Hochschule für Technik Stuttgart

HFT Stuttgart

zafh.net

Tools for Urban Planning

3D Model District Grünbühl Ludwigsburg

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Our research institute : zafh.net Stuttgart

- **Renewable energy techniques** (photovoltaics, solar thermal, geothermal, biomass)
- Development of **technologies** for solar heating and cooling systems
- Development of **dynamic simulation tools and models** of energy systems and buildings
- Monitoring techniques, communication and optimised system controls
- Development of integrated processes for energy efficient buildings and districts with **3D Models** (CityGML, Sketch Up)

→ a team of 25 researchers

→ close collaboration with Geoinformatics, Architecture and Urban Planning departments of the Hochschule für Technik

Motivations and Challenges of 3D City Modeling

A rapid transition of urban areas towards energy efficiency and the adaption to challenges posed by climate change are highly required…

•3D city modeling can play an essential role for energy planners and municipal managers, supporting them with:

- energy diagnosis of the present situation
- coordination of strategies to decrease building energy demand
- …and increase sustainable energy supply concepts
- development of strategies for sustainable transport

•A common, flexible and open city modeling standard is need to:

- deal with different levels of details and data availabilities/qualities
- store and exchange numerous and miscellaneous urban data on a unique support
- provide a visualization of results

Overview city simulation tools

URBAN MODELS

CITYSIM: Microsimulation urban model based on Suntool (2002), includes CitySim scene creation based on XML data exchange, simplified radiosity model for irradiance and daylighting calculations, simplified capacity-resistor multizone building model, occupant behaviour models, simple energy conversion models

MODELICA with libraries as a general non causal simulation environment

BUILDING SIMULATION MODELS

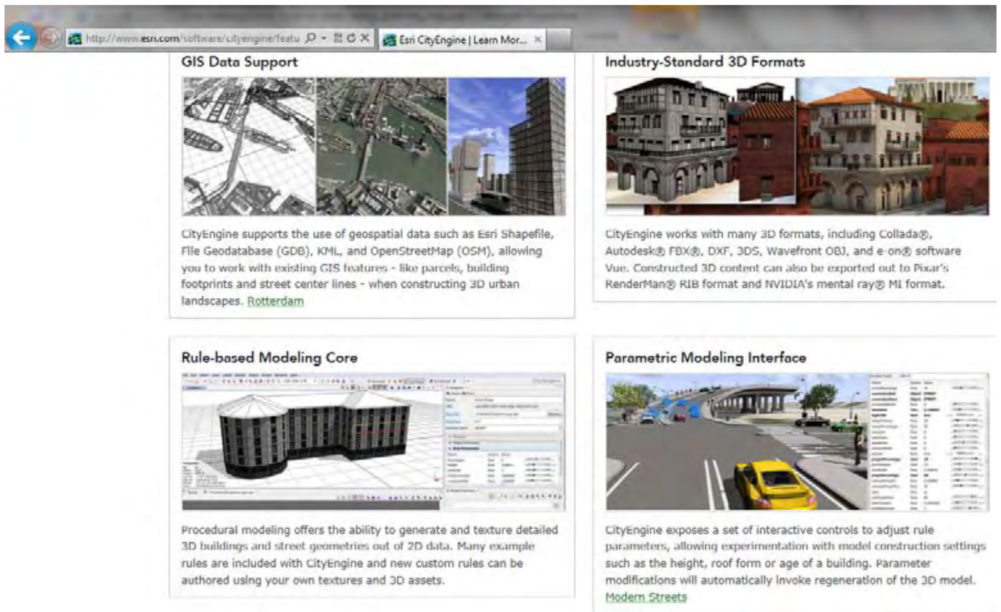
ENERGYPLUS: building simulation tool, can include external scenes (building obstructions), TRNSYS, ESP-r, IDA-ICE (mit IFC Import)

DECISION SUPPORT SYSTEMS

UrbanSim (Lawrence Berkeley Laboratory) supporting planning and analysis of urban development

GIS BASED URBAN SIMULATION

mainly visualisation tools



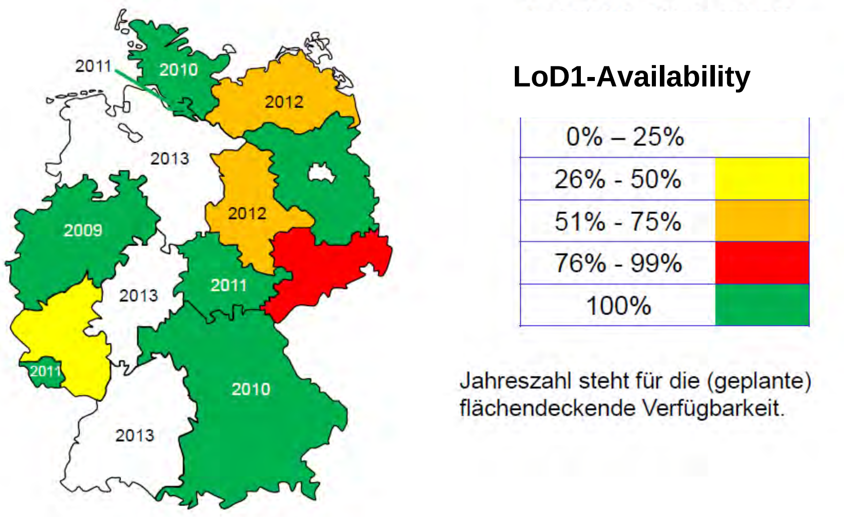
3D Citymodels based on CityGML

CityGML

•Standardized (OGC) open data model for virtual 3D Citymodels

•Based on ISO 19139 Standard GML (XML based), extended for urban structures

•Spatio-semantic Model, linking geometry, topological relationships, semantic data and design property (for visualization)



Strengths

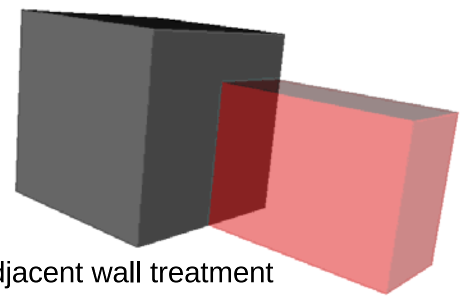
•open standard, regularly updated

•already wide-used (at least in Germany)

•XML based and extendable

•many possibilities of spatial analysis

•modeling with 4 possible Level of Details (LOD)



Adjacent wall treatment

Level of Details in CityGML

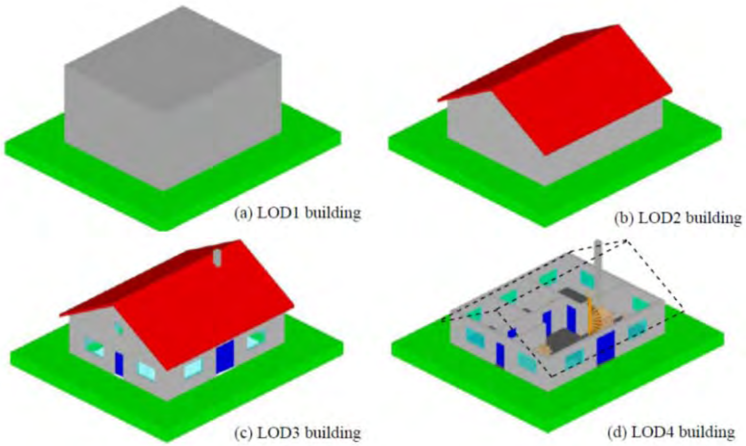
LoD 0: Land model with textures

LoD 1: Citymodel, building blocks without roof structure

LoD 2: Citymodel with roof structure and texture

LoD 3: Detailed Architecture model (Outside)

LoD 4: Detailed Architecture model (Outside and Inside)

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        <gml:name>A08212000031100009________1</gml:name>
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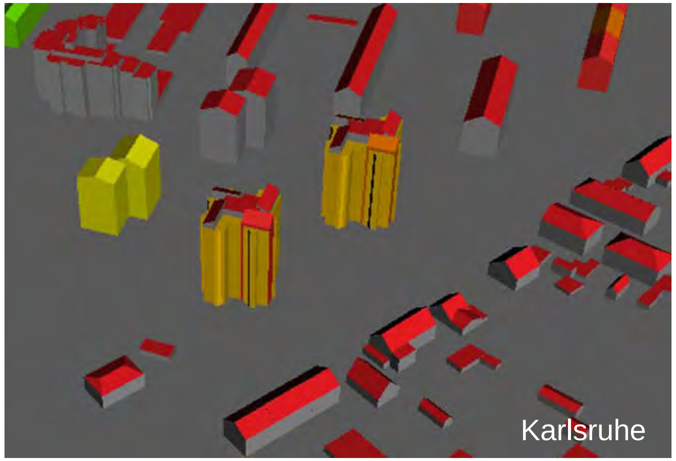


District heat demand calculation

Development of an integrated process of district heat demand calculation

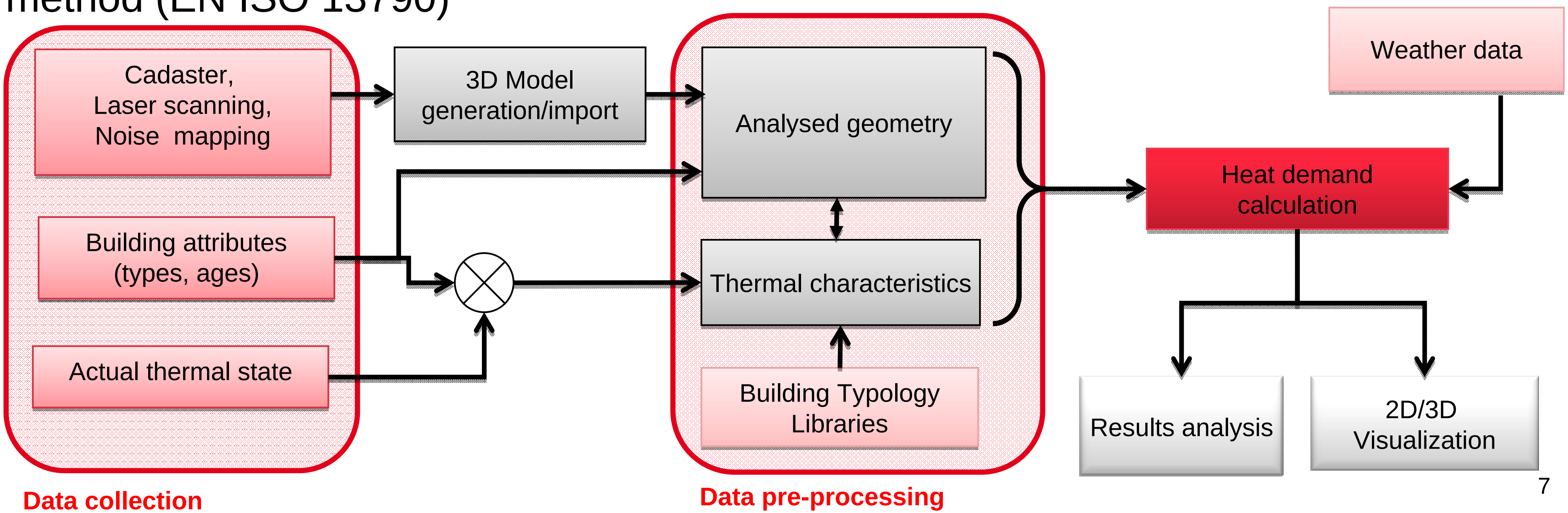
1.Generation/Import and quality control of a **3D Citymodel** (CityGML LoD1/LoD2)

2.Automatized calculation of **building envelop thermal characteristics**

- use of national **building libraries** (building types/ages)
- **updated** with additional information (precise Uvalues, refurbishment etc.)

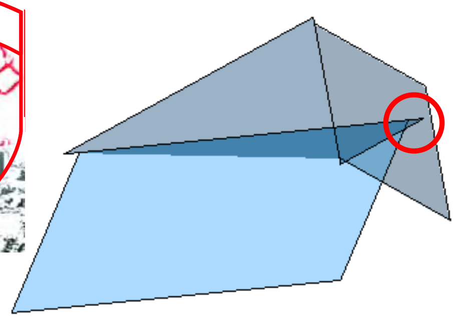
3.Geometrical Analysis of 3D Model, pre-processing with building parameters

4.Heat demand calculation for each building through the **monthly energy balance** method (EN ISO 13790)

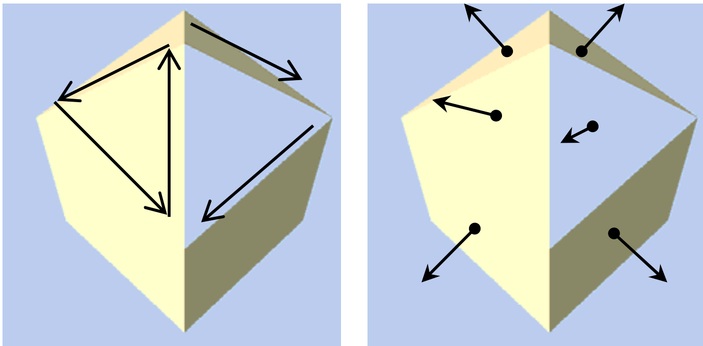


Quality control and analysis of 3D City model

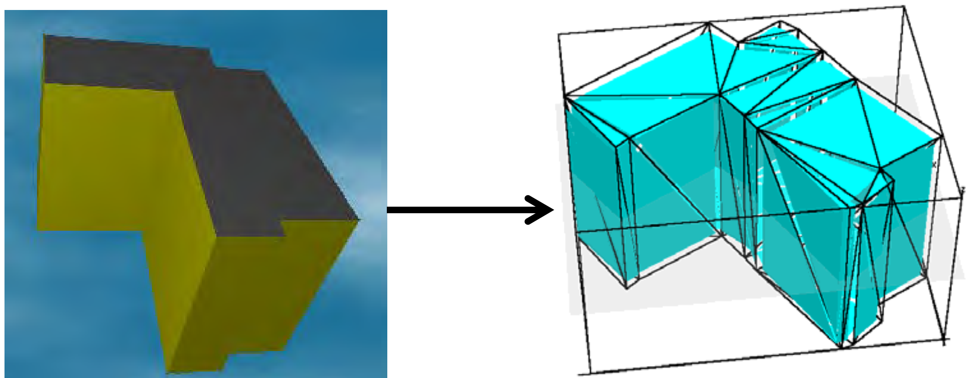
- Quality Control
  - Control closed volume, surface connections



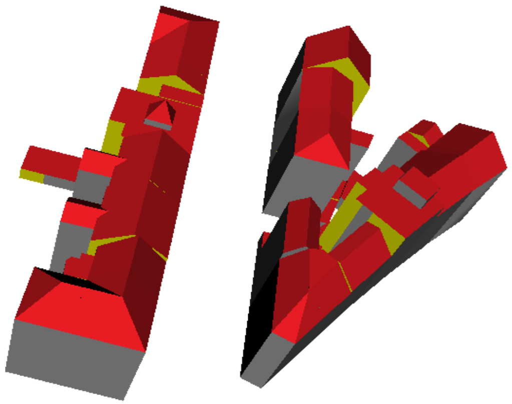
- Volume Calculation
  - tetraeders decomposition



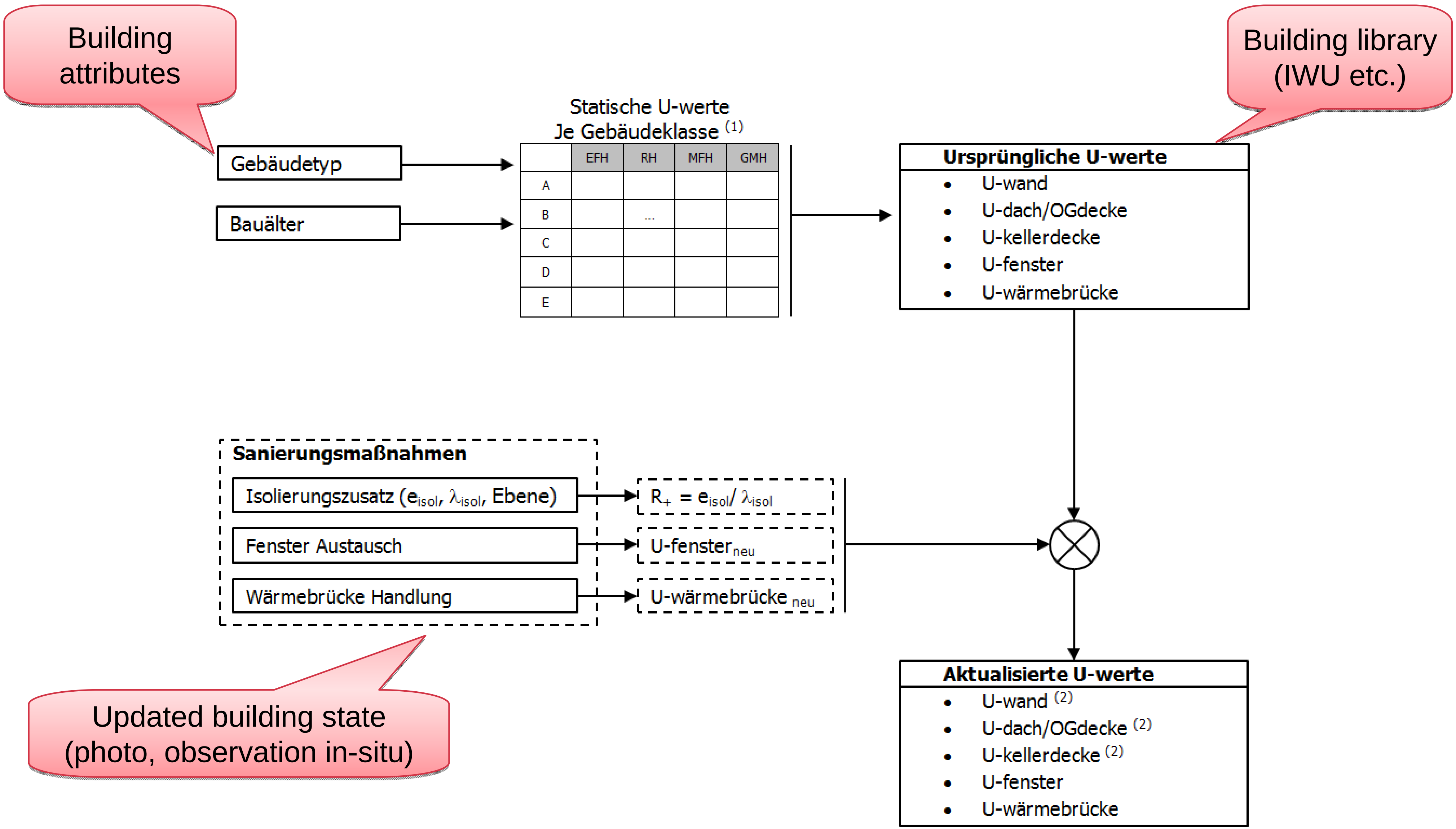
- Extraction adjacent walls



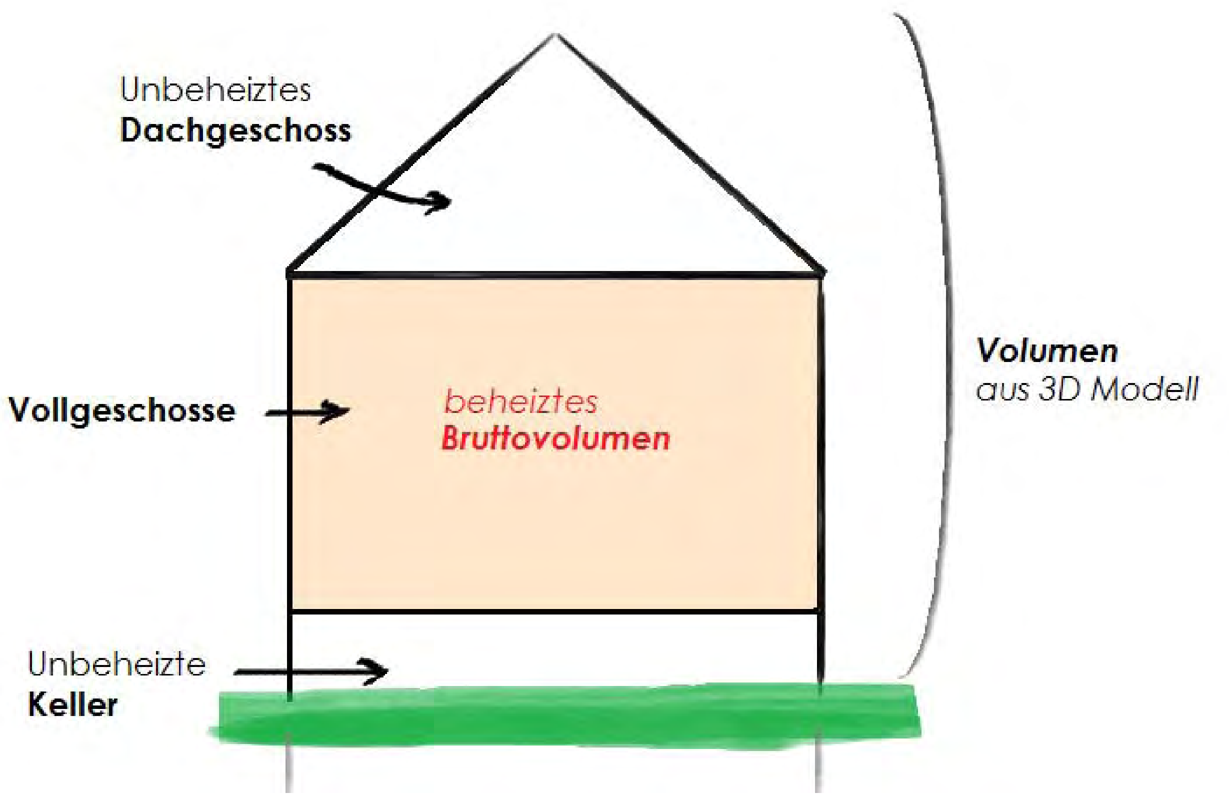
$$V = \sum_{i=1}^{n} \frac{|\det(a_i - b_i, b_i - c_i, c_i - d_i)|}{6}$$



Thermal Data processing



Geometrical data processing



The **heated volume, wall, cellar wall and window areas** must be corrected between the 3D Model and the thermal building model, particularly if**:**

•**Cellar type** = heated/non-heated

•**Attic storey type** = non-heated

•**Usage ALKIS** = commercial-residential building

Results Visualization

2D GIS – Heat demand in Grünbühl

3D Visualisation – Heat demand in Grünbühl

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

District Heat Demand Calculation – Case studies

Three case studies of District Heat Demand Calculation, with different level of details and input data qualities

- District Grünbühl, in Ludwigsburg
- District Rintheim, in Karlsruhe
- District Neuaubing, in Munich

Case study 1 : Ludwigsburg – Grünbühl

Case Study 1: Post-war district

Ludwigsburg – Grünbühl

•Living area: 77.000 m²

•Energy supply: mainly Gas boilers

•3D model : LoD1 (roof area from laser scanning)

•Uvalues deduced from building age and types Information, updated with outside observations

Case study 1 : Ludwigsburg – Grünbühl

Data collection

•For apartment dwellings → building data collected from owner companies

•For private buildings → on-site observation (survey)

EnEff:Stadt Ludwigsburg - Grünbühl-Sonnenberg
ALLGEMEINE ANGABEN

Strassenname: Pregelstrasse Hausnr: 7

Eigentümer/Hausverwaltung:

Dokumentation Aufnahmen (Fotos)

Fotonummer	Ansicht	Anzahl/Sonstiges
	Fassade Nord	
	Fassade Ost	
	Fassade Süd	
	Fassade West	
	Eingangsbereich	

Gebäude Allgemein

Gebäudetyp(1) Baualter Anzahl Vollgeschosse Anzahl Wohneinheiten

Bauweise (2)

Hauptnutzung: Turn- und Sportverein Grünbühl

Nutzung _ EG

zu (2):
Baustoffe: Holz, Beton, Mauerwerk, Andere
Baukonstruktion: Massiv- oder Leichtbauweise
Bauverfahren: Fertigteilbauweise, Großtafelbauweise, Raumzellenbauweise

zu (3):
Wohnen, Verwaltung, Handel/Gewerbe, Bildung&Forschung, Kultur, Religion, Gesundheit, Soziales, Sicherheit&Ordnung, Industrie, Mischnutzung

Sockel (J/N und Höhe)

Kniestock (J/N und Höhe)

☐ Dachausbau beheizt ☐ Keller keine Info
☐ Dachausb. unbeheizt ☐ Keller unbeheizt
☐ kein Dachausbau ☐ Keller beheizt

Dachzustand

GEB_ID	
STRASSE_NAME	
STRASSE_NR	
NUTZ_ALK	nach ALK Definition (Whs; Wghs; Schule …)
WOHNTYP	nach IWU Definition (EFH; RH; MFH; GMH…)
GEBALTKLASSE	nach IWU Definition (A; B;…; J)
VOLLGESCHOSSE	Integer
DACHGESCHOSS_TYP	Kein / Unbeheizter/ Beheizter Dachgeschoss
KELLER_TYP	Keine / Unbeheizte / Beheizte Keller
SANIER	

FASSADE_ID	
WRICHTUNG	Azimuth
WDAEMD	Dicke der Isolierstoff
WDAEMLAMBDA	Wärmeleitfähigkeit der Isolierstoff
WUWERT	Wand U-Werte wenn bekannt
FANTEIL	Fenster Anteil (%)
FTYP	(1 – 5)
FUWERT	Fenster U-Wert wenn bekannt
FSCHATTEN	Fenster Schatten Faktor
WSCHAD	Wand Schädigung (1 - 5)

Case study 1 : Ludwigsburg – Grünbühl

Outside facade state of post-war buildings

Elbestr. 30-36 – Ost

Memelstr. 6– Süd

Adalbert Stifter Str. 38-42

Adalbert Stifter Str. 38-42

Memelstr. 6– Süd

Case study 1 : Ludwigsburg – Grünbühl

Integration of a „facade damage index“ (0 - 5) in the 3D Model dataset

•Used for the infiltration rate assessment

•Potential use to define refurbishment priorities in a refurbishment scenario

Fassade Schädigung

- 0 - kein Schaden,
- 1 - Putzschädigung, geringe Feuchtigkeitsprobleme
- 2 - Kleine Risse, Infiltration
- 3 - Außenfassade in schlechtem Zustand
- 4 - Große Risse
- 5 - Undichtes Gebäude

Case study 1 : Ludwigsburg – Grünbühl

Building and refurbishment year

•1/3 post-war buildings

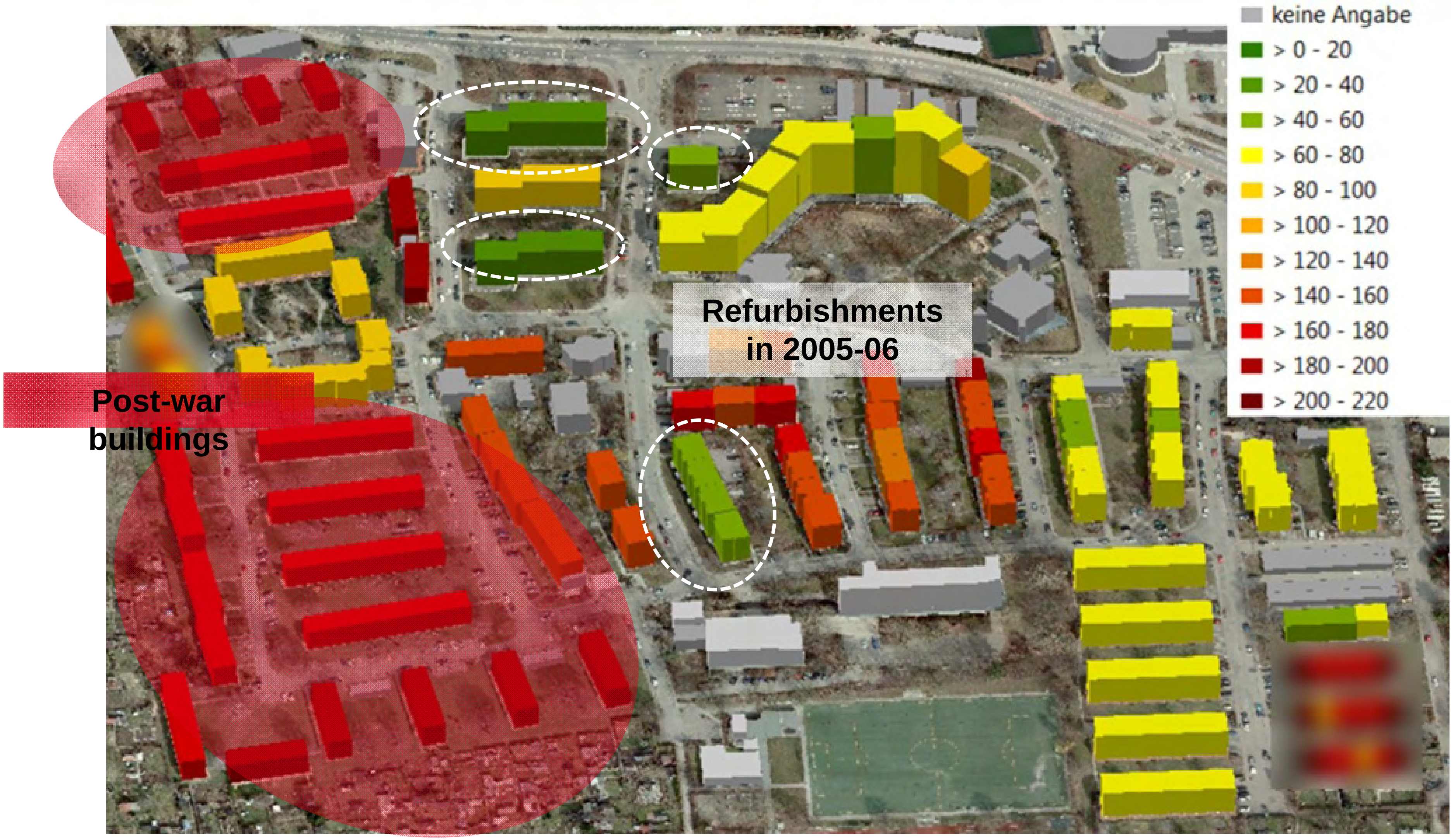
•Since 1990, 1% of the district living area is refurbished yearly

Case study 1 : Ludwigsburg – Grünbühl

Heat demand calculation

•Average: 106 kWh/m²/yr

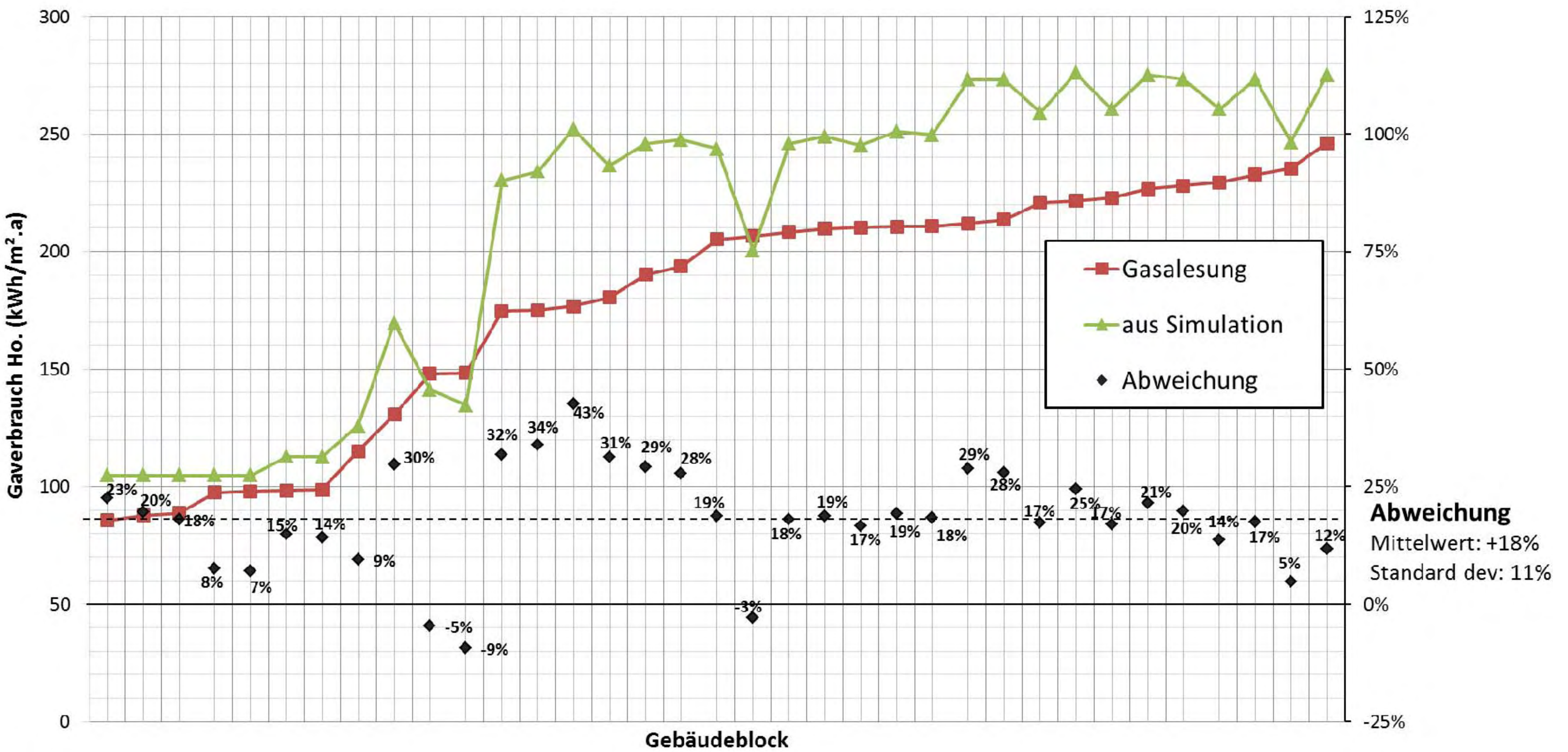
- from 30 for newly refurbished buildings to 216 kWh/m²/yr for old leaky buildings



Case study 1 : Ludwigsburg – Grünbühl

Comparison with gas consumptions* (average over the last 6 years)

➢Global Deviation: 18%



* Assumptions : Domestic hot water: 20 kWh/m²; Gas boiler efficiency: 85%

Case study 2 : Karlsruhe – Rintheim

Case Study 2: partly refurbished Apartment dwellings

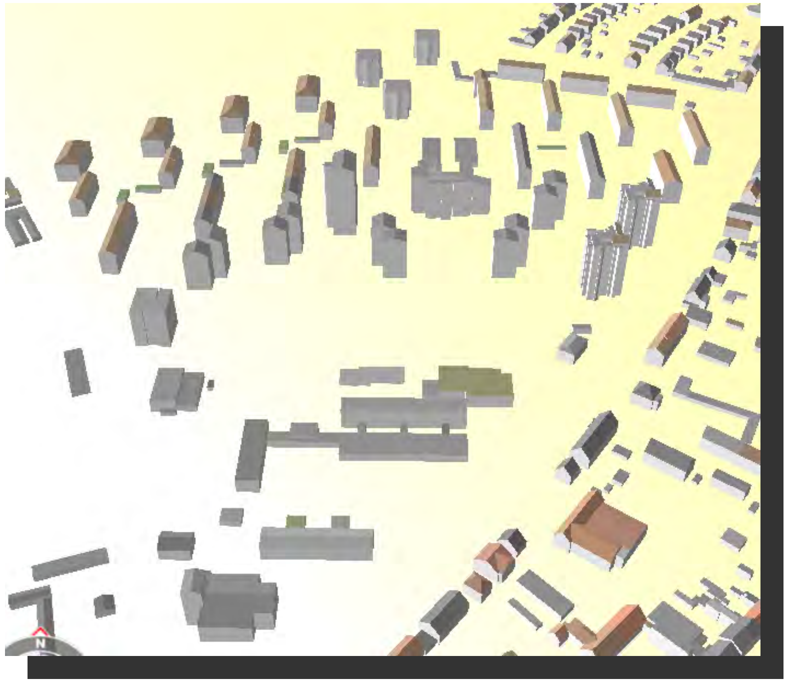
Karlsruhe – Rintheim

•Living area: 65.000 m² (36 Buildings – 1/3 refurbished)

•Energy supply: Gas boilers

•3D model: Karlsruhe LoD2 model (roof area from laser scanning)

•Precise information on Uvalues (building classification in 6 types)



Case study 2 : Karlsruhe – Rintheim

Classification of the building stock in 6 Building Types with same thermal characteristics

- Type 1 and 2: original state, not refurbished
- Type 3: partly refurbished (facade in 1975, roof in 2003)
- Type 4 to 6.2: full-refurbishment of buildings between 1998 and 2008

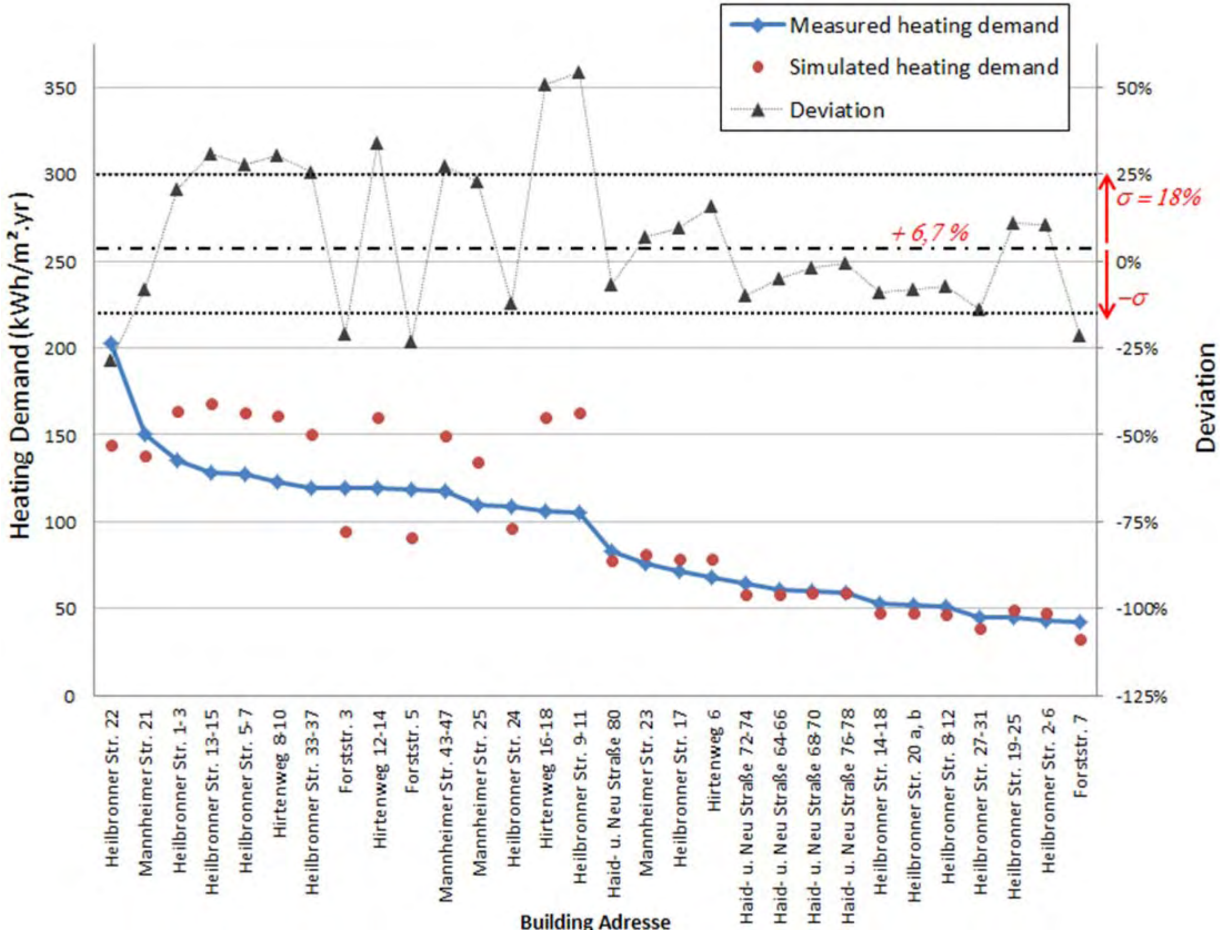
Building Class	Type 1	Type 2	Type 3	Type 4	Type 5	Type 6.1	Type 6.2
Building Type	Multi family	High rise	Large multi family	Multi family	Multi family	High rise	Multi family
Year of construction / Full refurbishment	1954-1956	1974	1975	1998	2000	2007	2008
U-value wall	1,40	0,80	0,40	0,30	0,20	0,10	0,10
U-value roof / top level	1,17	0,35	0,20	0,35	0,35	0,10	0,20
U-value basement ceiling	1,65	0,71	0,85	0,47	0,47	0,25	0,38
U-value window	3,20	2,70	2,70	1,70	1,40	1,30	1,30
g-value window	0,80	0,76	0,76	0,63	0,62	0,60	0,60
ΔU thermal bridge	0,10	0,10	0,10	0,05	0,05	0,03	0,03
air exchange rate	0,70	0,70	0,70	0,60	0,60	0,60	0,60

Uvalues from Büro IGK-Kaiserslautern

Case study 2 : Karlsruhe – Rintheim

Individual building comparison – Simulated and measured heat demand*

- •Average gas consumption over 3 years
- •Total district deviation: **6,7%**
- •Standard deviation: 18%



* Assumptions: domestic hot water: 20 kWh/m²/yr; Gas boiler efficiency: 88%

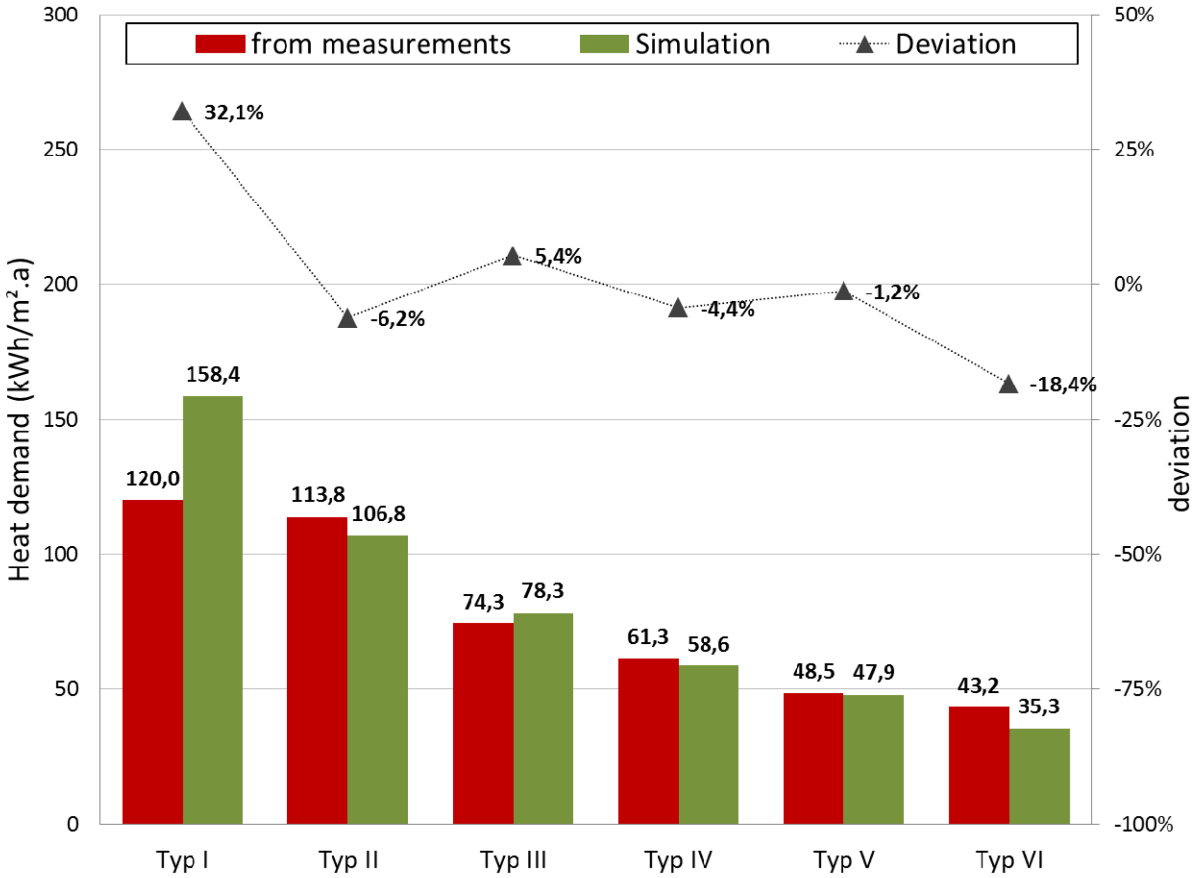
Case study 2 : Karlsruhe – Rintheim

Building type comparison – Simulated and measured heat demand*

•Building types II - V match well (deviation ~5%)

•Low-energy building type VI → - 18% under-estimated heat demand

•Non-refurbished building type I → 32% over-estimated heat demand



* Assumptions: domestic hot water: 20 kWh/m²/yr; Gas boiler efficiency: 88%

Case study 3 : München – Neuaubing

Case Study 3: 80s Residential complex

München – Neuaubing

•Living area: 28.000 m² (335 apartments)

•Energy supply: central gas heating

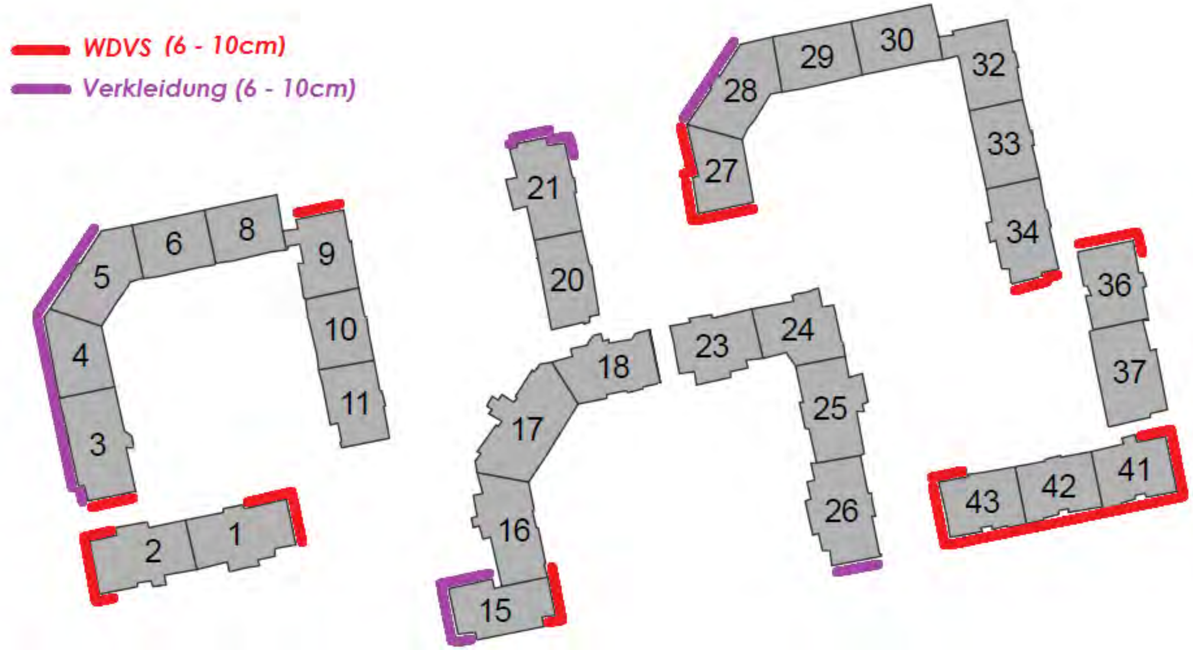
•3D model: LoD2 (generated manually with original plans)

•Uvalue from original plans, updated with refurbishment measures

Case study 3 : München – Neuaubing

Residential complex partly insulated

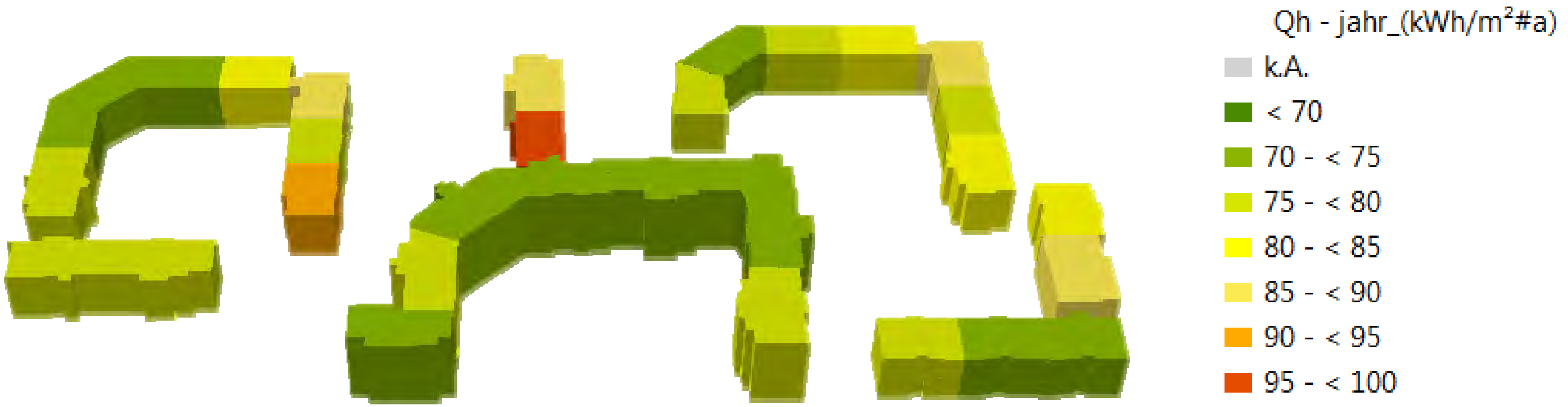
- Original Roof insulation
- Outwalls originally not insulated
- … but after 1990 partly and variably insulated



Case study 3 : München – Neuaubing

Heat demand calculation

•Because of different wall insulations, solar gains (orientation of windows) and relative positions, the heat demands vary between **70 and 96 kWh/m²/yr** for the different buildings blocks (**average: 78 kWh/m²/yr**)



Comparison with the central gas consumption* (average over the last 3 years)

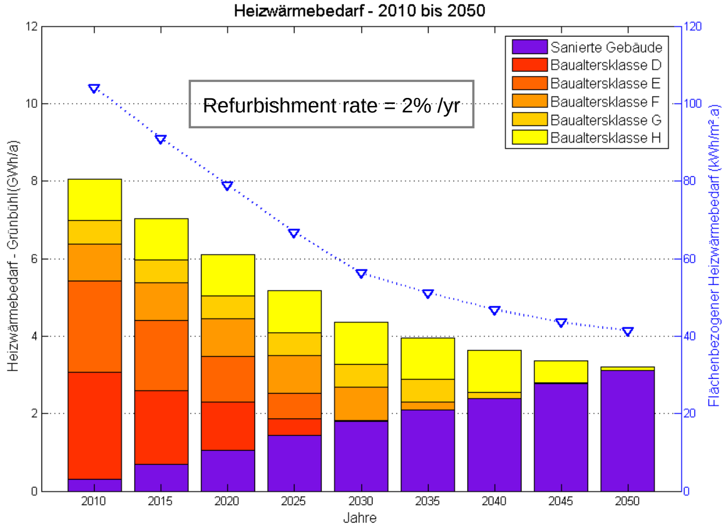
•Heat demand from gas consumption: **74,9 kWh/m²/yr → deviation: 4%**

* Assumptions : Domestic hot water: 20 kWh/m²/yr; Gas boiler efficiency: 85%; heating network losses: 5%

Potential causes of the deviation

- Geometry
  - the heated volume is often over-estimated
- Set-point temperature and heating operation plans
  - day and night heating plans are the same for all in the simulation (night: 7h/day)
  - individual room heating, dependent on the usages (sleeping room vs. living room), is not taken into account in the simulation (instead: monozone building model)
- Air change
  - the air change in naturally ventilated buildings (especially old buildings) in winter seldom reaches the assumptions, corresponding to hygienic requirements (0,6 AC/H)
- Missing information concerning heat systems
  - influences the comparison with gas consumption data
- Missing information on recent refurbishment operations
- User behaviour
  - Individual consumer behaviour regarding energy usage is always difficult to simulate

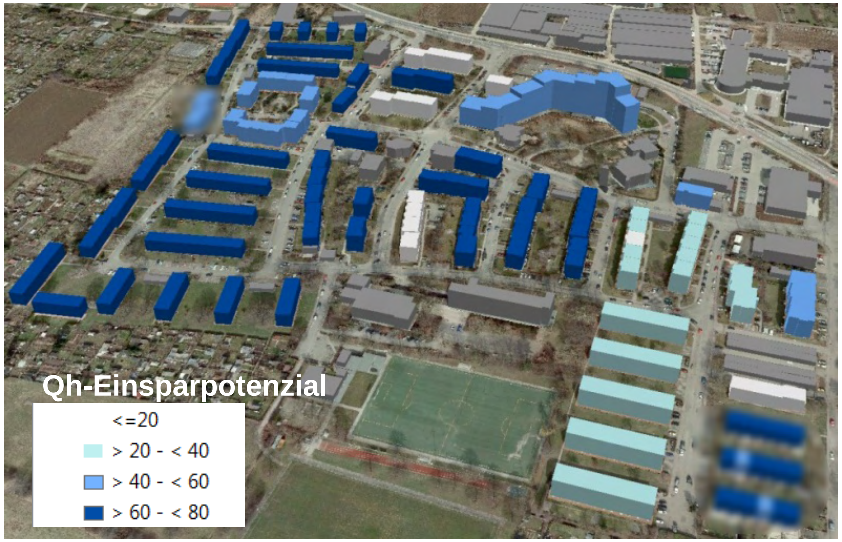
Use of 3D City Model for urban planning



Heat demand decrease
Grünbühl 2010 – 2050

Use of 3D City Model for urban planning

- Refurbishment scenario and energy saving potentials
- Definition of refurbishment priorities, temporal planning of the urban renewal
- Calculation of refurbishment investment/global energy costs



Energy savings [%] - Grünbühl

Refurbishment Costs [€/m²] - Grünbühl

Outlook and conclusions

- Very large 3D data based based on CityGML standard available
- Many models available for urban radiation, occupant behaviour (CitySim) or renewable energy systems (INSEL, TRNSYS)
- General modeling languages availables, where libraries are rapidly developing (Modelica)
- Interfacing between simulation tools and 3D data (BIM or CityGml) still a challenge
- 3D city simulation based on CityGML allows good possibilities for urban heat demand simulation, planning of district heating system extension, decentralised renewables production, in coordination with heat demand decrease strategies

Thank you for your attention!