

Semantic 3D City Models for Strategic Energy Planning in Berlin & London

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Motivation

- ▶ Climate and environmental policy measures involve a **reorganisation of the energy supply** in many cities
 - **Buildings** account for **40% of the total energy demand**
- ▶ A cut-down on energy be achieved through
 - Prediction of the energy demand
 - Location of currently unused / renewable energy sources (solar heat & photovoltaics, wind power, geothermal energy)
→ Use of a geospatial model → Energy Atlas
- ▶ Why is a 3D model required?
 - To estimate the energy demand at building level (heated building volume, number of windows, etc.)
 - To perform aggregations on the buildings

Energy Atlas Berlin and London – Concept

- ▶ Creation of an integrative, common **ontology**
 - For **spatial-semantic representation** of the urban space
 - Including energy-relevant information from different disciplines
 - Based on the semantic information model of **CityGML**
- ▶ The virtual 3D city models of **Berlin and London** serve as data base



The Aim of the Energy Atlas Berlin

► **Tool for holistic energy planning**

- Analysis and representation of the actual state of objects and their energy-relevant parameters within a city
- Investigation and balancing of options and measures
- Decision support for various measures by visualizing the effects

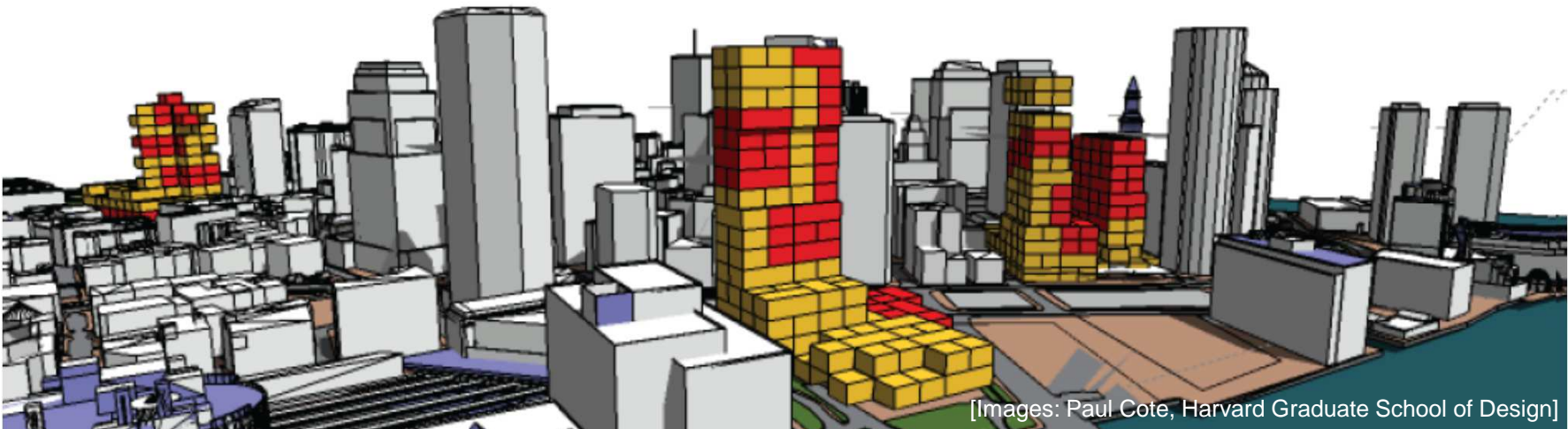


► **Data backbone** for common analysis and simulations

- Estimation of heating energy and electricity demands
- Energetic building characteristics and rehabilitation potentials
- Design of an optimal electricity network
- Location planning for recharge facilities for e-mobility
- Use of geothermal and solar energy potentials

Spatio-Semantic Decomposition of Urban Space

- ▶ Many urban assets are directly related to physical objects
- ▶ Physical objects are thematically classified into discrete topographic objects → 3D decomposition of urban space
- ▶ In different, discrete scale levels (LODs)
- ▶ City is decomposed into discrete objects with clear semantics and defined spatial and thematic properties
 - Buildings, roads, railways, terrain, water bodies, vegetation, bridges
 - Objects may be further decomposed



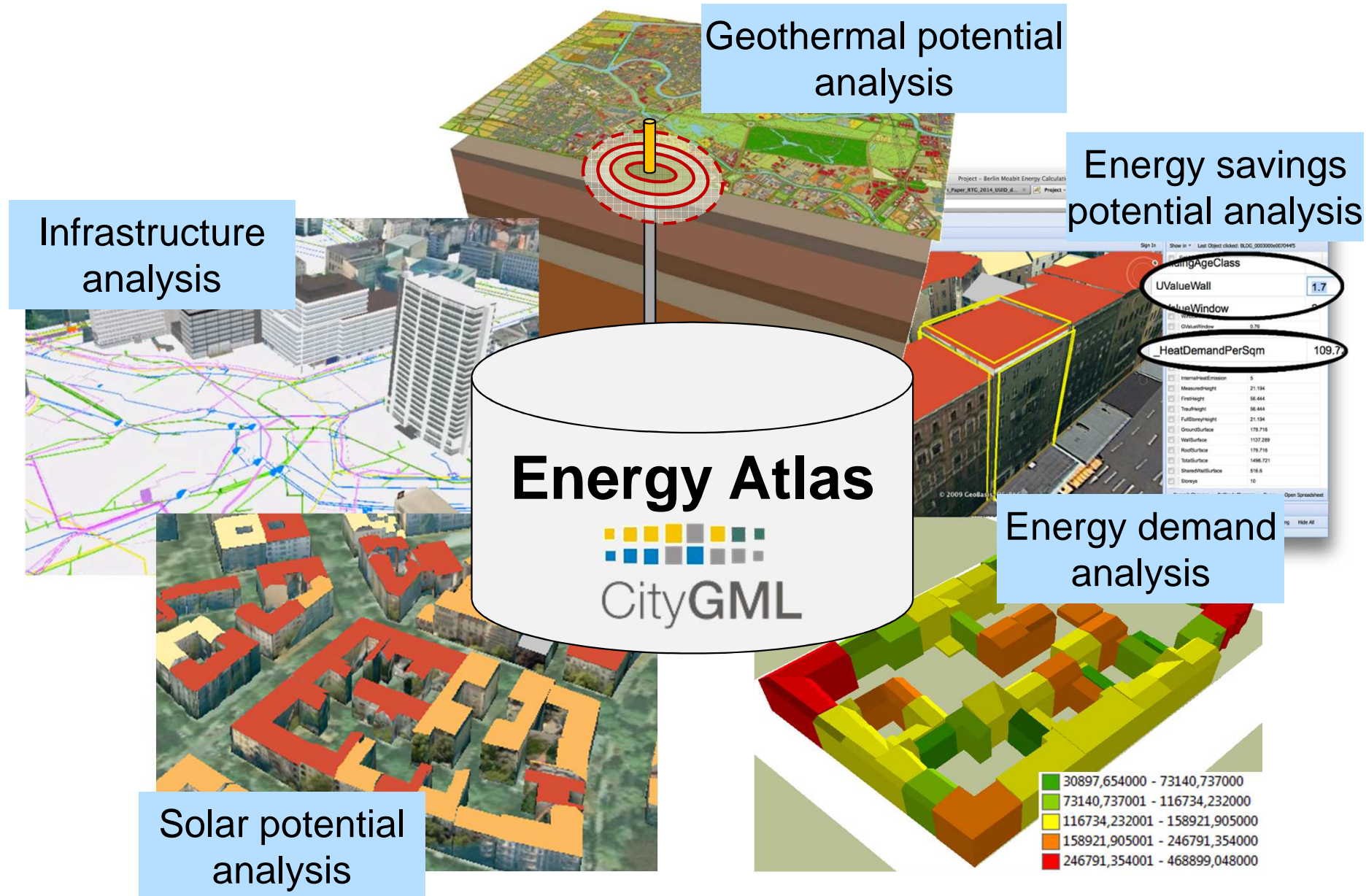
[Images: Paul Cote, Harvard Graduate School of Design]

City Geography Markup Language (CityGML)

- ▶ Application independent geospatial information model for semantic 3D city and landscape models
- ▶ comprises different thematic fields (buildings, vegetation, water, terrain, traffic, tunnels, bridges etc.)
- ▶ International standard of the Open Geospatial Consortium
 - V1.0.0 adopted in 08/2008; V2.0.0 adopted in 3/2012
- ▶ Data model (UML) + Exchange format (based on GML3)
- ▶ CityGML represents
 - 3D geometry, 3D topology, semantics, and appearance
 - in 5 discrete scales (Levels of Detail, LOD)

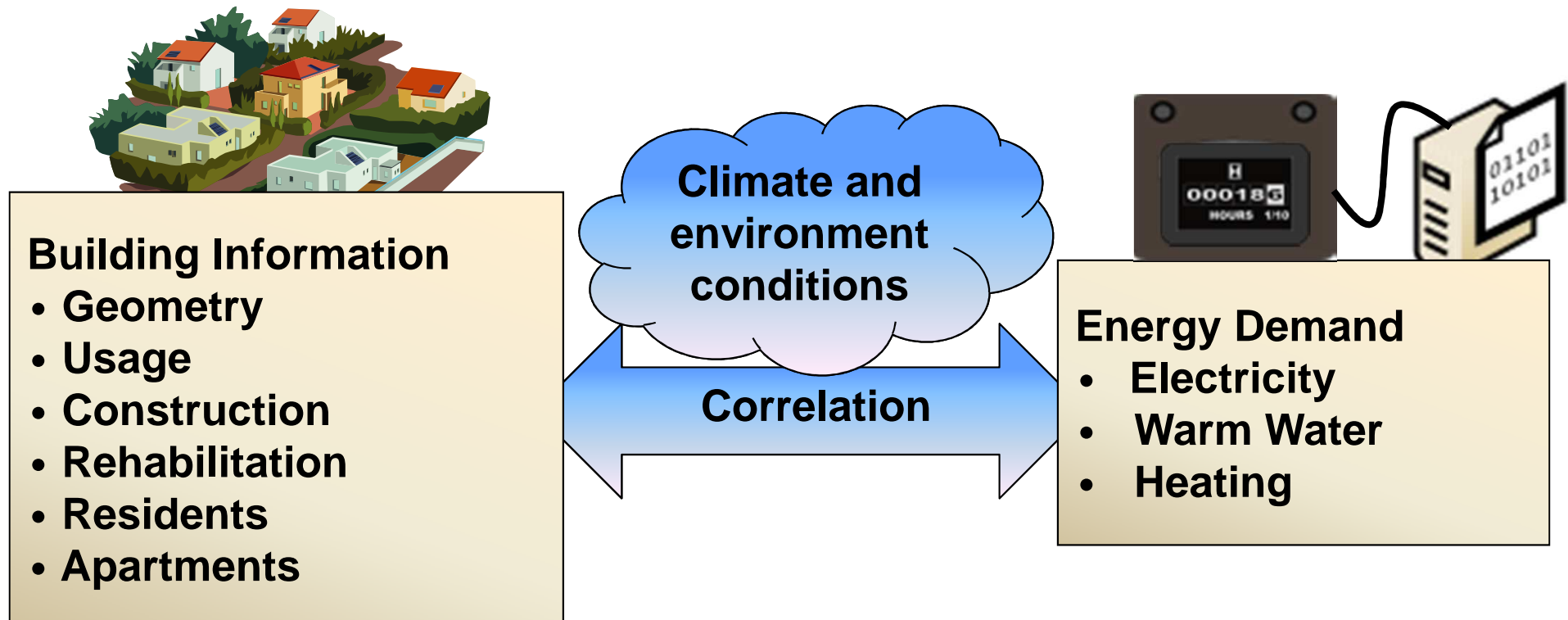


Information Fusion of Different Disciplines



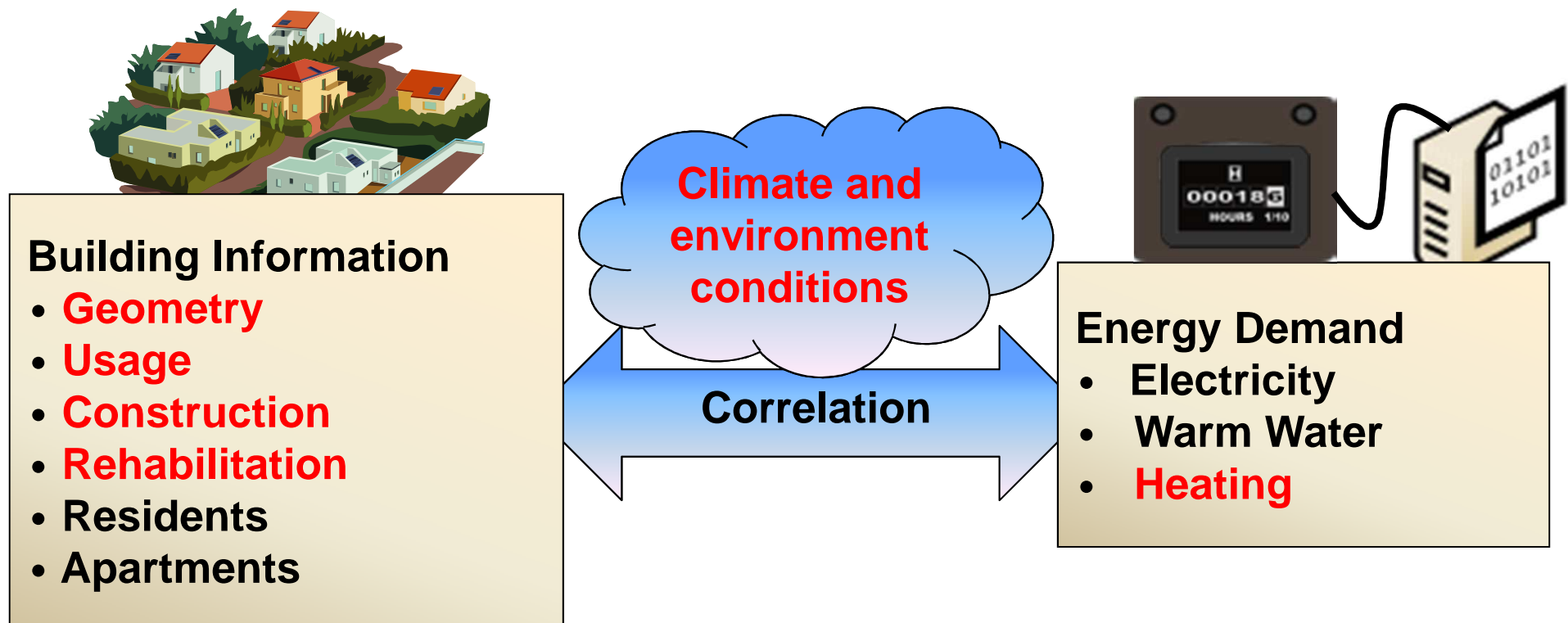
Correlation: Building and Energy Demand

- ▶ Estimates of the energy demands are based on the hypothesis that there is a strong correlation between the building characteristics and the needed energy



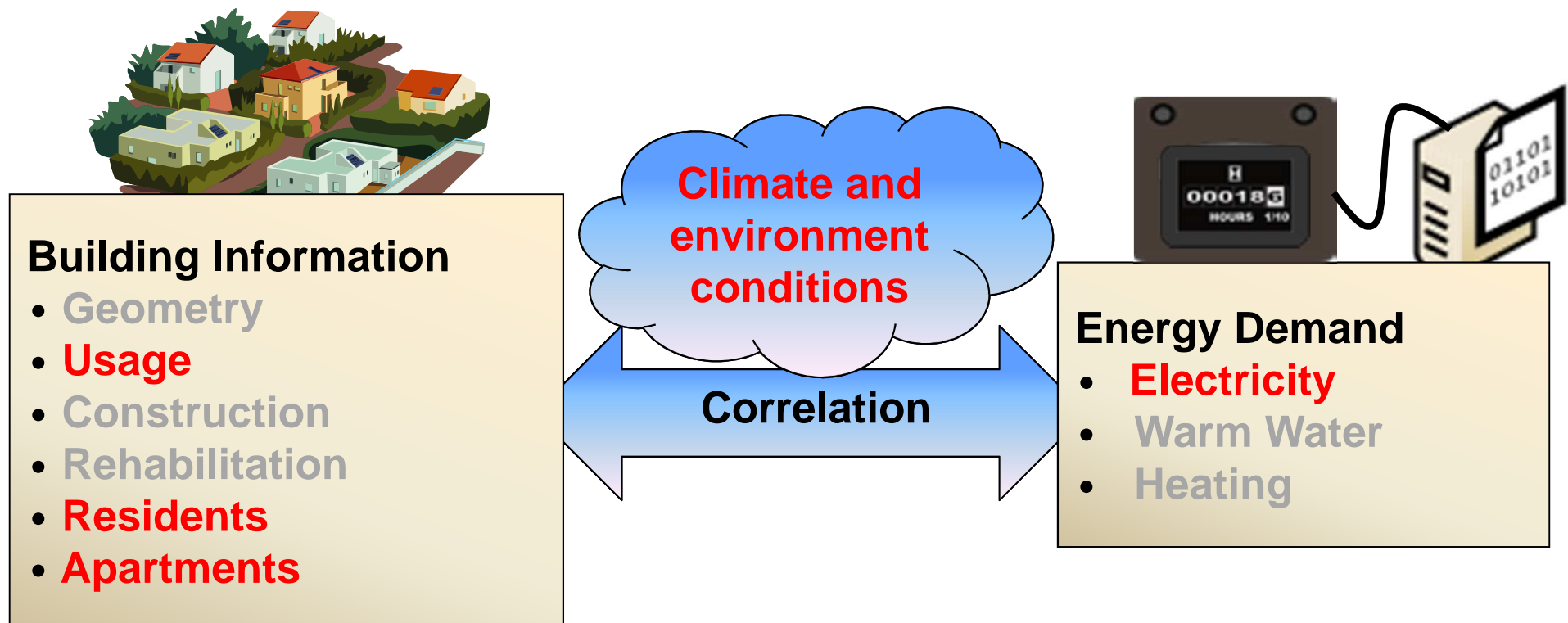
Estimation of Heating Energy Demand

- ▶ Building-specific and city-wide calculation based on algorithms of the *Institut Wohnen und Umwelt (IWU)*
- ▶ Based on the virtual 3D city model and official geobase data within the Energy Atlas Berlin



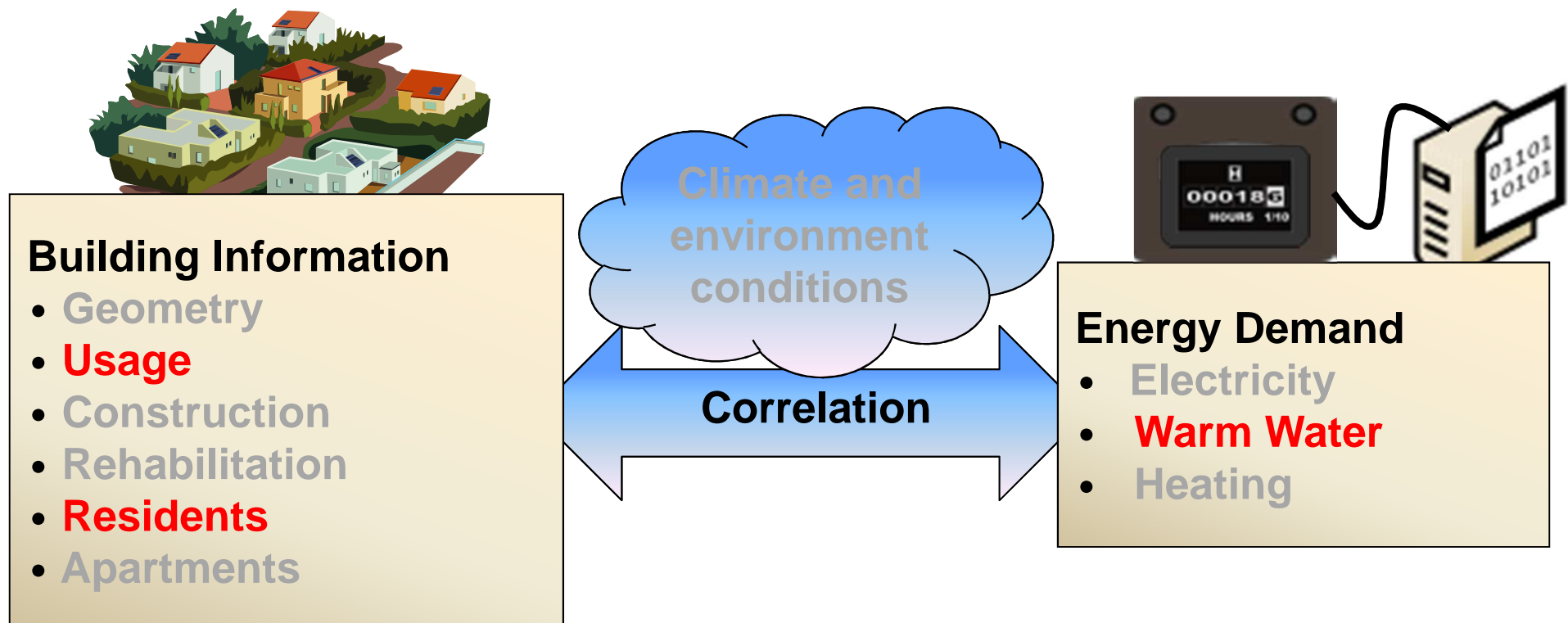
Estimation of Electricity Demand

- ▶ Building-specific and city-wide estimation based on average electricity consumption statistics for households
- ▶ Based on the virtual 3D city model and official geobase data within the Energy Atlas Berlin



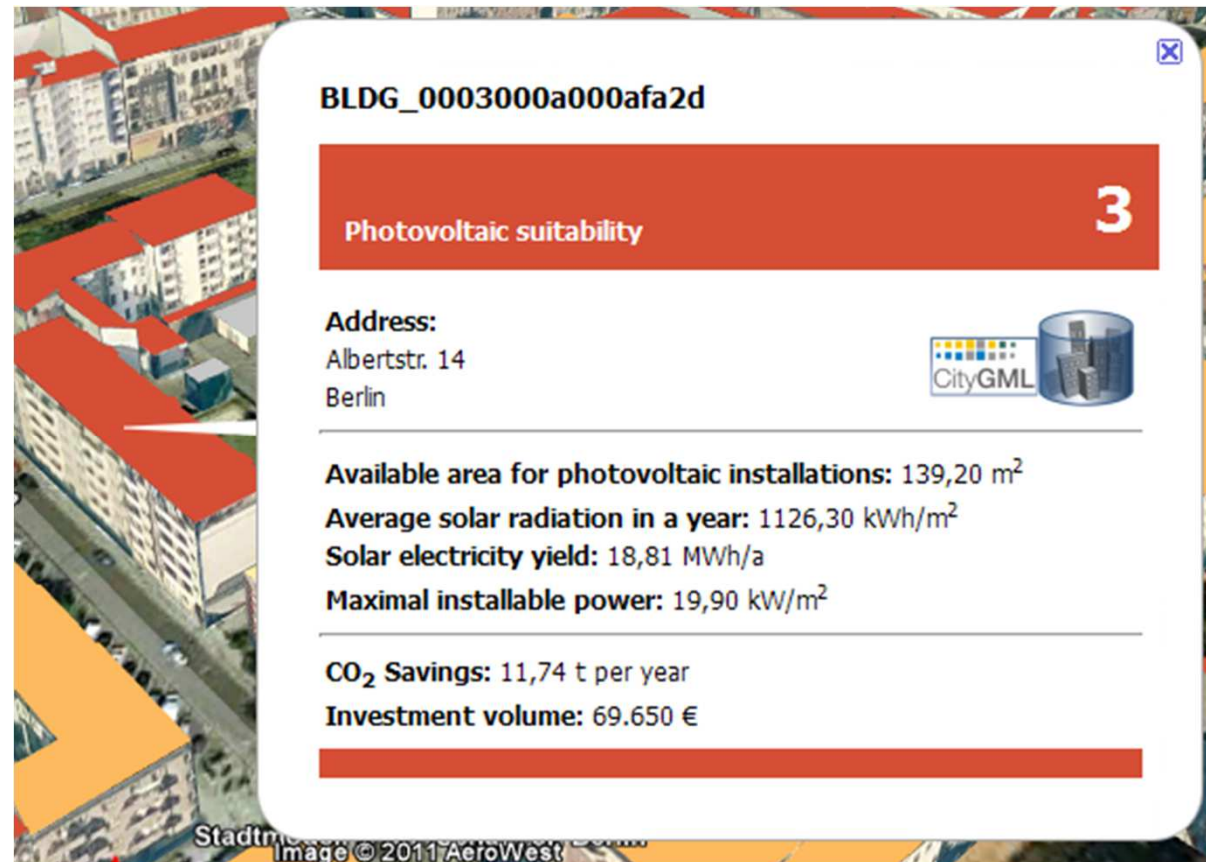
Estimation of Energy Demand for Warm Water

- ▶ Building-specific and city-wide calculation bases on algorithms of the *Institut Wohnen und Umwelt (IWU)*
- ▶ Based on the virtual 3D city model and official geobase data within the Energy Atlas Berlin



Solar Potential Analysis for Buildings

- ▶ Estimation of the energy production potentials for PV and solar thermal, required investments and achievable CO₂ reductions
- ▶ Done for each of the 550,000 buildings on the level of roof surface segments



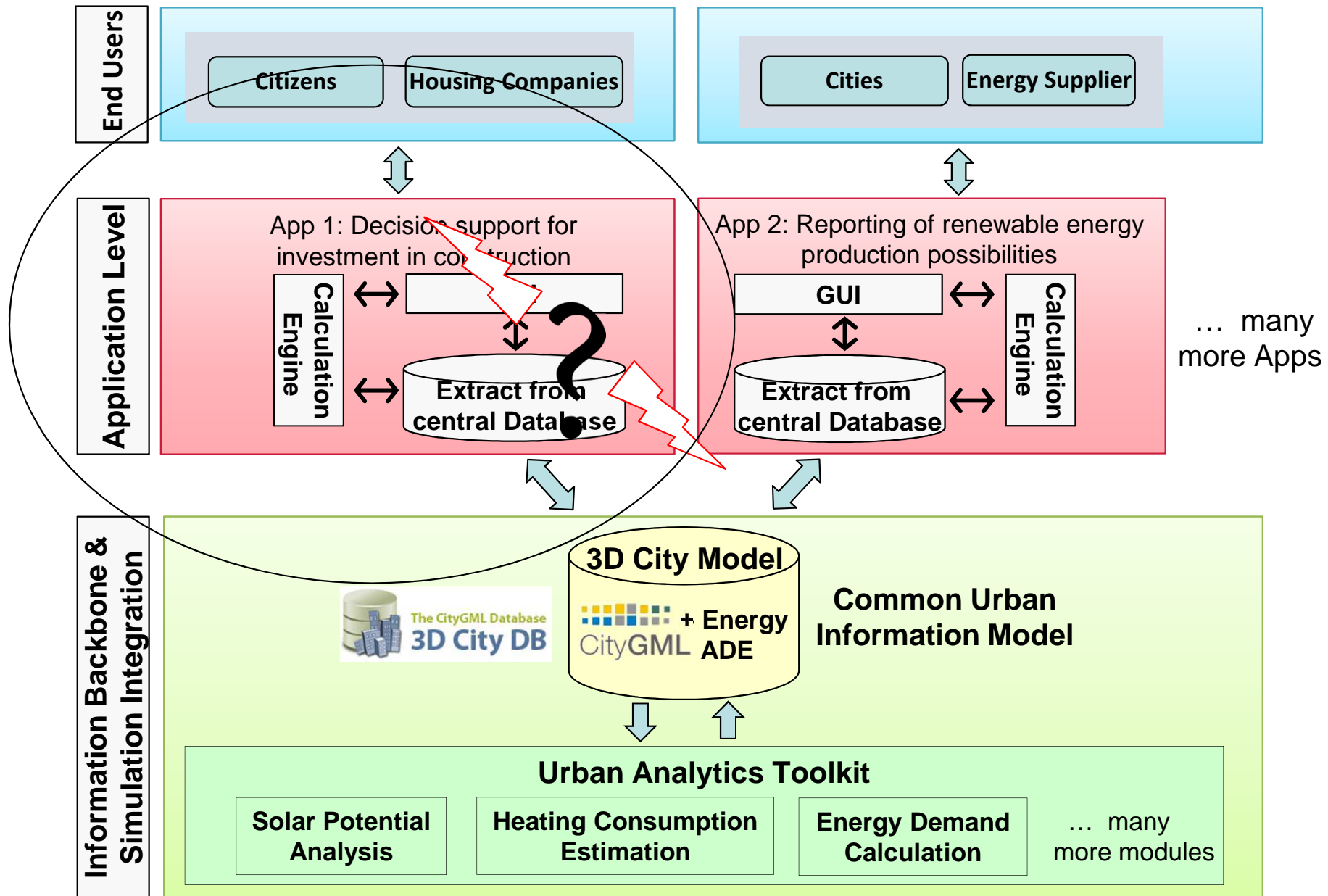
Heating Energy Demand and Solar Thermal Potentials on the Building Level



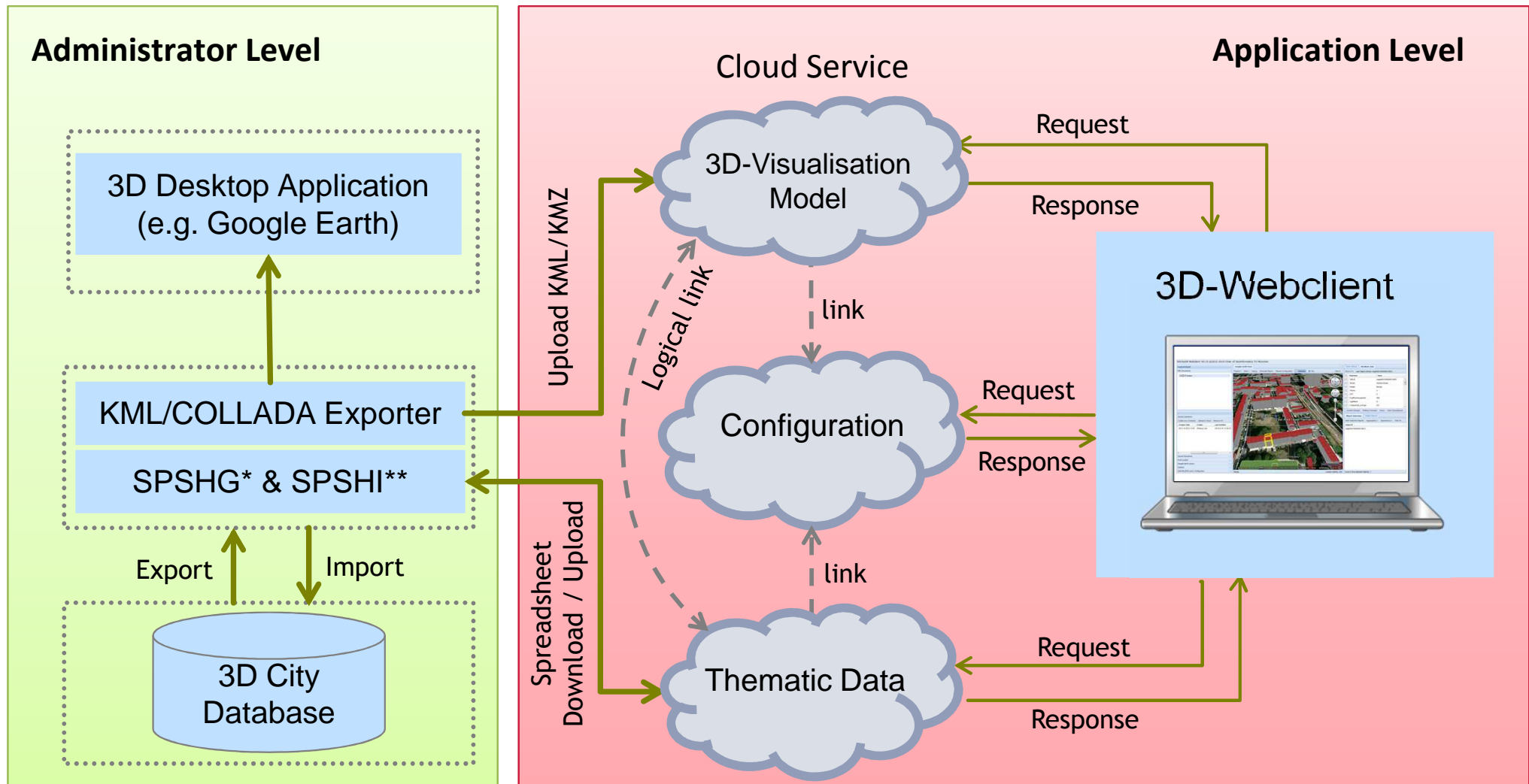
Solar Thermal Potential on District Level



Multi-level System Architecture



Realisation using Cloud Services



*Spreadsheet Generator **Spreadsheet Importer

Demo – 3D City Model Berlin

Information about energy demand for each building

Fieldname	Value
Apartments	20
MeanResidentsPerApartment	1.55
OnePersonHousehold	13
TwoPersonHousehold	4
ThreePersonHousehold	2
FourPersonHousehold	1
_EnergyReferenceArea	1526.3505
_FullStoreyVolume	4884.3216
_HeatLoss	309867.05337496
_HeatGain	58437.296751668
_HeatDemand	251429.756623292
_HeatDemandPerSqm	164.726094447699
_WarmWaterDemand	18600
_ElectricityDemand	53260
_TotalEnergyDemand	323289.756623292
_TotalEnergyDemandPerSqm	211.805713447398
ElectricityYieldPV	13090
HeatYieldST	39160
SuitabilityClassPV	3
SuitabilityClassST	1

Object ID: BLDG_0003000e007044f3

Demo – 3D City Model Berlin

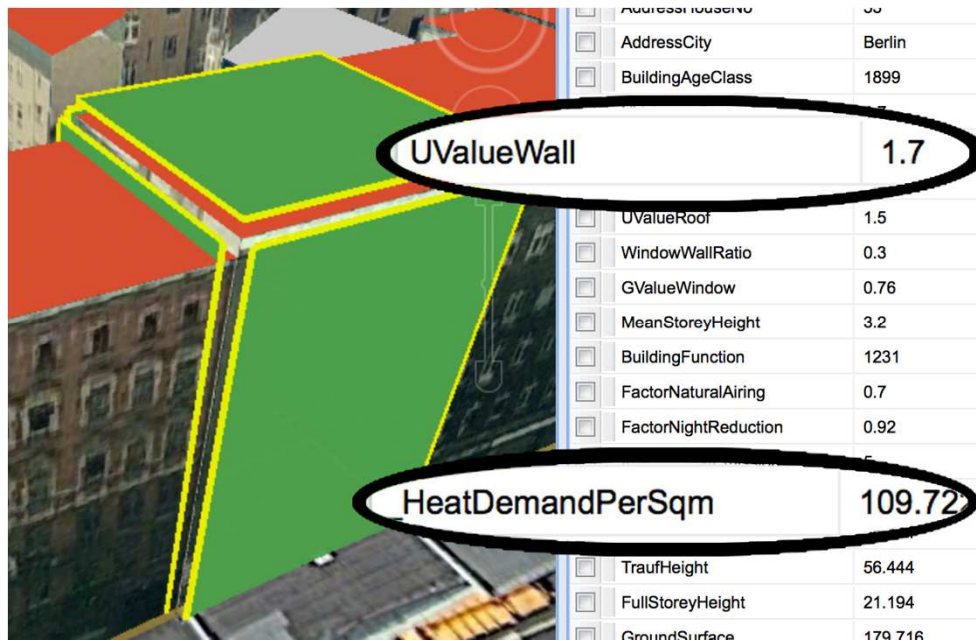
Aggregated energy demand of several buildings

Fieldname	Value
Stores	
Residents	
Apartments	
MeanResidentsPerApartment	
OnePersonHousehold	
TwoPersonHousehold	
ThreePersonHousehold	
FourPersonHousehold	
_EnergyReferenceArea	
_FullStoreyVolume	
_HeatLoss	
_HeatGain	
_HeatDemand	
_HeatDemandPerSqm	
_WarmWaterDemand	
_ElectricityDemand	
_TotalEnergyDemand	1235323.494716667
_TotalEnergyDemandPerSqm	
ElectricityYieldPV	
HeatYieldST	
SuitabilityClassPV	
SuitabilityClassST	

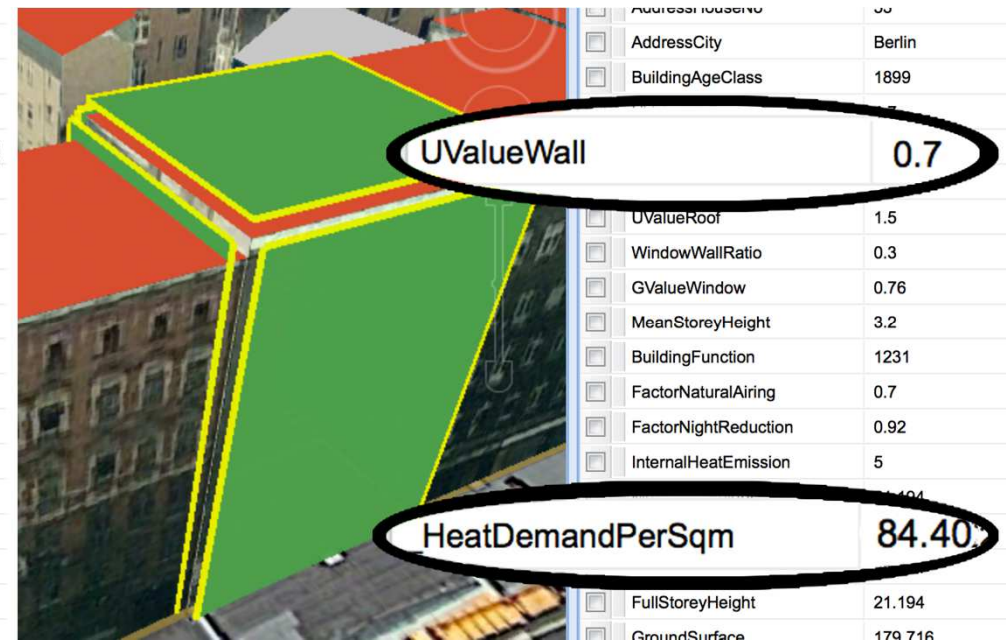
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BLDG_0003000b002ea1e4

Demo – Use of the 3D Web Client in Berlin

- ▶ Ad hoc estimation of the heating energy demand
- ▶ Interactive modification of parameters by the planner
 - E.g. degree of heat insulation
 - Immediate recalculation of the energy demand values

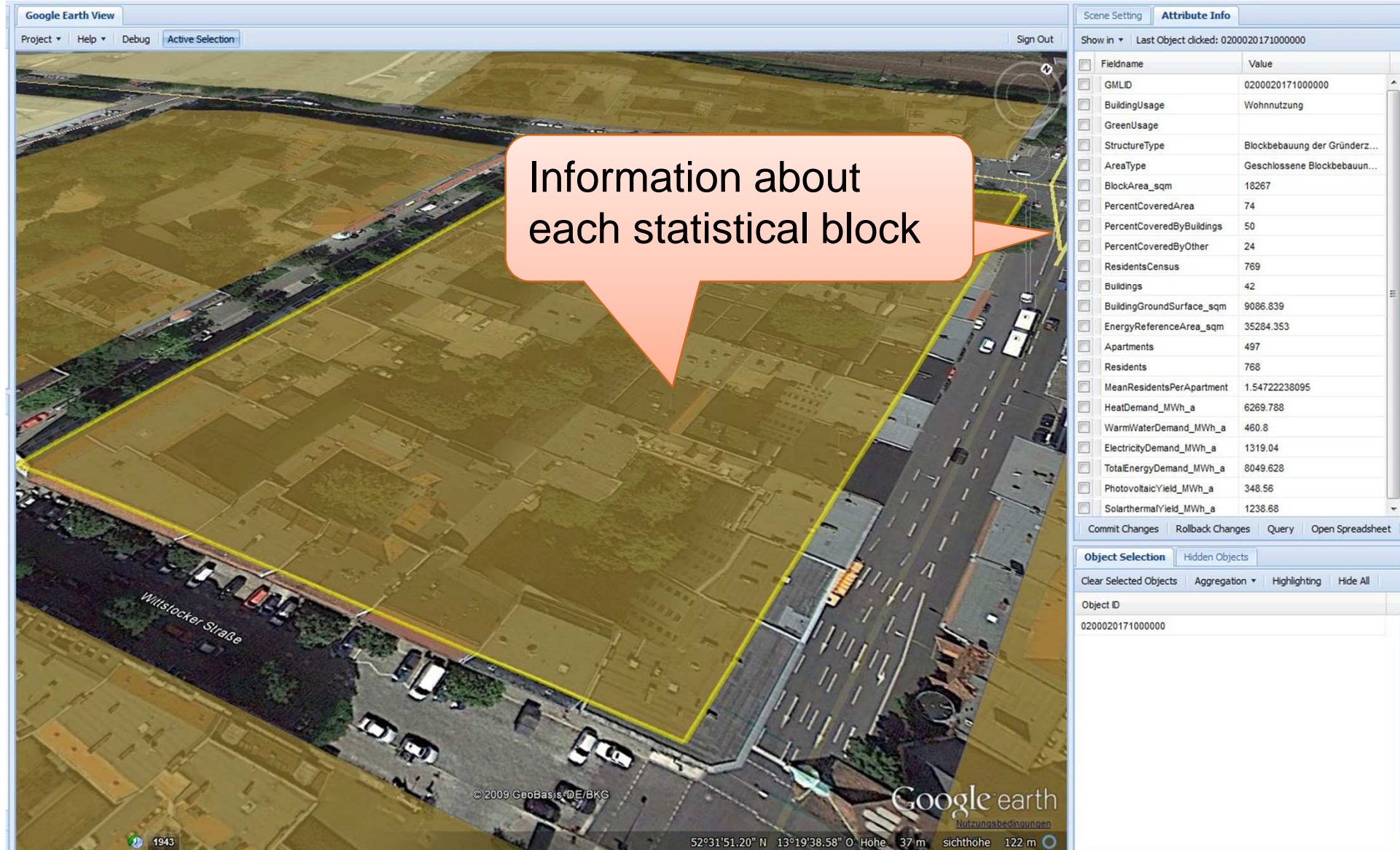


before modification



after modification

Demo – 3D City Model Berlin



Information about each statistical block

Fieldname	Value
GMLID	0200020171000000
BuildingUsage	Wohnnutzung
GreenUsage	
StructureType	Blockbebauung der Gründerz...
AreaType	Geschlossene Blockbebauun...
BlockArea_sqm	18267
PercentCoveredArea	74
PercentCoveredByBuildings	50
PercentCoveredByOther	24
ResidentsCensus	769
Buildings	42
BuildingGroundSurface_sqm	9086.839
EnergyReferenceArea_sqm	35284.353
Apartments	497
Residents	768
MeanResidentsPerApartment	1.54722238095
HeatDemand_MWh_a	6269.788
WarmWaterDemand_MWh_a	460.8
ElectricityDemand_MWh_a	1319.04
TotalEnergyDemand_MWh_a	8049.628
PhotovoltaicYield_MWh_a	348.56
SolarthermalYield_MWh_a	1238.68

© 2009 GeoBasis DE/BKG

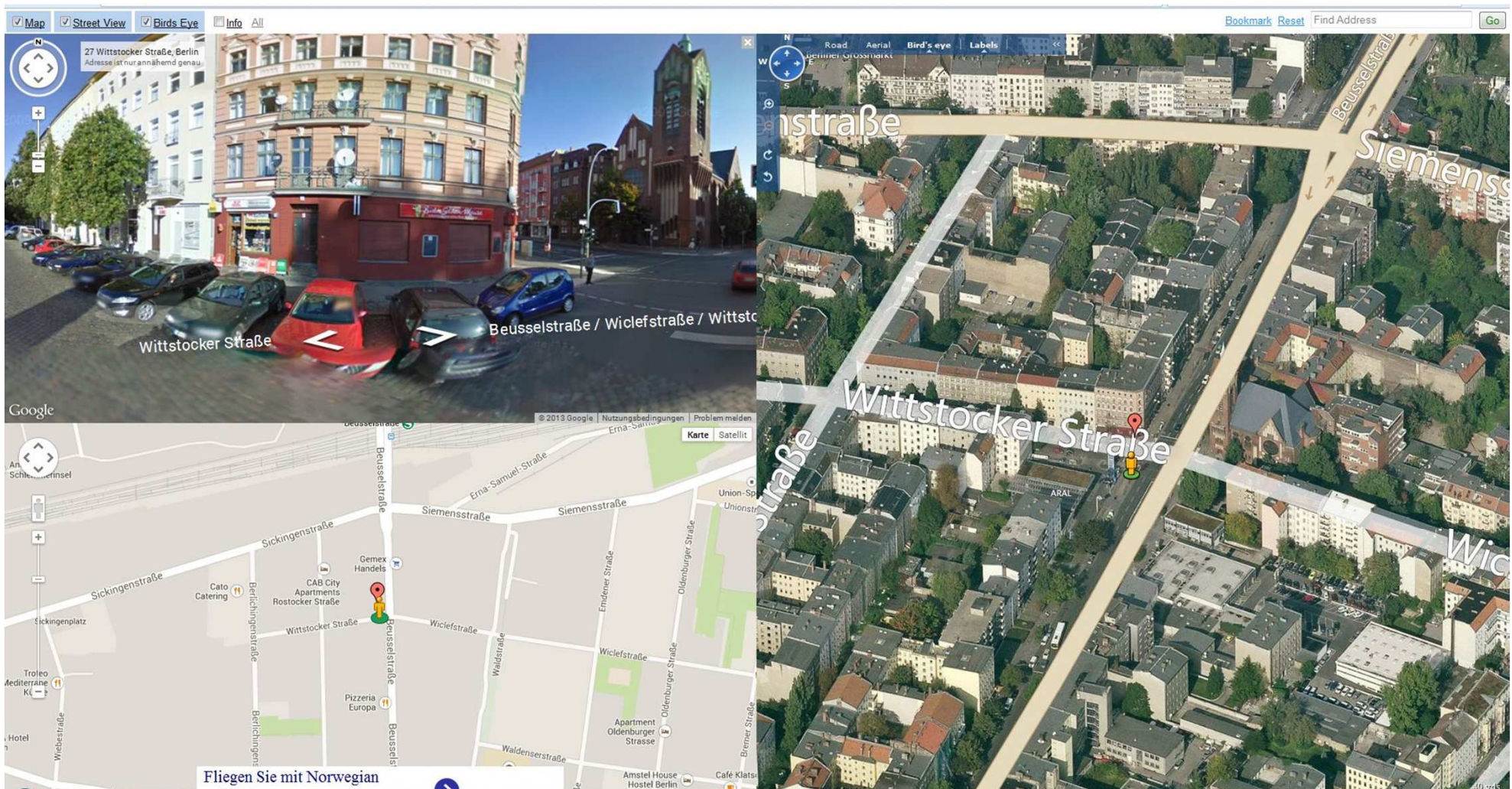
Google earth

Nutzungsbedingungen

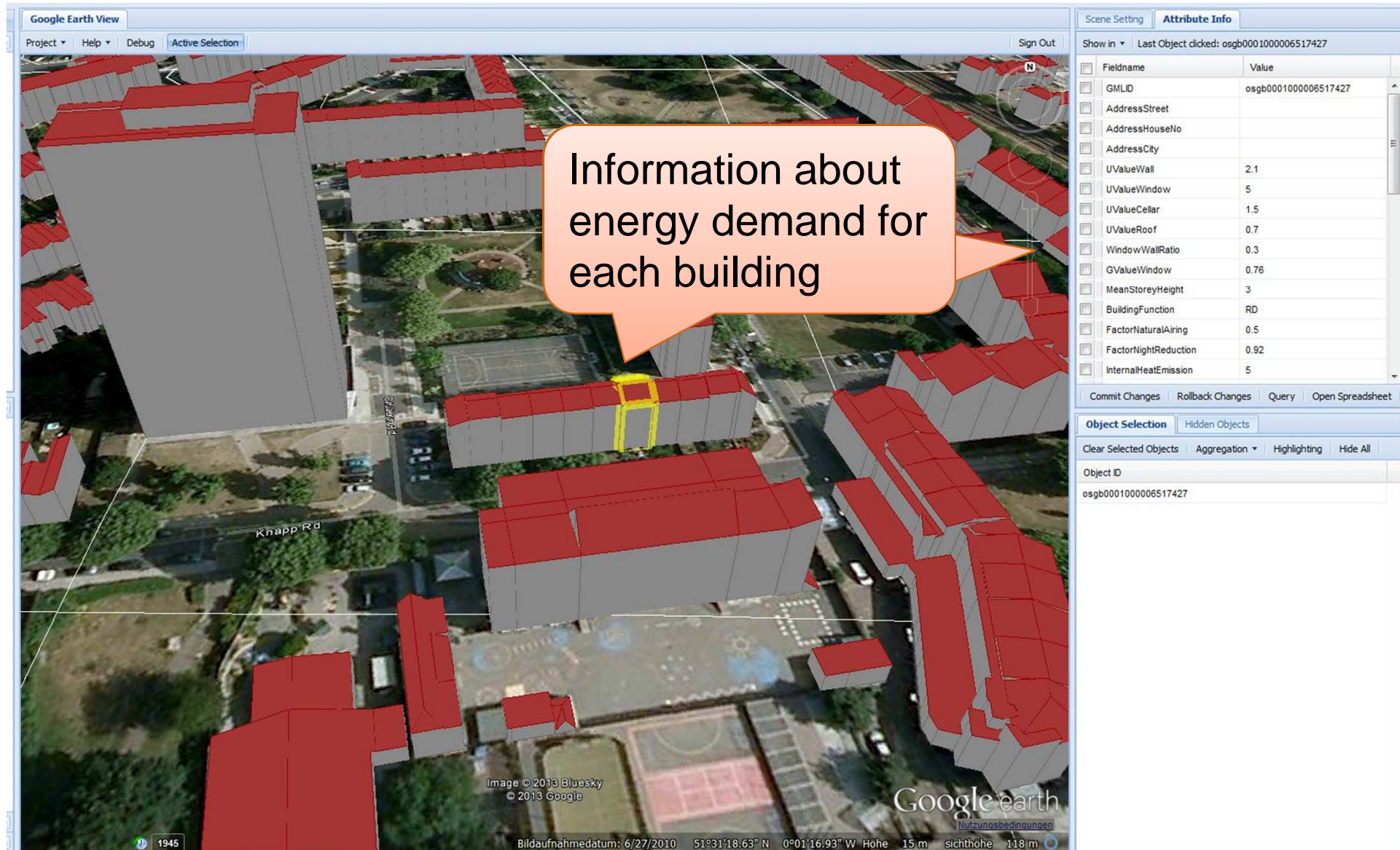
52°31'51.20" N 13°19'38.58" O Höhe 37 m sichthöhe 122 m

Demo – 3D City Model Berlin

Visual inspection of a building using the mash-up project 'Dual Maps' (www.dualmaps.com)



Demo – 3D City Model London



Information about energy demand for each building

Fieldname	Value
GMLID	osgb0001000006517427
AddressStreet	
AddressHouseNo	
AddressCity	
UValueWall	2.1
UValueWindow	5
UValueCellar	1.5
UValueRoof	0.7
WindowWallRatio	0.3
GValueWindow	0.76
MeanStoreyHeight	3
BuildingFunction	RD
FactorNaturalAiring	0.5
FactorNightReduction	0.92
InternalHeatEmission	5

Object ID: osgb0001000006517427



Scenario 1 : **Original State**



Scenario 2 : **Current State**

	kWh/m ² a
CLASSE A+	≤30
CLASSE A	≤40
CLASSE B+	≤50
CLASSE B	≤60
CLASSE C+	≤80
CLASSE C	≤120
CLASSE D	≤180
CLASSE E	≤225
CLASSE F	≤270
CLASSE G	>270

Source:
www.energia.provincia.tn.it



Scenario 3 : **Total Refurbishment**

Conclusions

► Energy Atlas Berlin

- Provision of a common information model for the holistic environmental and energy planning based on CityGML
- Data base: virtual city models of London and Berlin plus specialized information
- Basis for multidisciplinary analysis and simulation

► Analyzes and simulations

- Investigation of the actual state, e.g. estimation of energy demands
- Investigation of energy-saving and production potentials
- Comparison of the energy demands and potentials on various aggregation levels

Conclusions

- ▶ Multi-layered system architecture and cloud-based 3D web client allow for
 - Energy simulations using complex-structured semantic 3D city models
 - Simple and intuitive access to 3D city models for users through reduction of the complexity of the semantic city models necessary
- ▶ Outlook: Stronger abstraction from concrete products (such as Dropbox, Google Earth & Spreadsheets)