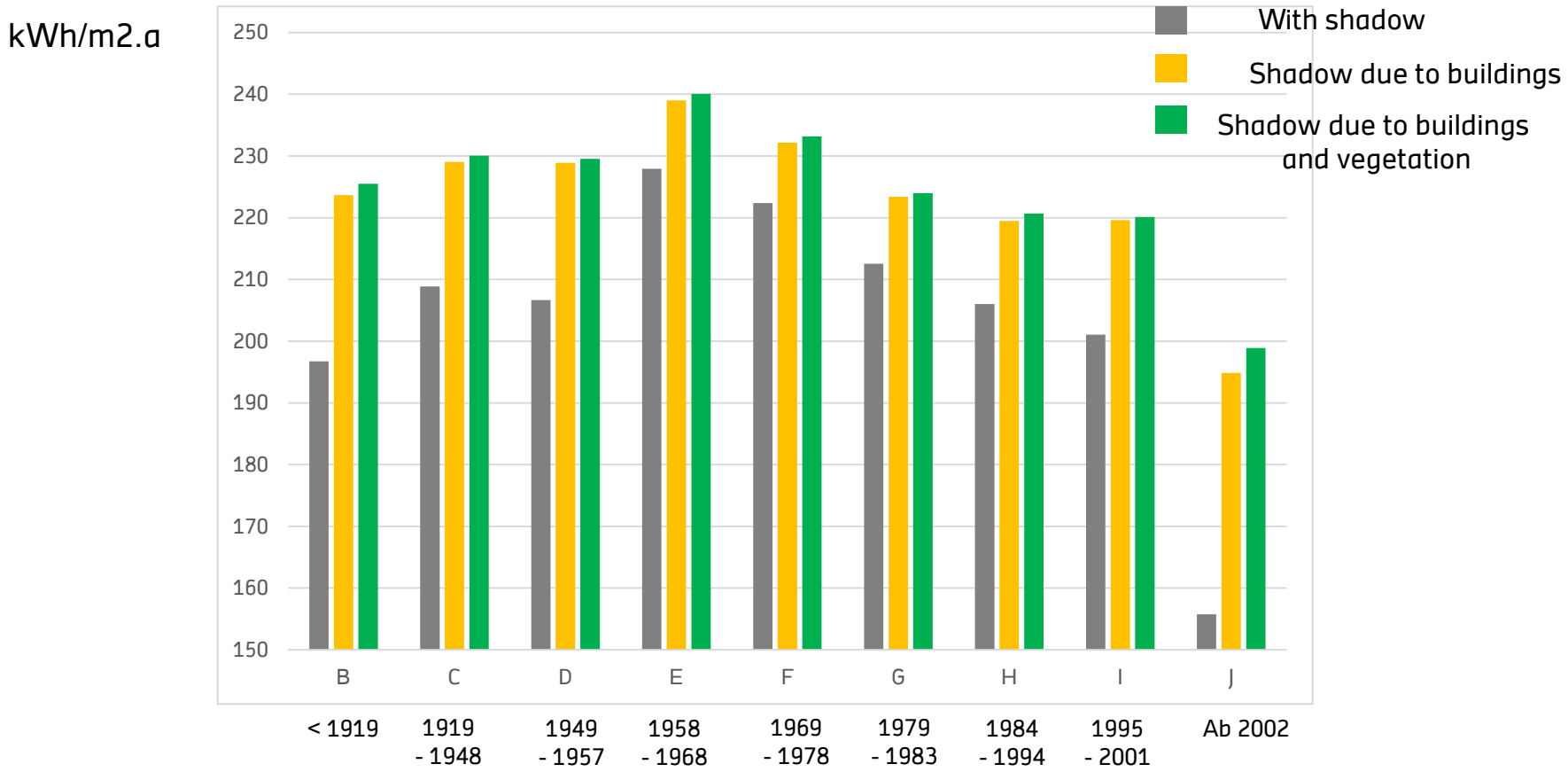
Experimental: impact of Vegetation

Heat demand (monthly energy balance)



Mean heat demand per year of construction

EnViSaGe

Gefördert durch:

Bundesministerium für Wirtschaft und Technologie

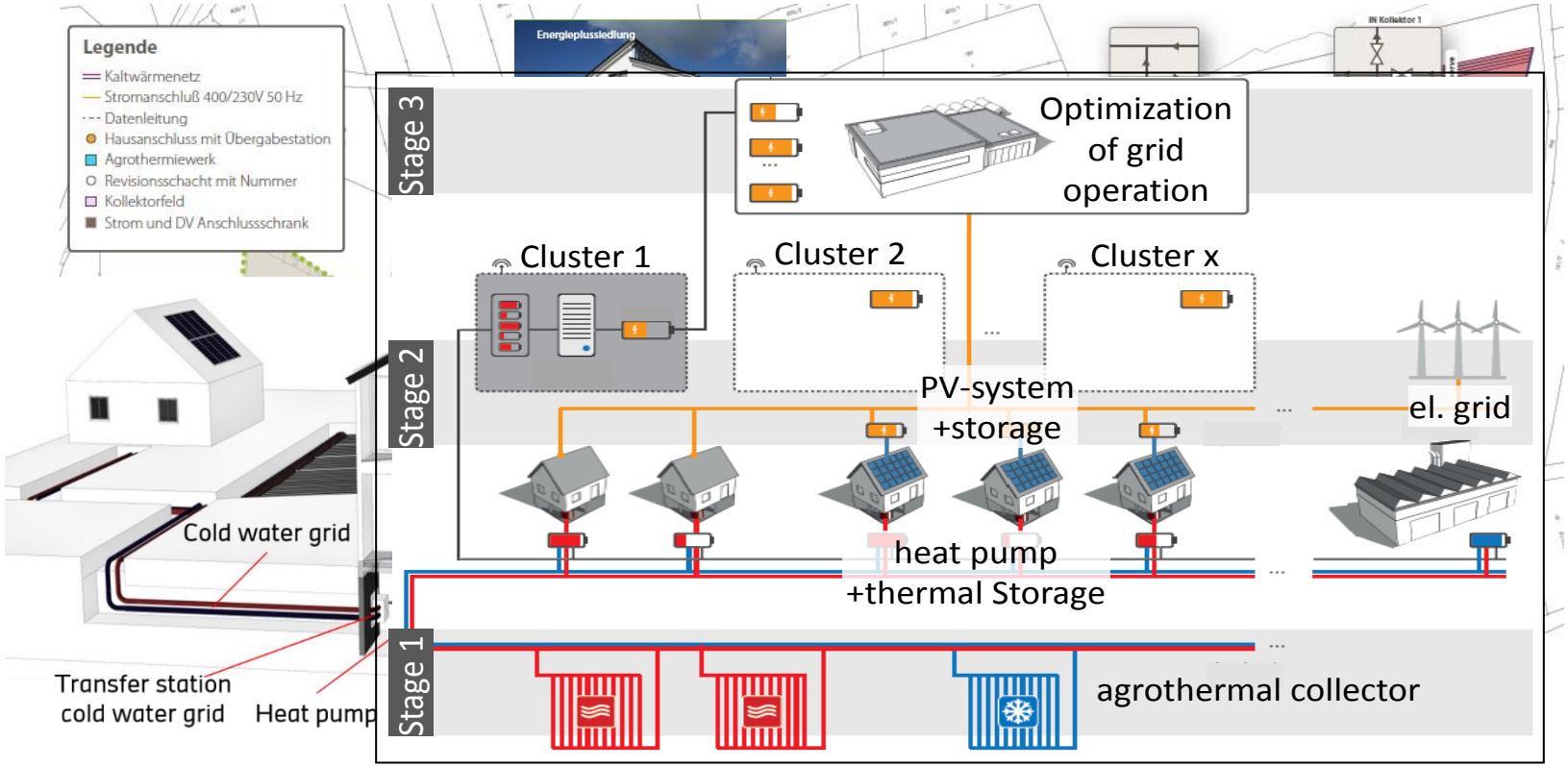
aufgrund eines Beschlusses des Deutschen Bundestages

EnViSaGe - Kommunale netzgebundene Energieversorgung - Vision 2020 am Beispiel der Gemeinde Wüstenrot

...die Wohl-Fühl-Gemeinde Wüstenrot ... mitten im Naturpark

- Wüstenrot aims to become Plus-Energy Community in 2020
- Renewables: PV, Solartheramal, geothermal, biomass
- District Heating Network

Use case: Plus-Energy District



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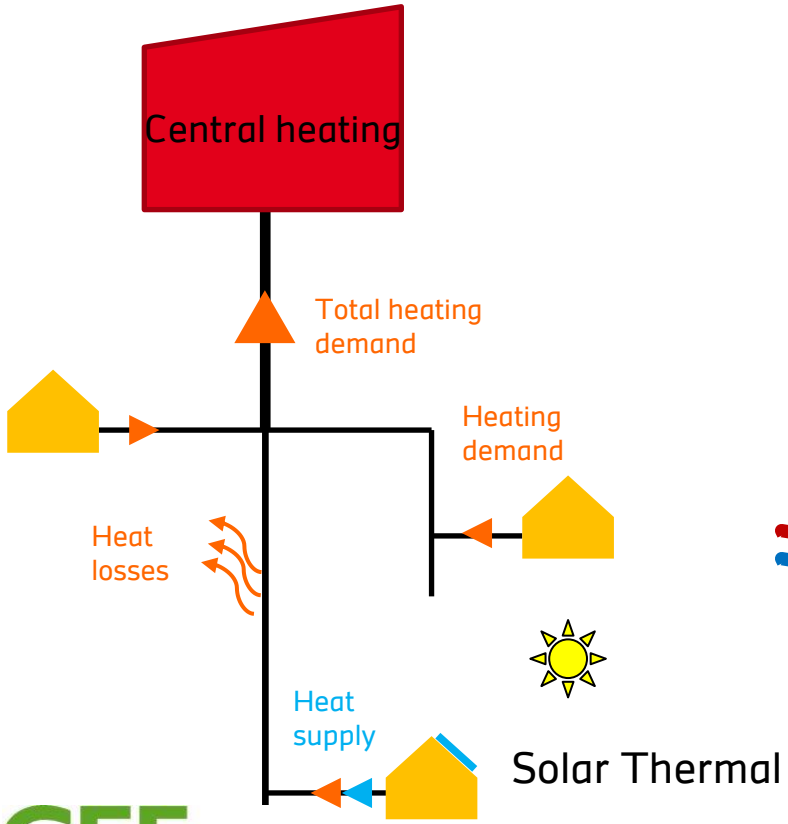
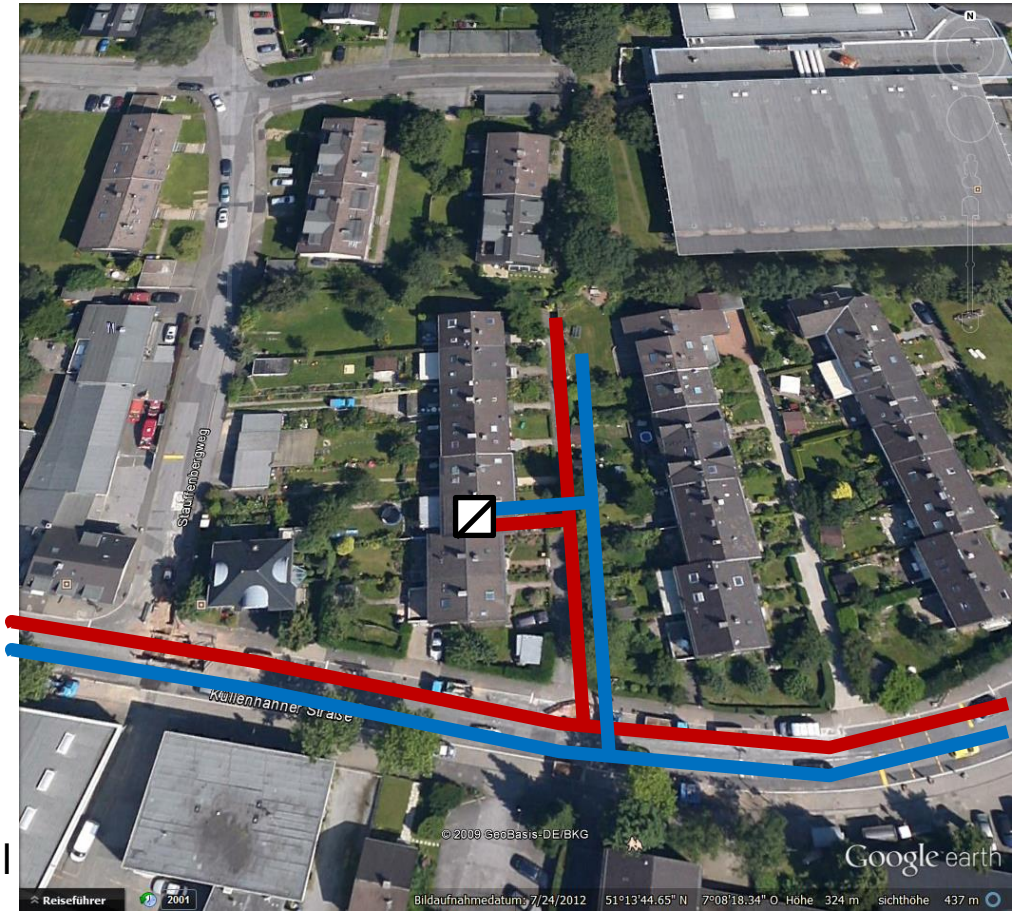
District Heating Network





GEF Ingenieur AG

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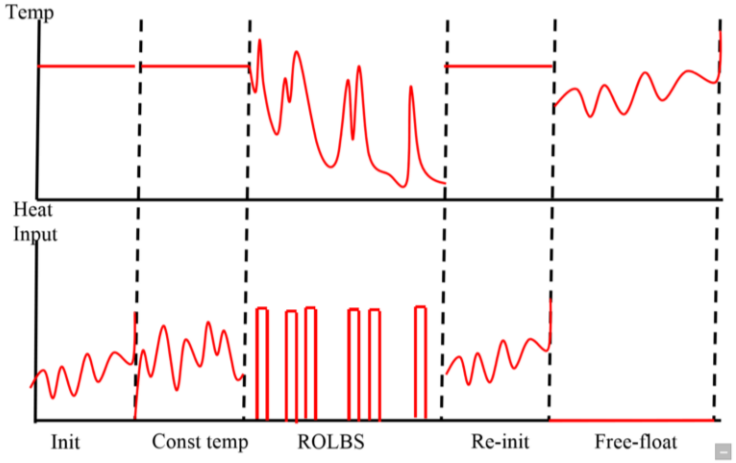
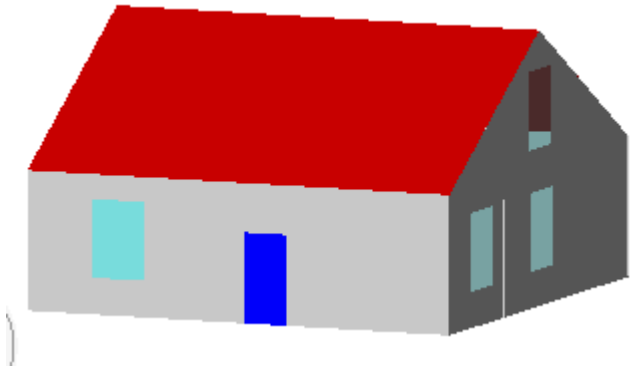
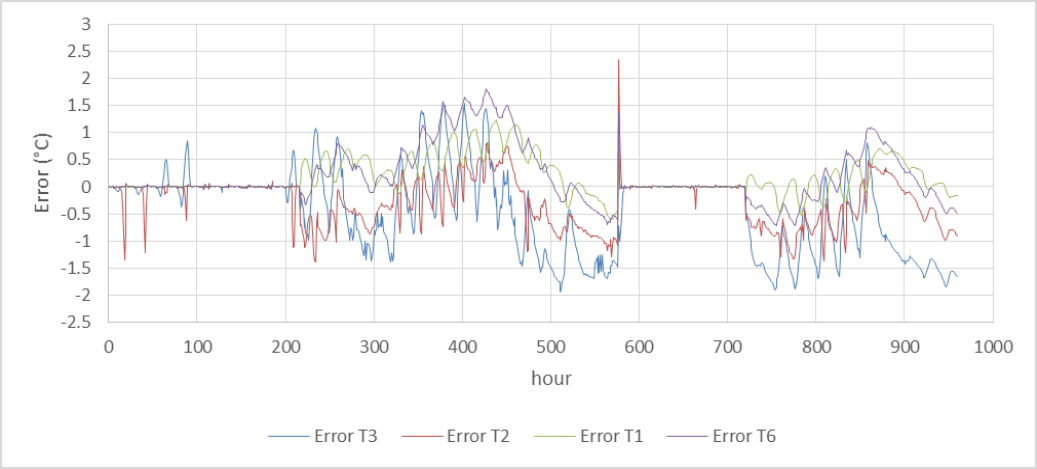
Dynamic Building Simulation (work in progress)

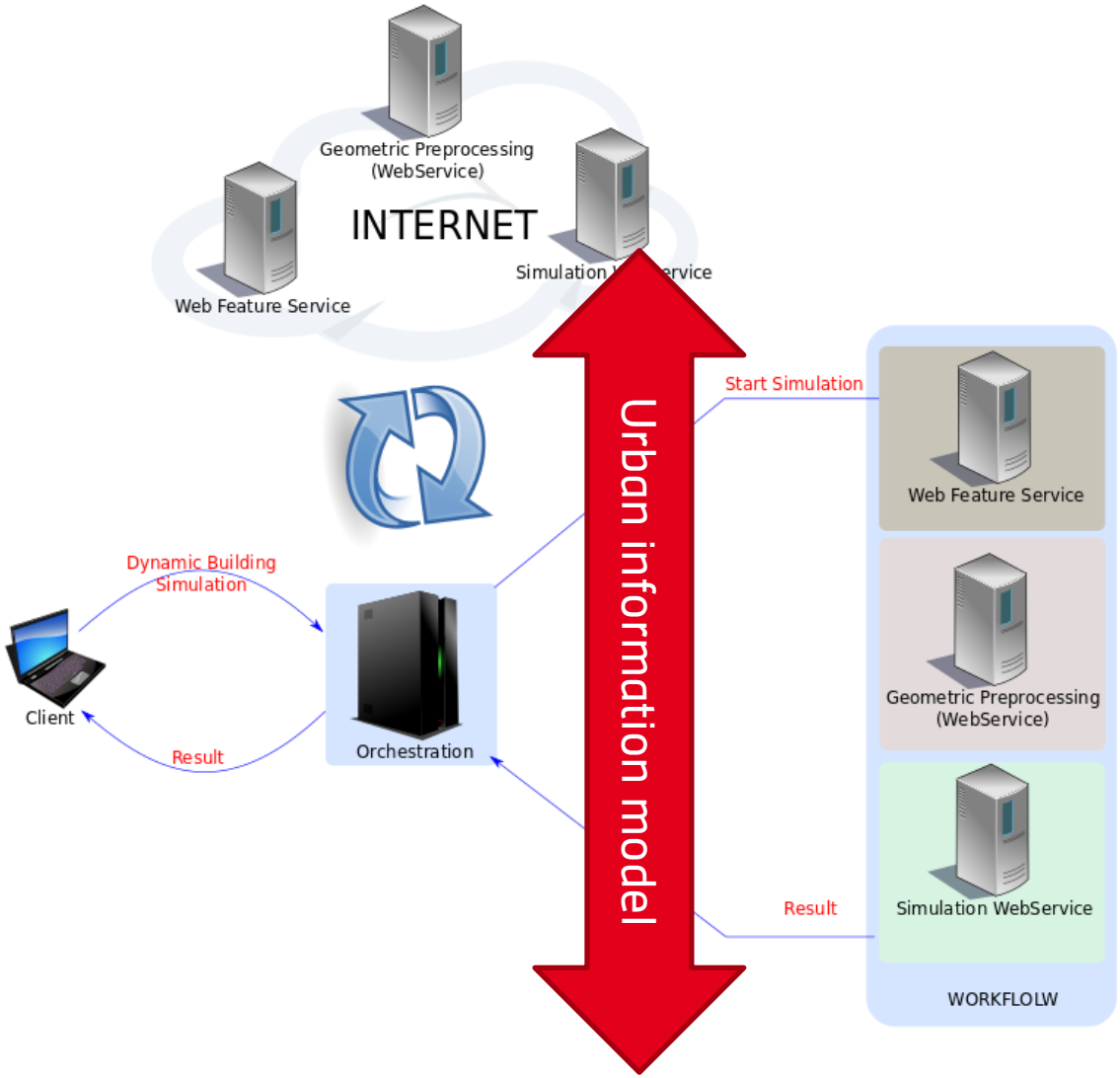






Pilar Monsalvete Álvarez de Uribarri / Claudia Schulte

Experimental: Simulation as a Service



Deegree WFS
+ 3D CityDB

SimStadt
Workflow Step

INSEL
Simulation

Hochschule für Technik Stuttgart

Development of the CityGML ADE Energy

contributions:
Jean-Marie Bahu – EIFER
Romain Nouvel, Claudia Schulte, Marcel Bruse – HFT Stuttgart

Starting Point

- No widely applicable open model standard exists until now for Urban Energy Modelling (like IFC or gbXML for buildings)

- CityGML, open standard for exchanging 3D urban data, doesn't contain any **energy-related objects or attributes.**
- CityGML is **extensible** through **ADEs**.

- Urban energy tool developers (CitySim, UMI) have developed their **own tailor-made urban information model**

Our Objectives

- Store relevant energy-related data in a common open city data model
- …to offer **data exchange** and **interoperability** possibilities between urban energy stakeholders and tools
- …as well as with other expert fields (acoustics, statics). Combine data collection effort!

➢ **Energy ADE for CityGML**

Stakes

- **Flexibility**: Following the philosophy of CityGML and its Levels of Detail (LoDs)

- **Compatibility:** Allowing to be used in different urban energy platforms for different analysis methods, using data from different data specification standards

- **Modularity**: connection with other CityGML ADEs, use and extension of ADE Energy in other fields

A participative development process

Hochschule für Technik Stuttgart
University of Applied Sciences

TUM
TECHNISCHE UNIVERSITÄT MÜNCHEN

CSTB
le futur en construction

EPFL
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

SINERGIS

HCU HafenCity Universität Hamburg

E.ON Energy Research Center
RWTH AACHEN UNIVERSITY

M.O.S.S.
Computer Grafik Systeme
Geoinformationssysteme

EIFER
EUROPEAN INSTITUTE FOR ENERGY RESEARCH

eDF

KIT
Karlsruhe Institute of Technology

ETH zürich

A participative development process

- Representing the development of 6 urban energy modelling and simulation tools

ENERGIE-ATLAS BAYERN

EDF CURTIS

EDF citylab

SimStadt

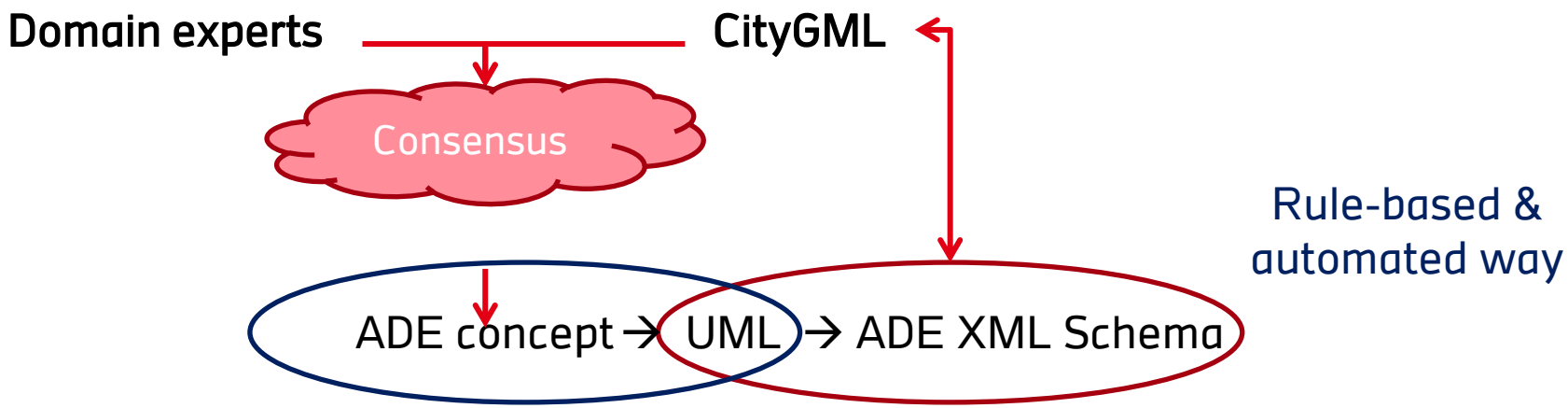
CITYSIM DESIGNER

SUNSHINE
Smart UrbaN ServIces for Higher eNergy Efficiency

AixLib

CityGML ADE concept

- What is an **ADE**?
  - Extension of the CityGML model for **specific application domains**
  - Formal specification in separate XML schemas referencing the CityGML schemas
- 2 types of ADEs:
  - Extension of existing CityGML feature types
  - Definition of new feature types



Reference document: *Modeling an application domain extension of CityGML in UML - OGC Best Practice*, 2014

Preliminary development phase

- Study of **existing data specification projects** concerning Building energy at urban scale
- List of **Use cases** (simulation and modelling) from the different partners
- List of **requirements** enabling these Use cases
- Development of class diagramms

History

Stuttgart (May 2014) – Kick-off

- Gathering partners
- Organisation of development in Working group
- Requirements collection, identification of other related initiatives

Karlsruhe (Oct 2014)

- Class diagramms of the different modules
- Unification in one XML scheme
- Organisation of revision process on GitHub repository

Nice (May 2015)

- Integration of Energy ADE Scheme in softwares
- Testing phase on concrete projects
- Preparation of a documentation, code list definition

Organisation of the revision process

- A **participative and iterative** process
- Organized in **Working Groups** related to the module structure
- Issues signaled on GitHub, discussed and centralized by the Working Group coordinators
- An **"XML team"** in charge of updating the XML Schema.

CityGML Energy ADE Modules

Time series

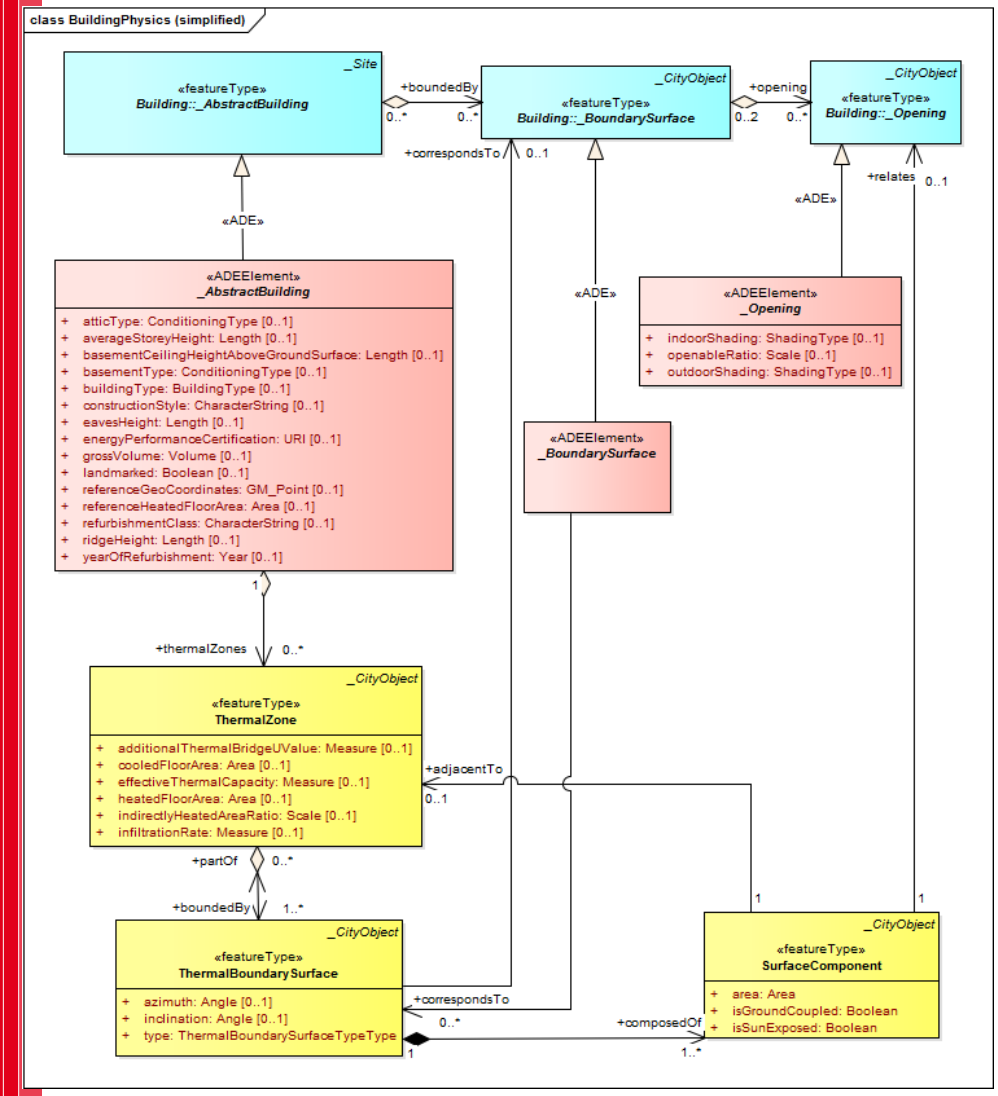
Energy and Systems

Energy ADE Core

Construction and Material

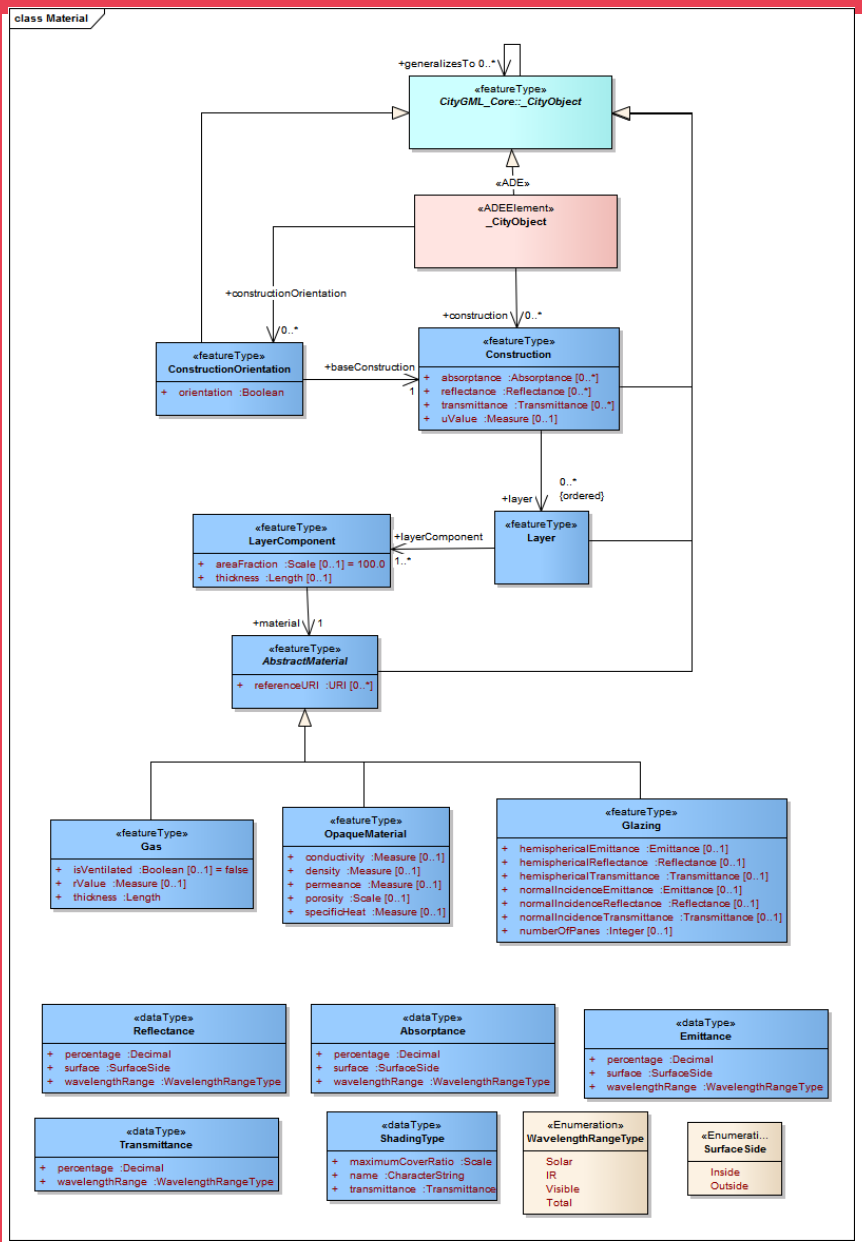
Occupancy and Schedule

ADE Energy core



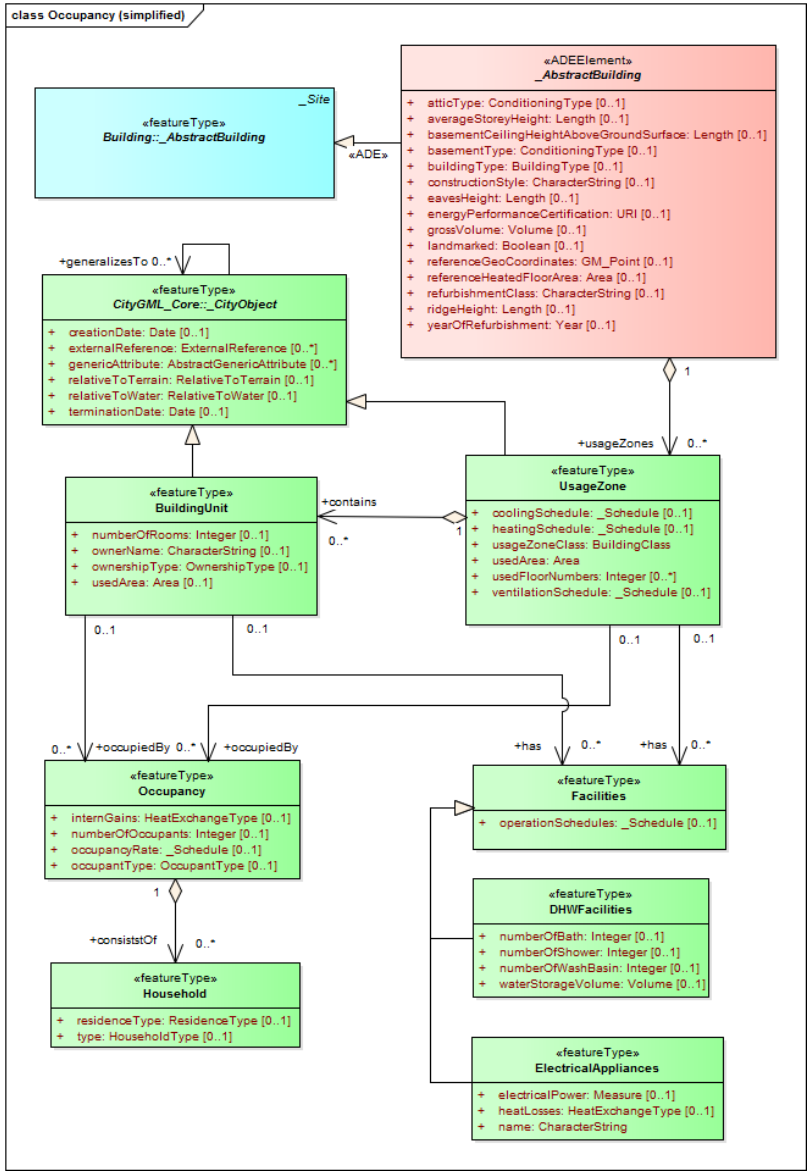
- Contains **thermal building objects** required for building energy simulation
- integrated to the CityGML standard schema through its **AbstractBuilding**, **BoundarySurface** and **Opening** classes.
- Compatible with the **4 LoDs**

Construction and Materials



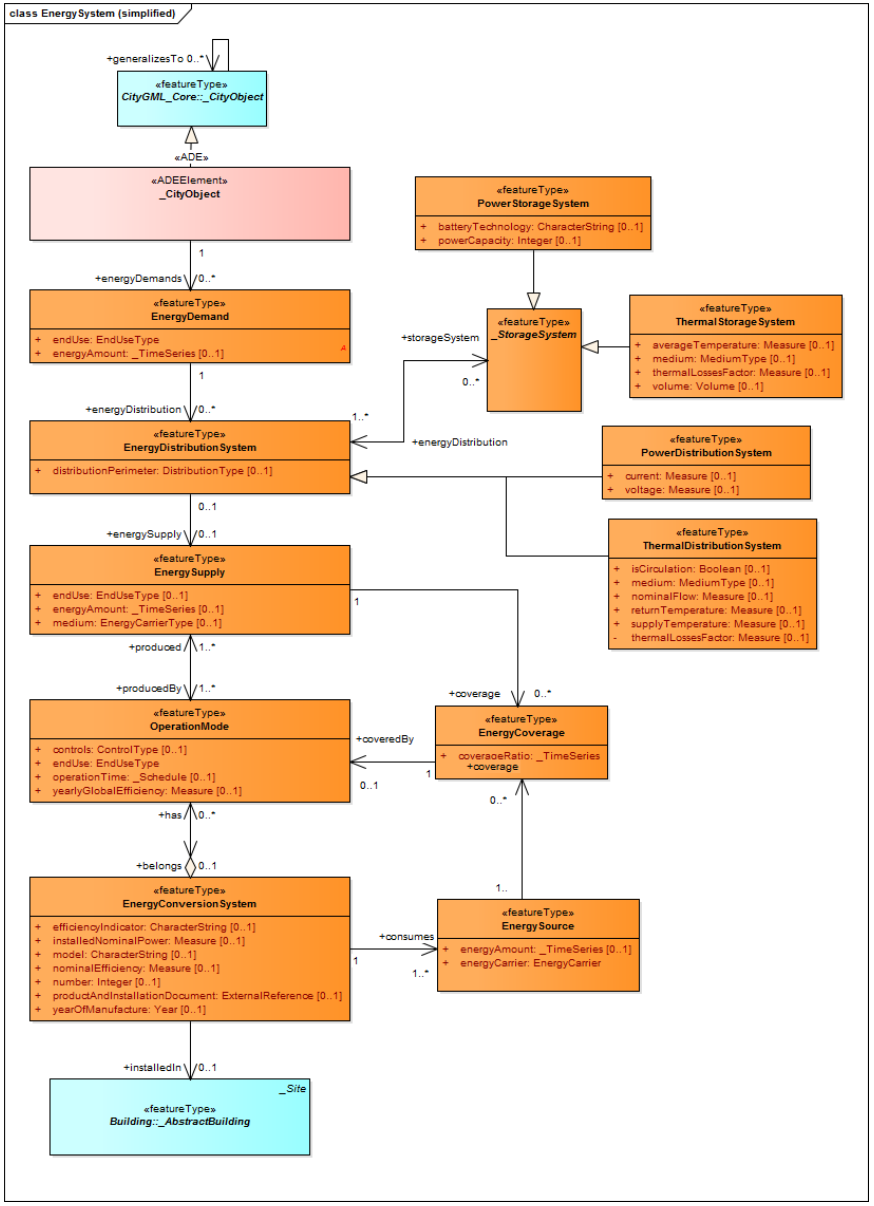
- Contains **physical characterization** of building construction elements
- Compatible with **static energy balance** (U-Values) **AND complex dynamic heat simulation** (λ, ρ, c_p).
- May be used and further extended for **multi-field analysis** (e.g. statics, acoustics).

Occupancy



- Contains **building usage characterization** including HVAC operation, ownership and occupancy information
- Temporal variables (e.g. occupancy rate or operation schedules) can be **modelled with different LoDs**
- May be used and further extended for **multi-field analysis** (e.g. socio-economics).

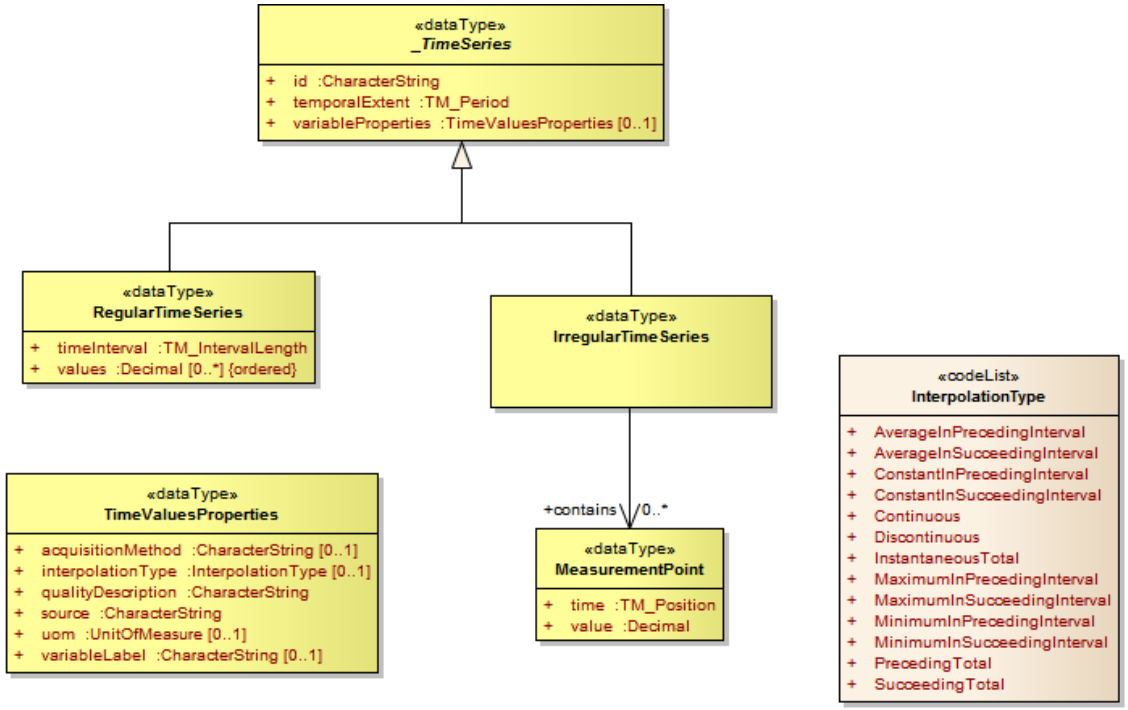
Energy and Systems



- Contains **energy amounts** (demand, supply, sources)
- …and **energy systems information** (conversion, distribution, storage systems)
- …related to the different **end use types** (e.g. space heating, cooling, DHW)

- Energy amounts may be associated to **any CityObject**

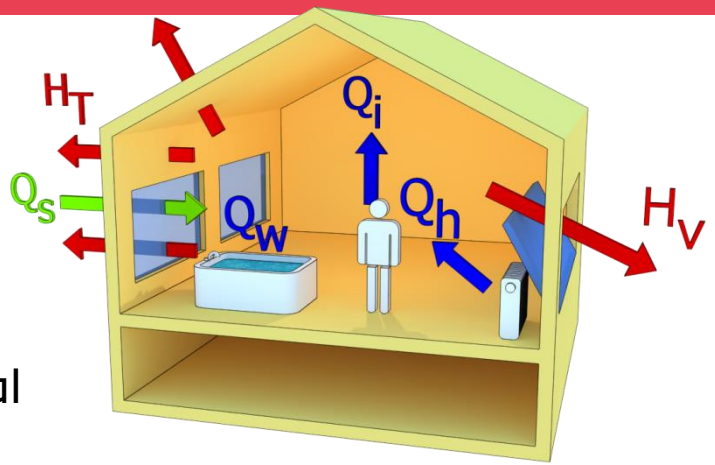
Time series



- Inspired from other ADE (WaterML), applied to Energy Amount
- Models both **regular** and **irregular time series**
- May store both **simulation results** and **metering data** for comparison purpose

Modelling Example

Thermal Zones



A thermal zone combines building areas with equal

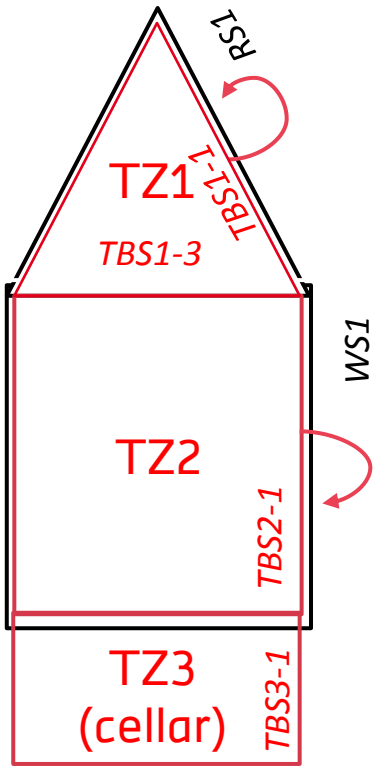
- usage,
- amount of useful energy («Nutzenergiemenge»),
- conditional parameters (temperature, humidity, etc.),
- technical appliances (HVAC, lighting, hot water, etc.).

Thermal zones are used to simulate the air exchange between different adjacent building areas and/or the outer surrounding.

Topogological conditions and other requirements on the thermal zone definition:

- A thermal zone must now it's adjacent thermal zones
- A thermal zone ís defined by it's enveloping physical or virtual surfaces
- A thermal zone must contain information about it's physical parameters

CityGML LoD 2 Building Modeling



For thermal Zones in LoD2 the following is valid:

A building is modelled by it's exterior boundary Surfaces such as :

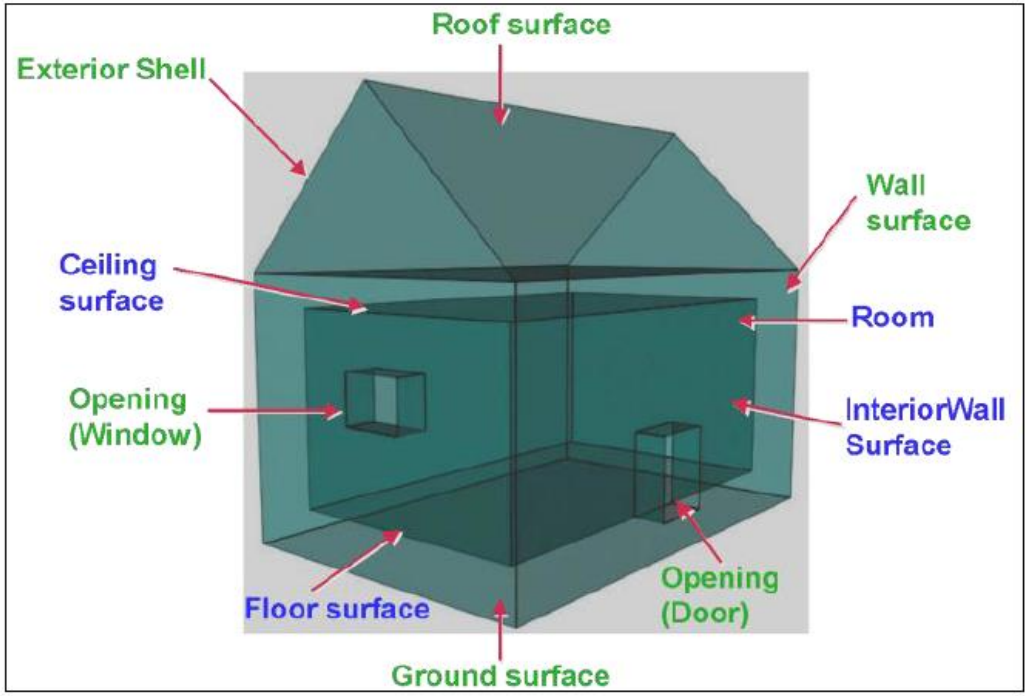
- WallSurface
- RoofSurface
- GroundSurface

One **<energy:ThermalZone>** is **<boundedBy>** at least one **<energy:ThermalBoundarySurface>**.
A **<energy:thermalBoundarySurface>** is **<partOf>** a **<energy:thermalZone>**.

One **<energy:ThermalBoundarySurface>** refers to 0 or 1 **<bldg:BoundarySurface>**

If a **<bldg:BoundarySurface>** corresponds to a **<energy:thermalBoundarySurface>** then the **<energy:thermalBoundarySurface>** has to reference the **<bldg:BoundarySurface>** via the association **<correspondsTo>**

CityGML LoD4 Building Model



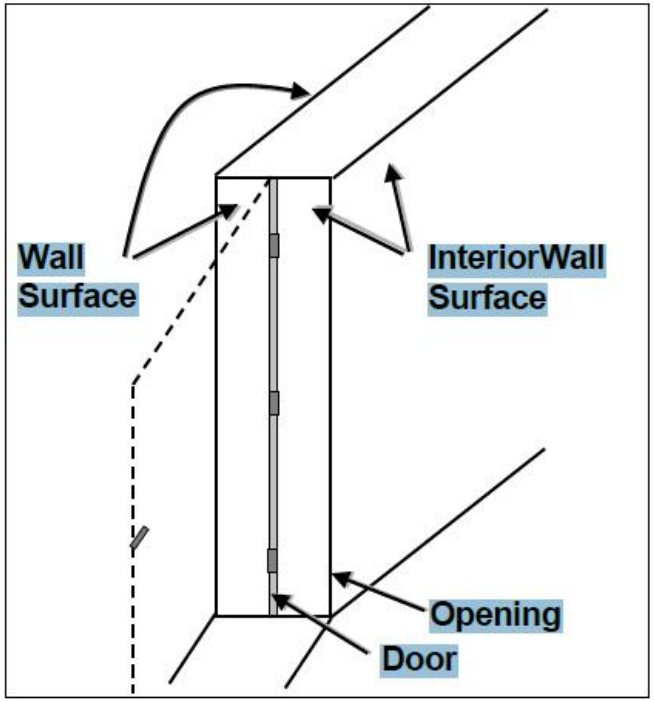
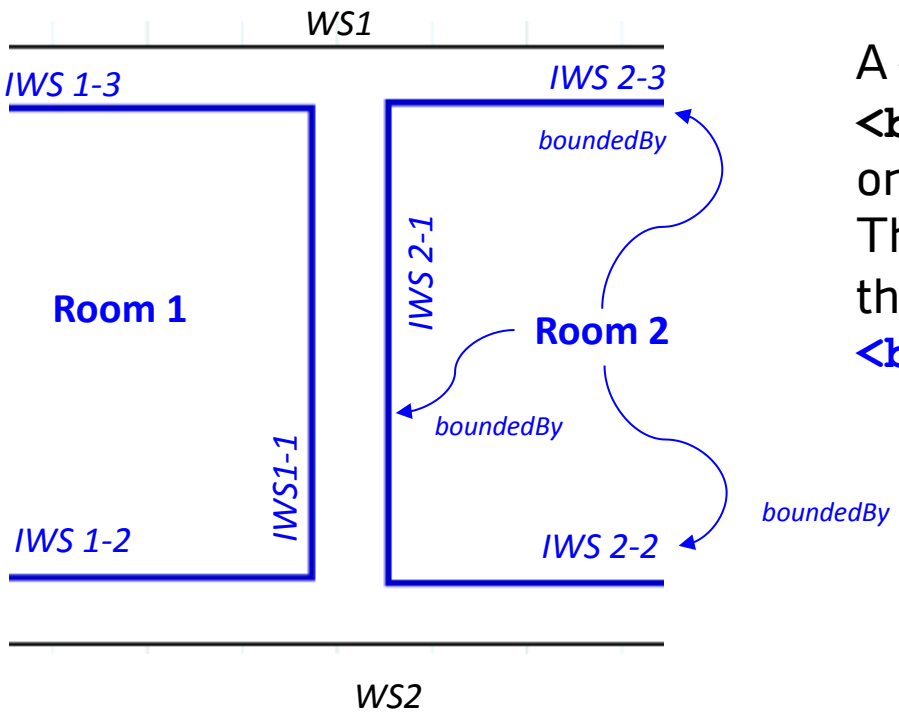


Fig. 32: Classification of *BoundarySurfaces* (left), in particular for *Openings* (right) (graphic: IGG Uni Bonn).

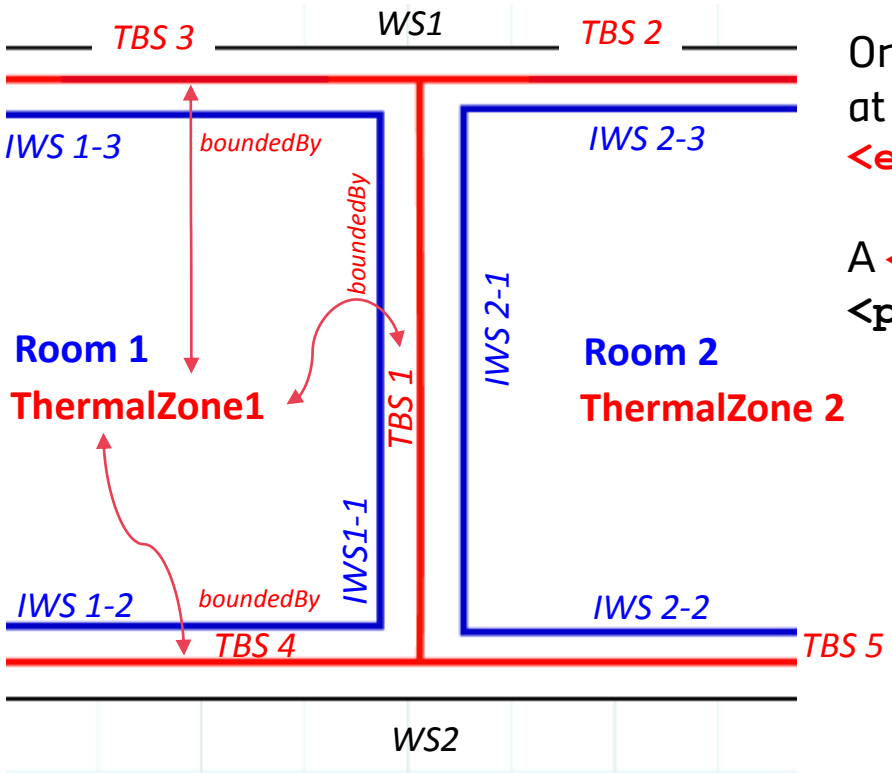
CityGML LoD 4: Two rooms with shared walls



A **<bldg:Building>** or a **<bldg:BuildingPart>** consists of one or more **<bldg:Room>**.
The **<bldg:Room>** is **<boundedBy>** three or more **<bldg:InteriorWallSurface>**

IWS = InteriorWallSurface
WS = (Exterior) WallSurface
TB S= ThermalBoundarySurface

Thermal zones

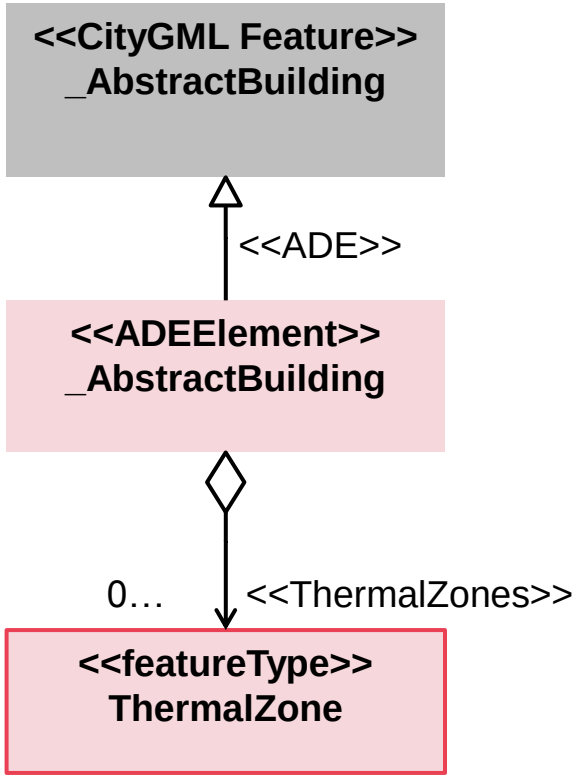


One **<energy:ThermalZone>** is **<boundedBy>** at least one **<energy:ThermalBoundarySurface>**

A **<energy:thermalBoundarySurface>** is **<partOf>** a **<energy:thermalZone>**

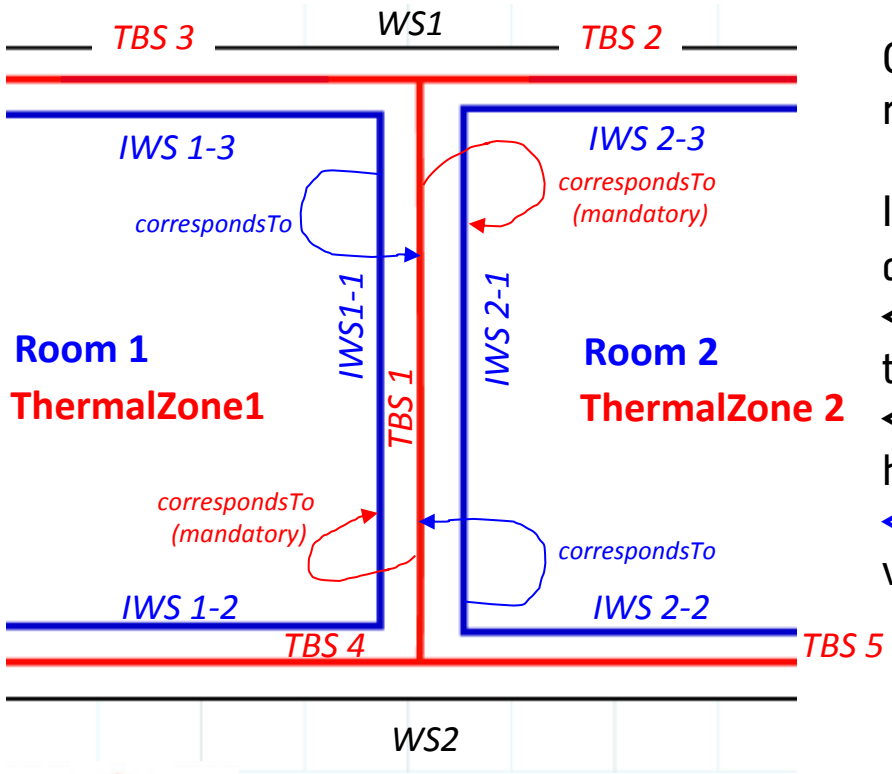
IWS = InteriorWallSurface
WS = WallSurface
TB S= ThermalBoundarySurface

ThermalZone




```
<bldg:Building>
    <energy:thermalZones>
        <energy:ThermalZone gml:id="TBZ1">
          <energy:cooledFloorArea />
         <energy:heatedFloorArea />
         etc…
        </energy:ThermalZone>
        <energy:ThermalZone gml:id= ="TBZ2"/>
    </energy:thermalZones>
</bldg:Building>
```

ThermalBoundarySurface



One **<energy:ThermalBoundarySurface>** refers to 0,1 or 2 **<bldg:BoundarySurface>**

If one or two **<bldg:BoundarySurface>** corresponds to a **<energy:thermalBoundarySurface>** then the **<energy:thermalBoundarySurface>** has to reference the **<bldg:BoundarySurface>** via the association **<correspondsTo>**

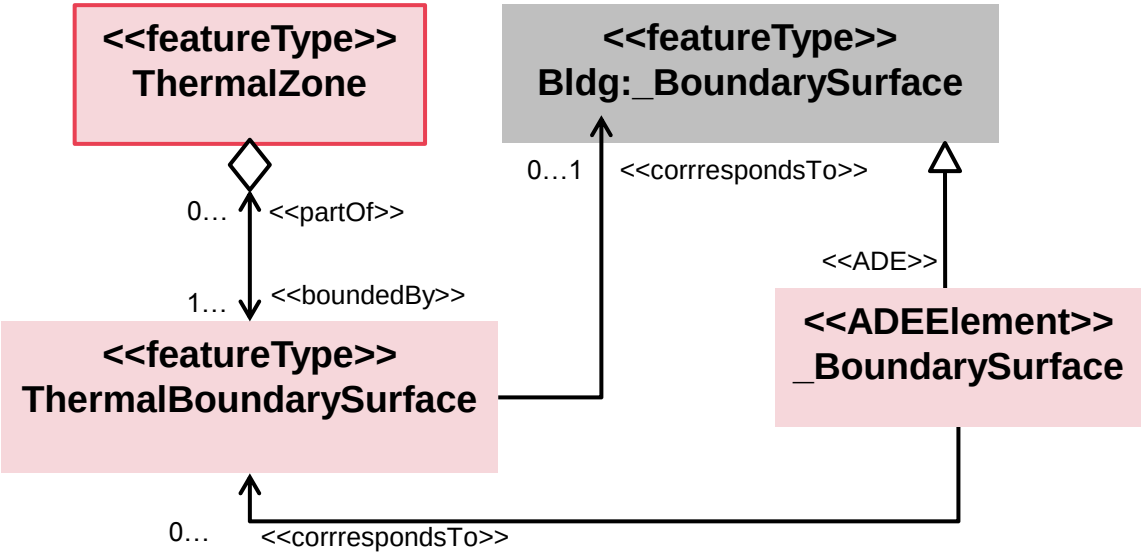
TBS represents a volumetric object!

IWS = InteriorWallSurface

WS = WallSurface

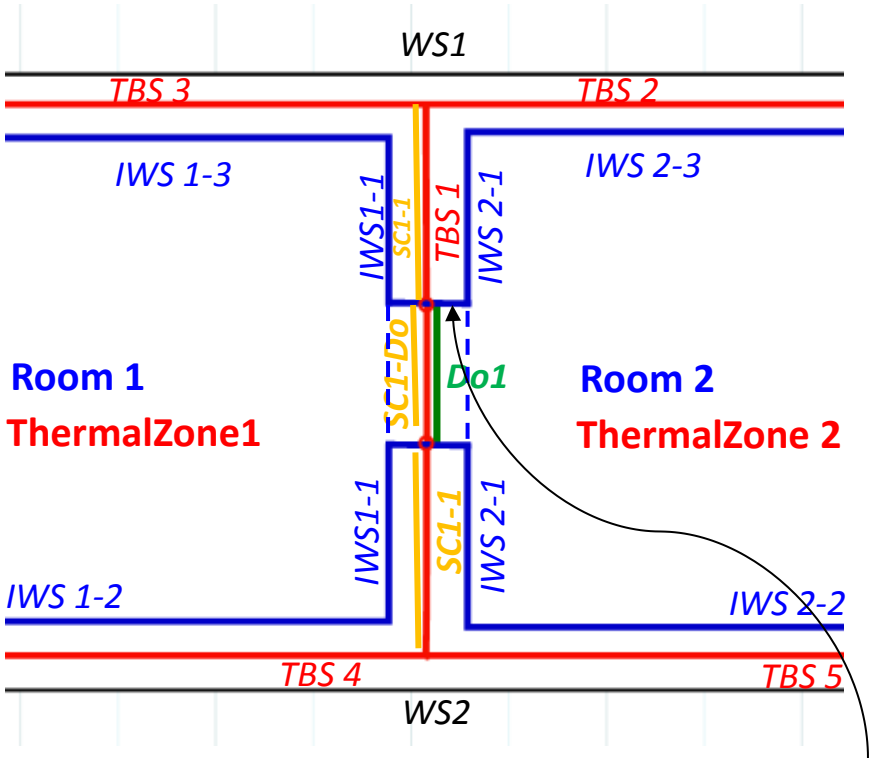
TB S= ThermalBoundarySurface

ThermalBoundarySurface




```
<energy:ThermalZone gml:id="TBZ1">
   <energy:boundedBy>
     <energy:ThermalBoundarySurface gml:id= TBS1/>
   </energy:boundedBy>
   <energy:boundedBy /> …
</energy:ThermalZone>
```

Surface Components

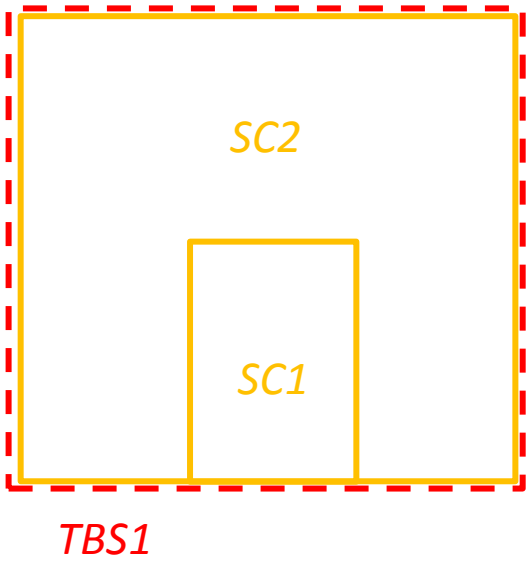


A door or Window has always different thermal conditions as the Wall in which it is inserted.

A `<bldg:Window>` or `<bldg:Door>` is associated to a `<bldg:_BoundarySurface>` via the association `<opening>` as well as to the `<energy:surfaceComponent>` **via** `<relates>`.
A `<thermalBoundarySurface>` is always `<composedOf>` at least one `<surfaceComponent>` but can be composed of multiple `<surfaceComponents>`.

The BoundarySurface which models the window or door jamb (Laibung) ***is not*** associated to the thermalBoundarySurface

SurfaceComponent

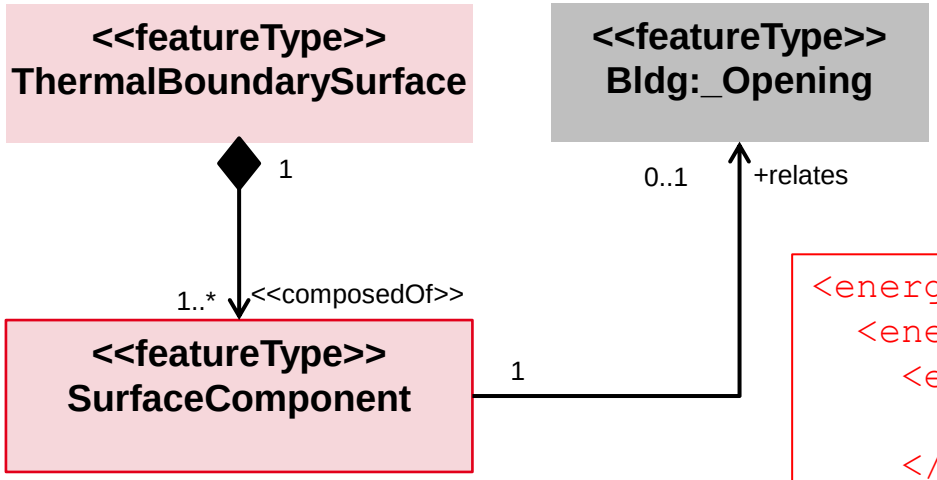


One `<energy:ThermalBoundarySurface>` is `<composedOf>` one or more `<energy:SurfaceComponent>`.

A typical surfaceComponent combination within one thermalBoundarySurface is a Wall and a Door.

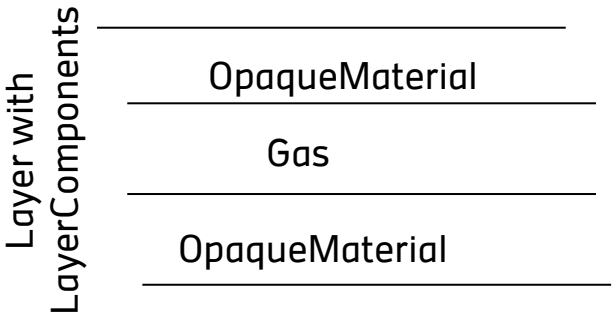
SC = SurfaceComponent
TB S= ThermalBoundarySurface

SurfaceComponent




```
<energy:ThermalBoundarySurface>
  <energy:composedOf>
    <energy:SurfaceComponent>
        …
    </energy:SurfaceComponent>
  </energy:composedOf>
  <energy:correspondsTo xlink:href="#RS_3"/>
</energy:ThermalBoundarySurface>
```

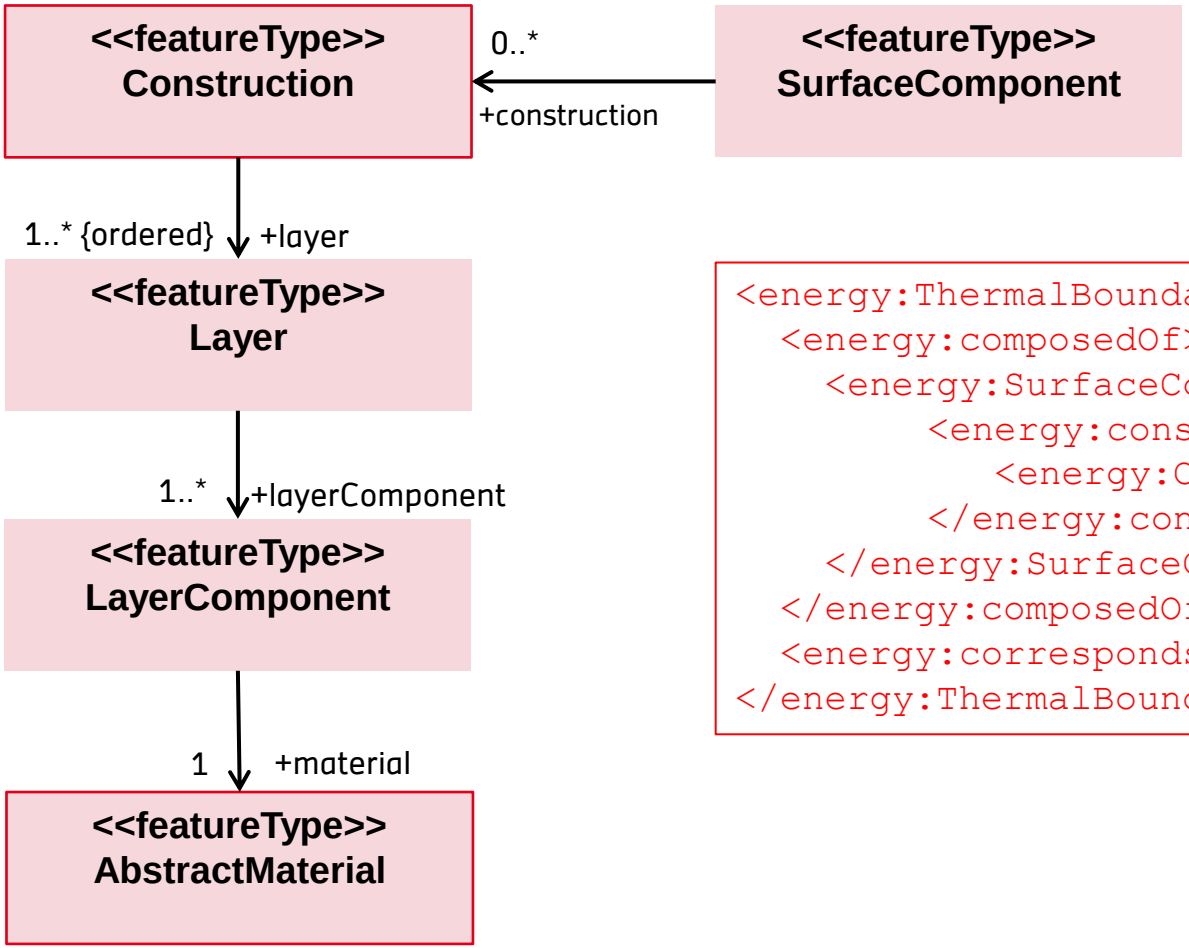
Construction and Materials



The **`<energy:Construction>`** element describes the construction of physical elements like Walls, Roofs, Windows or the building in general.
It consists of **`<energy:Layers>`** containing **`<energy:layerComponents>`** each describing one particular Material by including an **`<energy:Material>`** element.

```
<energy:construction>
  <energy:Construction gml:id="C_1">
    <energy:uValue uom="W/m&#178;K">0.3</energy:uValue>
    <energy:layer>
      <energy:Layer>
        <energy:layerComponent>
          <energy:LayerComponent>
            <energy:thickness uom="cm">10.0</energy:thickness>
            <energy:material><energy:OpaqueMaterial />
            </energy:material>
          </energy:LayerComponent>
        </energy:layerComponent>
        <energy:layerComponent>
          <energy:LayerComponent>
            <energy:thickness uom="cm">20.0</energy:thickness>
            <energy:material><energy:Gas /></energy:material>
          </energy:LayerComponent>
        </energy:layerComponent>
        <energy:layerComponent>
          <energy:LayerComponent>
            <energy:thickness uom="cm">10.0</energy:thickness>
            <energy:material><energy:OpaqueMaterial /></energy:material>
          </energy:LayerComponent>
        </energy:layerComponent>
      </energy:Layer>
    </energy:layer>
  </energy:Construction>
</energy:construction>
```

Construction and Materials




```
<energy:ThermalBoundarySurface>
  <energy:composedOf>
    <energy:SurfaceComponent>
        <energy:construction>
            <energy:Construction/>
        </energy:construction>
    </energy:SurfaceComponent>
  </energy:composedOf>
  <energy:correspondsTo xlink:href="#RS_3"/>
</energy:ThermalBoundarySurface>
```

CityGML Energy ADE

http://en.wiki.energy.sig3d.org/index.php/Main_Page

Next workshop:
30.11. – 1.12.2015 TU Munich

Join the team

Contact

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http://www.coors-online.de