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

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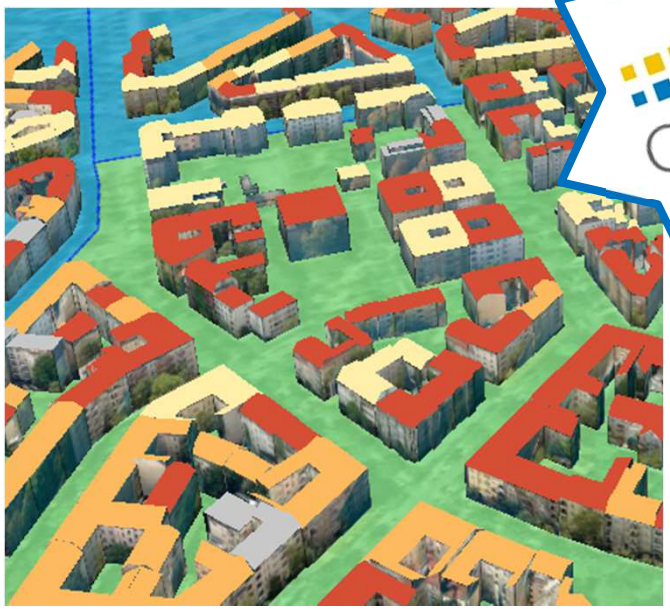
Motivation

- 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



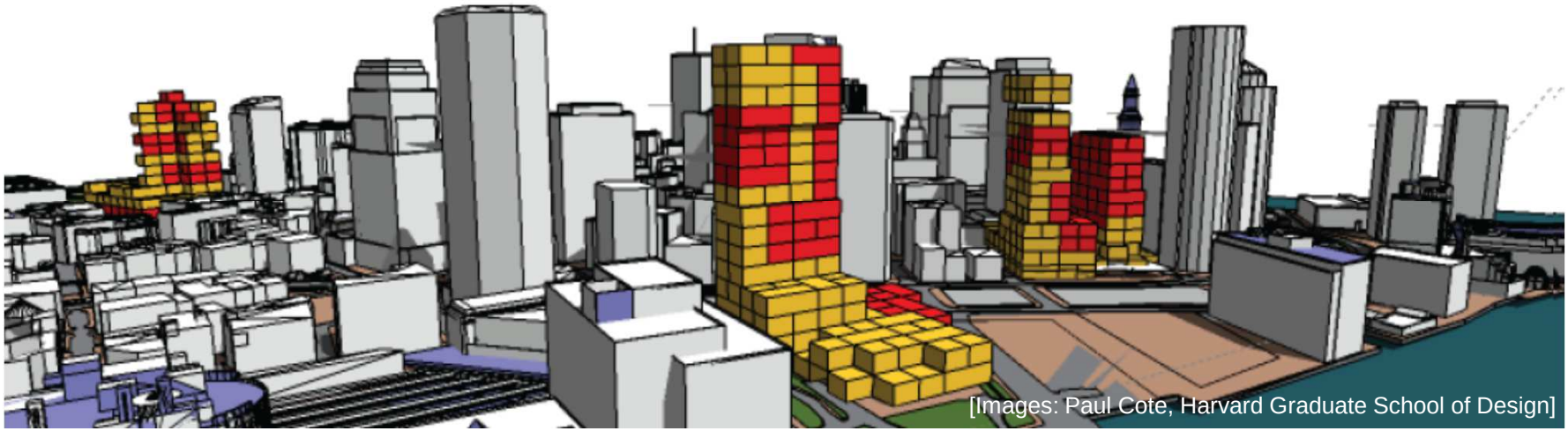
The Aim of the Energy Atlas Berlin

- **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

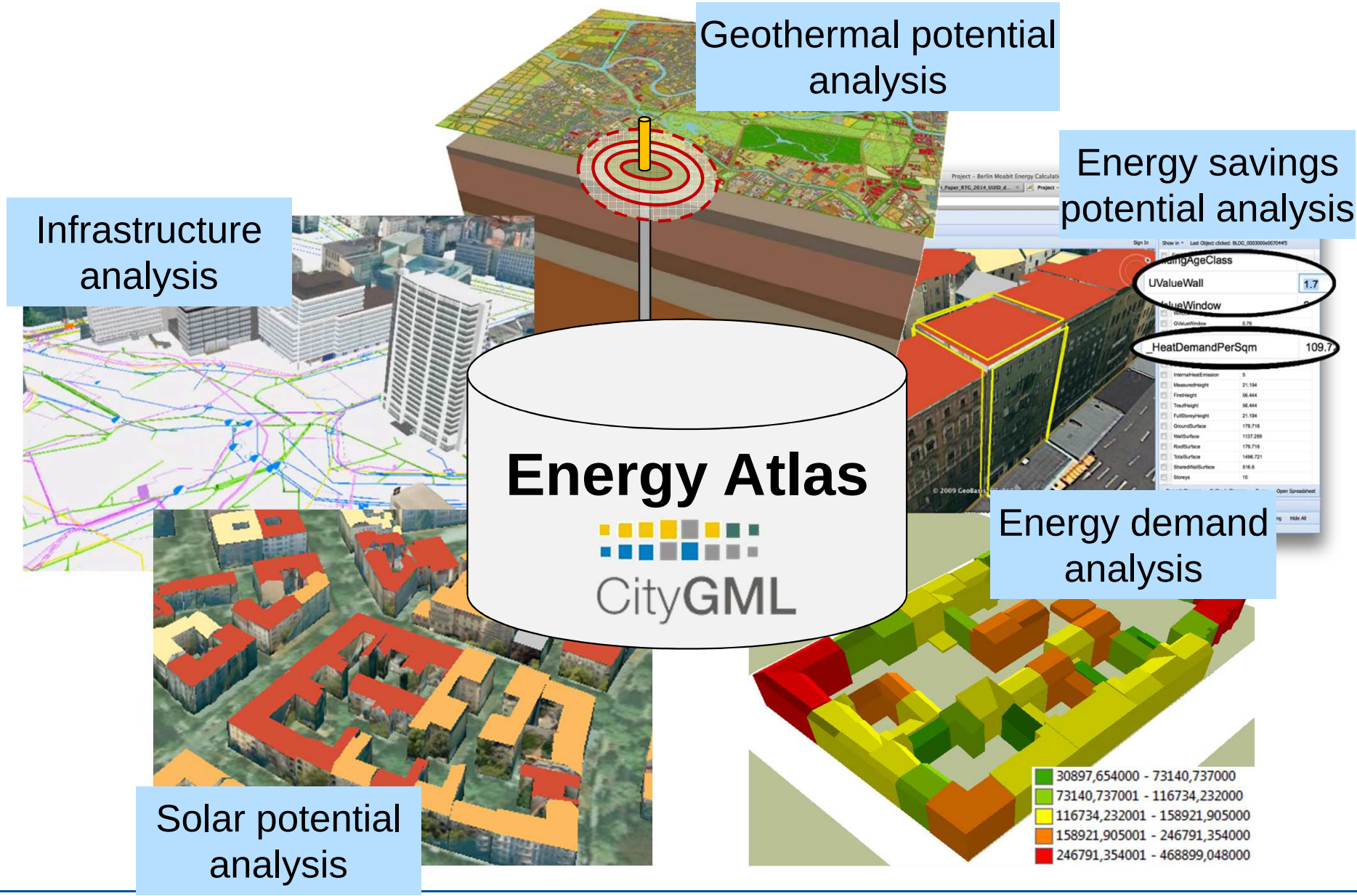


City Geography Markup Language (CityGML)

- 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

Building Information
- **Geometry**
- **Usage**
- **Construction**
- **Rehabilitation**
- **Residents**
- **Apartments**

Climate and environment conditions

Correlation

Energy Demand
- **Electricity**
- **Warm Water**
- **Heating**

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

Building Information
- **Geometry**
- **Usage**
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Climate and environment conditions

Correlation

Energy Demand
- **Electricity**
- **Warm Water**
- **Heating**

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

Building Information
- Geometry
- **Usage**
- Construction
- Rehabilitation
- **Residents**
- **Apartments**

Climate and environment conditions

Correlation

Energy Demand
- **Electricity**
- Warm Water
- Heating

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

Building Information
- Geometry
- **Usage**
- Construction
- Rehabilitation
- **Residents**
- Apartments

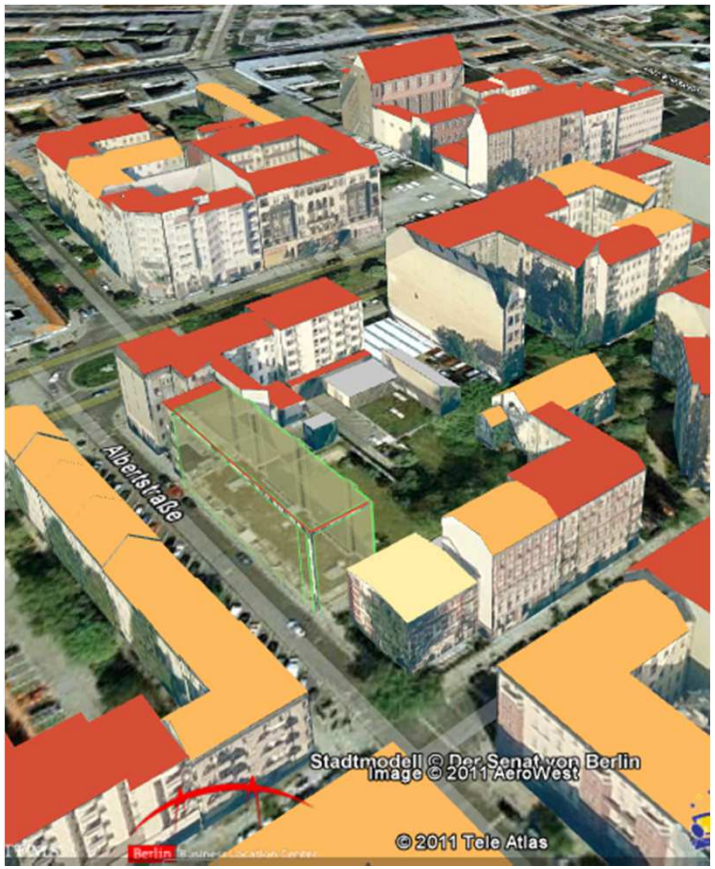
Climate and environment conditions

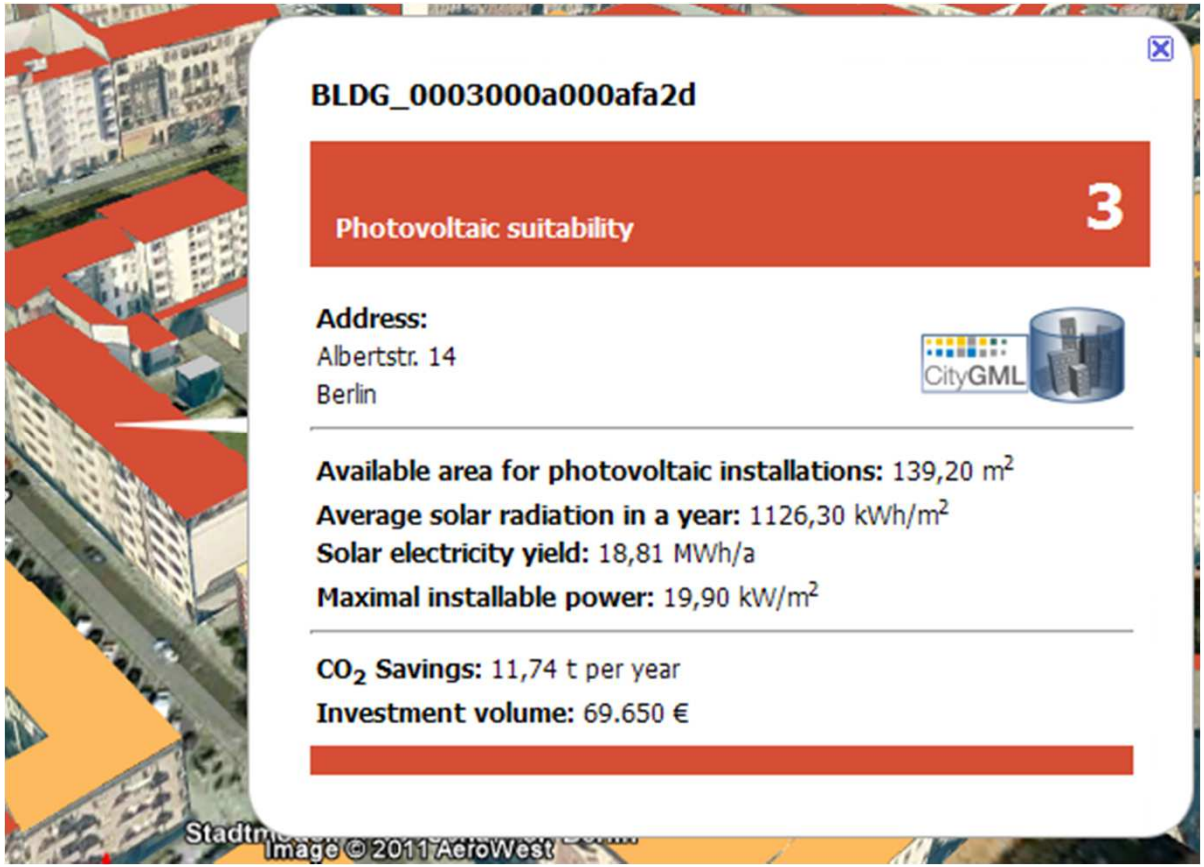
Correlation

Energy Demand
- Electricity
- **Warm Water**
- Heating

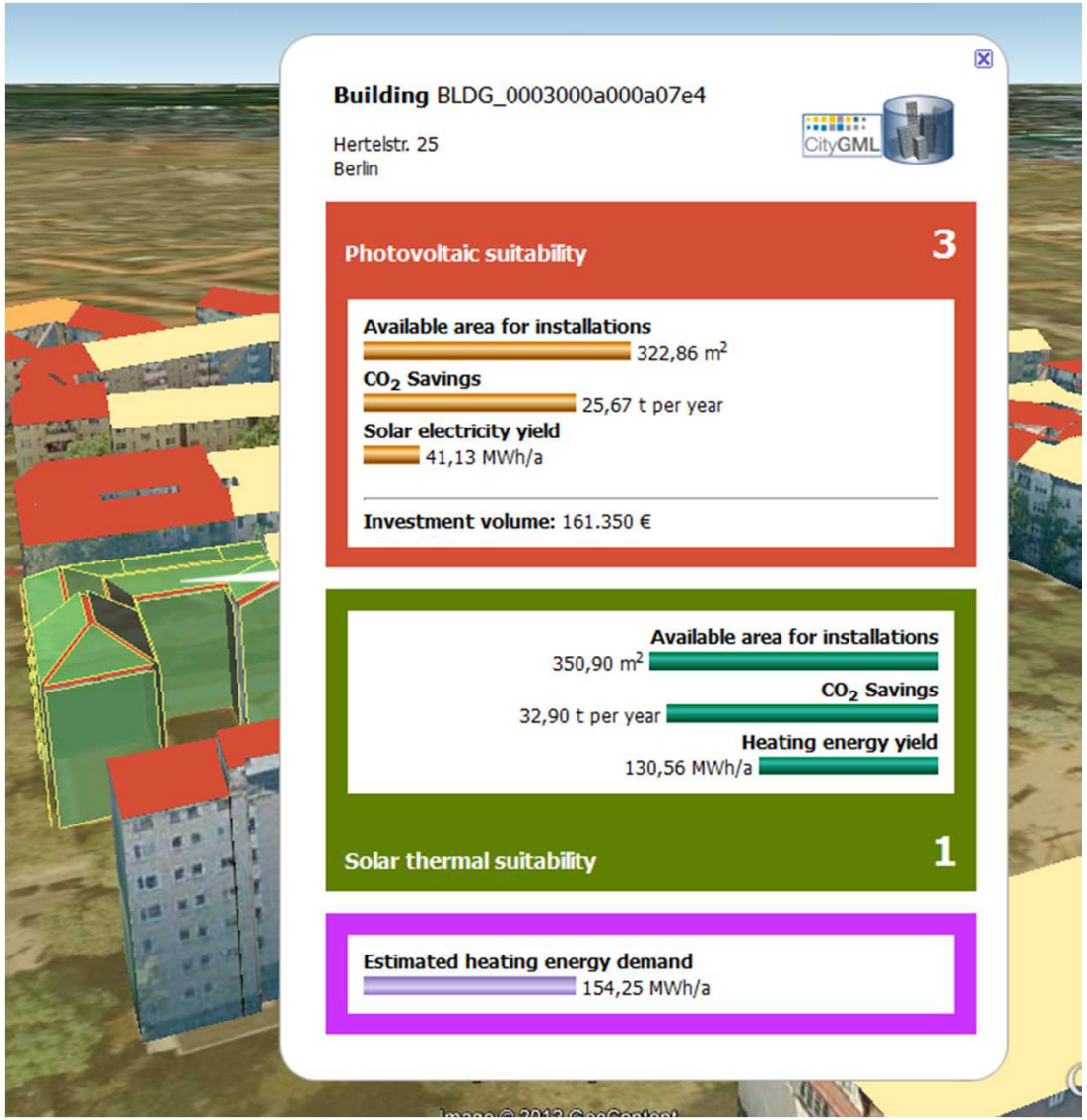
Solar Potential Analysis for Buildings

- Estimation of the energy production potentials for PV and solar thermal, required investments and achievable CO_2 reductions
- Done for each of the 550,000 buildings on the level of roof surface segments



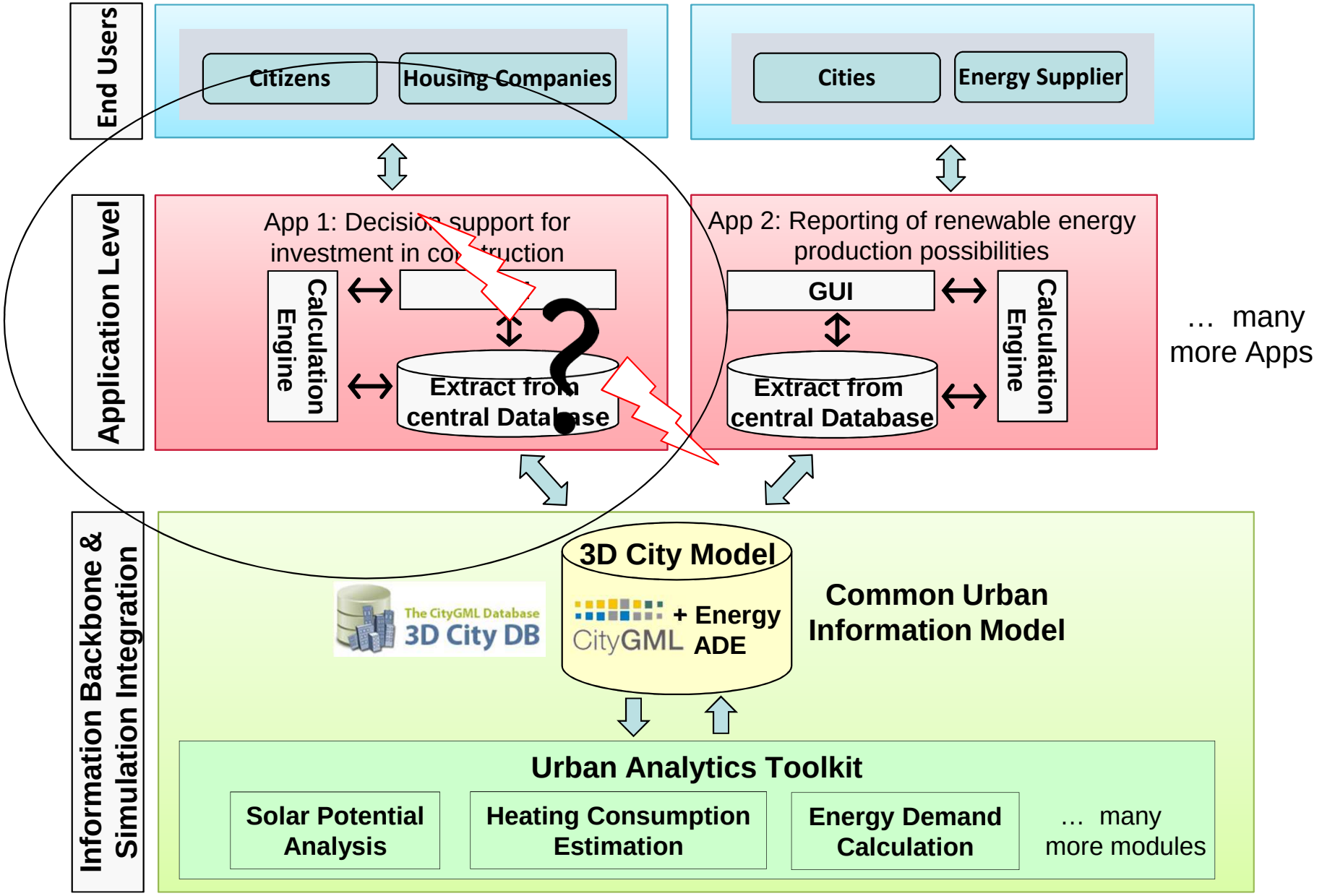


Heating Energy Demand and Solar Thermal Potentials on the Building Level

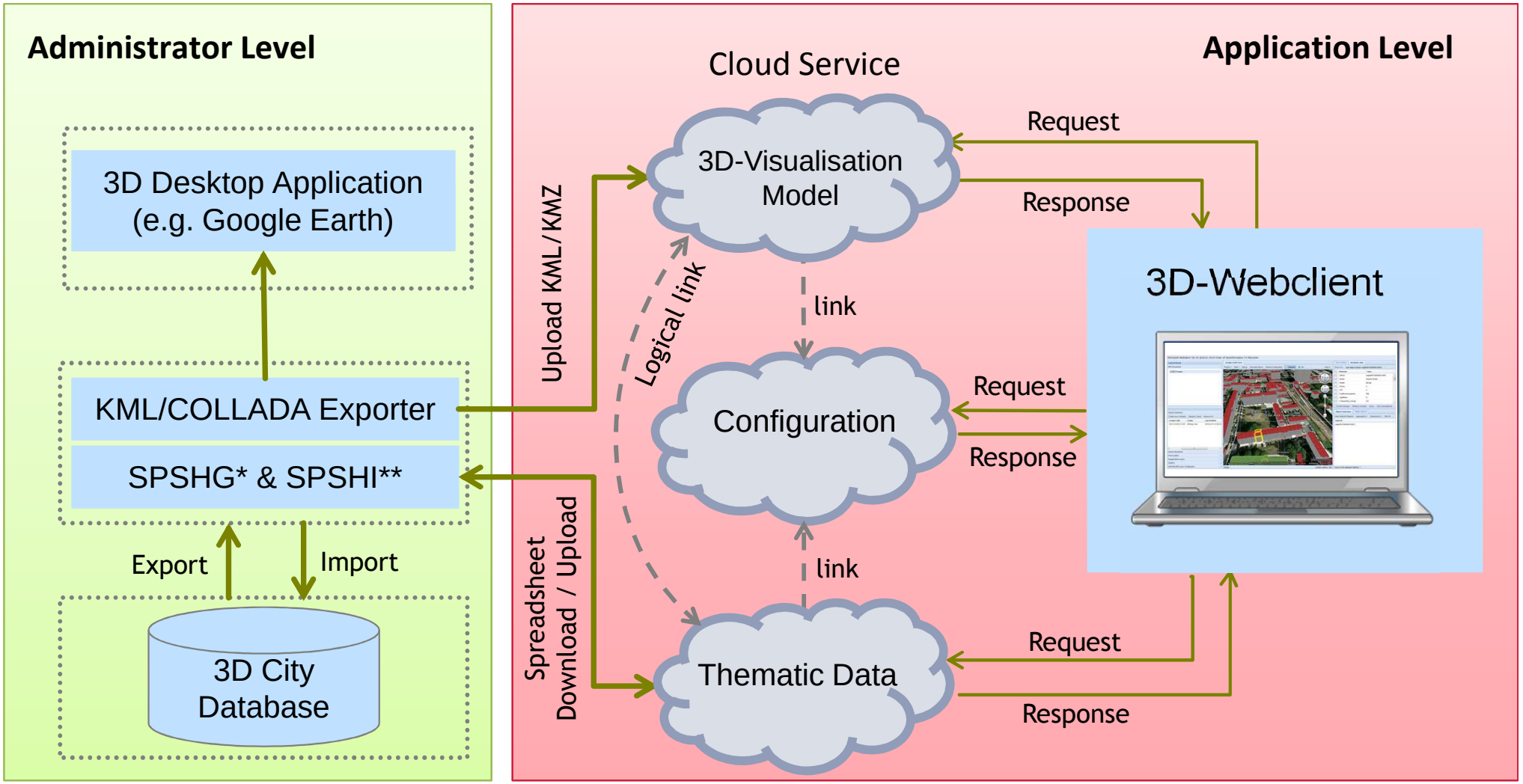


Solar Thermal Potential on District Level

Multi-level System Architecture



Realisation using Cloud Services



*Spreadsheet Generator **Spreadsheet Importer

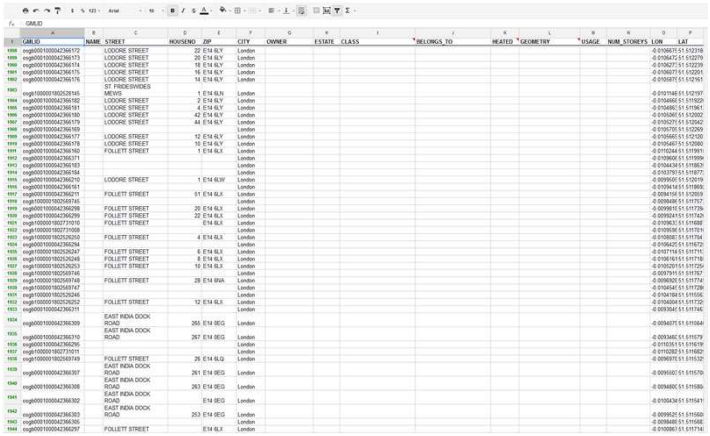
Interactive 3D Exploration

Visualisation model

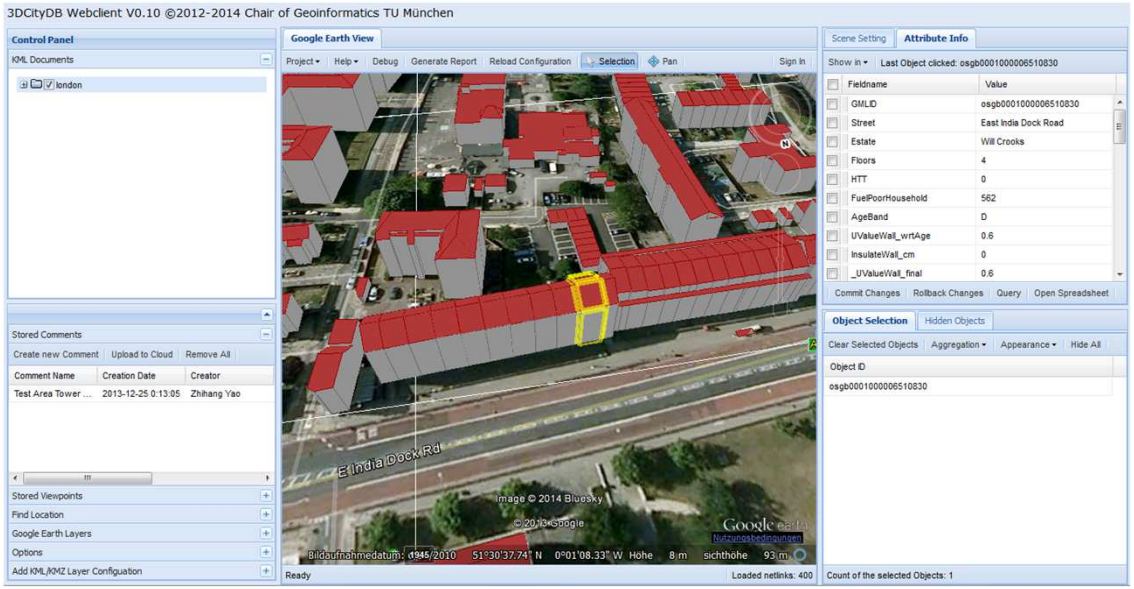
KML file via Dropbox

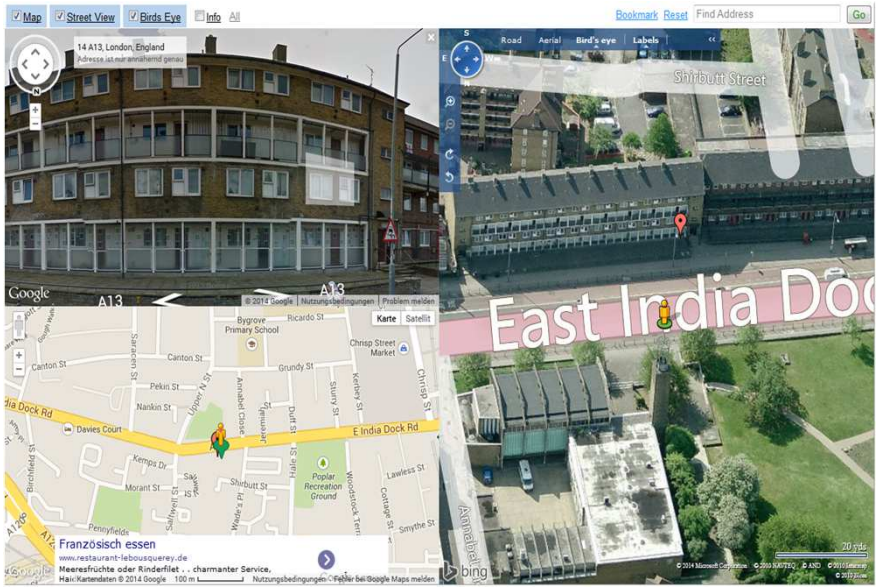
Logical join via GMLID

Thematic data

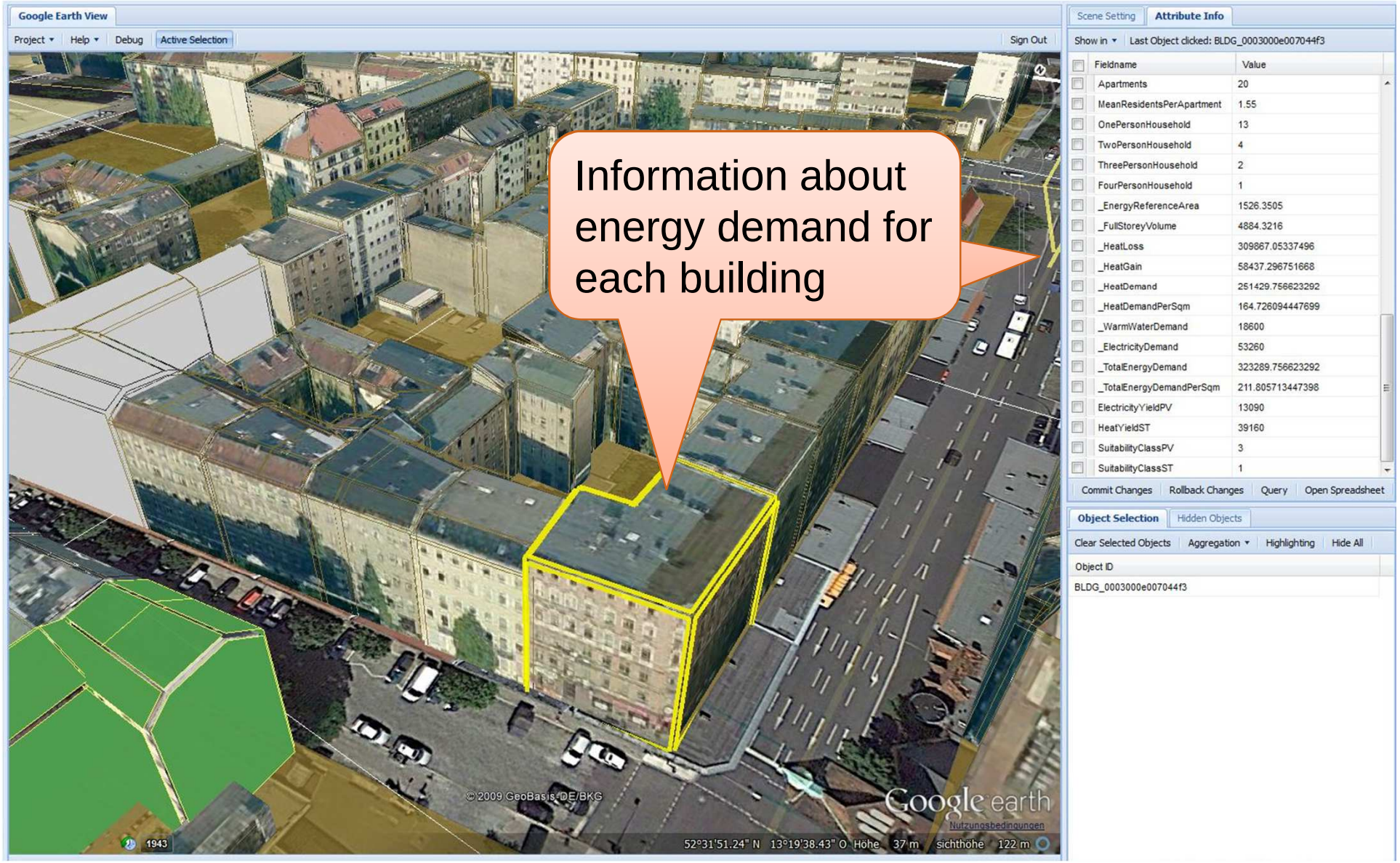


Google Spreadsheet





Demo – 3D City Model Berlin



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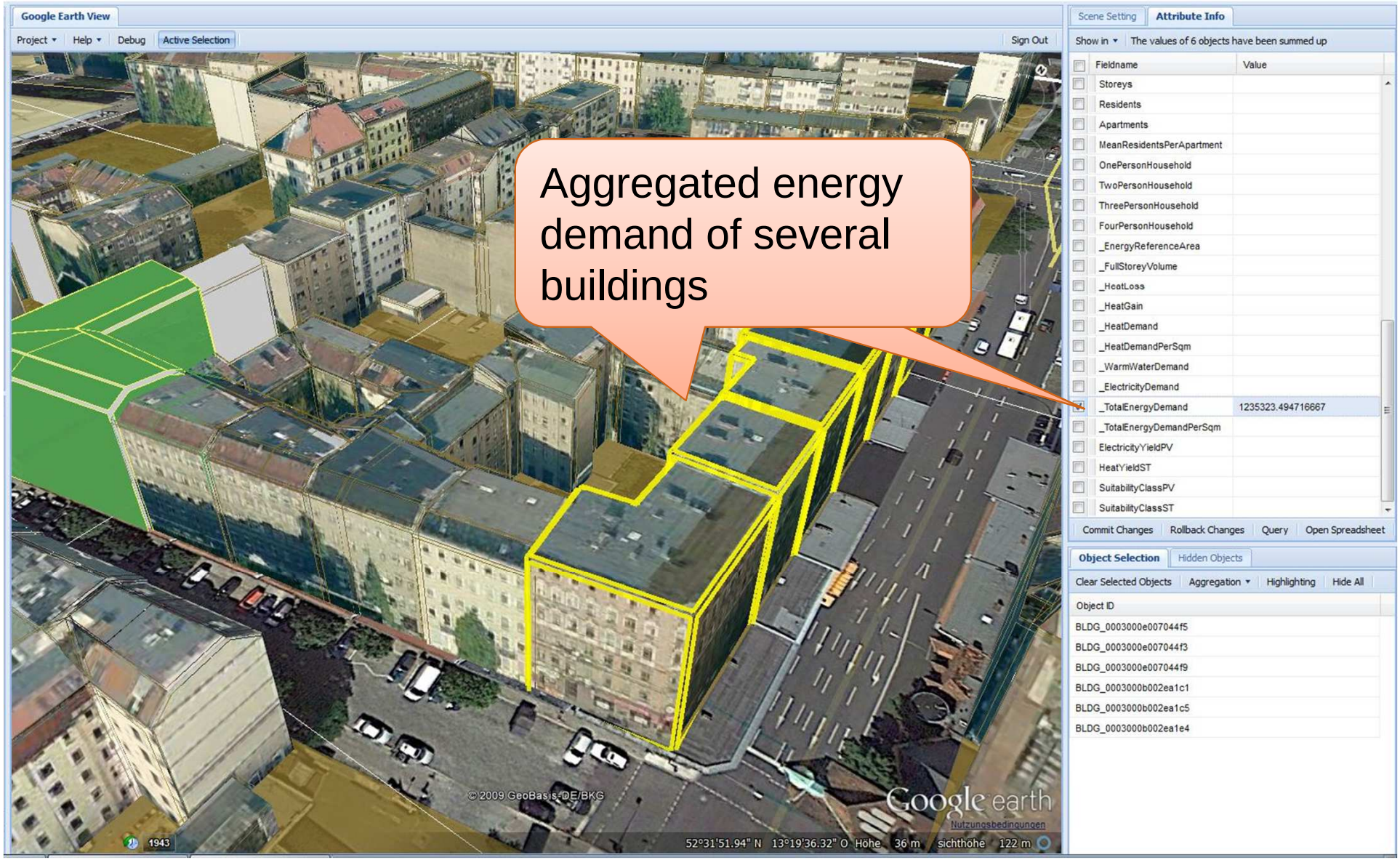
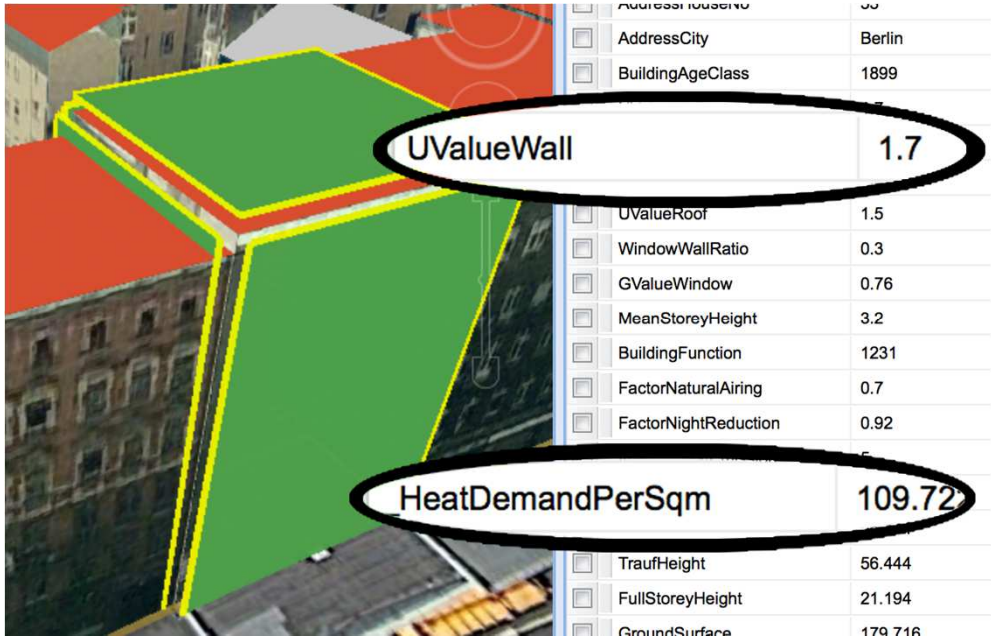
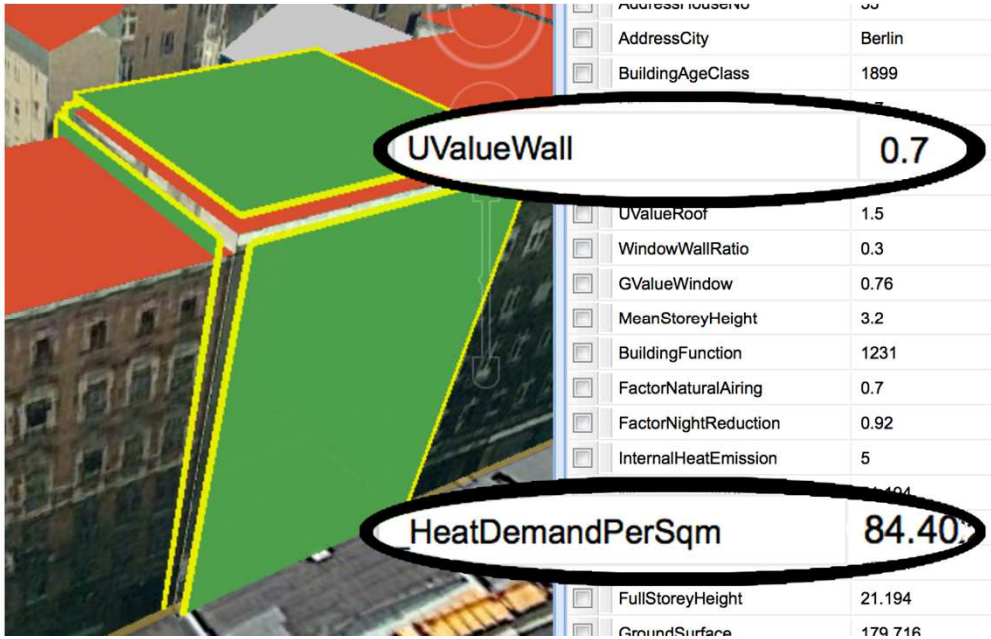


Demo – Use of the 3D Web Client in Berlin

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

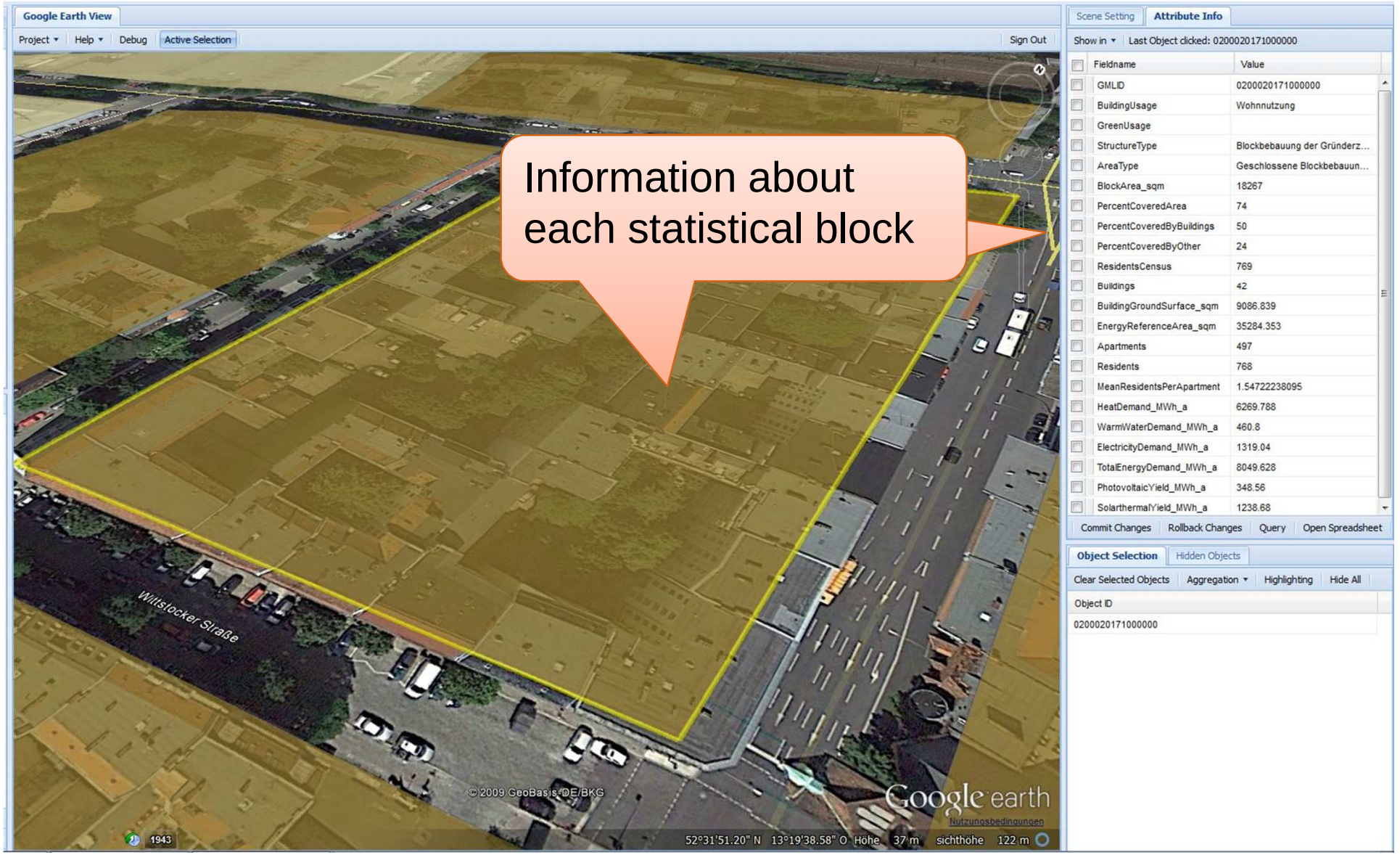


before modification



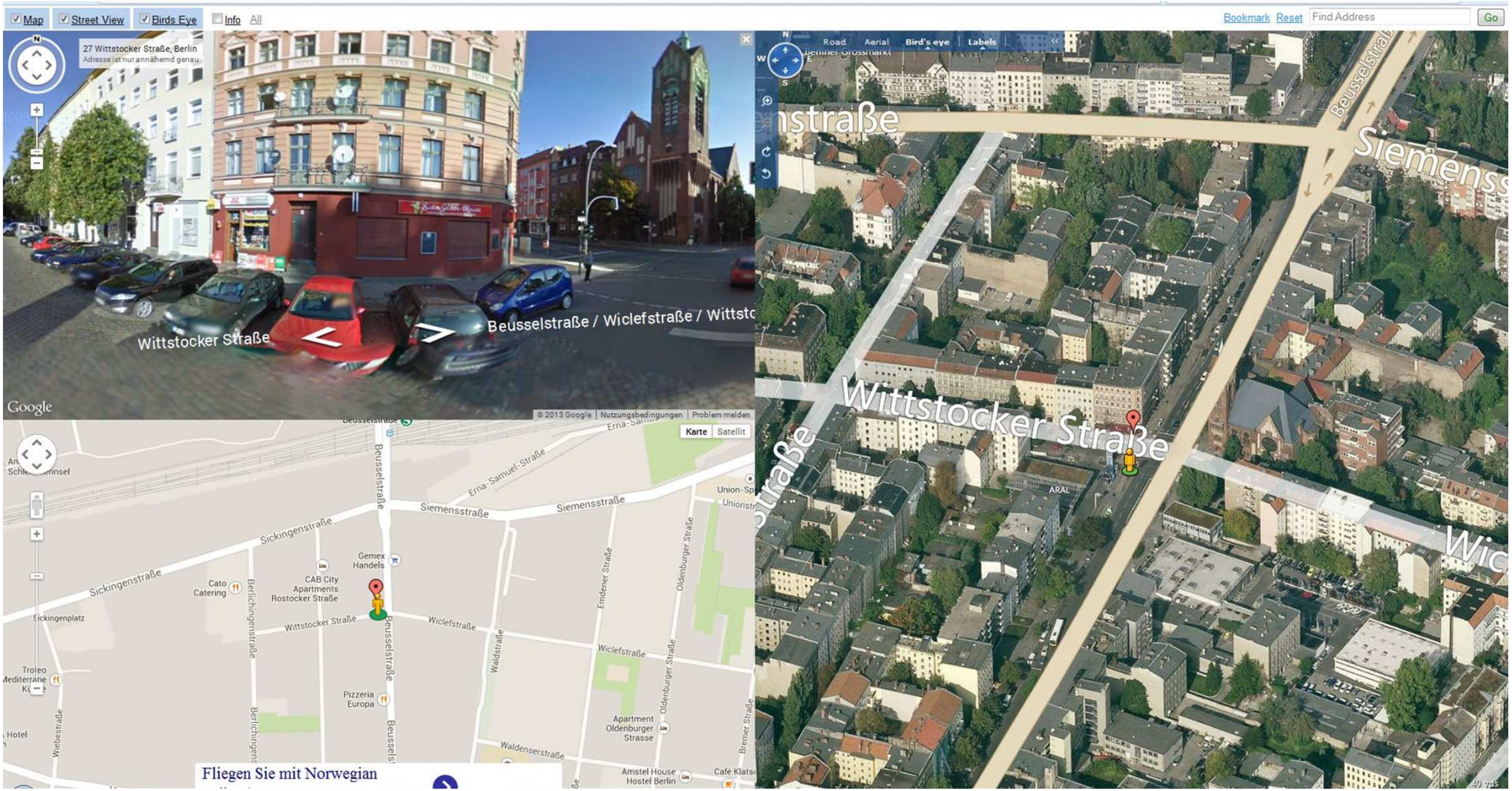
after modification

Demo – 3D City Model Berlin

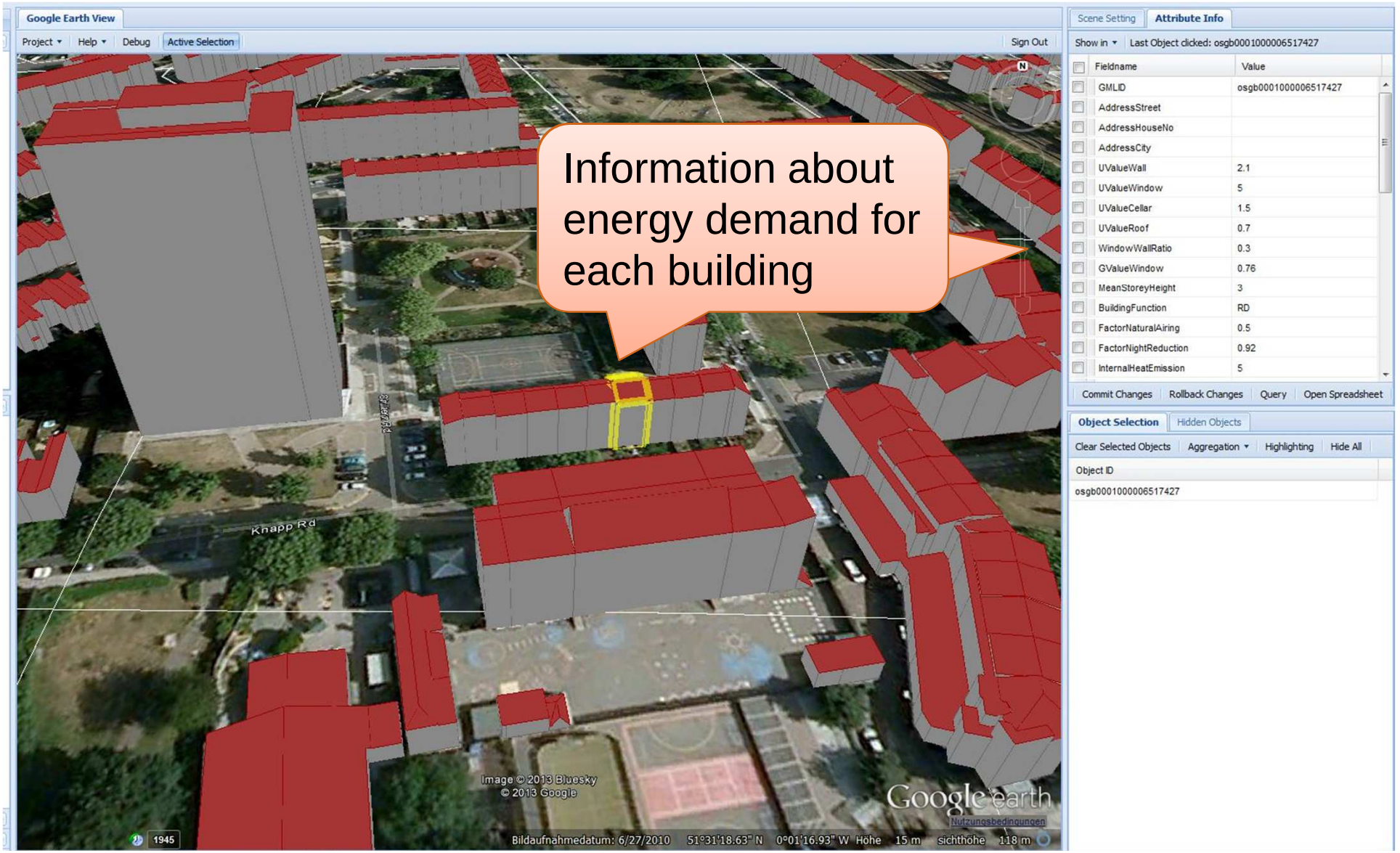


Demo – 3D City Model Berlin

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



Demo – 3D City Model London



Energy Simulation

	kWh/m² 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 1 : **Original State**

Energy Simulation

	kWh/m² a
CLASSE A+	≤30
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CLASSE F	≤270
CLASSE G	>270

Source:
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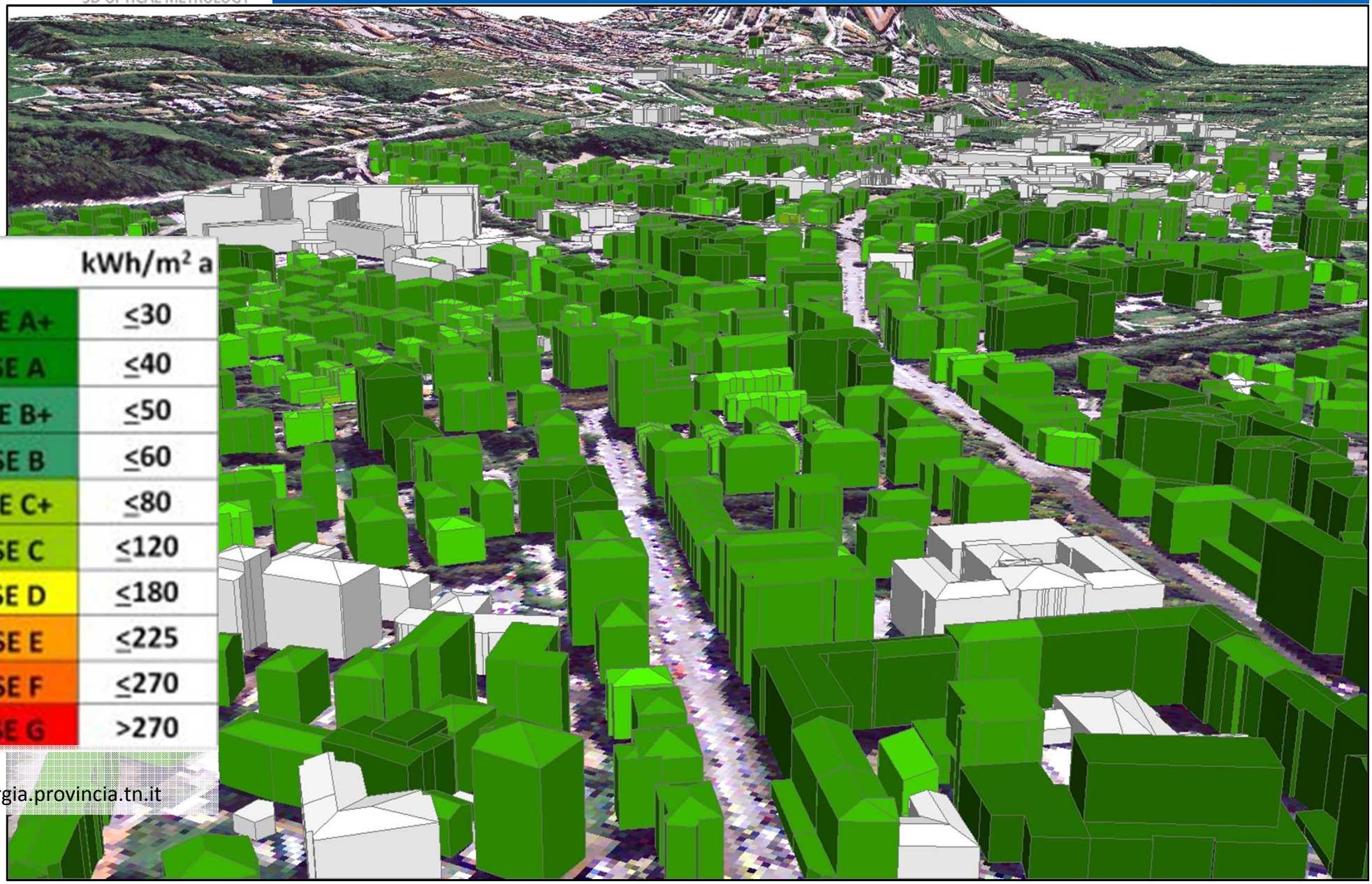
Scenario 2 : **Current State**

Energy Simulation



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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)