3D-SDI contribution to energy-efficient cities

3D CityModels for Energy Demand Simulation

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Motivation and Challenges – Energy demand

The construction sector is the highest energy consumer in the EU (about 40%) and main contributor to GHG emissions (about 36% of the EU's total CO_2 emissions)

In residential buildings most of the energy used is required for space heating and cooling (39%), domestic hot water (12%), ventilation and lighting.

→ An increase of energy-efficiency and usage of renewables is highly required!

The EeB – Advisory group states:

Working at district level, or on large groups of buildings, is the right scale for urban energy planning such as:

- groups of dwellings (sharing and managing energy production,…);
- residential and non-residential building level (insulation, EMS, integration of renewables,…);
- Heat and electricity networks and grids…

European Union (2010): ENERGY-EFFICIENT BUILDINGS PPP, MULTI-ANNUAL ROADMAP AND LONGER TERM STRATEGY. (EUR 24283 EN)

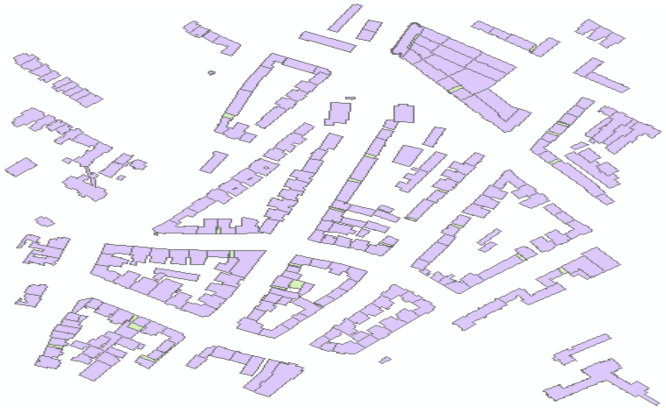
→Spatial Data Space required

Motivation – Application of virtual 3D Citymodels (CityGML)

3D City Models can play an essential role for energy planners and municipal managers, supporting them as basis for:

- Analysis of the actual energy demand
- Calculation of refurbishment and energy scenarios (Costs vs. Savings)
- Coordination of strategies to decrease building energy demand
- …and increase sustainable energy supply concepts

→ Supports the development of strategies for reduction of urban energy demand and increase of energy efficiency on district level



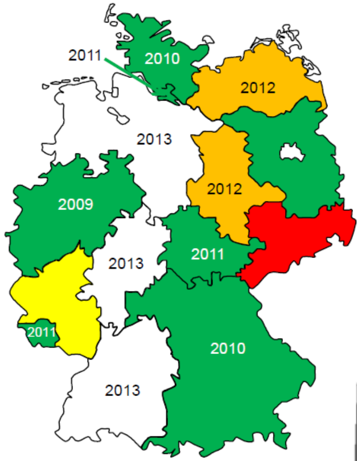
Source: Freie und Hansestadt Hamburg, Landesbetrieb Geoinformation und Vermessung

3D City Model based on CityGML

- Standardized (OGC[1]) open data model for virtual 3D City Models
- Based on the standard GML[2] (ISO 19139), extended for urban structures
- Urban space modeling in different levels of detail is possible
- CityGML has a spatio-semantic model, which links geometry, topology, semantic data and design properties (for visualization)

Strengths

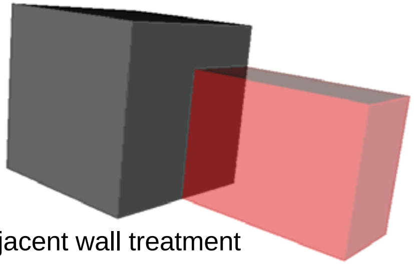
- Flexible open standard, regularly updated
- Already wide-used (at least in Germany)
- XML/GML based and extendable
- Geometric and semantic 3D spatial analysis
- Intuitive 3D visualization



LoD1-Availability

Verfügbarkeit 2009	
0% – 25%	
26% - 50%	
51% - 75%	
76% - 99%	
100%	

Jahreszahl steht für die (geplante)



Adjacent wall treatment

[1] Open Geospatial Consortium
[2] Geography Markup Language

Levels of Detail in CityGML

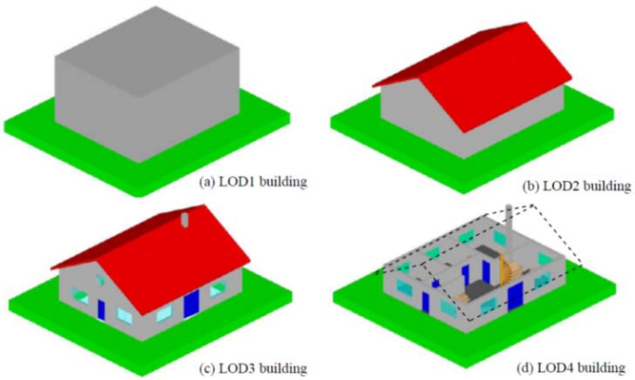
LoD 0: Land model with textures

LoD 1: City Model, building blocks without roof structure

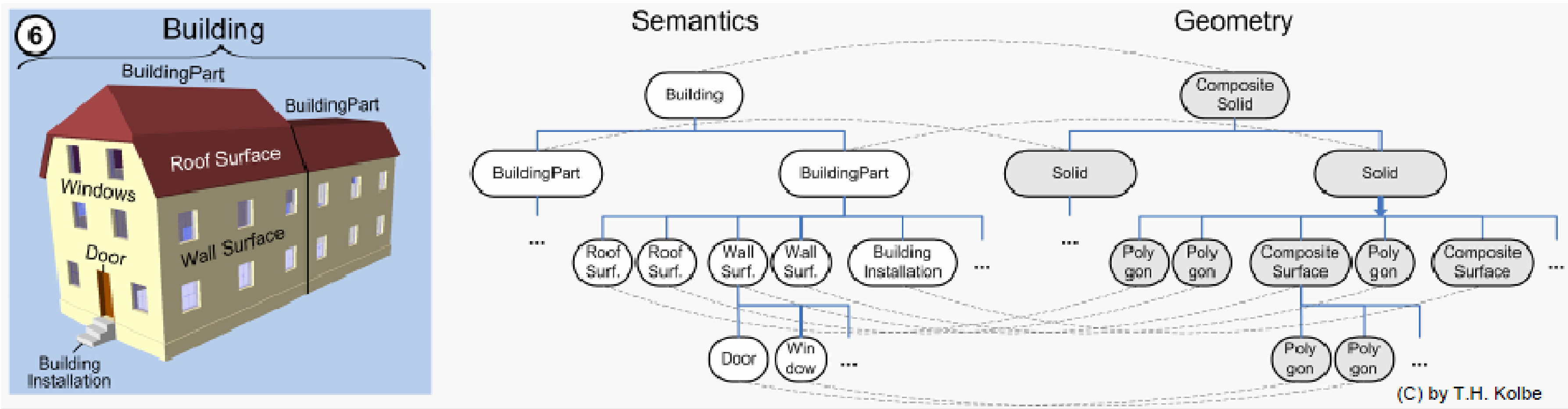
LoD 2: City Model with roof structure and texture

LoD 3: Detailed Architectural model (Outside)

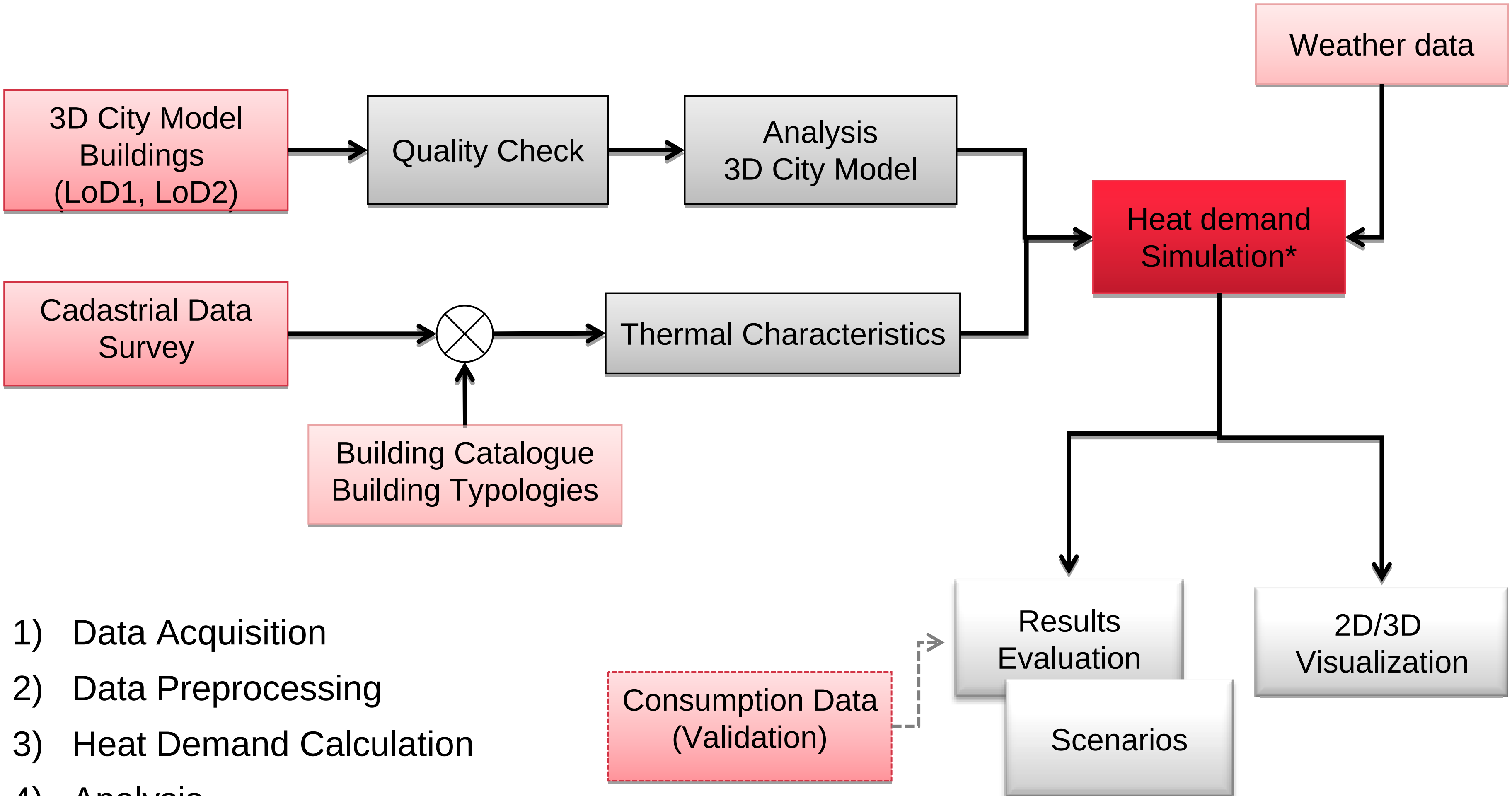
LoD 4: Detailed Architectural model (Outside and Inside)



Spatio-semantic model



Best practice Example:
Heat demand simulation on urban level

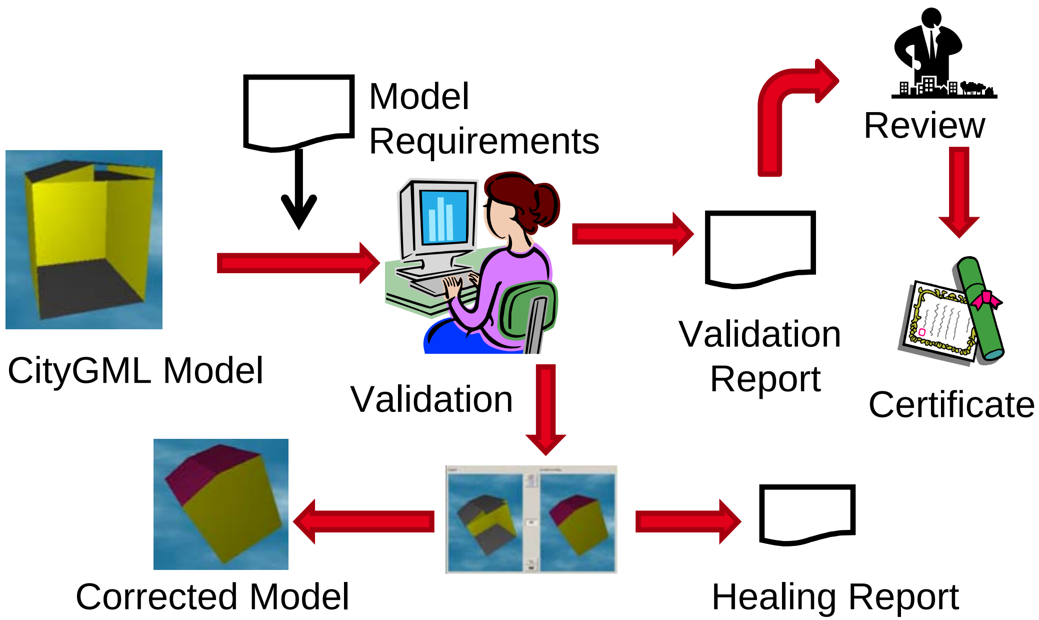


1) Data Acquisition
2) Data Preprocessing
3) Heat Demand Calculation
4) Analysis

* DIN 18599 (monthly balance approach) (EN ISO 13790)

Data Quality Check – Virtual 3D City Models (CityGML)

Research Project: CityDoctor, Coordination Prof. Coors



CityGML 2.0

- Data Quality Check
  - Planarity, Intersection
  - Closeness, Solid
  - Surfaces, Edge checks,
  - Surface normal
  - Plausibility checks, semantics
- Healing

→ Certificate

Plug-Ins for CPA SupportGIS, FME,

CityServer 3D as well as Standalone Tool

Webservice planned

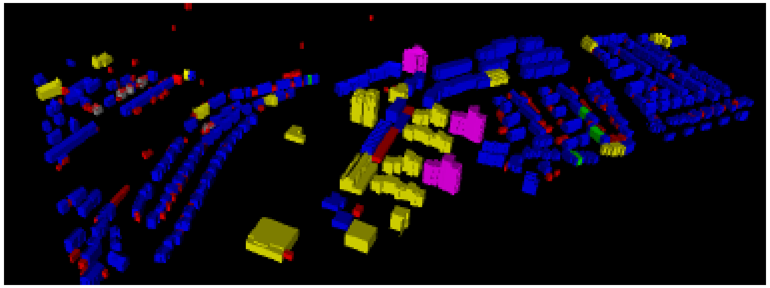
http://citydoctor.hft-stuttgart.de/ , Funded by Federal Ministry of Education and Research

Bundesministerium
für Bildung
und Forschung

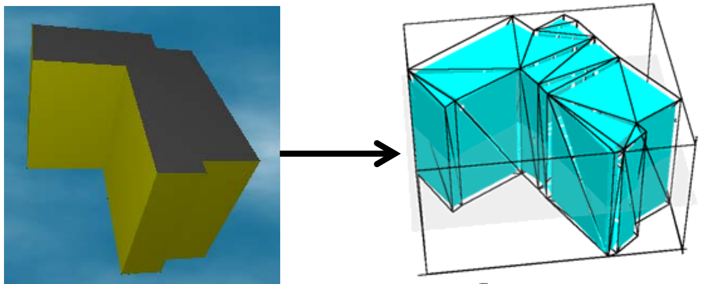
Analysis of 3D City Models

- Building Classification

  (Residential Buildings, MFH, HH, EFH)

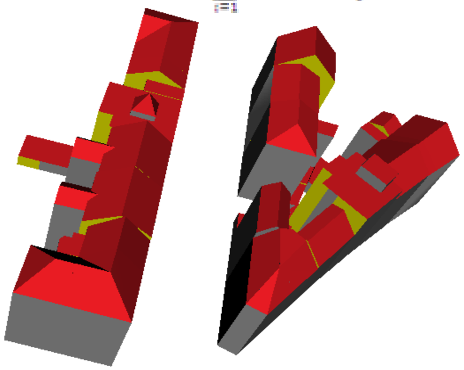


- Volume Calculation

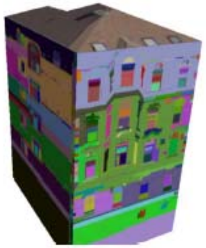


$$V = \sum_{i=1}^{n} \frac{|\det(a_i - b_i, b_i - c_i, c_i - d_i)|}{6}$$

- Extraction adjacent walls

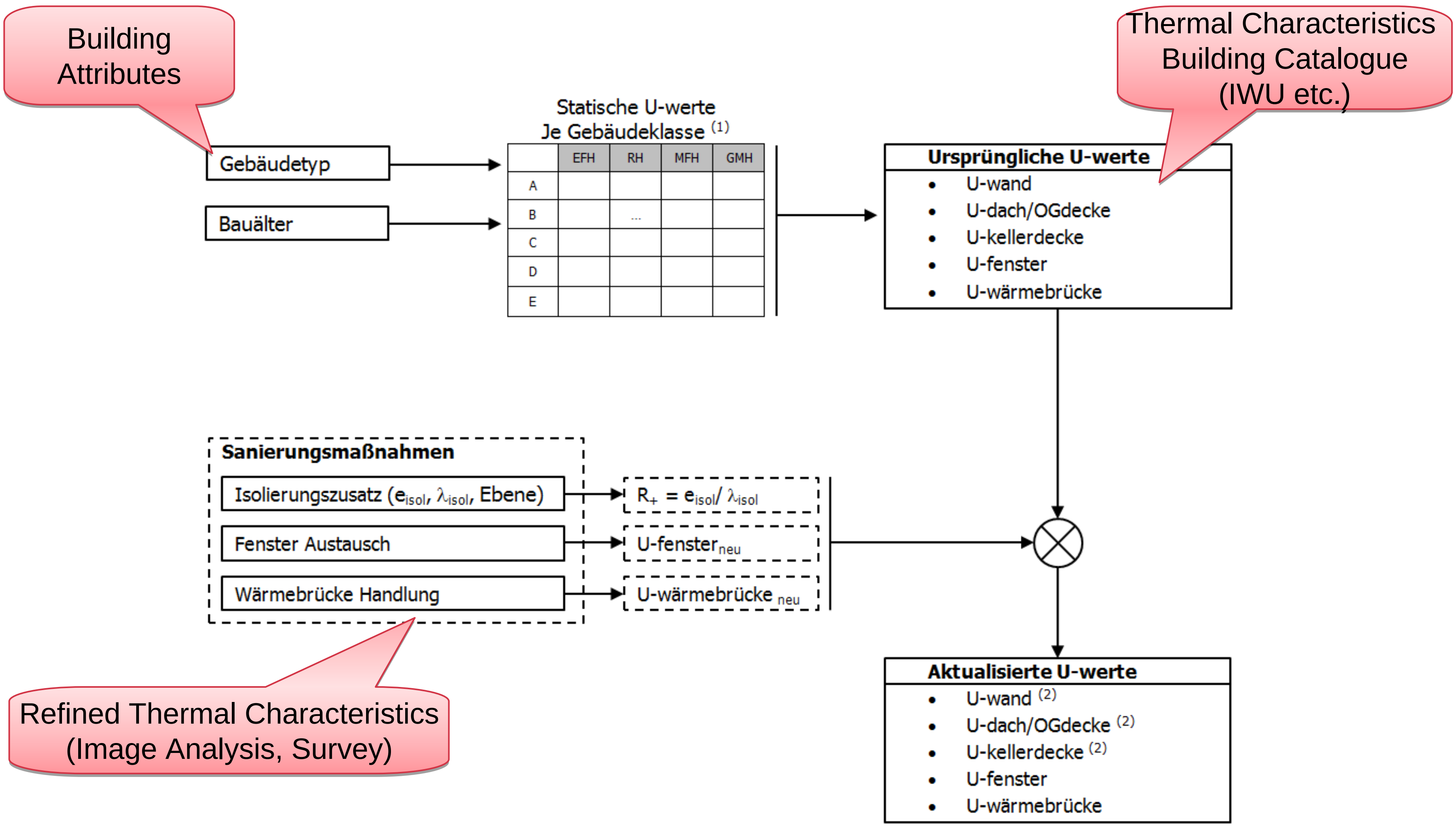


- Window extraction from textures



Segmentation and Window detection

Data enrichment – Thermal building characteristics



Input Data to Energy demand calculation

- **Volume [m^3]**
- Roof Surface [m^2]
- Wind-exposed walls [m^2] (sun / wind exposed)
- **Non-wind exposed [m^2] (Neighborhood bldg.)**
- Ground Surface [m^2]
- Orientation Roof and Wall Surfaces
- **Window area per wall [%]**
- **U-Values (Thermal Characteristics)**

Method

Monthly energy balance

National Standard calculation method DIN 18599-2 (2005)

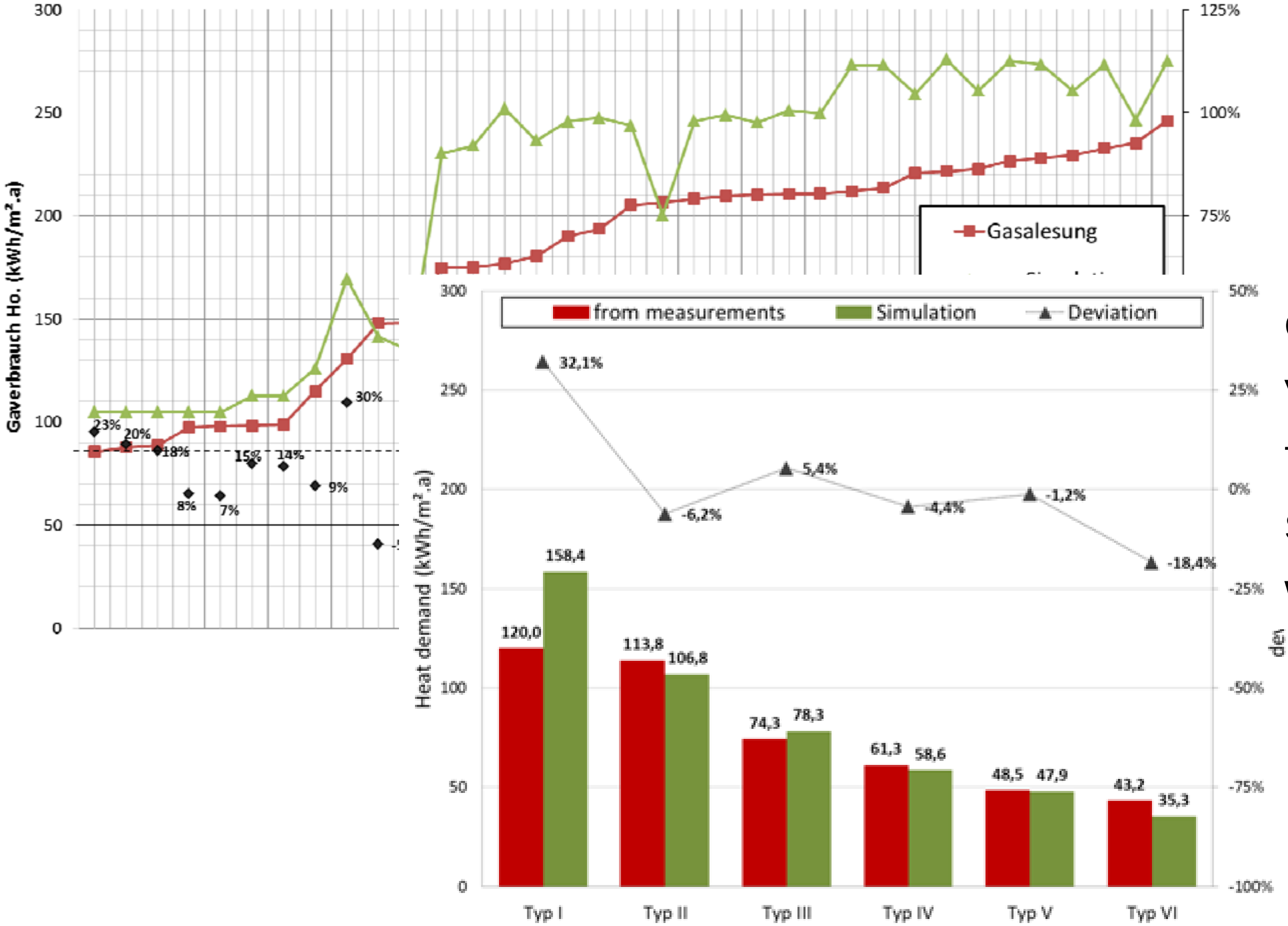
Result:

Yearly heat demand per building in

kWh/m²a in relation to

effective area A_N

Validation: Comparison with consumption data



Case Study 1: LB-GR

Bad data records, LoD1

Total Deviation: 18%

Std. Deviation: 11%

Case Study 2: KA-RI

Very good data records, LoD2

Total Deviation: 7%

Std. Deviation : 18%

Without GTyp1: 6% and 5%

→ Promising results, calculated values 5-25% above the real conumption values (typical: 20%)

→ Impact Factors: User behaviour spec. Ventilation, heating technologies, overestimation of heated building volume

2D/3D Visualization

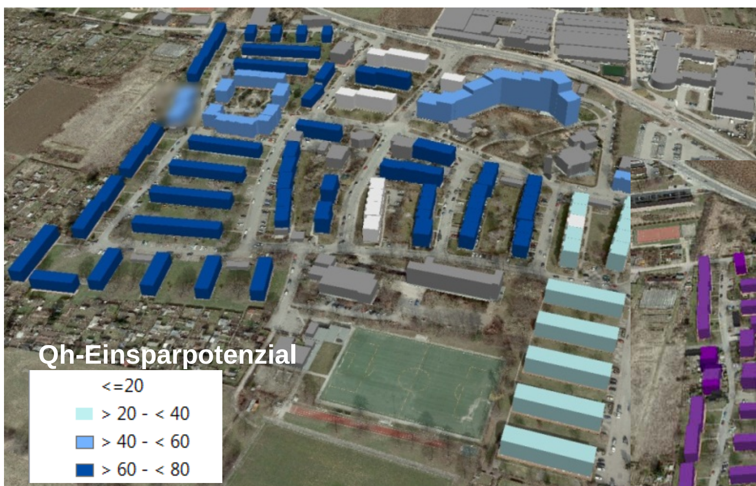
2D Visualisation – heat demand

3D Visualisation – Heat demand (LoD 1)

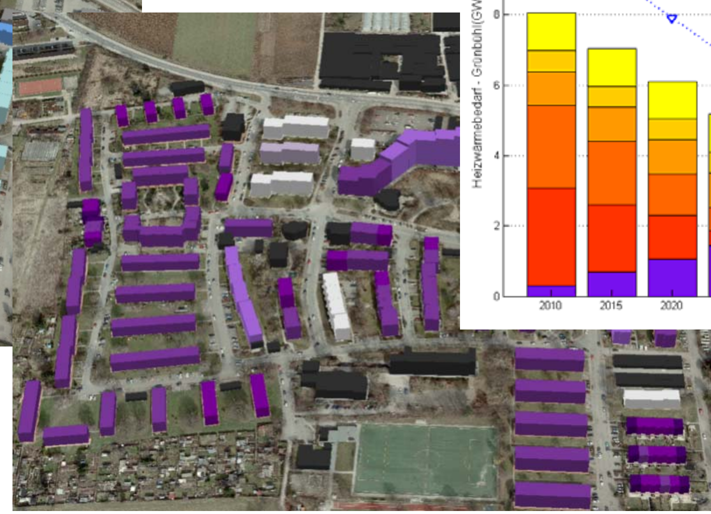
© European Institute for Energy Research, 3D-Print of Stuttgart (1km x 1 km)

Visualization – 3D CityModels for urban energy planners

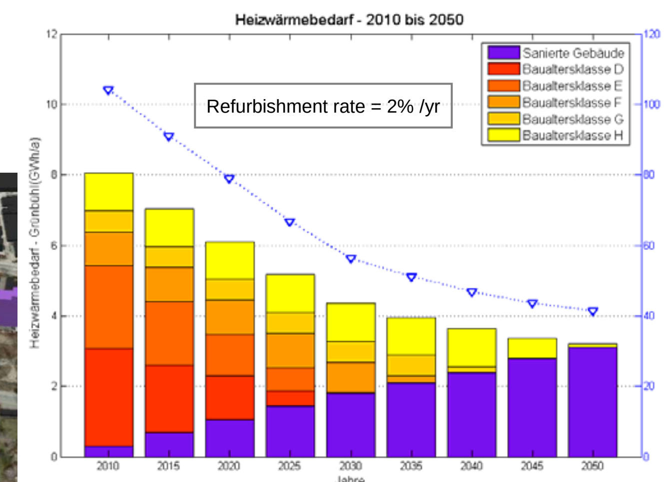
- Refurbishment Scenarios – Calculation of saving potentials
- Calculation of refurbishment costs vs. energy costs
- Definition of refurbishment priorities, time planning



Energy savings [%] - Grünbühl



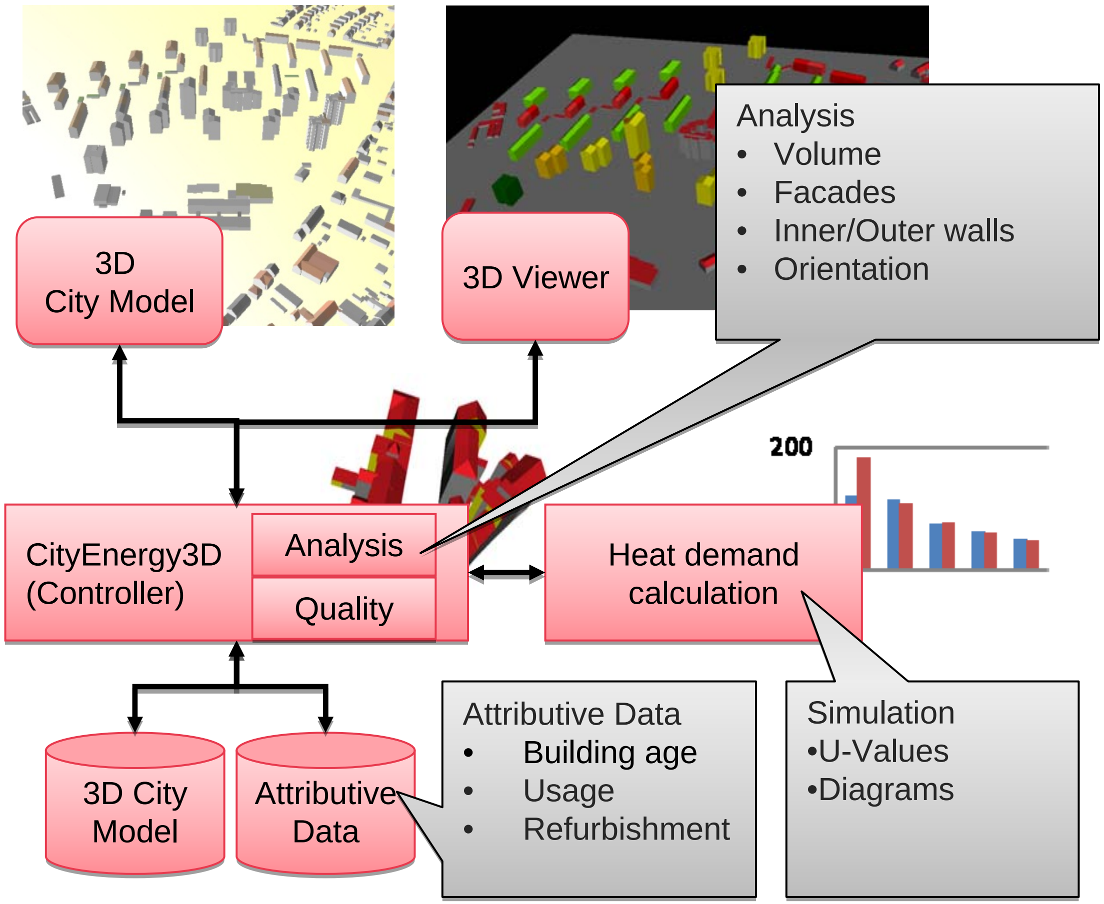
Refurbishment Costs [€/m²] - Grünbühl



Heat demand decrease
Grünbühl 2010 – 2050

Software development at HFT Stuttgart

CityEnergy3D



- Input: 3D spatial database or CityGML file
- Simulation of energy demand and scenarios
- PV analysis and shadow calculation
- Standardization: OGC services and CityGML ADE
- Extendible to other aspects of urban planning

Summary

- The heat demand of urban quarters can be estimated with good accuracy
- Basic information about building age and usage are required (→ Building Catalogue IWU)
- User behavior can highly influence the deviations between calculated and measured heat demand (20-30%)
- If detailed information about the buildings thermal characteristics are available, the calculation error can be reduced up to < 10%
- PV- and Solar thermal potential can be identified and scenarios for renewable energy supply concepts can be analyzed

→ 3D city models can be a basis for smart city concepts of the future (Adaption of Energy consumption and production, load management, Visualization of energy flows)

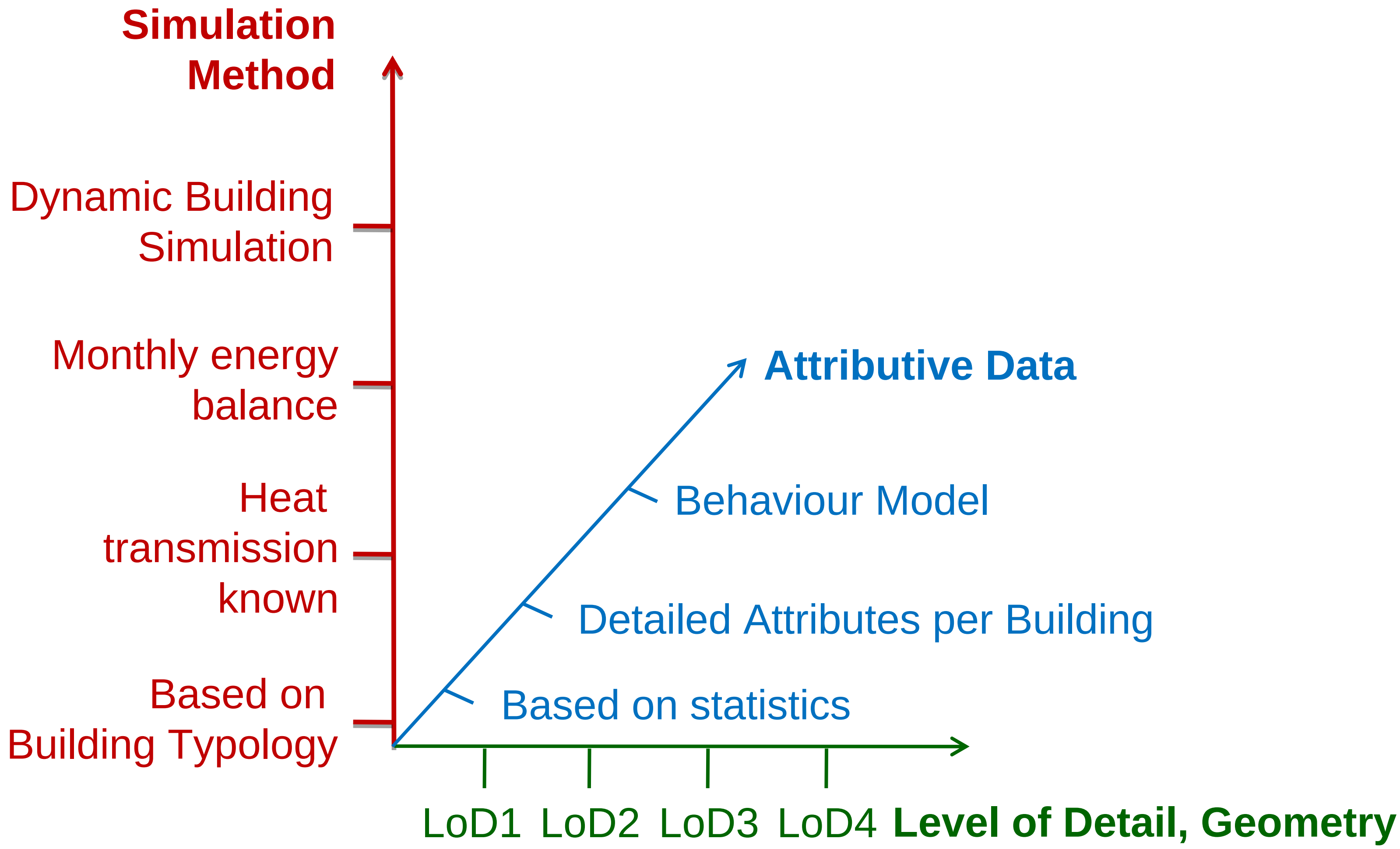
Summary - Challenges

3D city models can already play an essential role for energy planners and municipality managers

Challenges

- Enrichment of attributive data (Crowd Sourcing Approach)
- Improvement of data quality of 3D city models
- Development of standardized interfaces for 3D GDI
- Analyze optimization potential by usage of detailed building models (LoD 3, ,4) incl. Façade geometries and/or interior
- Increased accuracy of results by optimized parameters (e.g. user behavior, heated volume…)

Impact Factors on urban energy demand calculation



Thanks for listening

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