Modelling cities in CityGML: experiences from Trento & Vienna

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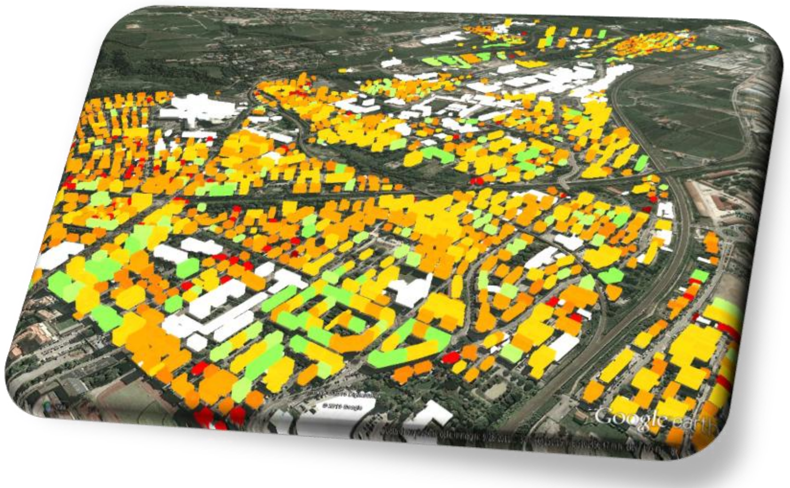


Overview

Modelling cities in CityGML: Experiences from…

- Italy: Trento – Project **EnerCity**
- Austria: Vienna – Project **Ci-Nergy**
- Conclusions
- Bibliographic references for Trento and Vienna
- Acknowledgements for Trento and Vienna

3D city models and energy

Yes, cool… BUT:

How easy / hard is the way till a *usable* 3D city model is created?

- Major / typical issues?
- Time / resources required?

TRENTO:
Project EnerCity (2012 – 2015)

- 2012, Conception @ FBK, **Trento**
  3D Optical Metrology unit

- 2013, First implementation @ TUM, **München**
  Department of Geoinformatics

- 2014-15, Refinement @ AIT, **Vienna**
  Sustainable Buildings and Cities unit

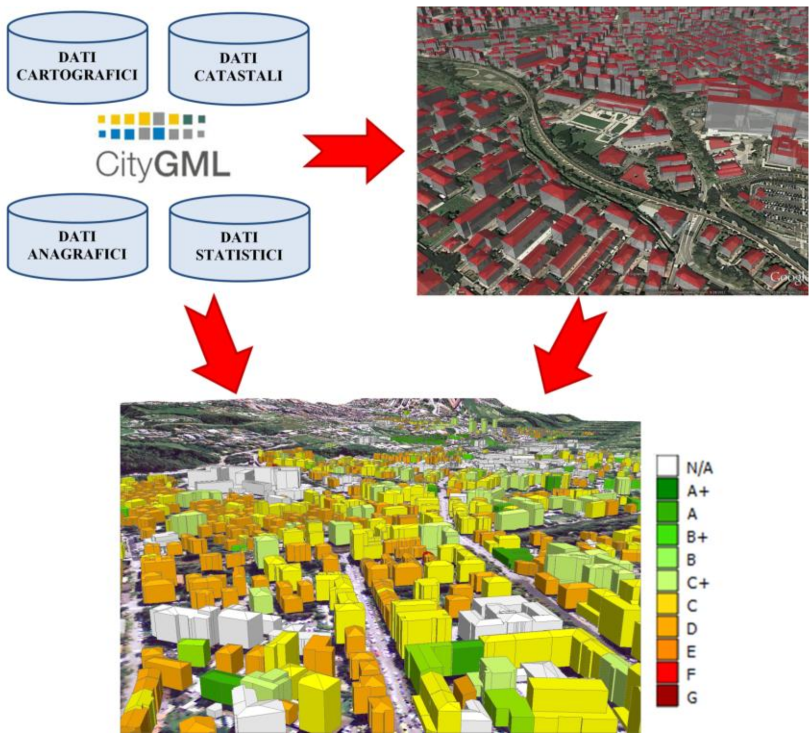
TRENTO: EnerCity

Overall question:

Can a CityGML-compliant 3D city model be created in Trento and used e.g. for energy-related applications? (Using only exiting data!)

Approach:

- **Step 1**: Creation of the 3D city model up to LoD2 (focus on geometries)
- **Step 2**: Enrichment of the 3D city model (focus on attributes)
- **Step 3**: Estimation of buildings' energy performance (not discussed here)



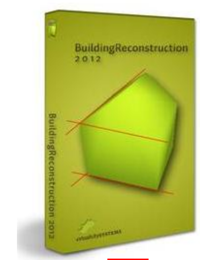
Step 1: Creation of the 3D city model up to LoD2

Semi-automatic generation of a 3D city model (up to LoD2)

1) Input data

- DSM (min 4, better 10 to 15 pt/m^2)
- Building footprints

2) 3D modelling SW



3) Import/export tools

The CityGML Database
3D City DB

4) Spatial RDBMS

PostGIS
Spatial PostgreSQL
CityGML

5) Output

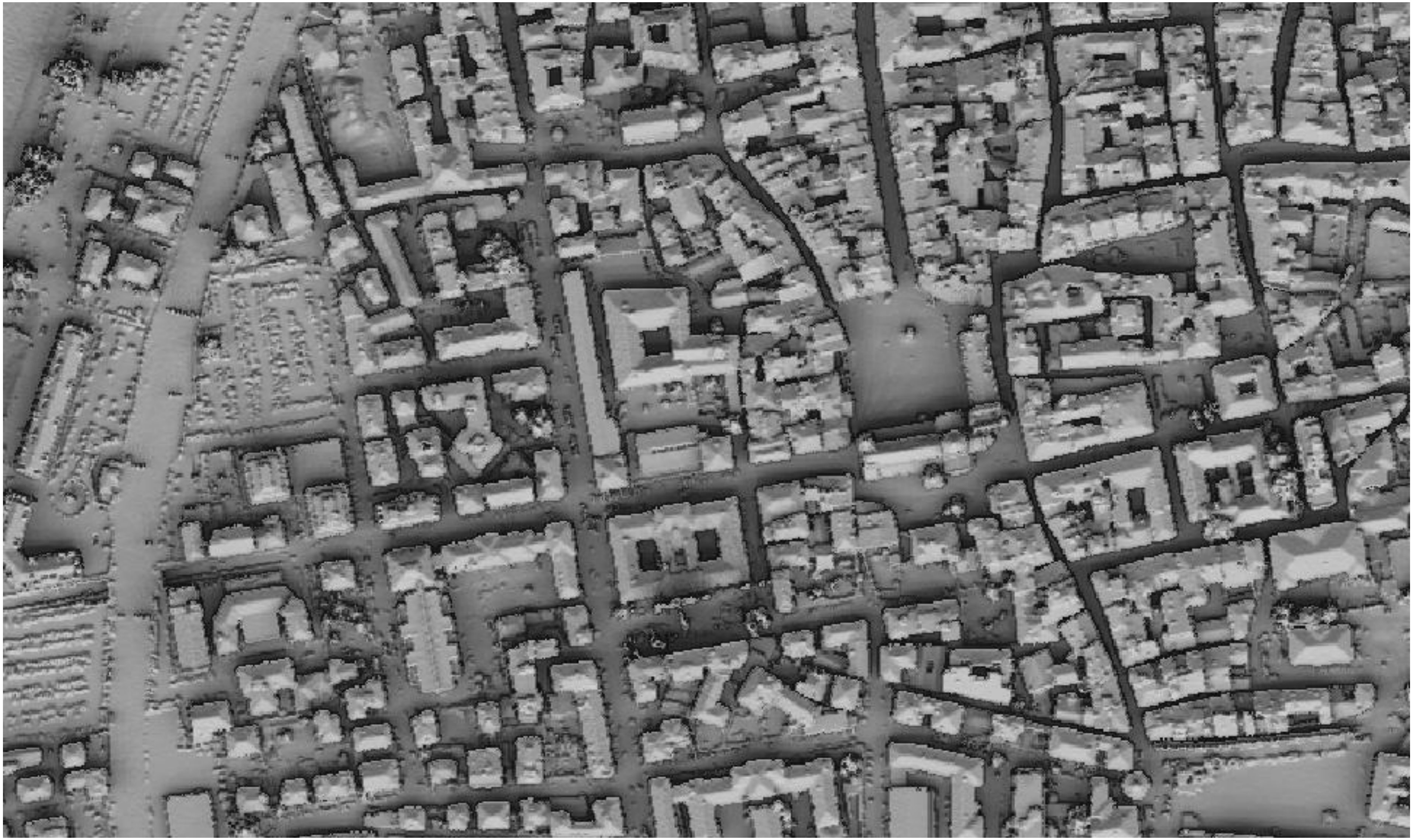
Step 1: Creation of the 3D city model

Trento study area: ca. 2300 heterogeneous buildings (size, usage, age, etc.)

DSM (open data)

- Density **1 pt/m²** (urban areas)
  - Sub-optimal density
- Time **2006/2007**
  - A bit outdated…
    (missing/newer buildings in red)

Step 1: Creation of the 3D city model



Step 1: Creation of the 3D city model

Building footprints, data sources:

- Catasto Tavolare (open data)
  - Dates back to the Austrian system, is still valid *only* in the territories annexed to Italy after WWI. For the rest of Italy: Catasto dei Terreni
  - Smallest unit is the „Particella catastale“ (land parcel)
  - Is geo-referenced, but there are *relevant* geometric distortions wrt. DSM
  - Built-up parcels have a unique ID, however multiple footprints may occur in the same parcel and share the same ID

- Topographic map of Trento (CTTN, Carta Tecnica Trento)
  - Aligns better with the DSM, no relevant geometric distortions
  - Is very detailed, contains sometimes building parts, allowing for a more detailed 3D reconstruction
  - Has a general classification of buildings' type/usage, however different from the cadastral one
  - Is missing links to cadastral maps

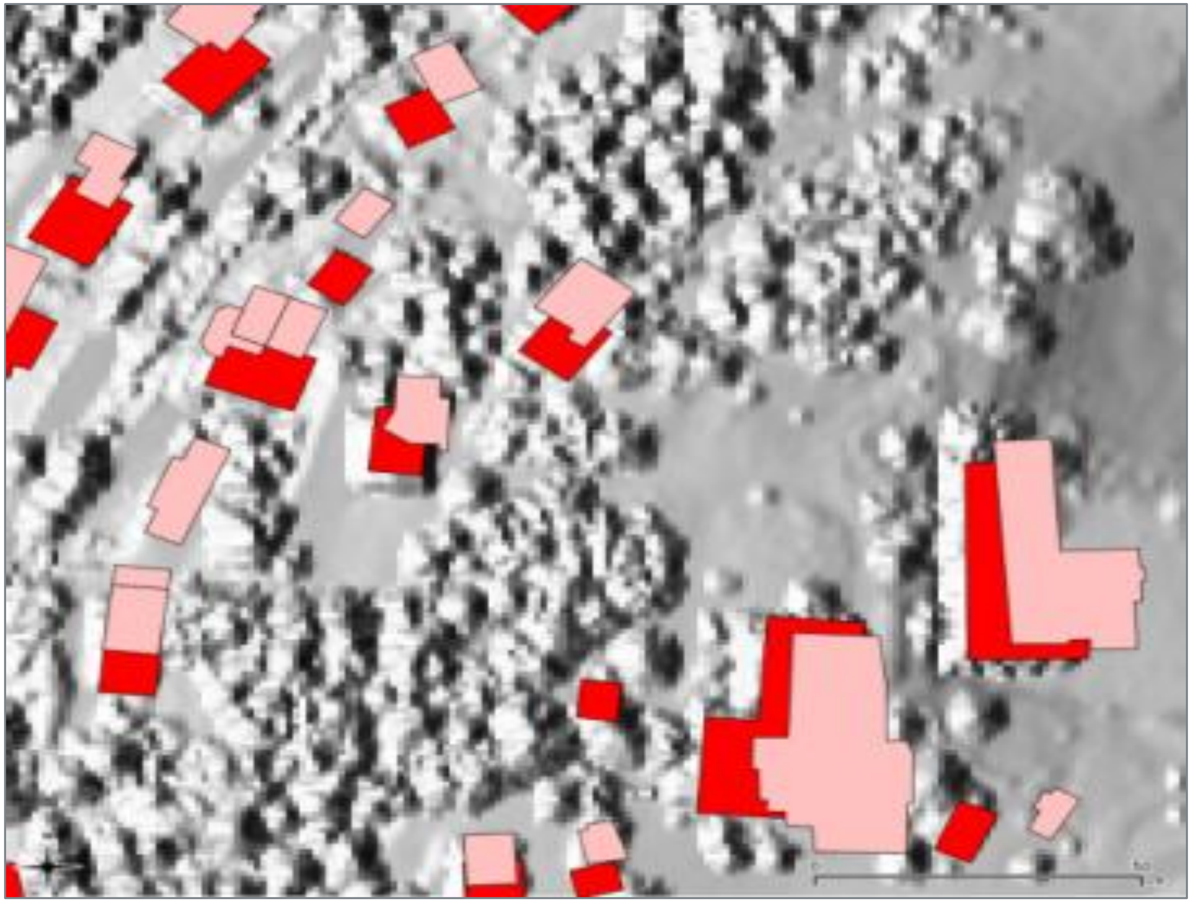
Step 1: Creation of the 3D city model

Catasto Tavolare, example of geometric problems:

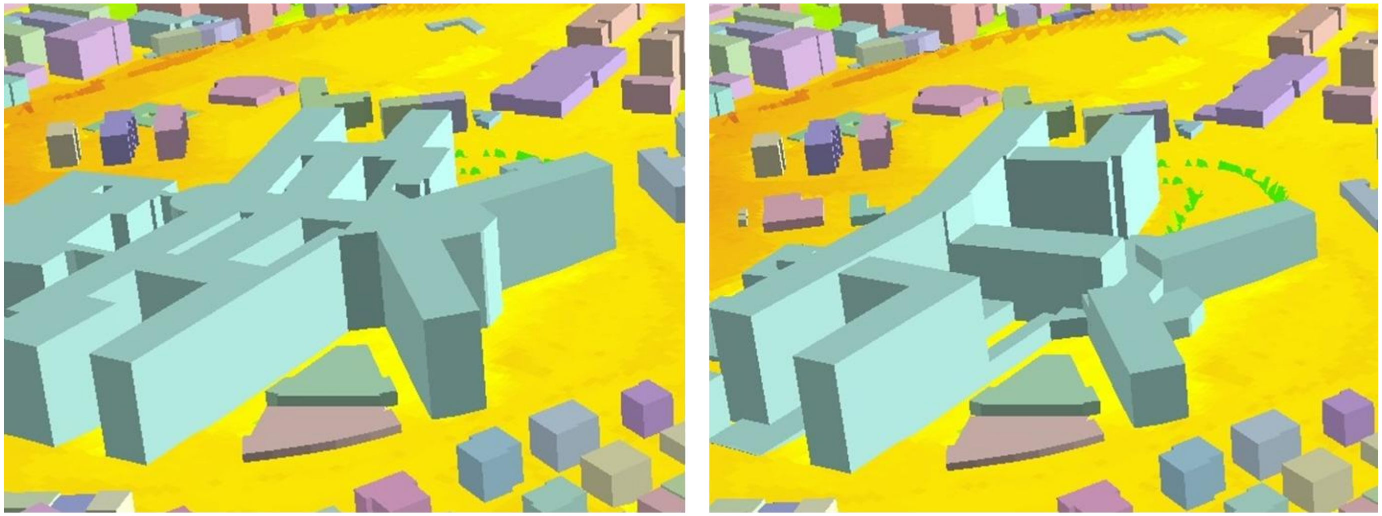
- shifts/distortions: footprints unsuitable to be overlaid onto the DSM
  - Lager distorsions outside the city centre
  - "Acceptable" distortions in the city centre

Pink:
Buildings' footprints in Catasto Tavolare

Red:
Buildings' footprints in Carta Tecnica Trento



Step 1: Creation of the 3D city model



LoD1 single-part building LoD1 multi-part building
obtained by extruding CTTN footprints

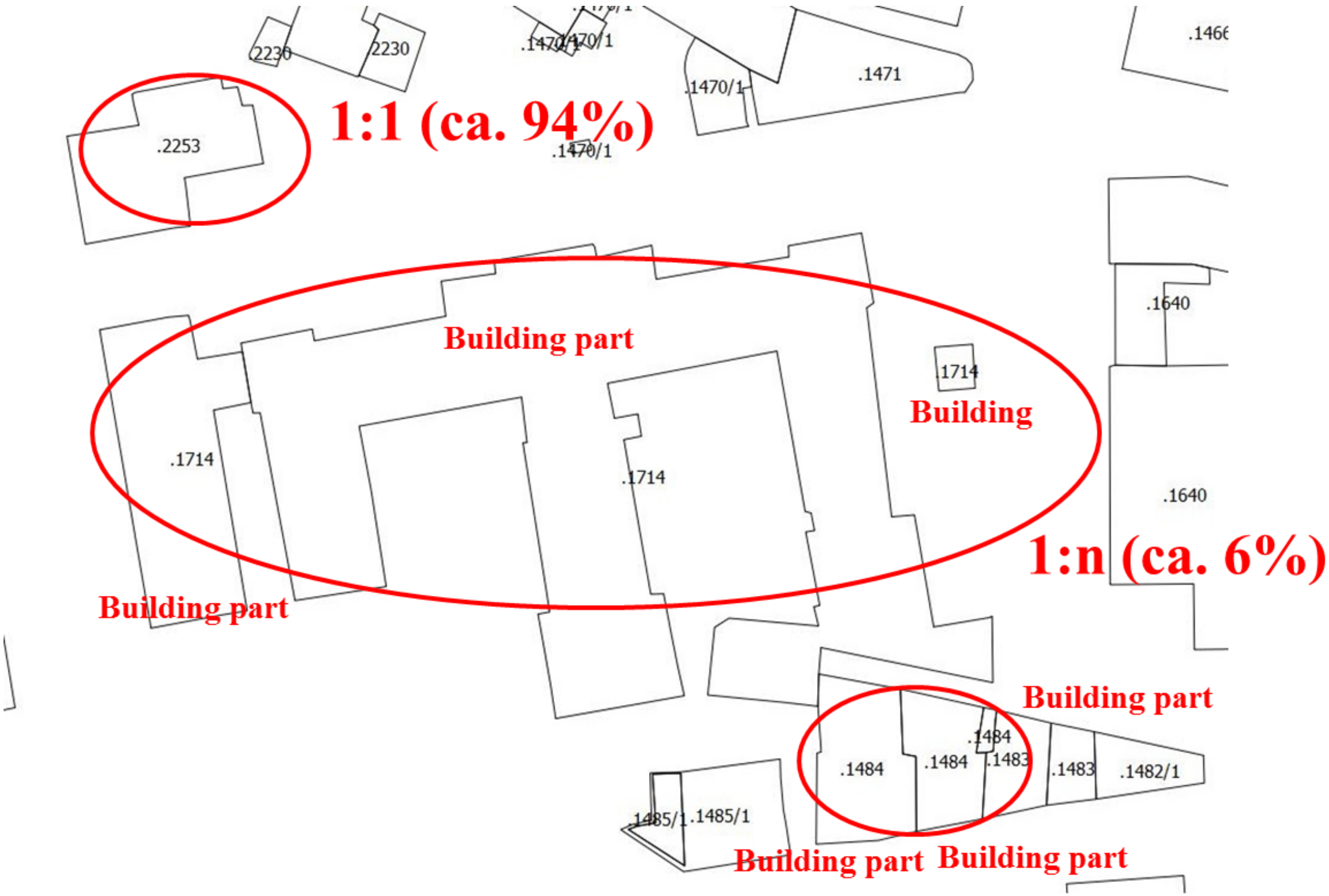
So, why not simply dump the cadastre geometries?

- Catasto dei Fabbricati („Buildings' cadastre")
  - Same system for whole Italy
  - Smallest unit is the „Unità immobiliare": a whole building, or a part of it (flat, shop, garage, …)
  - In Trentino: „Unità immobiliari" have their own codes <u>+ a reference to the Catasto Tavolare</u>
  - Floor plans are generally provided as ungeoreferenced tiff/pdf files

Step 1: Creation of the 3D city model

Catasto Tavolare, example of cardinality issues:

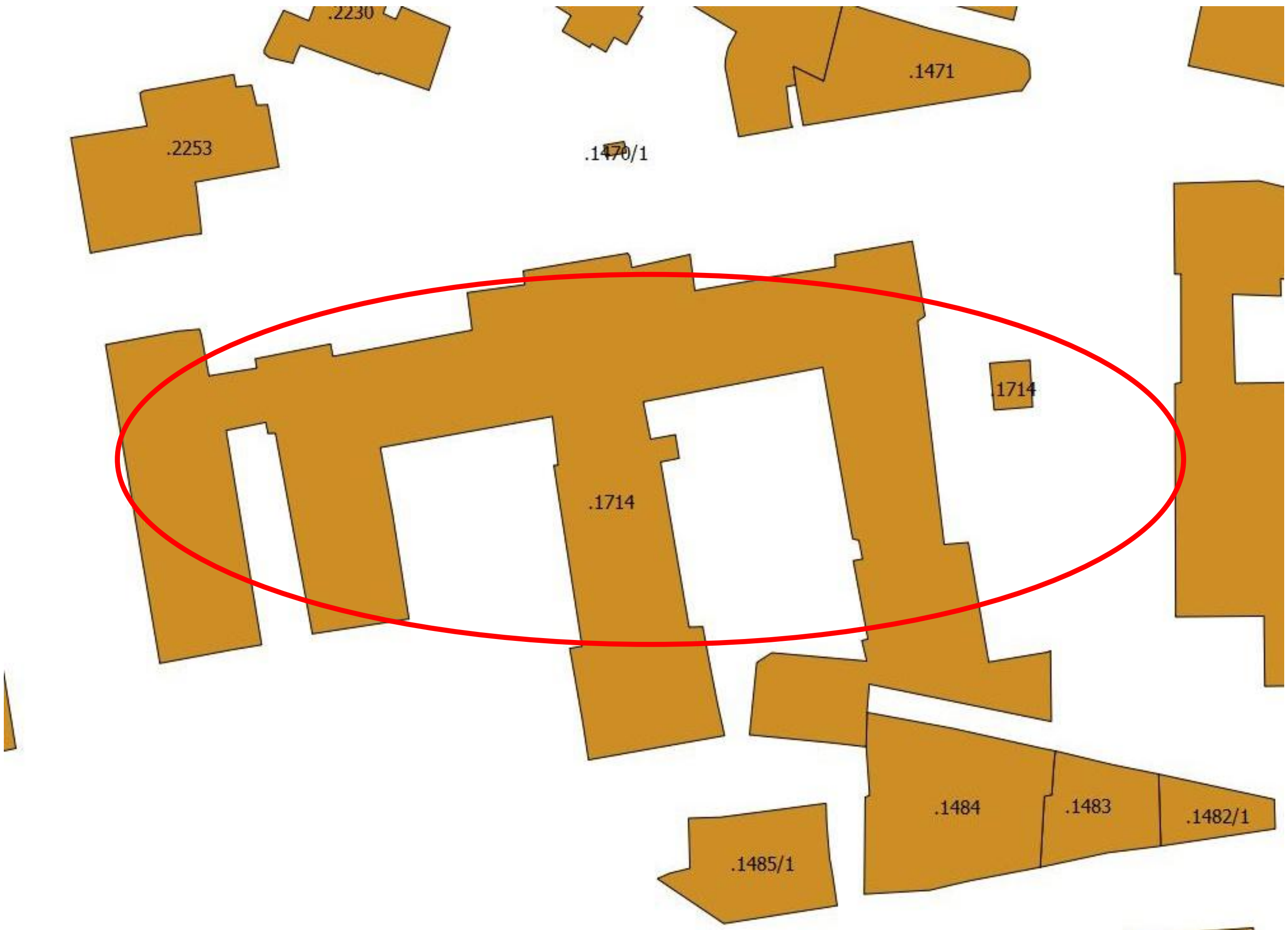
- (Sometimes) no clear identification of a building inside the same parcel: multiple building „parts“ AND/OR multiple buildings



Step 1: Creation of the 3D city model

Catasto Tavolare, example of cardinality problems:

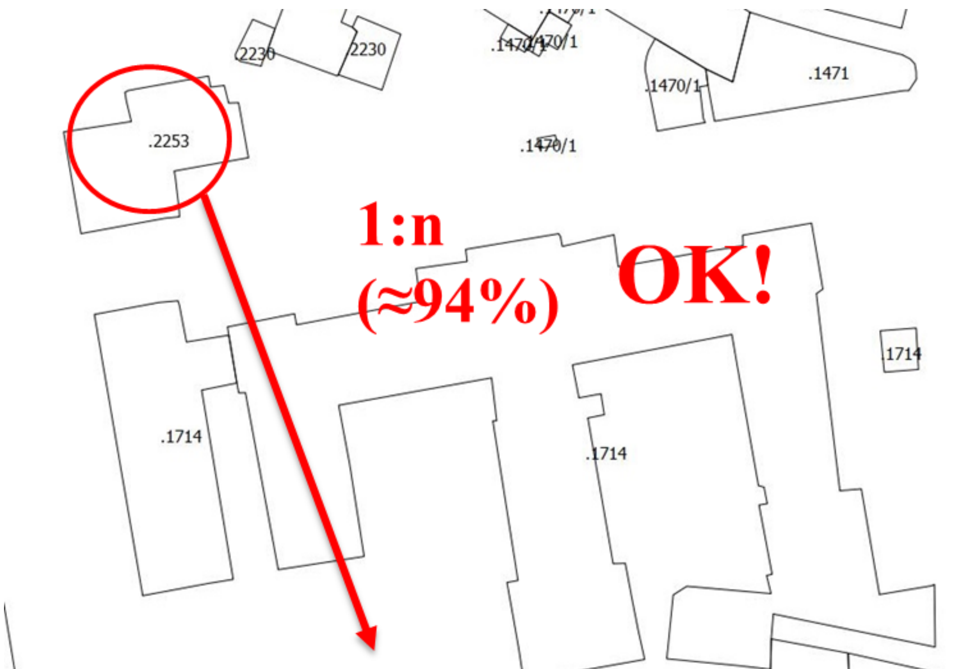
- Successive aggregation AND disaggregation required
- The parcel ID is an attribute, not a primary key



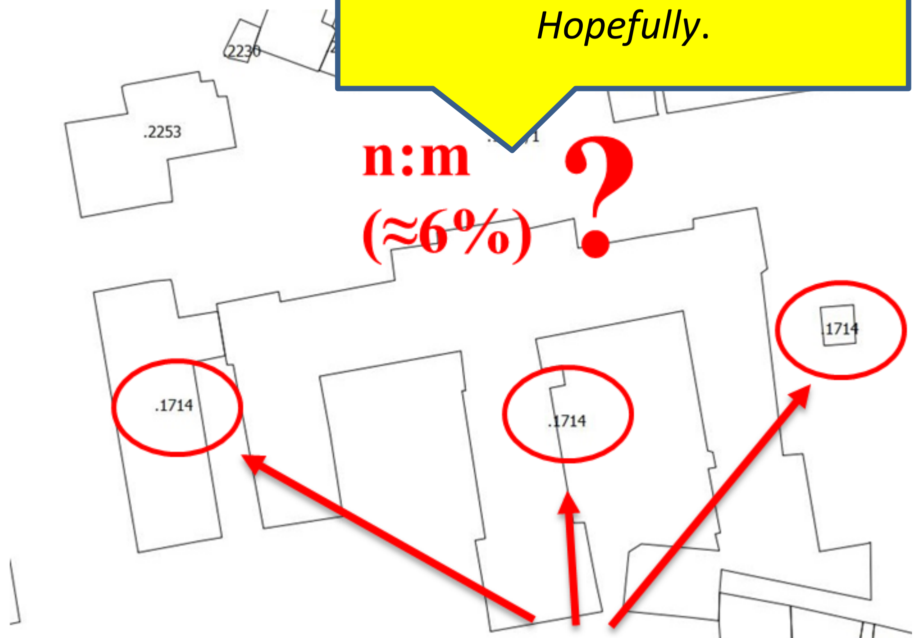
Step 1: Creation of the 3D city model

Catasto Tavolare + Catasto Fabbricati, example of cardina

This can be resolved only *manually* or (partially) using addresses as second key. *Hopefully*.



Code1	Code2	Label	Class
.2253	1	Apartment 1	A/01
.2253	2	Apartment 2	A/02
.2253	3	Apartment 3	A/01
.2253	4	Apartment 4	A/01
.2253	5	Apartment 5	A/02
.2253	6	Apartment 6	A/01
.2253	7	Apartment 7	A/01
.2253	7	Shop 1	C/01
.2253	8	Shop 2	C/01
.2253	9	Garage 1	D/01



Code1	Code2	Label	Class
.1714	1	Garage 1	D/01
.1714	2	Garage 2	D/01
.1714	3	Shop 1	C/01
.1714	4	Shop 2	C/01
.1714	5	Apartment 1	A/02
.1714	6	Apartment 2	A/01
.1714	7	Apartment 3	A/01
.1714	7	Apartment 4	A/01
.1714	8	Apartment 5	A/01
.1714	9	Apartment 6	A/01

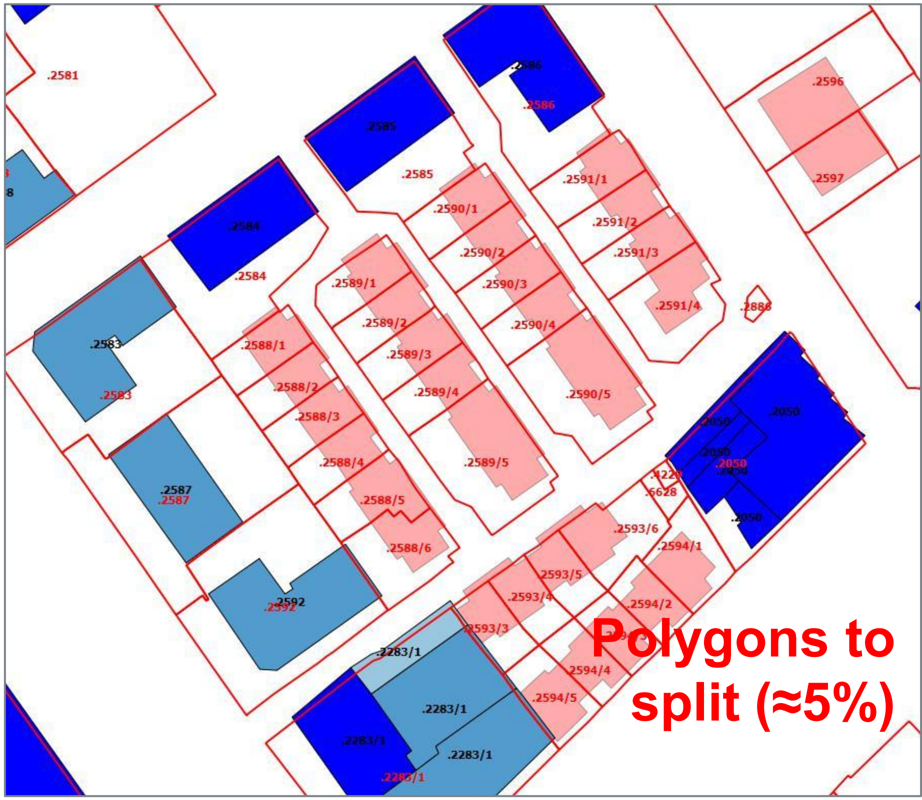
Step 1: Creation of the 3D city model

How to overcome the geometric problems of the cadastral cartography?

HYBRID APPROACH

Preserve cadastral information, but use topographic map as source of footprint geometries

1. Segment footprint from topographic map according to cadastral map
   - Take care of further cardinality problems between topographic and cadastral geometries
2. Define unique building IDs
3. Transfer cadastral codes to topographic map (by set of rules to take inexact overlaps into account)



Results

- 3D reconstruction carried out by means of B-REC by virtualCitySystems
- Ca. 2300 buildings, modelled as single-part or multi-part in LoD0, LoD1, LoD2
- Circa 40% of the buildings edited manually due to low density of the DSM
- Global height RMSE of all buildings wrt. DSM circa was 0,7 m.
- Time required: 1 month

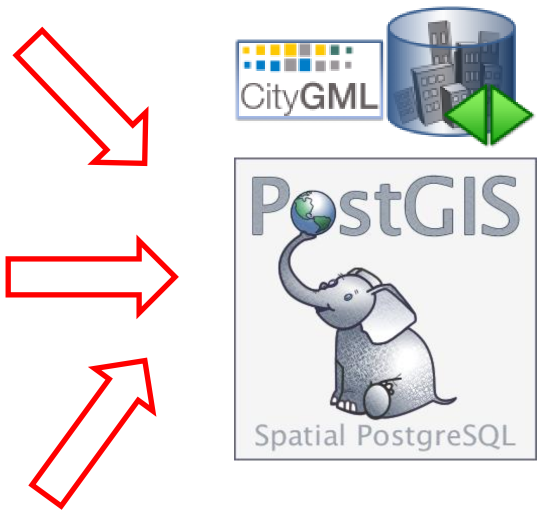
Step 1: Creation of the 3D city model

Step 1: Creation of the 3D city model

Step 2: Enrichment of the 3D city model

Integration of heterogeneous datasets at building level:

- Cadastral information (building usage, year of construction, n. units, n. floors, n. rooms, …, etc.)
- Addresses
- Number of residents and families
- List of refurbishments till 1992 and from 1993 till today
- Energy Performance Certificates (at building OR apartment level)
- …



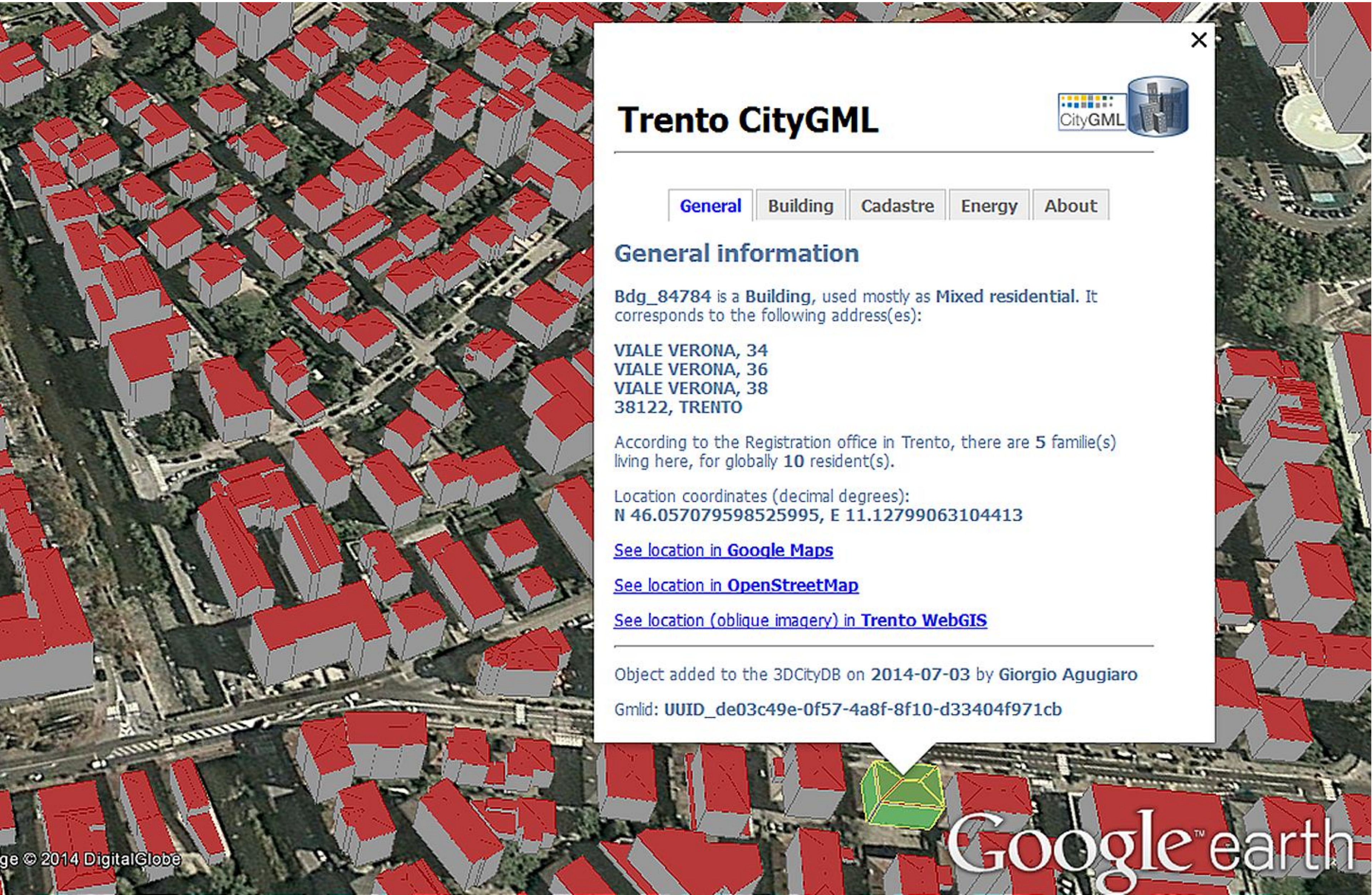
Implementation of automatic & semi-automatic checks for data consistency and error detection

Step 2: Enrichment of the 3D city model

Addresses before

Step 2: Enrichment of the 3D city model

Step 2: Enrichment of the 3D city model



Conclusions TRENTO (Part 1 + 2)

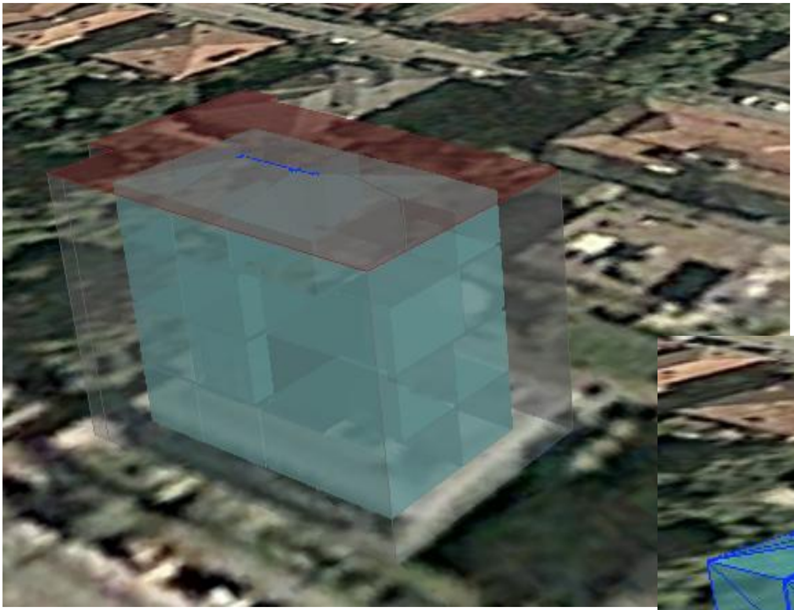
- Creation of a CityGML-based 3D model of Trento IS POSSIBLE

- Approach is extensible to the whole city, but cannot be applied fully automatically
- Some datasets are a bit old and sub-optimal, but they are being updated (e.g. Lidar and Catasto Tavolare)
- Mutual benefit in data integration: no redundancies and greater control on data quality

- Initial effort not negligible, but: "**Do once, use many!**"

- Approx. estimated time effort for completing the whole city:
  - 2 or 3 (experienced and trained) persons for up to one year

Bonus slide

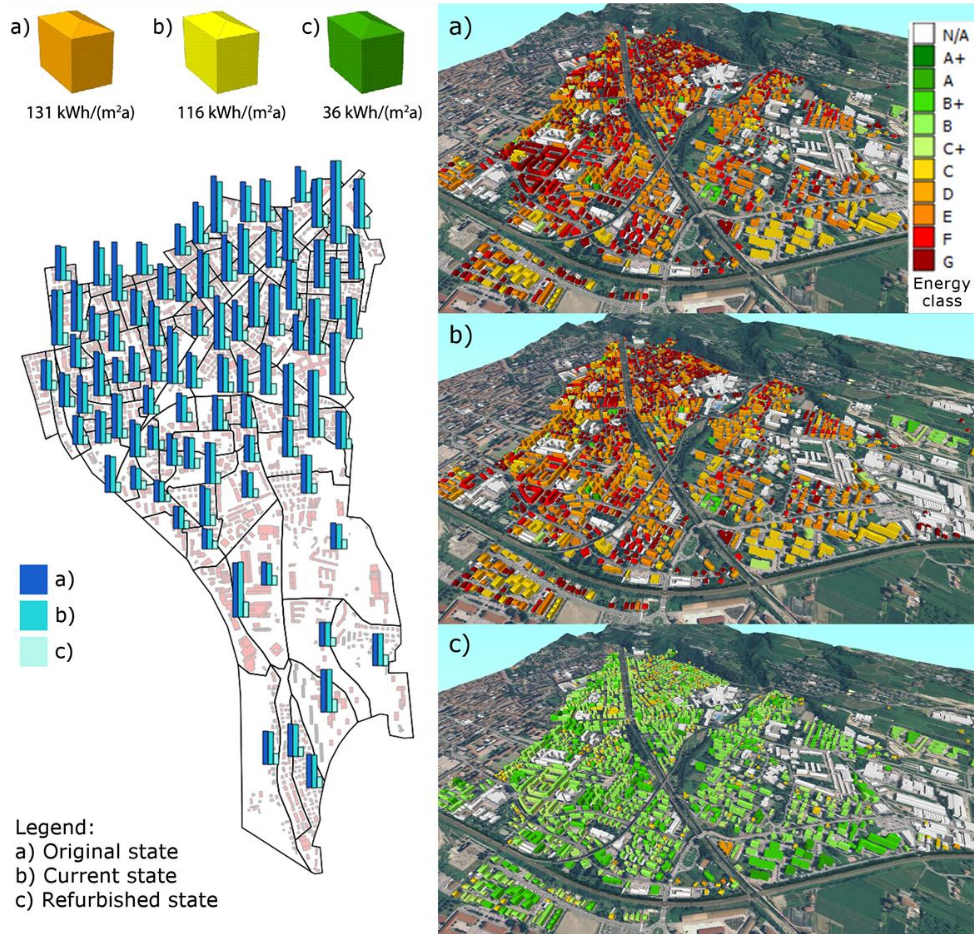


Automatic integration of Docfa 4 into CityGML

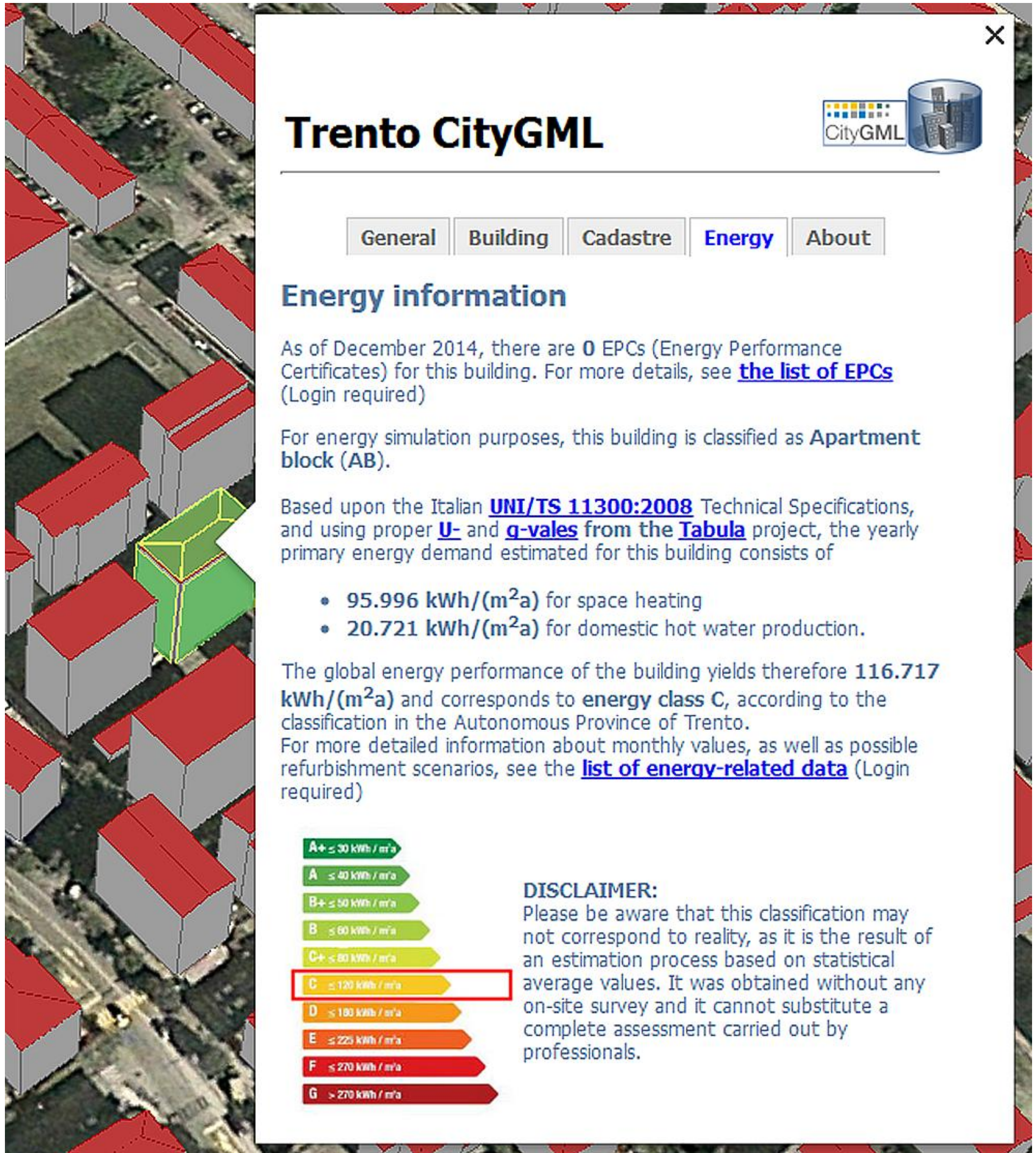
In co-operation with
Servizio Catasto Trento
and Geopartner s.r.l.

Step 3: Estimation of buildings' energy performance

- Energy-balance method based on the Italian Technical Specifications UNI/TS 11300 (monthly and yearly values)
- Energy demand for:
  - Heating
  - Domestic hot water production
- Original + current state refurbishment scenarios



Step 3: Estimation of buildings' energy performance



VIENNA:
Project Ci-Nergy (2013 – 2017)

- Ci-nergy: **Smart Cities with sustainable energy systems**
- Marie Curie Action, Initial Training Network (ITN) Project
- Multi-disciplinary PhD programme: 11 PhDs, 3 Post-Docs
- Members:
  - HFT (Stuttgart), EPFL (Lausanne), University of Nottingham, Polito (Turin), UCD (Dublin), AIT (Vienna), TUW (Vienna)
  - Siemens, EDF, IES
  - City of Vienna, City of Geneva

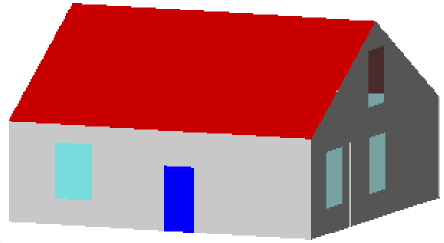
- http://www.ci-nergy.eu

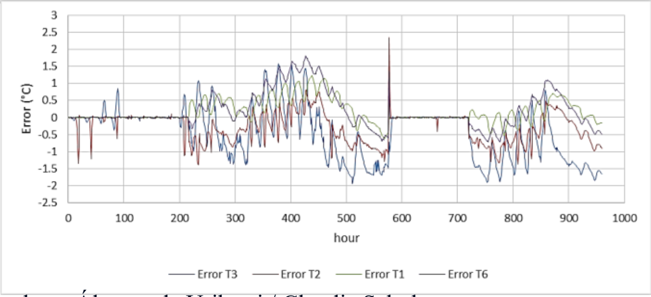
Co-funded by the Intelligent Energy Europe
Programme of the European Union

Project Ci-nergy: Goals

- A coherent platform aimed at supporting decisions for urban energy planning
  - Using (also) geo-referenced city data
  - Variable scale: buildings, district, city
  - Model interaction between energy demand, supply, networks and storage

- Use cases
  - Buildings' energy demand prediction
  - Dynamic building simulation
  - District heating network (co)-simulation
  - Service-oriented infrastructure



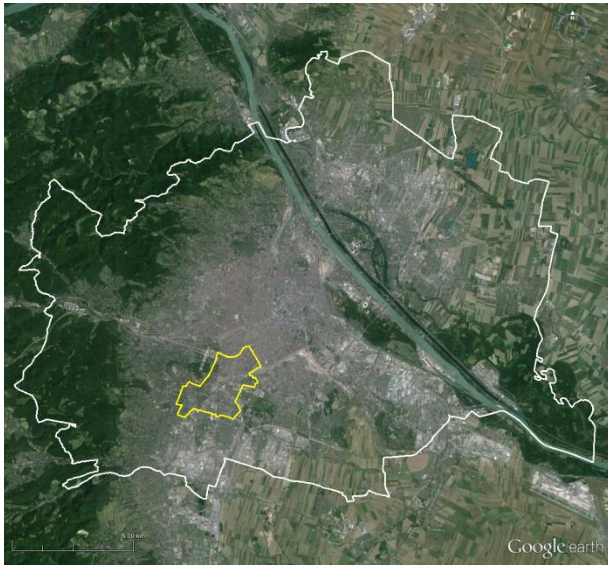


Pilar Monsalvete Álvarez de Uribarri / Claudia Schulte

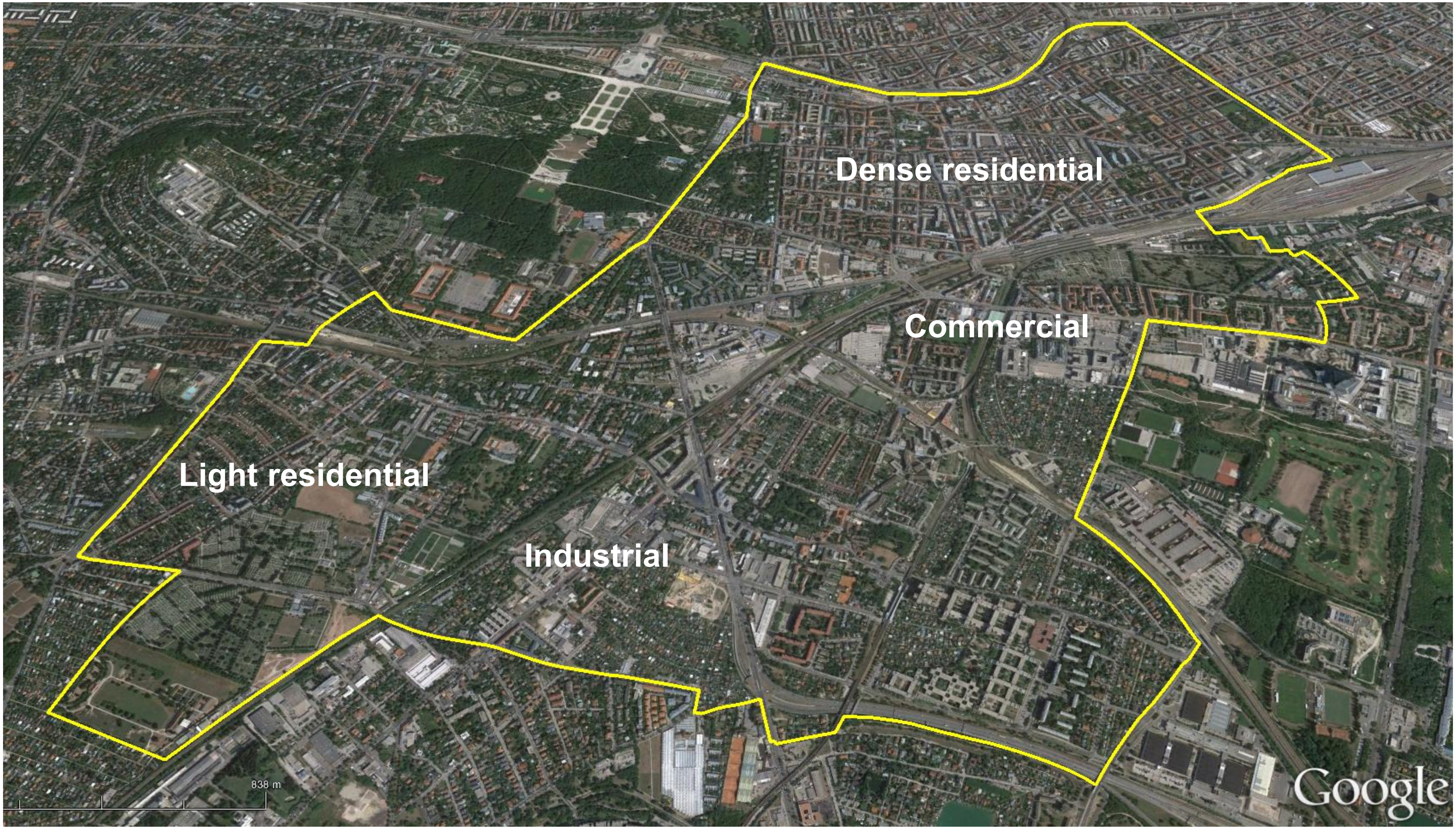
3D city model of Vienna

- CityGML-compliant, since 2015 in development @ AIT
  - Fits Ci-nergy project needs & goals
  - Availability of geometries up to LoD2
  - Lots of data (spatial, non-spatial, energy-related) published recently as OGD

- Study area: 12th district (Meidling)
  - ≈ 8.2 km^2, ≈ 90000 inhabitants
  - ≈ 7500 buildings, ≈ 5500 residential buildings
  - Heterogeneity of building types, sizes, functions, etc.



3D city model of Vienna: Meidling district



Data sources

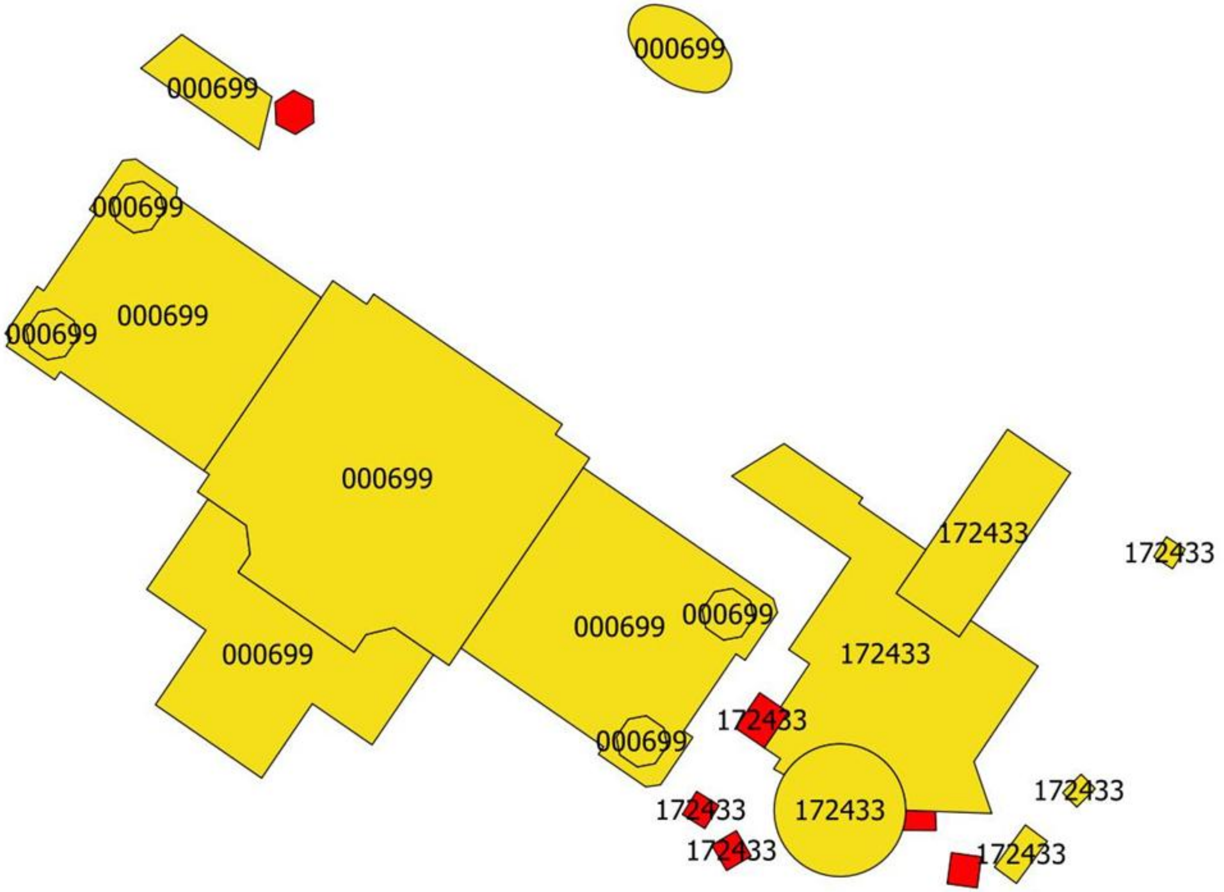
- Buildings
  - LoD0: **Flächen-Mehrzweckkarte (F-MZK)** (open data)
    - Polygon-based topographical "multi-purpose" 2D map
    - Reference map for all successive products
    - Objects are classified into 50 classes (buildings, traffic, water bodies, etc.)

  - LoD1: **Baukörpermodell** (open data)
    - Derived by the F-MZK and constantly updated by the city
    - Pure geometry, no semantics

  - LoD2: **CityGML geometries** from 2012 DSM
    - Input Lidar ≈ 4 pt/m^2 + spot wise updates by photogrammetry)

Data integration issues

- Cardinality issues due to absence of a unique building ID



Data integration issues

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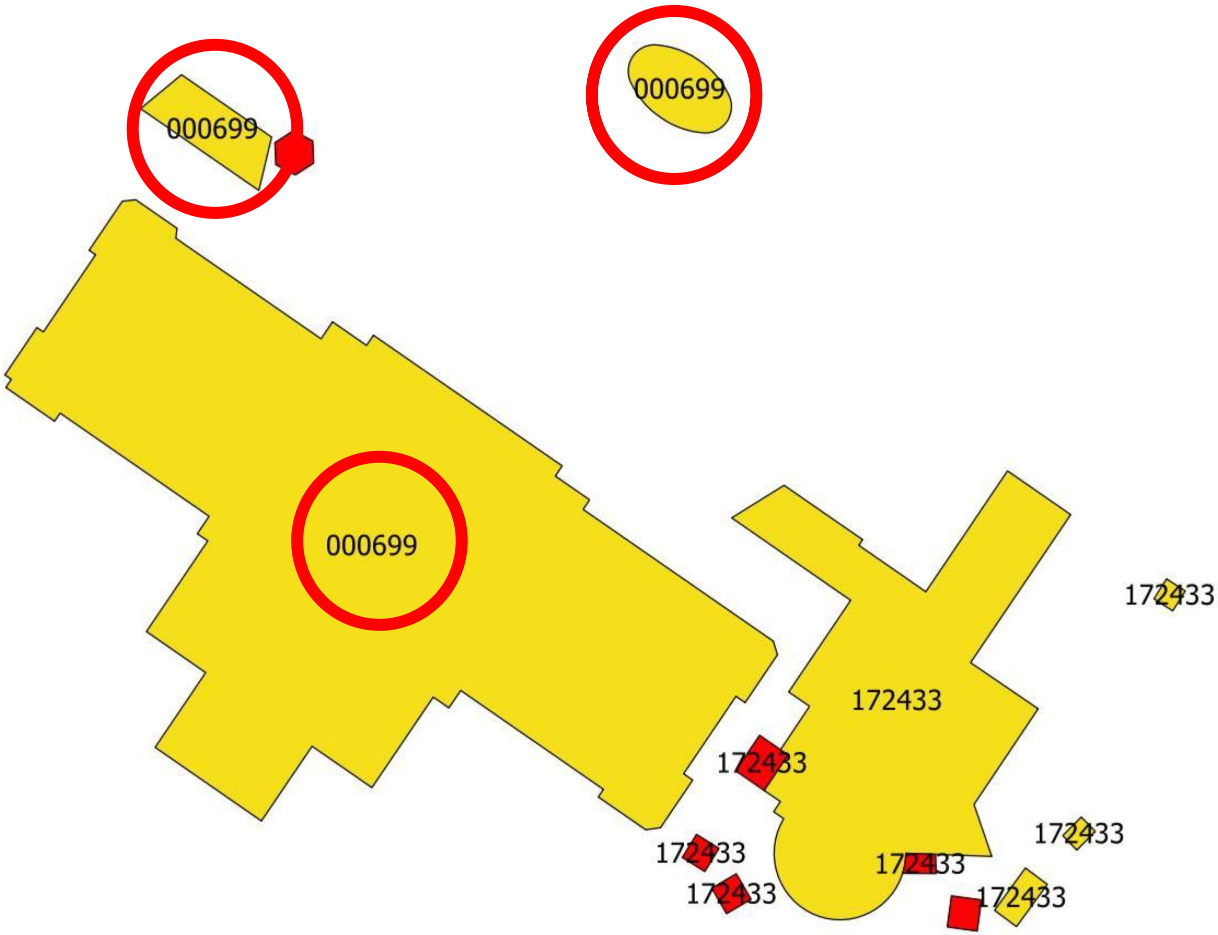
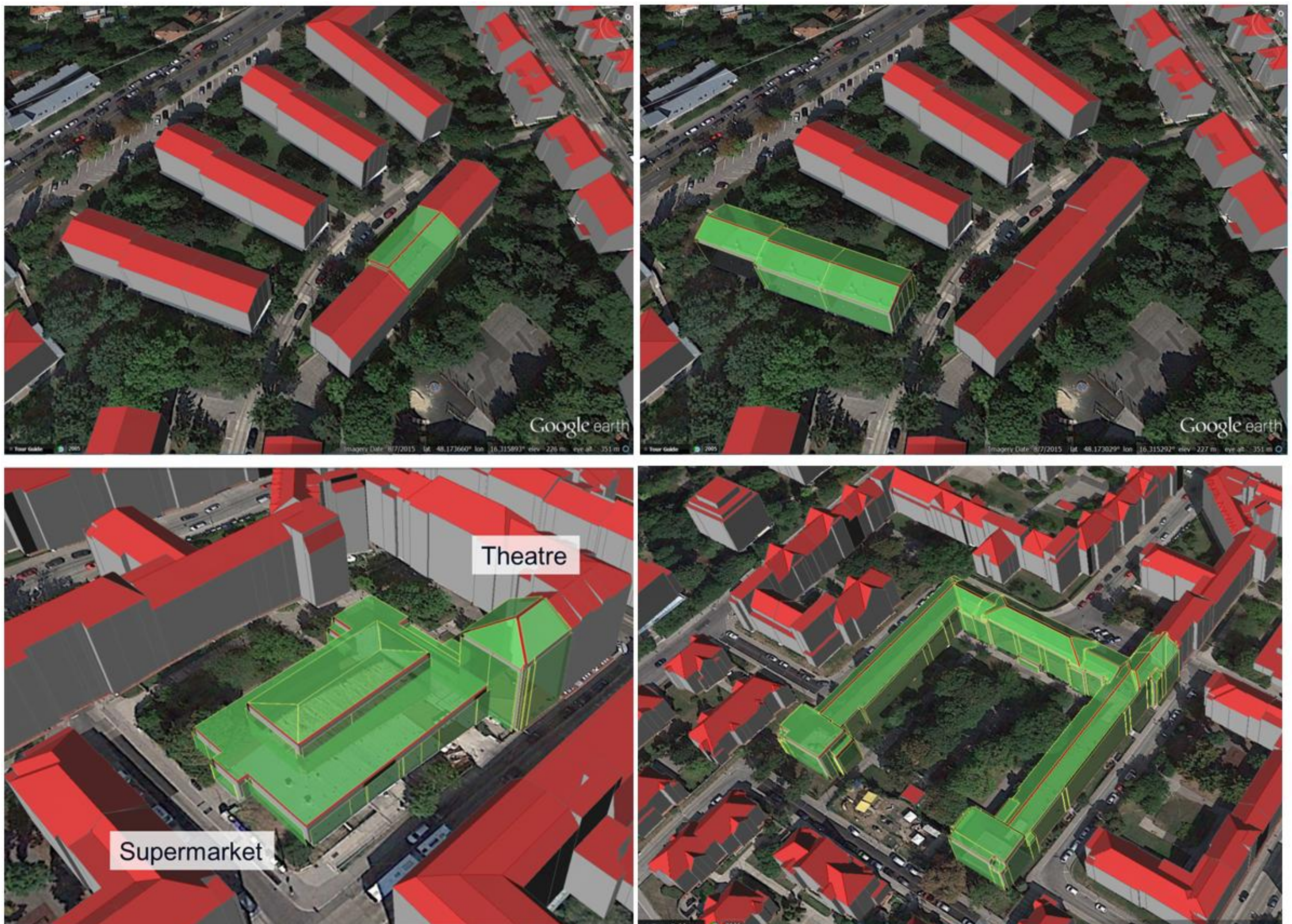


Data integration issues

- Issues with hierarchies and grouping of buildings / building parts



Other data sources

- Addresses (point geometries)
- Buildings' information:
  - Year/period of construction
  - Number of floors above / below ground
  - Building use (residential, commercial, industrial, etc.)
  - Building / site name
  - Number of residents
- Specific info for social housing buildings
  - Number of households
  - Past refurbishment
  - History, architect, etc.
- District heating network, Gas network
- Plenty of other data, mostly open data
  - Solar and PV installed panels
  - 2D Tree cadastre

Other data sources: issues

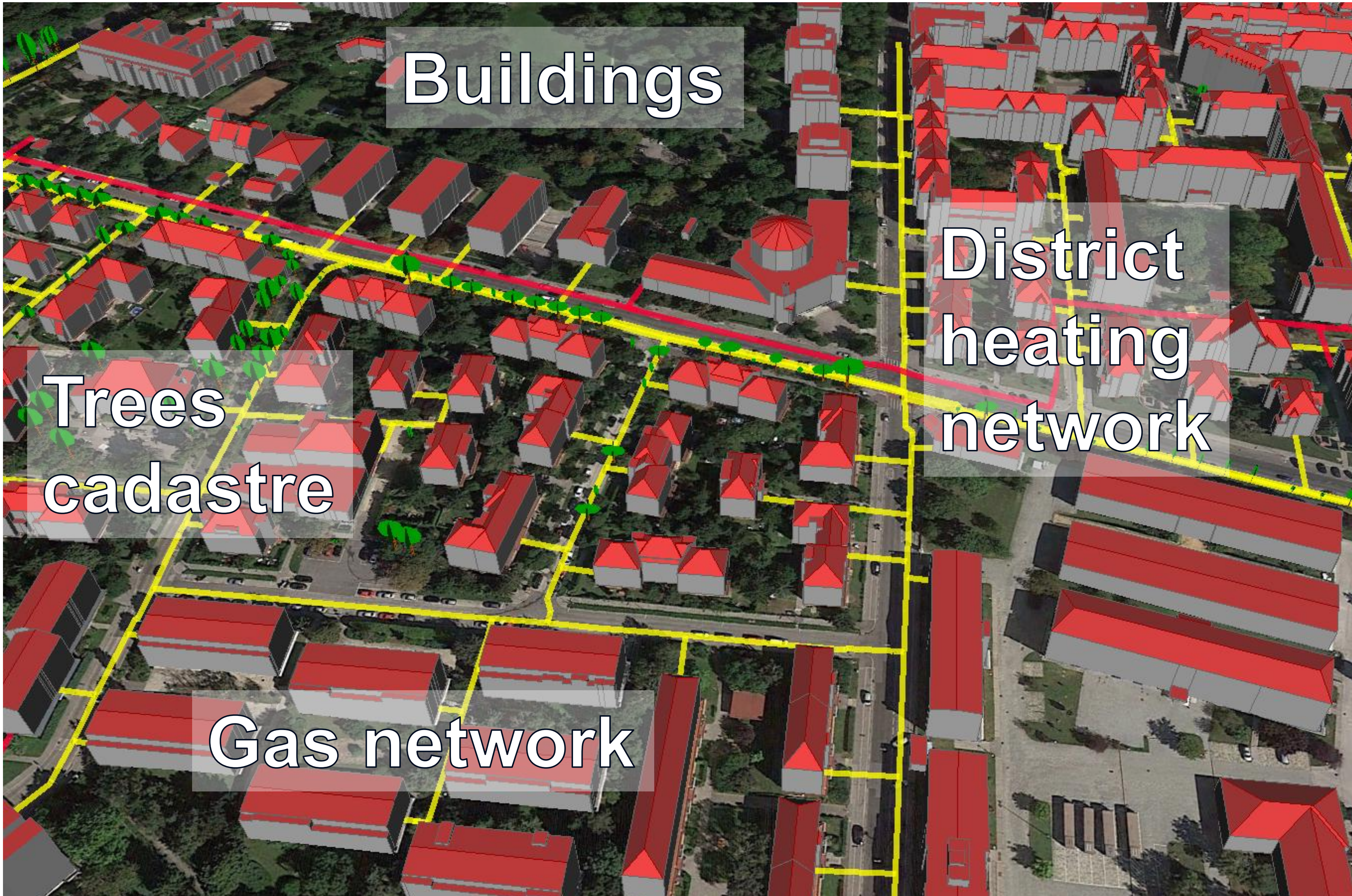
- Due to lack of unique buildings' ID, most datasets are linked to address data
- If no direct reference to address, point geometries are used
- Integration possible only via spatial overlay, but…

Address points:

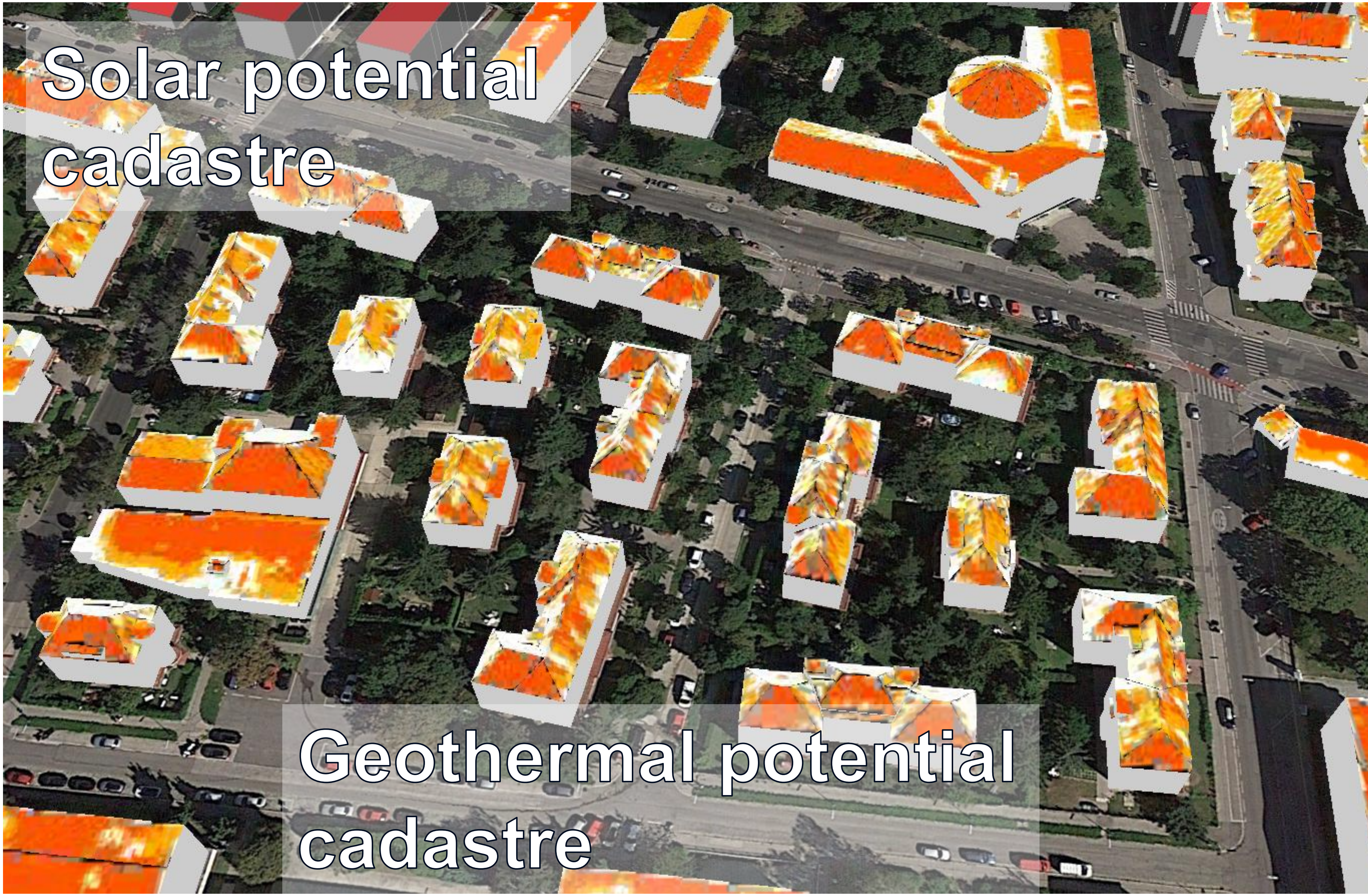
RED: before editing

GREEN: after editing

VIENNA 3D CITY MODEL

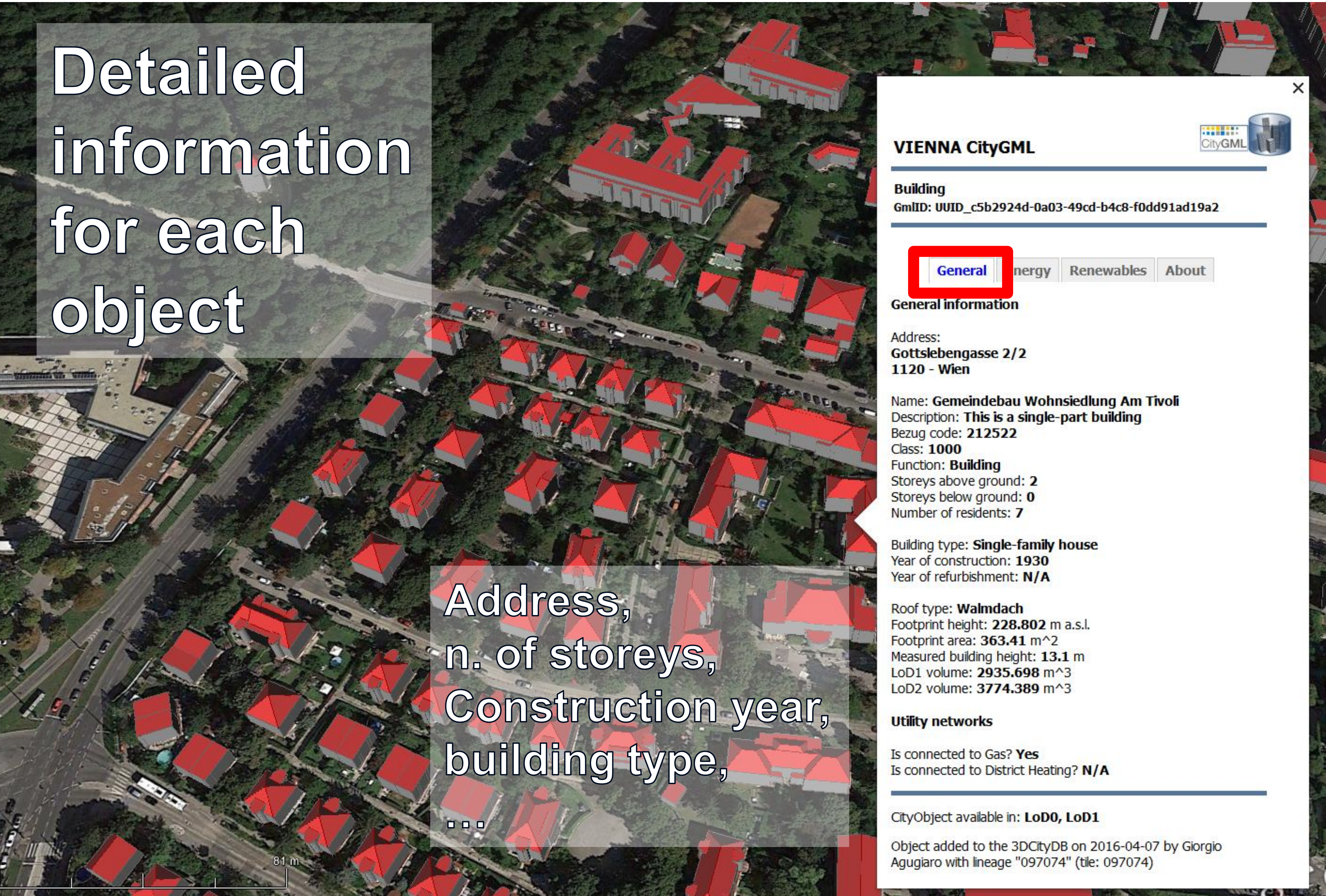


VIENNA 3D CITY MODEL



VIENNA 3D CITY MODEL

Detailed information for each object



Address,
n. of storeys,
Construction year,
building type,
...

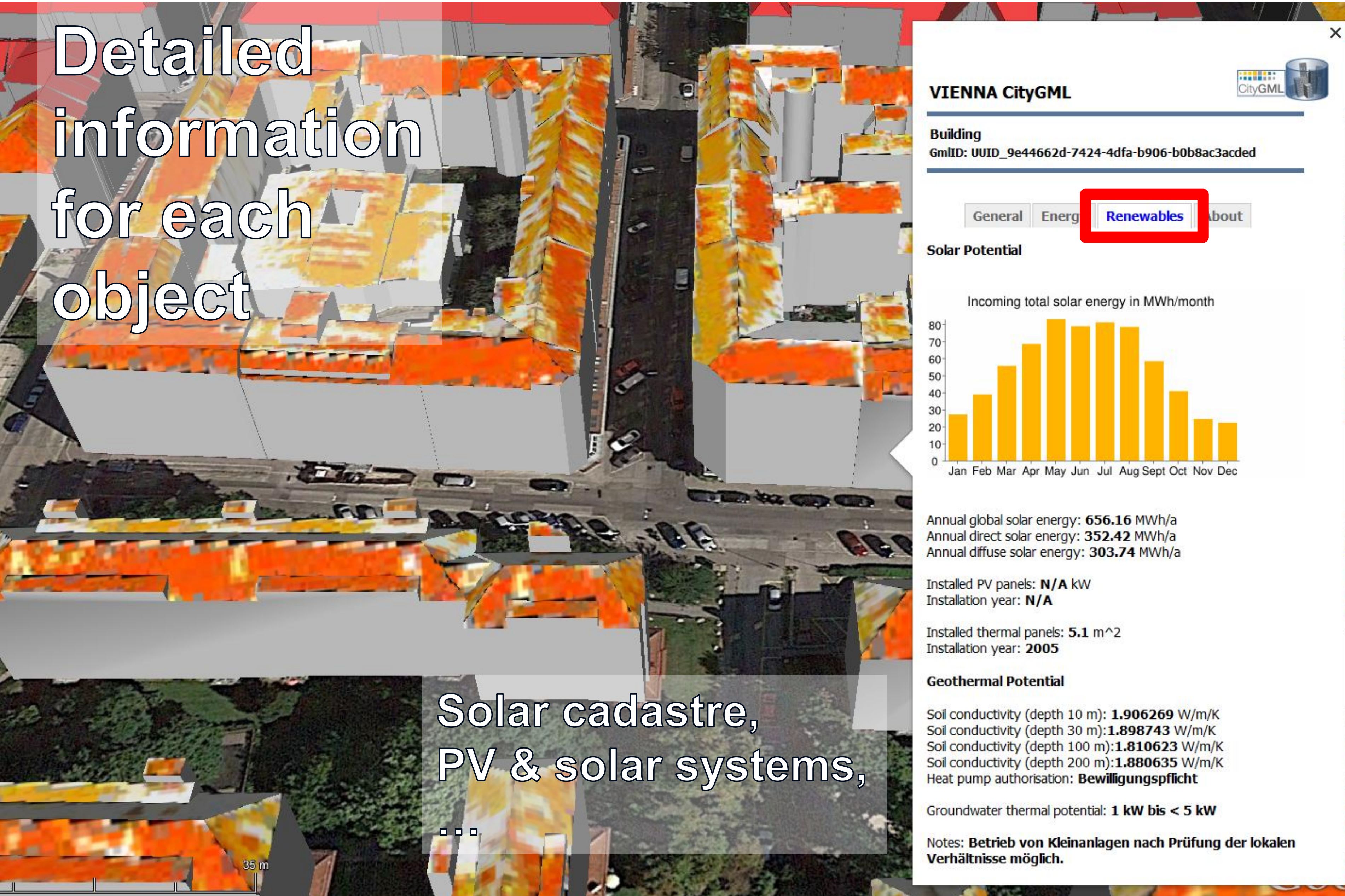
VIENNA 3D CITY MODEL

Detailed information for each object

Energy demand, refurbisment scenarios, ...

VIENNA 3D CITY MODEL

AUSTRIAN INSTITUTE OF TECHNOLOGY



Conclusions VIENNA

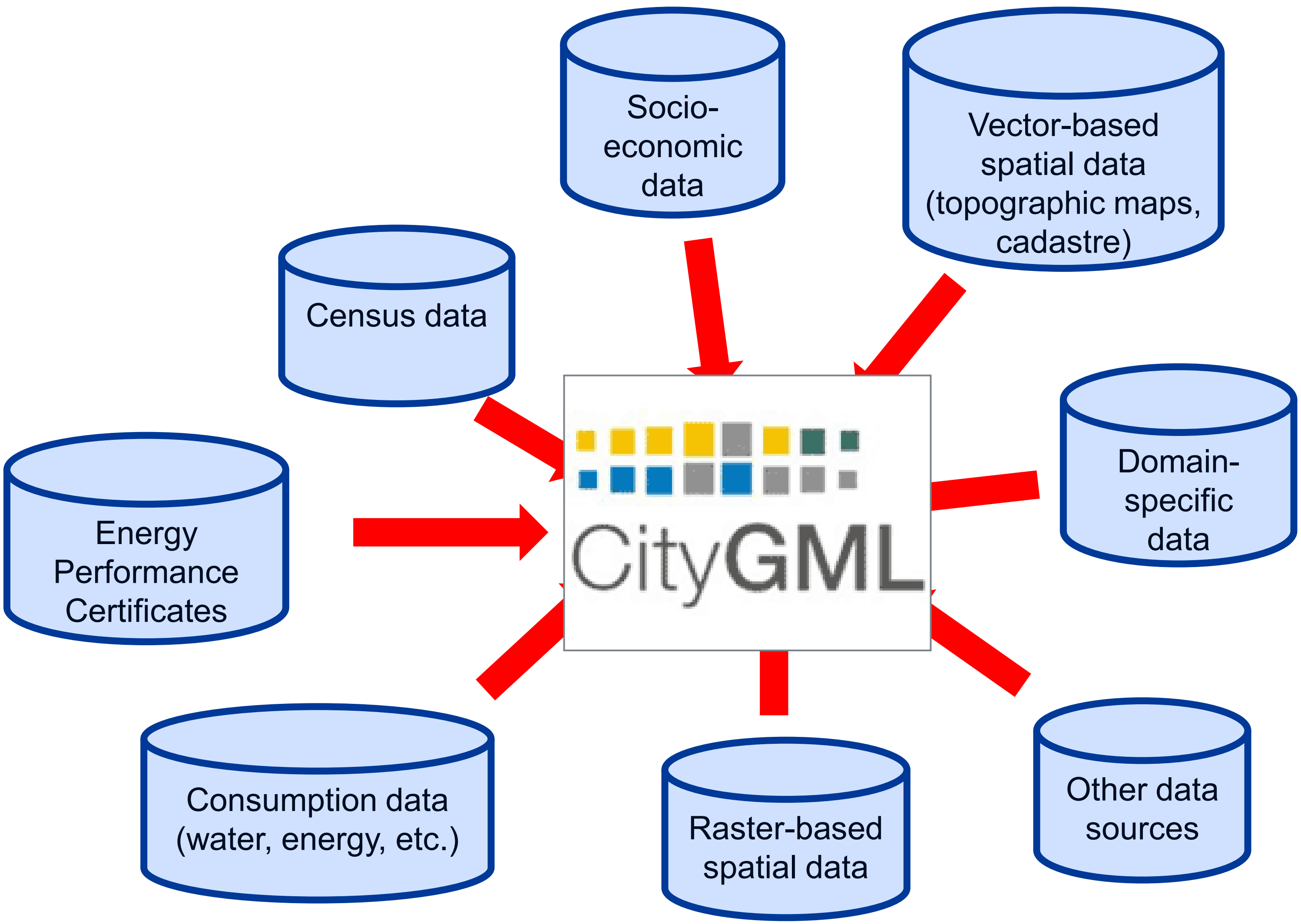
- Similar conclusions as with Trento: approach is extensible to the whole city, but cannot be applied fully automatically

- Nevertheless, the more datasets are integrated, the easier it is to fill the gaps and check for potential errors.

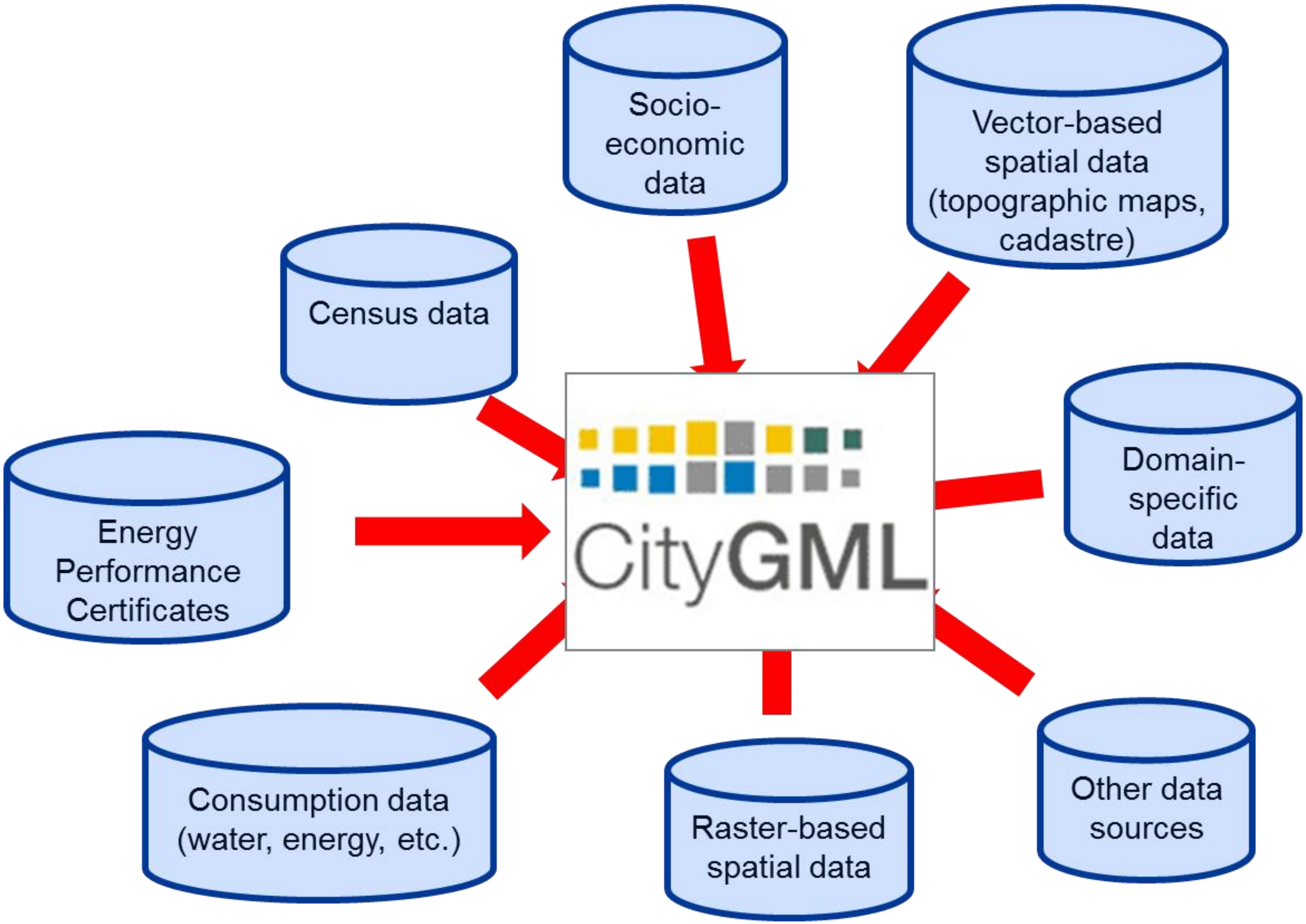
- Initial effort not negligible, but: "**Do once, use many!**"

- Approx. estimated time effort for completing the whole city (250k buildings):
  - Extremely depending on the amount of desired datasets to be added!!
  - Up to five (experienced and trained) persons for one year

Which DATA MODEL for cities?



Which ENERGY DATA MODEL for cities?



Which ENERGY DATA MODEL for cities?

- CityGML lacks specific features and attributes for energy-related applications (e.g. thermal zones, time series, etc.)
- BUT: extendable via Application Domain Extensions (ADE)

ENERGY ADE

- Extends CityGML and defines standardised entities needed for building energy simulation purposes at city scale
- See next presentation by Romain Nouvel

Conclusions

- **Standard-based** 3D semantic city models represent a useful **information hub** for energy-related applications at urban scale (but not only!)
  - Help focus more on WHAT than on HOW

- Tools can be developed to help answer questions for urban (and energy) planning at city scale, but with a granularity which reaches down to the single building

- CityGML does NOT solve all problems, but it helps to optimise and standardise internal and external processes!
  - A city (and its model) it is not a static entity
  - Procedures to keep the city models up-to-date are <u>as important as</u> the data themselves!!

- In case yoou didn't get it:
  Data integration is time-consuming, so: ***Do once, use many!***

AUSTRIAN INSTITUTE OF TECHNOLOGY

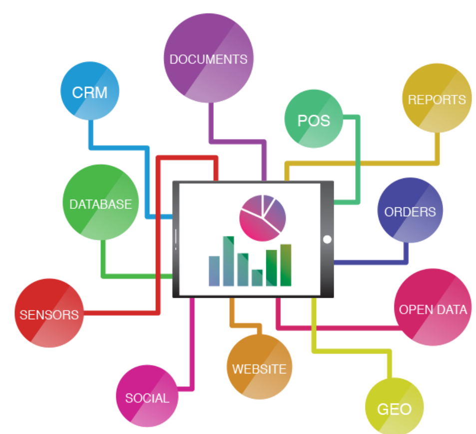
Smart cities

need...

Smart applications

and require...

SMART (geo)DATA!!



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- Comune di Trento
  - Servizio Sistema Informativo
  - Servizio Urbanistica
  - Ufficio Anagrafe
  - Archivio Storico
- Stadt Wien
  - Magistratsdirektion Strategische Energieangelegenheiten
  - Magistratsabteilung 14 Informations- und Kommunikationstechnologie
  - Magistratsabteilung 39 Prüf-, Überwachungs- und Zertifizierungsstelle
  - Magistratsabteilung 41 Stadtvermessung

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