ELISE action
Webinar Series

3D city models to predict energy heat demand

Giacomo MARTIRANO, European Commission JRC (consultant)
Francesco PIGNATELLI, European Commission JRC
Simon VREČAR, European Commission JRC (consultant)
Volker Coors Institute of Applied Research HFT Stuttgart
GemaHernández Moral CARTIF Foundation

17/06/2021 14:00 CEST (UTC+2)

European Location Interoperability Solutions for e-Government

Enabling Digital Government through Geospatial and Location Intelligence

ISA^2

European Commission

What is ELISE?

A BIT OF HISTORY...

2004
IDABC: Interoperable Delivery of European eGovernment Services

2010
ISA: Interoperability solutions for public administrations

- **Actions**:
  - EULF
  - ARE3NA

2016
ISA²: Interoperability Solutions for European Public Administrations, Businesses and Citizens

- ELISE

2021
DIGITAL: Digital Europe Programme

ELISE builds upon the outcomes of the former ISA actions EULF and ARE3NA. It is the only action of the ISA² Programme, aiming to improve Digital Government through Location Interoperability.

WHAT?

ELISE stands for **E**uropean **L**ocation **I**nteroperability **S**olutions for e-Government. It is one of the more than 50 actions in the European Interoperability Programme ISA2

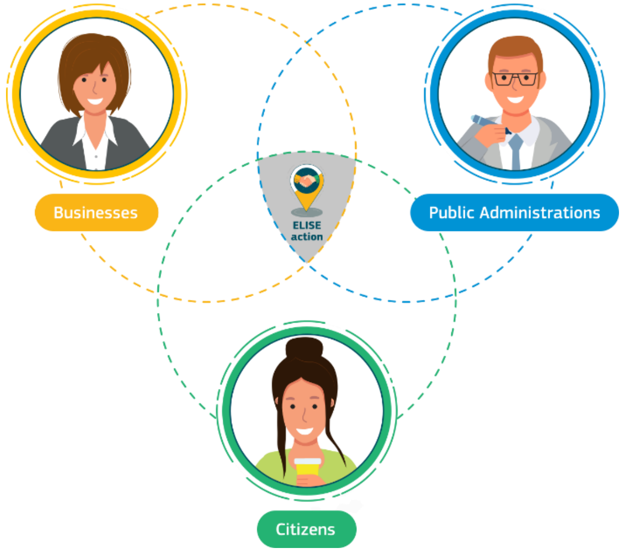
WHAT FOR?

To support Digital Government Transformation by making the best use of location data and technologies in an interoperable manner

FOR WHOM?

For all: citizens, businesses and public administrations

Location-enabled Digital Government Transformation



ISA²

ELISE action objectives

ELISE action

Policy support

Supporting different policy initiatives at European and national levels

Emerging trends and technologies

Discovering how emerging trends and technologies enable more effective use of location data for policy and digital public services

Interoperable frameworks and solutions

Providing reusable interoperable cross-border and cross-sector frameworks and solutions for public administrations, business and citizens

Building a Knowledge base

Building a Geo-Knowledge base to inform and train stakeholders and promote the adoption of good practices and innovations in location data

ELISE outputs and topics

STUDIES

APPLICATIONS

FRAMEWORKS AND SOLUTIONS

GEO KNOWLEDGE BASE SERVICE

- Evolution of Spatial Data Infrastructures
- Support of data ecosystems
- Technologies for location -enabled innovation
- Collaboration models
- Spatial skills for Digital Government Transformation
- Location data privacy
- Improving access to spatial datasets
- Supporting cross-border and cross-sector data sharing
- Location intelligence for policy and digital public services
- Supporting innovation, growth and Return of Investment
- Managing data quality
- Supporting the creation of common EU public services

European Commission

5 Years

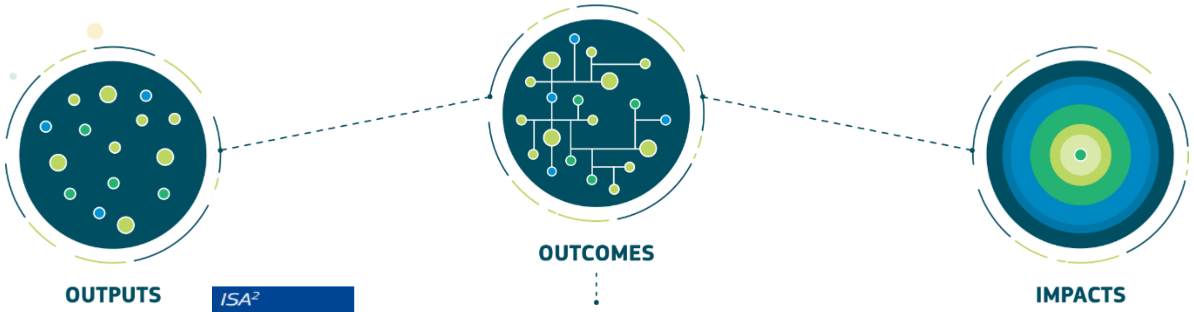
SOME ACHIEVEMENTS

Active engagement of ISA² Member States

- Complemented the EIF and NIFO with an extensive location interoperability framework and state of play assessments
- Helped put the INSPIRE Directive into practice with tools for data providers and a strong focus on use cases
- Built an extensive community of European and international stakeholders
- Raised awareness on new approaches to location-enabled digital transformation
- Helped to assess the role of SDIs in evolving business models, e.g. data ecosystems, digital platforms.
- Assessed new policies (e.g. GDPR, European Data Strategy) and technologies (e.g. Artificial Intelligence, Blockchain, API...)
- Promoted and facilitated better links on location data between public and private actors
- Provided guidance on improving spatial awareness and analytical skills for best use of data

3 EIF Toolbox solutions

Aims of Knowledge Transfer



Our speakers

Prof. Dr. Volker Coors
Scientific Director Institute of Applied Research
HFT Stuttgart, Germany

Hochschule für Technik Stuttgart

Gema Hernández Moral
Project manager and researcher
CARTIF, Spain

TECHNOLOGY CENTRE CARTIF

The views expressed are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

European Commission

What we will cover today

1. Introduction to ELISE Energy & Location Applications
2. State of the art of heating demand predictions
3. How different data sources and different simulation environments affect energy heat demand predictions
4. Key messages, challenges and future outlook
5. Q&A

1

Introduction to ELISE Energy & Location Applications

ELISE has developed cross-border pilots and applications to test location data interoperability principles in the following sectors:

APPLICATIONS

MARINE

Supporting Member States in the management of Marine Strategy Framework Directive (MSFD) related spatial information

https://youtu.be/ROJqljr8aDU

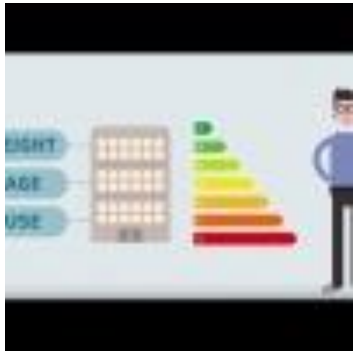
TRANSPORT

Developing and sharing best practices for the implementation of the Intelligent Transport Systems (ITS) Directive

https://www.youtube.com/watch?v=jnny5ATwTYE

ENERGY EFFICIENCY

Supporting public administrations, businesses and citizens engaged in energy policies' cycle

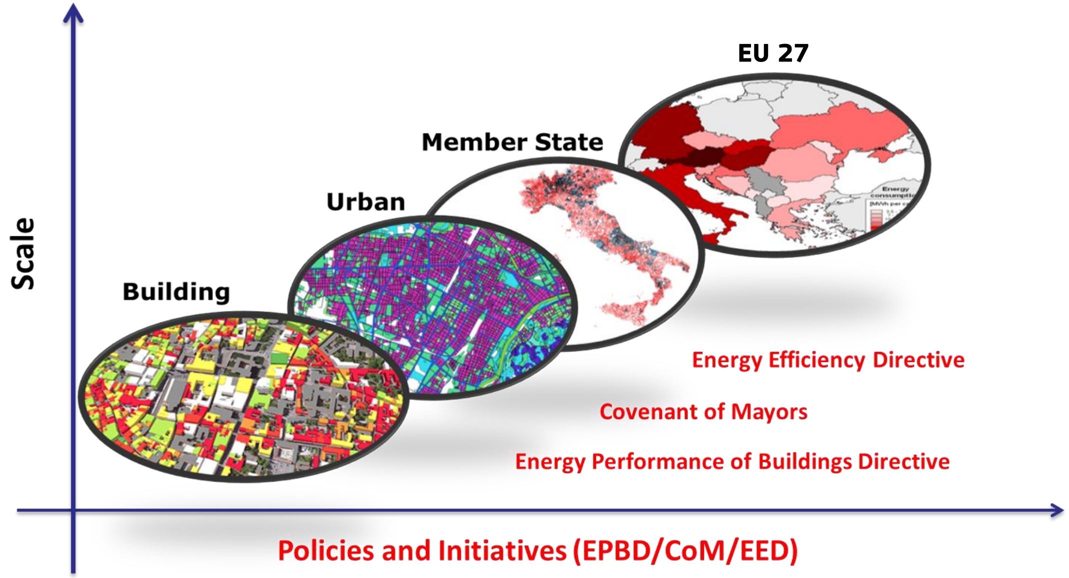


https://www.youtube.com/watch?v=Ftgy8uU9y2A

CULTURAL HERITAGE

Exploiting a pan-European gazetteer service

Location data interoperability principles and methodologies applied in the Energy Efficiency sector (1/3)

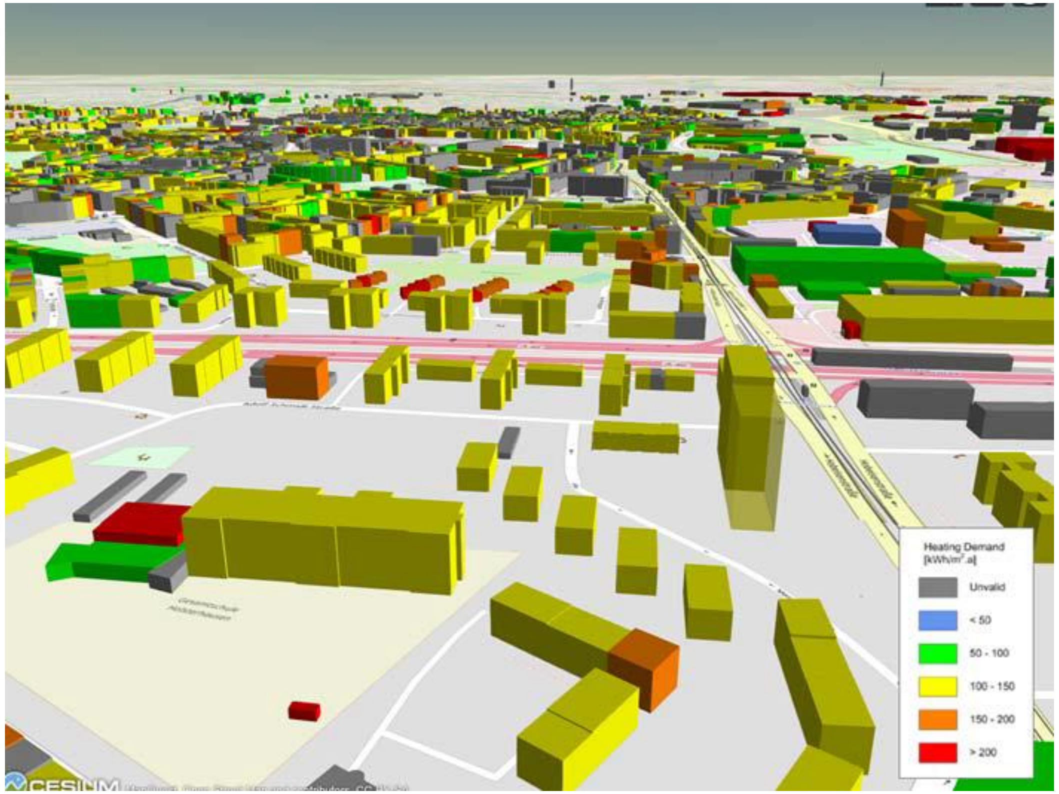


- To leverage location data at building level as an enabling factor to scale-up a set of methodologies to assess energy efficiency from local to district/city level and beyond.
- To use location-based data to support different types of stakeholders engaged in energy efficiency policies' cycle

Location data interoperability principles and methodologies applied in the Energy Efficiency sector (2/3)

- Buildings are responsible for the 40% of final energy consumption
- Over 75% of building stock is older than 25 years
- Averaged final energy consumption data: 185 kWh/m^2 for residential buildings and 280 kWh/m^2 for non-residential buildings
- Extensive renovation of buildings could cut 36% of their energy consumption by 2030

Location data interoperability principles and methodologies applied in the Energy Efficiency sector – use cases (3/3)



- Generalisation at EU level of a digital platform for public lighting being implemented in Italy in 8.000+ Municipalities
- Energy Performance Certificates (EPC) of Buildings harmonisation
- Harmonisation of SECAP (Sustainable Energy and Climate Action Plans), to support smart communities made by 100+ municipalities of the same Province, CoM signatories
- Harmonisation of energy simulations to assess the energy heat demand of buildings
- Assessment of energy performance of buildings using energy consumption data from smart meters.
- Role of geospatial information in in a regional energy strategy

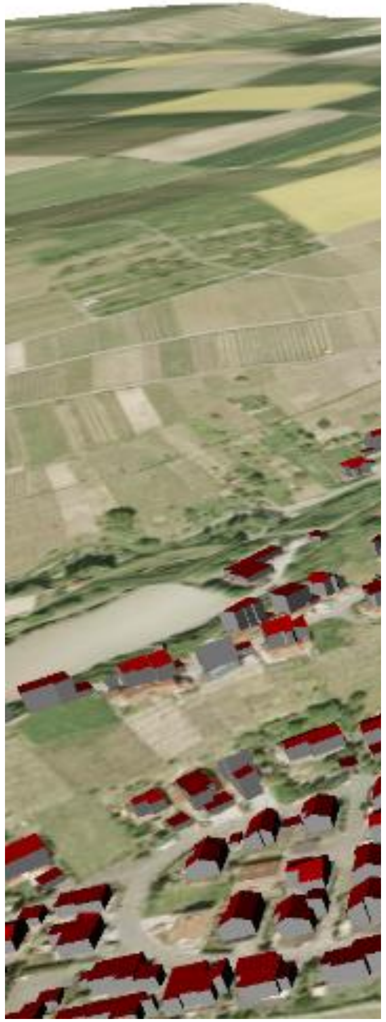
2

State of the art of heating demand predictions

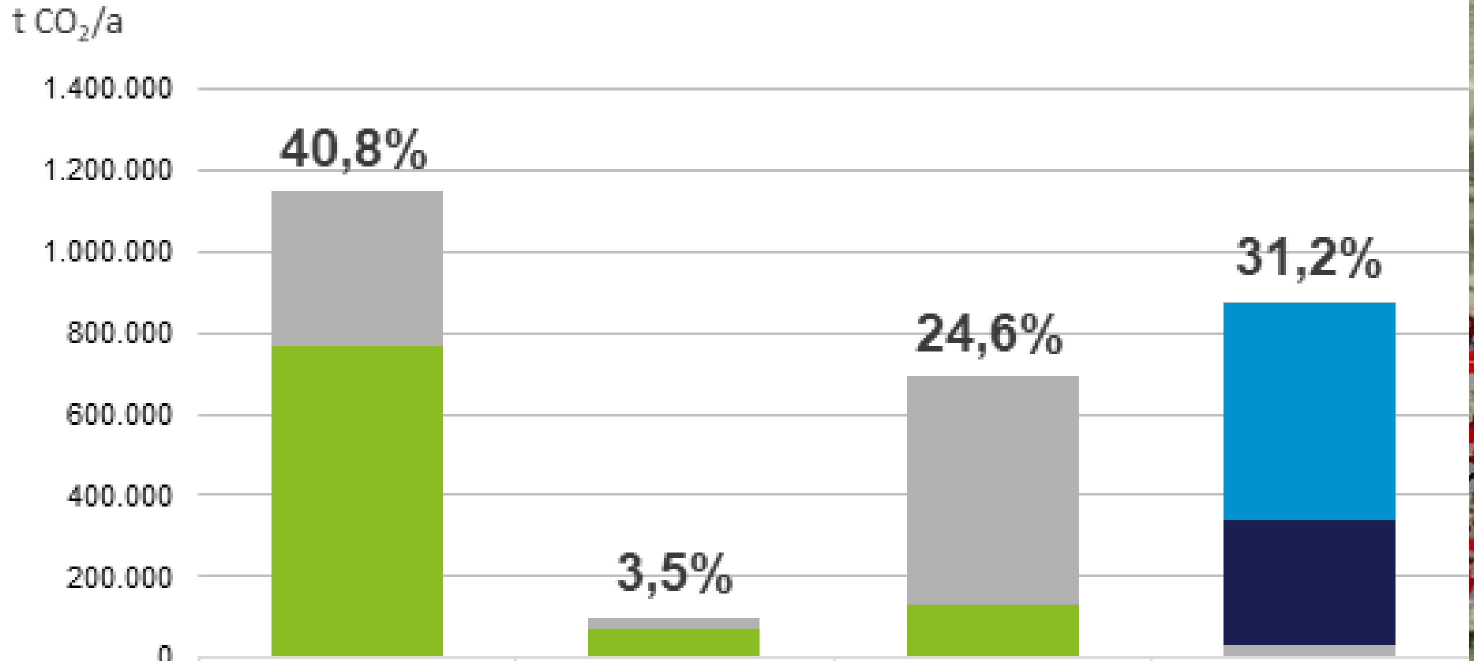
- „I have a dream“:
- Towards climate-neutral and socially innovative cities (EU Green Deal)
- Use digital Urban Twins to contribute to climate neutral cities
- Simulate heating demand and related CO_2 emissions of the entire EU building stock in 2030 / 2050 based on INSPIRE 3D-Building Model

Simulations carried out within the ELISE use case

- Essen (DE): input data LOD1 and LOD2
- Zwolle (NL): input data LOD1 and LOD2
- Enschede (NL): input data LOD1, creation of a Dutch Building Physics Library
- Valladolid (ES): different input data, 2 simulation environments – more details in the next presentation



CO2 Emissionen for different sectors and applications County of Ludwigsburg (34 city districts) 2013

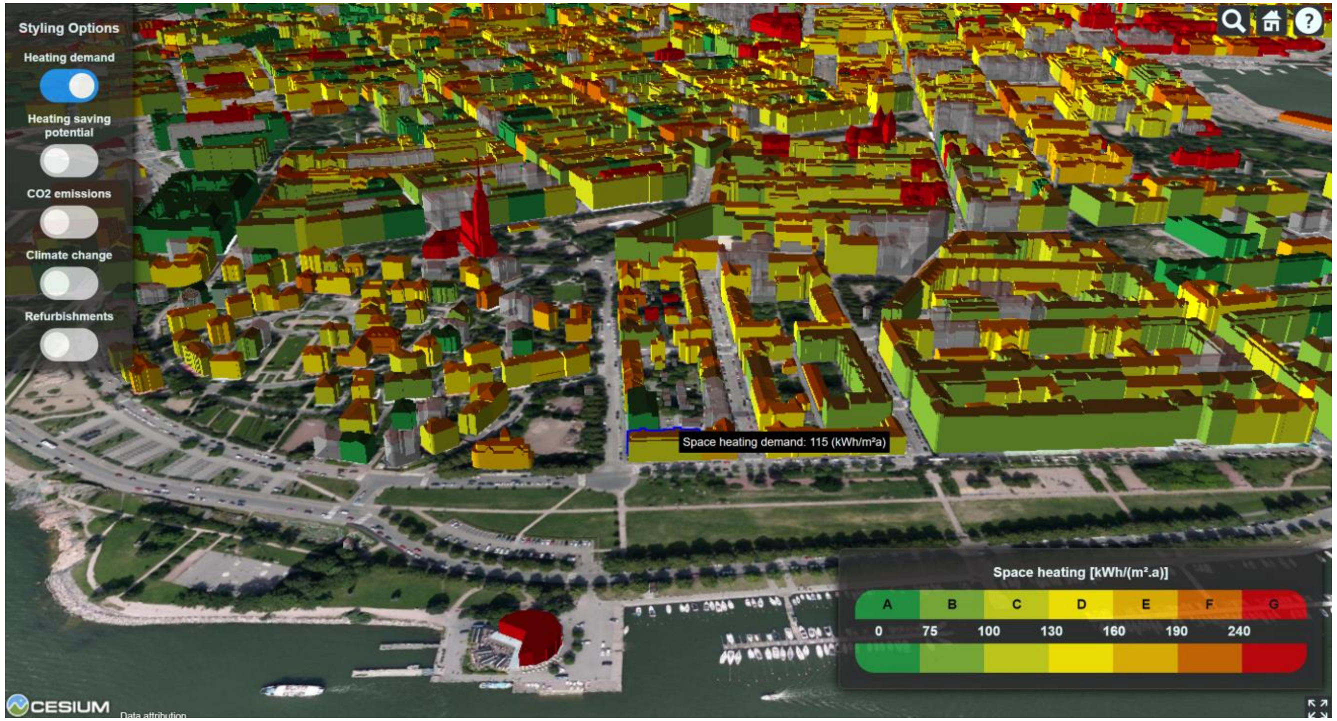


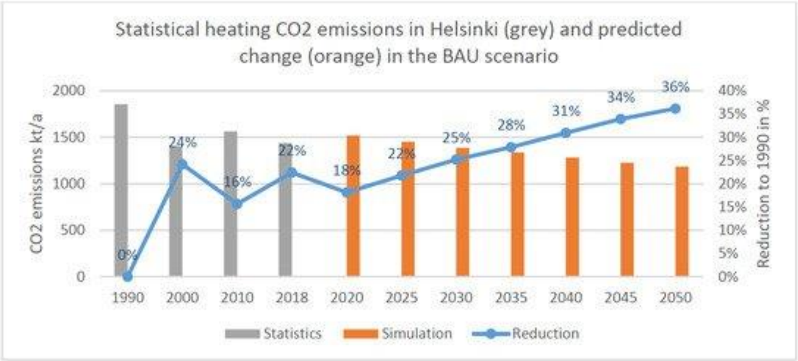
	Private Household	Public Adminstration	Industry, Commerce, Service	Transportation
Others	0	0	0	0
Diesel	0	0	0	539.923
Petrol	0	0	0	306.007
Electricity	377.525	29.506	558.054	31.846
Heat Energy Demand	770.514	69.497	133.944	0

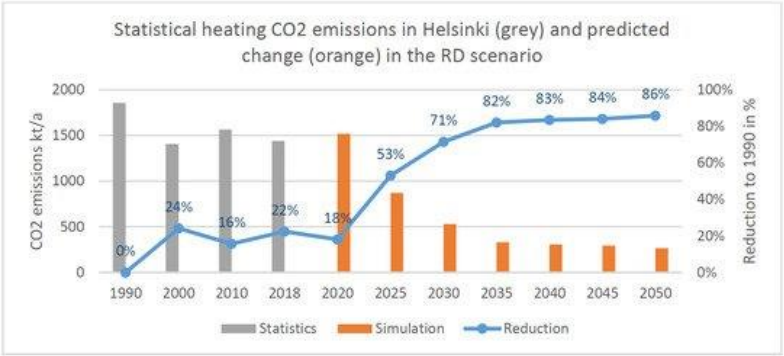
ISA²

Example: carbon-neutral Helsinki by 2035

„The goal of Helsinki City Strategy 2017–2021 is to create a carbon-neutral Helsinki by 2035.”







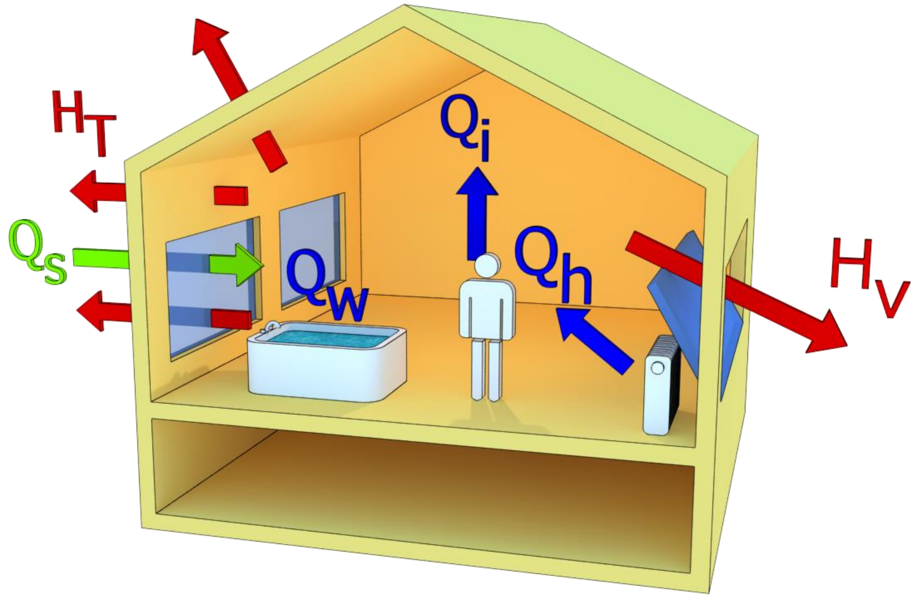
https://kartta.hel.fi/3d/heating/Apps/Helsinki/view.html

Rossknecht, M., and Airaksine, E.: Concept and Evaluation of Heating Demand Prediction Based on 3D City Models and the CityGML Energy ADE—Case Study Helsinki, *ISPRS Int. J. Geo-Inf.* 2020, *9*(10), 602; https://doi.org/10.3390/ijgi9100602

Heating demand

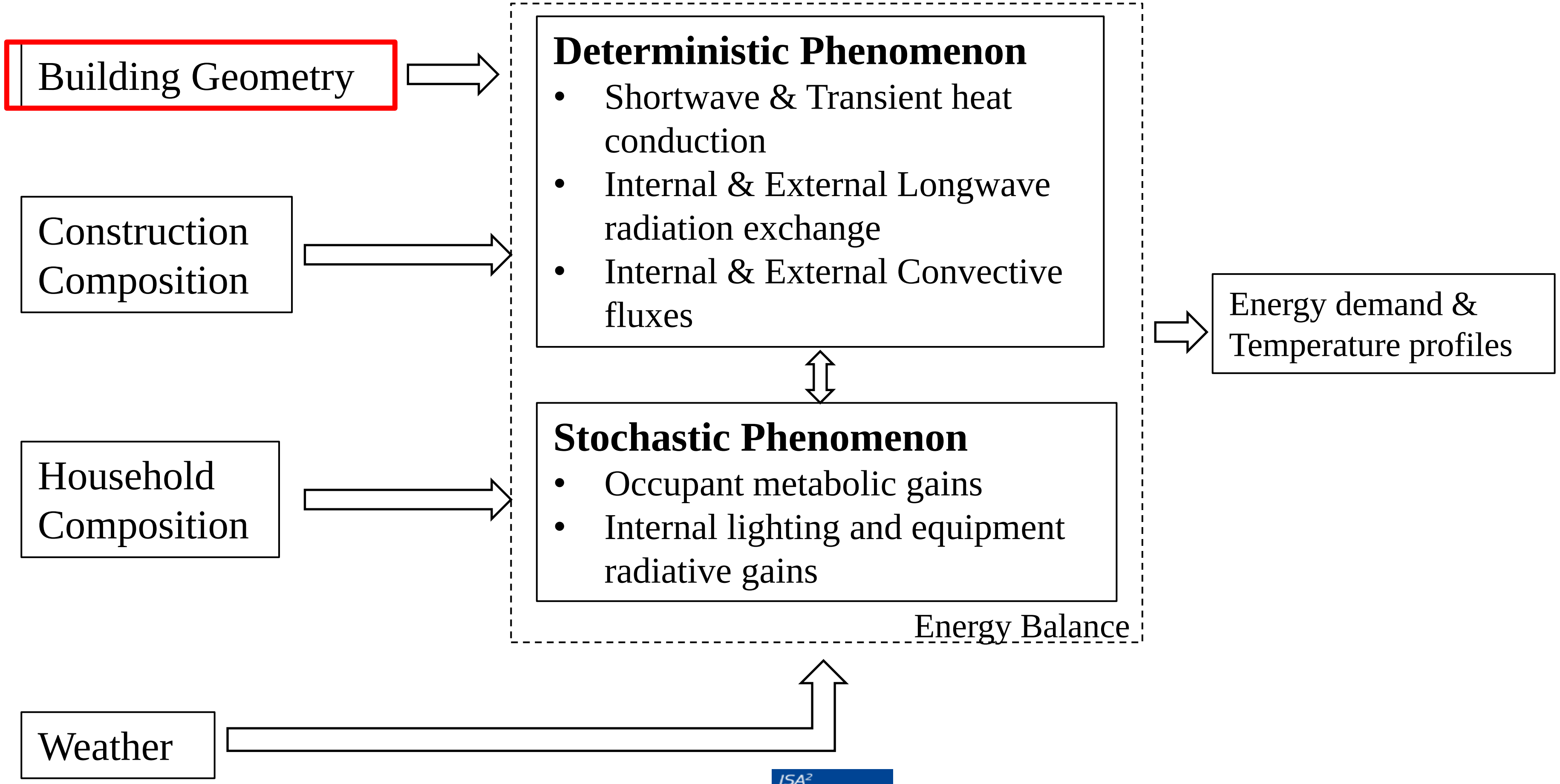
- Q_h heating demand
- Q_w hot water heating demand
- Q_s solar gains
- Q_i internal gains

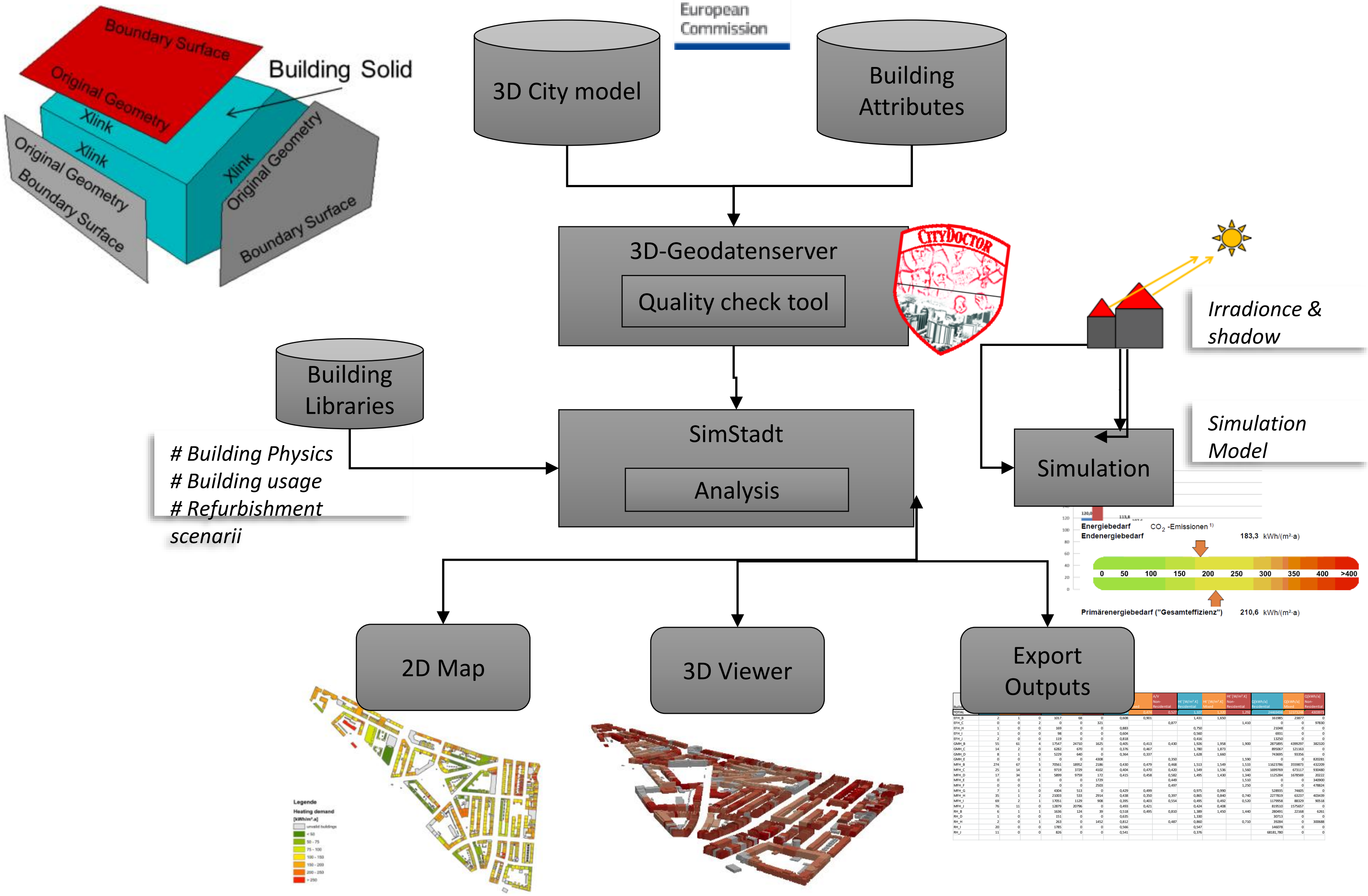
- H_T transmission heat loss
- H_V ventilation losses



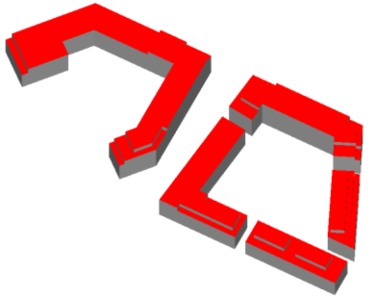
Bruse, M., Nouvel, R., Wate, P., Kraut, V., and Coors, V.: An Energy-related CityGML ADE and its Application for Heating Demand Calculation, International Journal of 3-D Information Modeling (IJ3DIM) 4(3), IGI GLobal, pp 59-77, DOI: 10.4018/IJ3DIM.2015070104

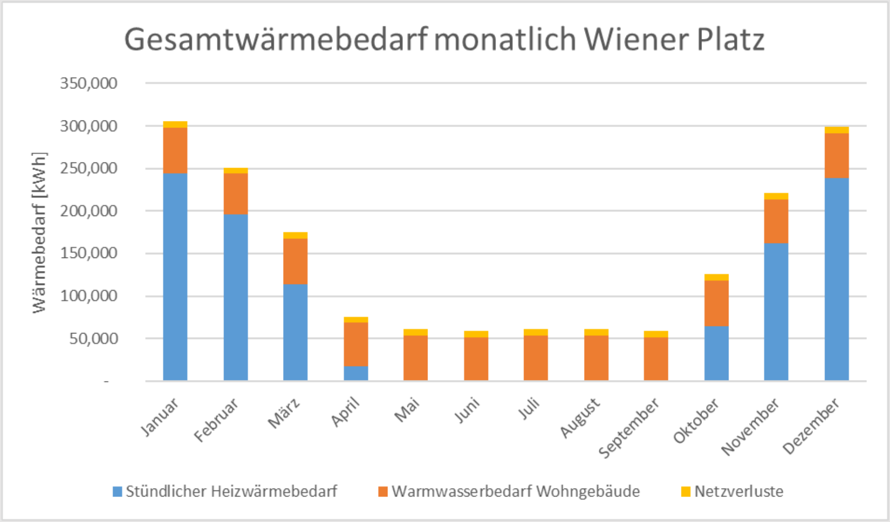
Simulation Model components

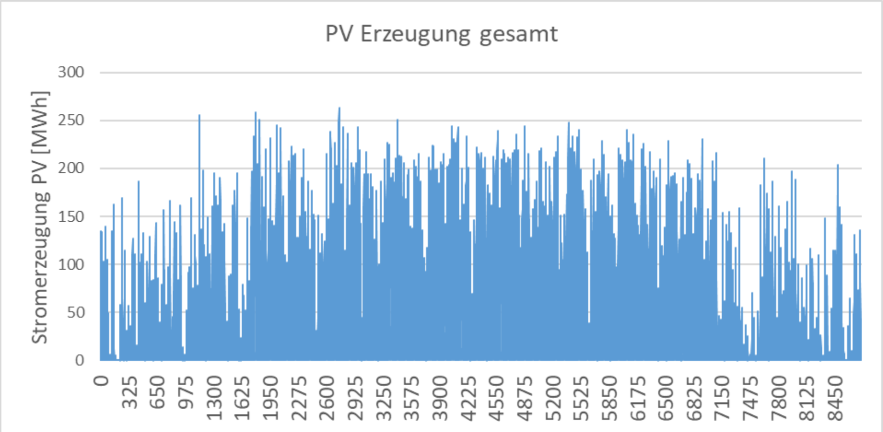


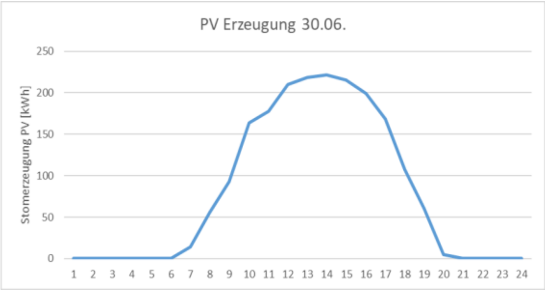

Boundary Surface
Building Solid
Original Geometry
Xlink
Xlink
Original Geometry
Boundary Surface
Xlink
Original Geometry
Boundary Surface
3D City model
Building Attributes
3D-Geodatenserver
Quality check tool
CityDoctor
Irradionce & shadow
Building Libraries
Building Physics
Building usage
Refurbishment scenarii
SimStadt
Analysis
Simulation
Simulation Model
Energiebedarf
Endenergiebedarf
CO2 -Emissionen
183,3 kWh/(m²·a)
0 50 100 150 200 250 300 350 400 >400
Primärenergiebedarf ("Gesamteffizienz")
210,6 kWh/(m²·a)
2D Map
3D Viewer
Export Outputs
Legende
Heating demand

Case Stuy Wiener Platz, Stuttgart







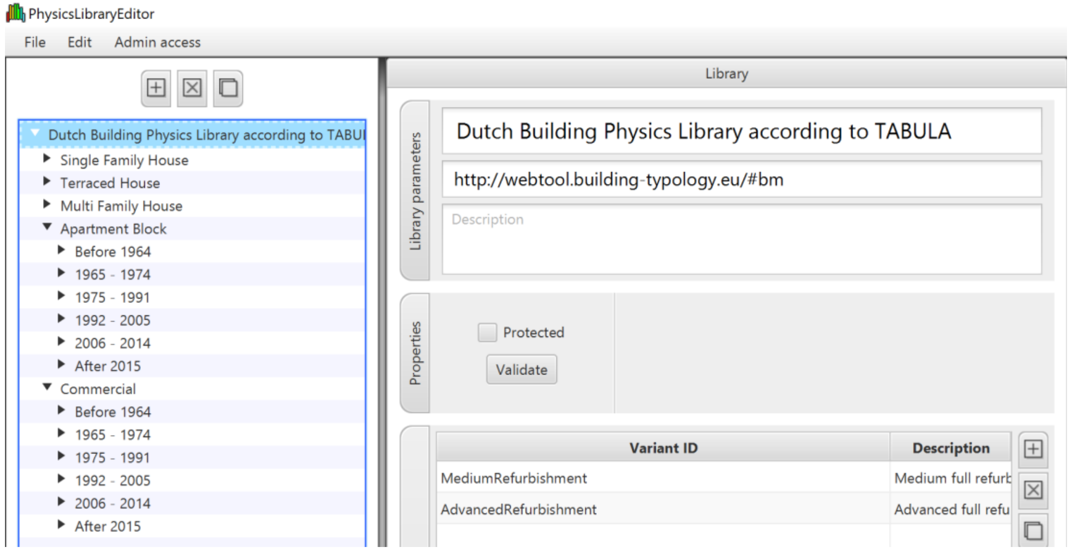


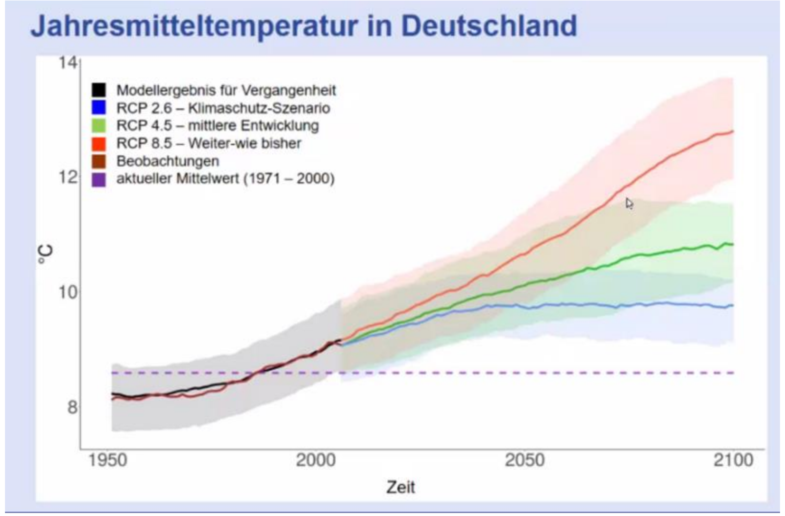
Configuration

- National Building Physics Libraries
  - TABULA

- Refurbishment scenarios
  - 3% refurbishment rate
  - Type of refurbishment
  - Used Energy Systems (-> CO2 emissions)

- Weather / climate scenarios
  - Irradiation & Temperature

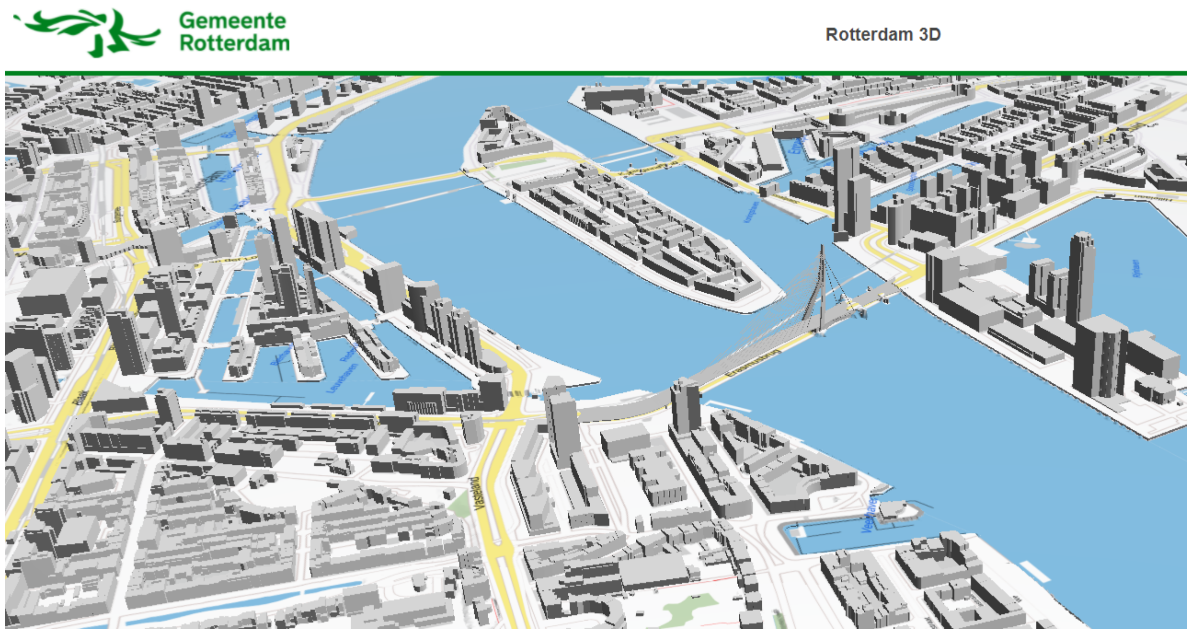


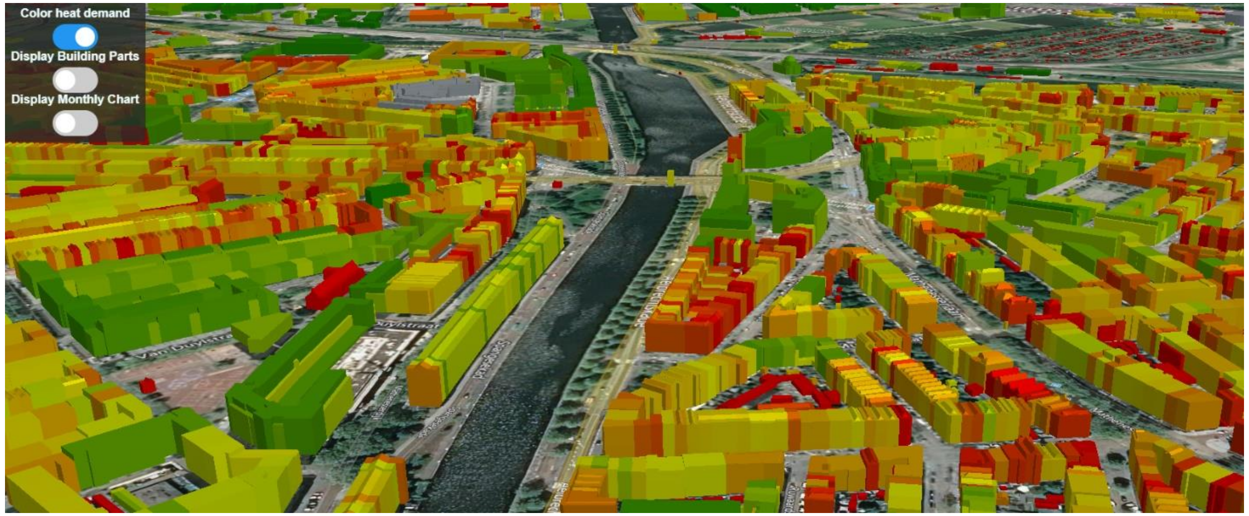


Source:
Deutscher
Wetter Dienst

Climate prediction (14 days to 10 years)
Climate project (30-100 years)

Example Rotterdam

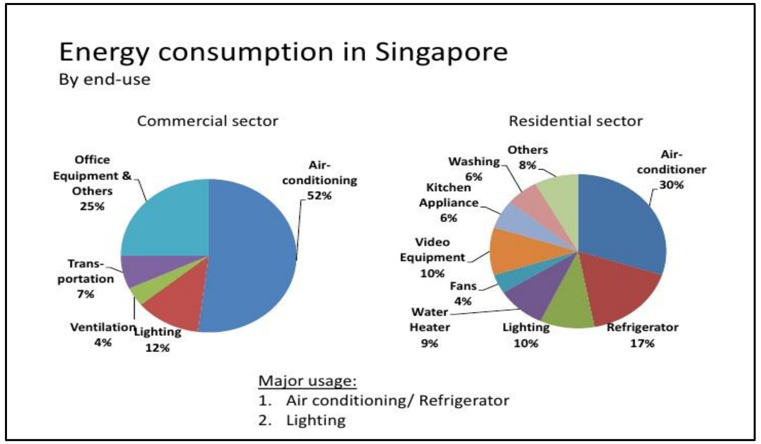


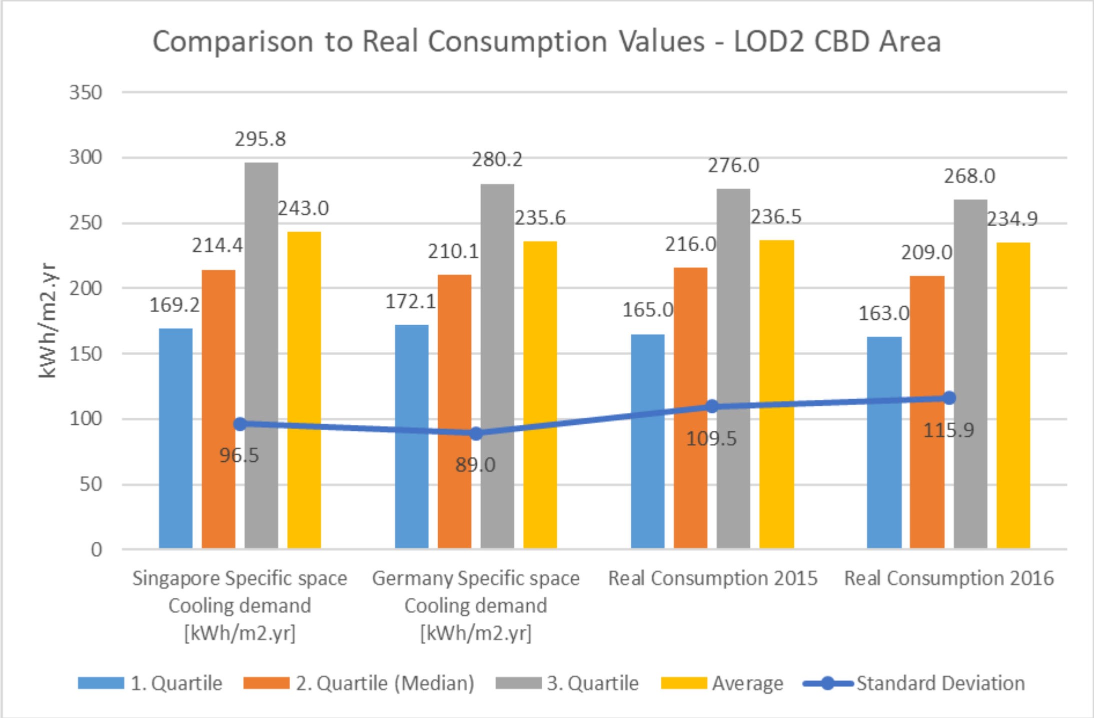


https://www.3drotterdam.nl/#/

https://transfer.hft-stuttgart.de/gitlab/simstadt/building-physics-library-nl

Cooling demand: Case Study Singapore





M. Fitzky, Simulation of Cooling Energy Demand Using the 3D Citymodel of Singapore, Master Thesis SS 2019, HFT Stuttgart & Singapore Land Authority (SLA)

Soon & Khoo: CITYGML MODELLING FOR SINGAPORE 3D NATIONAL MAPPING https://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XLII-4-W7/37/2017/isprs-archives-XLII-4-W7-37-2017.pdf

European Commission

Smart Data and Smart Cities
Conference 15.-17.9.2021

https://sdsc2021.hft-stuttgart.de/

Kontakt

Prof. Dr. Volker Coors
volker.coors@hft-stuttgart.de
http://www.coors-online.de

isprs International Journal of *Geo-Information*

an Open Access Journal by MDPI

The Applications of 3D - City Models in Urban Studies

Guest Editor
Prof. Dr. Volker Coors

ISA^2

3

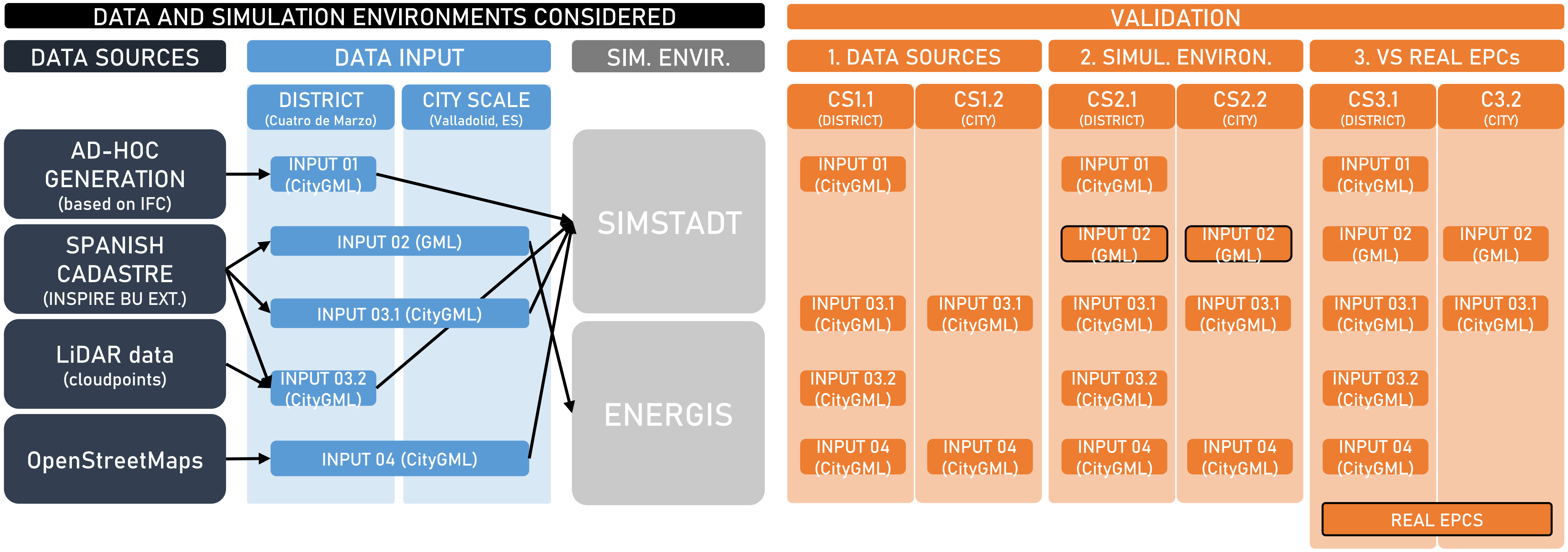
How different data sources and different simulation environments affect energy heat demand predictions

Comparative analysis of different methodologies and datasets for Energy Performance Labelling of buildings

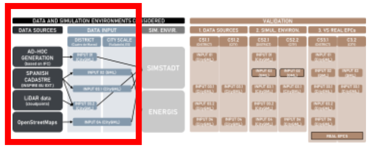
- Deployed in a **case study** in Spain
  - Two different scales: city scale (Valladolid), district scale (Cuatro de Marzo)

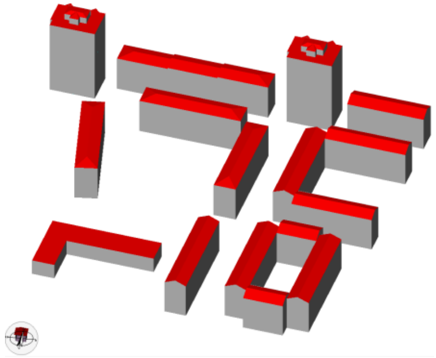
- **Objectives:**
  1. Analyse different **data generation** approaches:
     - Cadastral data, CityGMLs using different data sources (cadastral data, OSM, LiDAR)
  2. Analyse the impact of using different **simulation tools:**
     - SimStadt (developed by HTF) and ENERGIS (developed by CARTIF)
  3. Compare the results with real **Energy Performance Certificates**
     - Basic data is publicly available in the Castilla y León region

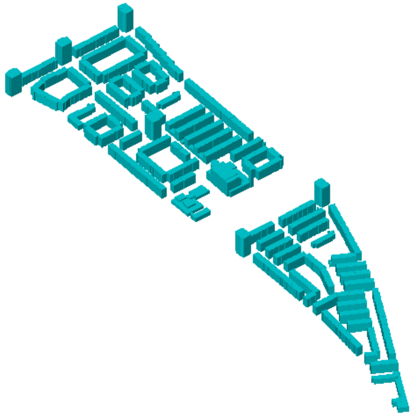
Comparative analysis of different methodologies and datasets for Energy Performance Labelling of buildings



Data sources and data input







- Only **district** level
- Generated **manually** (Skp plug-in)
- Based on **IFC (simplified)**
- Heights and dimensions based on **building plans**

INPUT 01 (CityGML)

AD-HOC GENERATION
(based on IFC)

- **District** and **city** level
- Used either **directly** (ENERGIS tool) – INPUT 02
- or **source to generate CityGML** LOD1 – INPUT 03.1

INPUT 02 (GML)

INPUT 03.1 (CityGML)

SPANISH CADASTRE
(INSPIRE BU EXT.)

- Only **district** level
- Combination of Spanish cadastre with **real heights extracted from LiDAR data**
- **Real heights** considered

INPUT 03.2 (CityGML)

LiDAR data
(cloudpoints)

- **District** and **city** level
- Not a lot of information in OSM (on heights / years of construction) >> consider 15 meters as overall height (5 floors approx.) if not enough info was available

INPUT 04 (CityGML)

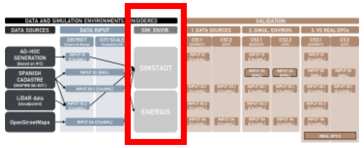
OpenStreetMaps

▲ Valladolid, Spain

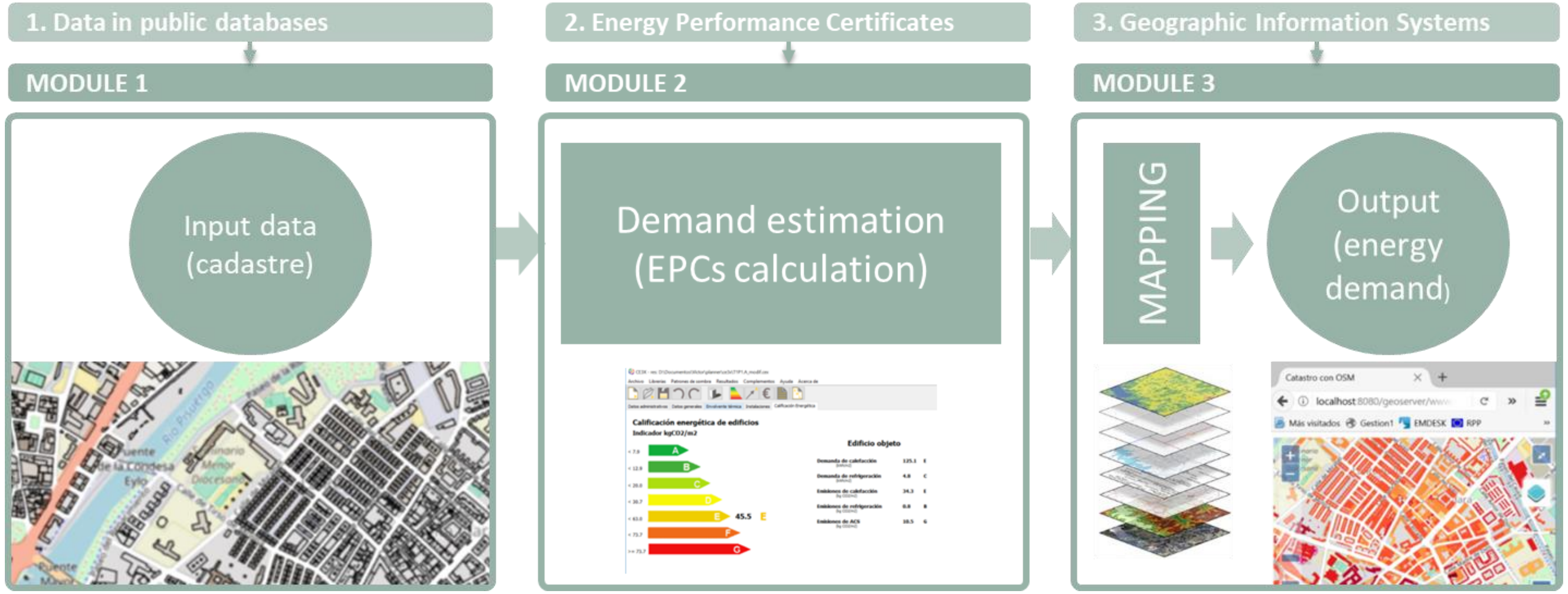
Cuatro de Marzo district (in Valladolid) ▶

▼

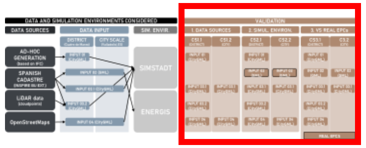
Simulation environments



- **Simstadt** (developed by HFT, already explained by Volker ☺)
- **ENERGIS** (developed by CARTIF): estimation of the calculation of energy demand at local scale, based on publicly available sources and automation of EPC tools (CE3X)



Validation process and results



1. How does the generation of datasets affect the final results? → **CS1.1** District level
2. How do the results vary in two different simulation environments that share the same objective? → **CS2.1** District level; **CS2.2** City level
3. Are the results comparable to real EPCs? → **CS3.1** District level; **CS3.2** City level

Validation process and results

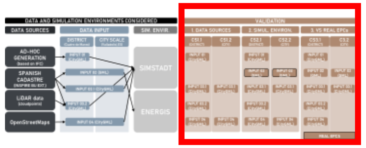


Table 34. Label comparison (CS2.2)

Case Study 2.2: Label comparison			
Label	**Input 02C**	**Input 031C**	**Input 04C**
Label A:	0.00%	0.35%	0.00%
Label B:	0.00%	0.30%	0.31%
Label C:	0.21%	2.88%	36.62%
Label D:	9.87%	20.57%	55.98%
Label E:	53.21%	40.22%	6.51%
Label F:	6.45%	7.23%	0.23%
Label G:	30.26%	28.44%	0.34%
Label error:	0.00%	0.02%	0.00%

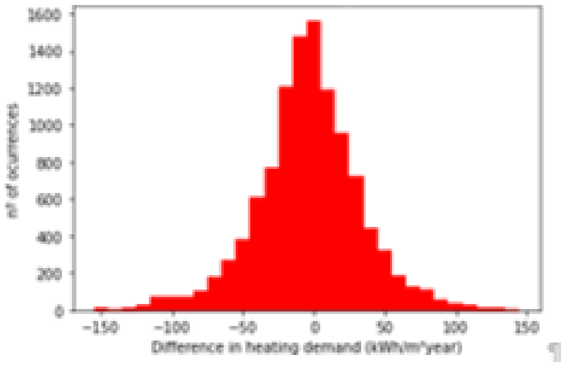
Source: own elaboration based on SimStadt and ENERGIS results

Examples of the analysis performed, considering the input in each case study (above) and then making a pair-wise comparison (right) **[check report for more info]**

Table 35. CS2.2: comparison of 03.1C and Input 02C

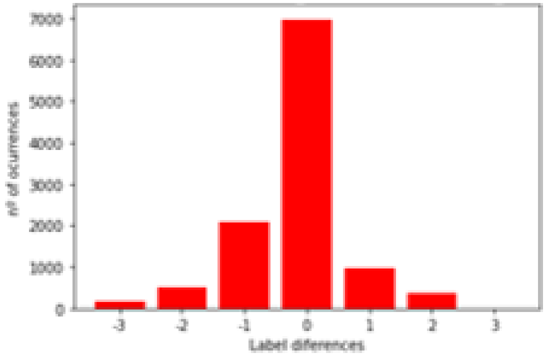
Case Study 2.2: Comparison of 03.1C and Input 02C								
Buildings in common	11,100	Label differences (in % and # buildings)						
All buildings were present in both datasets		-3	-2	-1	0	1	2	3
		1.57%	4.46%	18.84%	62.9%	8.79%	3.38%	0.06%
		174	495	2091	6981	976	375	7

Figure 80. → Heating demand differences for datasets: 03.1C and Input 02C



Source: own elaboration

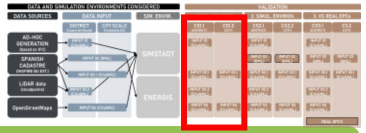
Figure 81. → Label differences for datasets: 03.1C and Input 02C



Source: own elaboration

Source: own elaboration

Validation process and results (data sources)



How does the generation of datasets affect the final results?

- **CS1.1 (District)**
  - **Degree of resemblance to reality:** Inputs 01 (ad-hoc generation) and 03.2 (LiDAR data) are able to capture differences and obtain different labels even in the very homogeneous Cuatro de Marzo district
    - More accurate heights
    - Accurate wall surfaces
  - **Energy performance is higher** when performing ad hoc modelling (Input 01) > Label D was obtained in comparison to other inputs where Label E was obtained.
  - **Homogeneity of results:** Input 03.1 (Spanish Cadastre), generated by applying 3m height / floor offers homogeneous results, since there are only two different building typologies in Cuatro de Marzo District

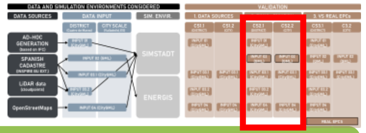
SimStadt

Table 15. Label comparison (CS1.1)

Case Study 1.1: Label comparison			
Label	Input 01D_small	Input 031D	Input 032D
Label A:	0.00%	0.00%	0.00%
Label B:	0.00%	0.00%	0.00%
Label C:	0.00%	0.00%	6.67%
Label D:	92.86%	0.00%	3.33%
Label E:	7.14%	100.00%	90.00%
Label F:	0.00%	0.00%	0.00%
Label G:	0.00%	0.00%	0.00%
Label error:	0.00%	0.00%	0.00%

Ad hoc CityGML | CityGML (cadastre) | CityGML (LiDAR)

Validation process and results (simulation env.)



How do the results vary in two different simulation environments that share the same objective?

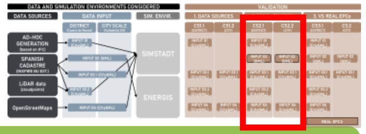
- **CS2.1 (District)**
  - **Homogeneity of results:** found in Inputs 02 (cadastre) and 04 (OSM):
    - The hypothesis applied for OSM (15 m total height / building) is very accurate for the Cuatro de Marzo district, where most of the buildings are 5 floors high, corresponding with the hypothesis applied in the case of the cadastre (3m/floor).
  - **Same labels obtained with SimStadt and ENERGIS** > differences in energy performance of around 25kWh/m2
  - **Slightly higher heating energy demand obtained with input generated with LiDAR** (more complex geometry / higher external wall surface).
  - **Some outliers detected in LiDAR generation** >> model needs to be checked

SimStadt + ENERGIS

Table 25. Label comparison (CS2.1)

Case Study 2.1: Label comparison				
Label	Input 02D	Input 031D	Input 032D	Input 04D
Label A:	0.00%	0.00%	0.00%	0.00%
Label B:	0.00%	0.00%	0.49%	0.00%
Label C:	0.00%	0.97%	2.93%	0.00%
Label D:	0.00%	2.91%	4.39%	0.00%
Label E:	100.00%	96.12%	91.22%	100.00%
Label F:	0.00%	0.00%	0.49%	0.00%
Label G:	0.00%	0.00%	0.49%	0.00%
Label error:	0.00%	0.00%	0.00%	0.00%
	Cadastre 2D	CityGML (cadastre)	CityGML (LiDAR)	CityGML (OSM)

Validation process and results (simulation env.)



How do the results vary in two different simulation environments that share the same objective?

- **CS2.2 (City) –**
  - More **difficulty to extract conclusions** due to **the variety of buildings**
  - **Label similarities** for inputs 02 and 03.1
  - **OSM** input resulted **in higher efficiencies**
    - Analysis of the overall building stock in Valladolid would be necessary to detect if the hypothesis applied is reasonable (15 m / building)
  - **Extreme differences** occur for a significant number of buildings (+50kWh/m2).

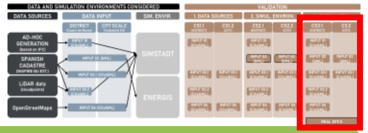
SimStadt + ENERGIS

Table 34. Label comparison (CS2.2)

Case Study 2.2: Label comparison			
Label	Input 02C	Input 031C	Input 04C
Label A:	0.00%	0.35%	0.00%
Label B:	0.00%	0.30%	0.31%
Label C:	0.21%	2.88%	36.62%
Label D:	9.87%	20.57%	55.98%
Label E:	53.21%	40.22%	6.51%
Label F:	6.45%	7.23%	0.23%
Label G:	30.26%	28.44%	0.34%
Label error:	0.00%	0.02%	0.00%
	Cadastre 2D	CityGML (cadastre)	CityGML (OSM)

European Commission

Validation process and results (vs real EPCs)



How do the results vary in two different simulation environments that share the same objective?

- **CS3.1 (District) and CS3.2 (City)**: caution when comparing EPCs

Table 39. Label comparison (CS3.1)

DISTRICT LEVEL

Case Study 3.1: Label comparison					
Label	01D_small	02D	031D	032D	Real EPCs
Label A:	0.00%	0.00%	0.00%	0.00%	0.00%
Label B:	0.00%	0.00%	0.00%	0.49%	0.00%
Label C:	0.00%	0.00%	0.97%	2.93%	0.00%
Label D:	92.86%	0.00%	2.91%	4.39%	3.85%
Label E:	7.14%	100.00%	96.12%	91.22%	64.10%
Label F:	0.00%	0.00%	0.00%	0.49%	13.46%
Label G:	0.00%	0.00%	0.00%	0.49%	18.59%
Label error:	0.00%	0.00%	0.00%	0.00%	0.00%

Adhoc CityGML | Cadastre | CityGML (cad) | CityGML (LiD.)

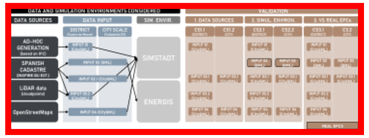
Table 46. Label comparison (CS3.2)

CITY LEVEL

Case Study 3.2: Label comparison			
Label	Input 02C	Input 031C	Real EPCs
Label A:	0.00%	0.35%	0.08%
Label B:	0.00%	0.30%	0.26%
Label C:	0.21%	2.88%	1.32%
Label D:	9.87%	20.57%	8.74%
Label E:	53.21%	40.22%	58.10%
Label F:	6.45%	7.23%	10.04%
Label G:	30.26%	28.44%	21.47%
Label error:	0.00%	0.02%	0.00%

Cadastre 2D | CityGML (cadastre)

Overall conclusions



1. **Extraction of conclusions**: Scale tackled mattered – clearer conclusions obtained when analysing an "easy" district (similar building typologies).
2. **Generation of models**: Essential to understand what assumptions and hypothesis have been applied when generating the models. Typologies and building characteristics are highly relevant.
3. **Identification of analysed elements**: when working with different data sources, it was necessary to have matching IDs to be able to compare buildings among each other. This represented a challenge especially when comparing Spanish cadastre inputs to OSM. Cadastral references were extremely useful.
4. **Level of granularity of models** is also fundamental, e.g. considering "buildings" or "building parts" can result in having a higher external wall ratio and distorting the results.
5. **Simulation environments comparison**: overall picture and results obtained with SimStadt and ENERGIS seemed quite similar, but a deeper analysis of each tool would be necessary.
6. **Comparison with EPCs**: closest to "real" data that we could get. But (1) only existing EPCs could be compared, (2) level of granularity of EPCs is varied, (3) comparison value was heating energy demand label, (4) outliers could be present.

Analysis presented as a **roadmap**, which needs to be **further analysed** and ideally compared and calibrated **with real data**. Balance effort with results obtained.

4 *Key messages, challenges and future outlook*

- Challenges of predicting heating demand: limitations to take into account the user behaviour

- Future outlook: re-use of the methodology presented to support the implementation of the energy efficiency related actions of the Recovery and Resilience National Plans

Q&A

Thank you

European Commission

Stay tuned

http:// Join the *ELISE* community in JoinUp JOIN THIS COLLECTION

@eu_location

eu-location@ec.europa.eu

ELISE channel SUBSCRIBE