10th Int. CityGML Energy ADE workshop

Knowledge exchange event

ENERGY AND THE DIGITAL BUILT ENVIRONMENT

Challenges and potentials of semantic 3D city models as hubs of harmonised information for energy applications

TU Delft, 6 December 2018

10th Int. CityGML Energy ADE workshop

A BRIEF OVERVIEW OF THE CITYGML ENERGY ADE

Giorgio Agugiaro

TU Delft, 6 December 2018

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Outline

- *Digital* cities & semantic 3D city models
  - Do we need standards at all?
- What about energy? The Energy ADE
  - Overview
  - Some experiences
- A mention to the Utility Network ADE
- Conclusions

City modelling

3D city models

Energy ADE

Utility Network ADE (glimpse)

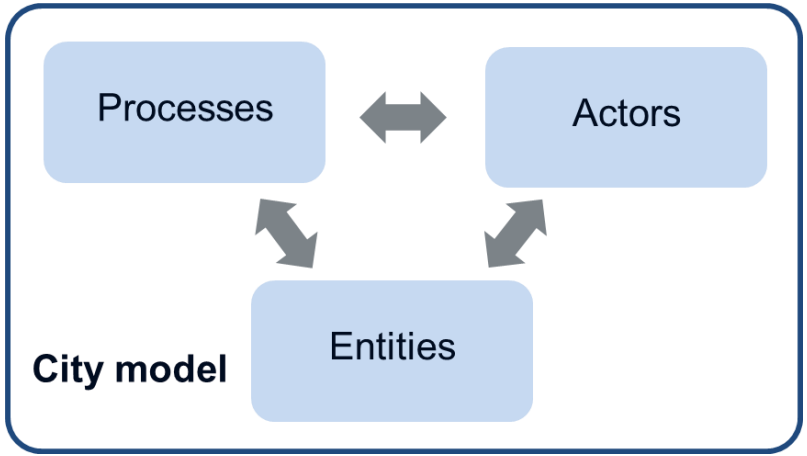
Conclusions

Real city

http://media.gettyimages.com/vectors/city-drawing-vector-id523441181?s=170667a

represented by

Digital twin



City modelling

3D city models

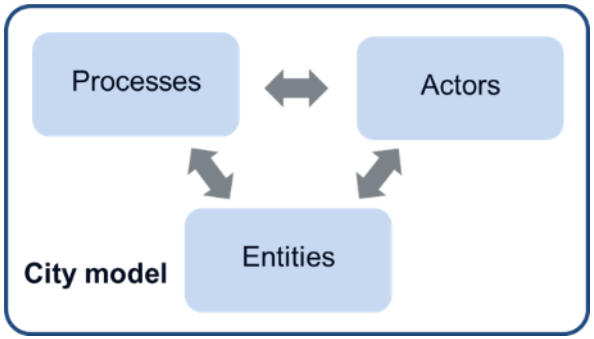
Energy ADE

Utility Network ADE (glimpse)

Conclusions

- Today: Separate modelling, generally by specific sectors, e.g.
  - Energy
    - Community
    - Models
    - Indicators
    - Planning
  - Mobility
    - Community
    - Models
    - Indicators
    - Planning
  - Ecology
    - Community
    - Models
    - Indicators
    - Planning
  - Economy
    - Community
    - Models
    - Indicators
    - Planning
  - Surveying
    - Community
    - Models
    - Indicators
    - Planning

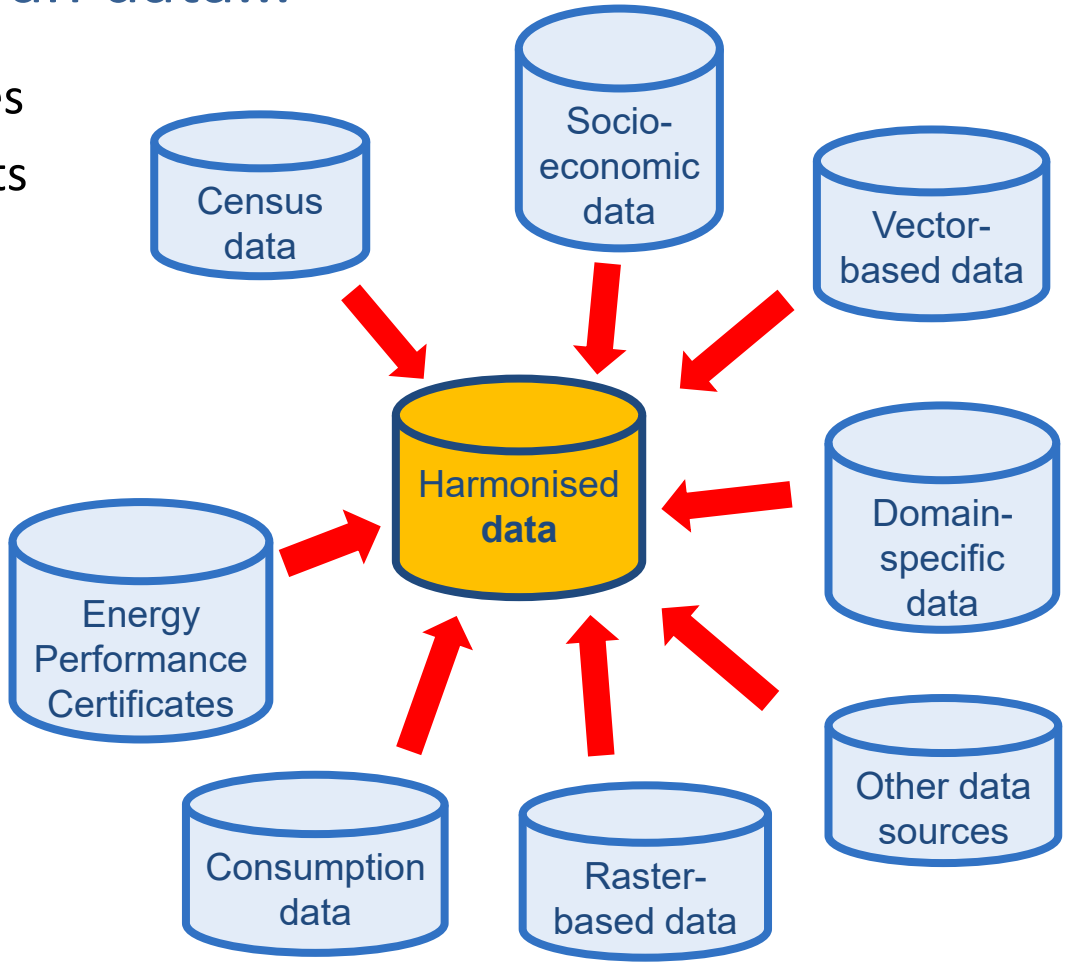
Which digital twin?



…“My” digital twin, of course!

Dealing with urban data...

- Different data sources
- Different data formats
- Different semantics
- Different scales
- Different accuracies
- …



3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

Dealing with urban data...

3D city models

Energy ADE

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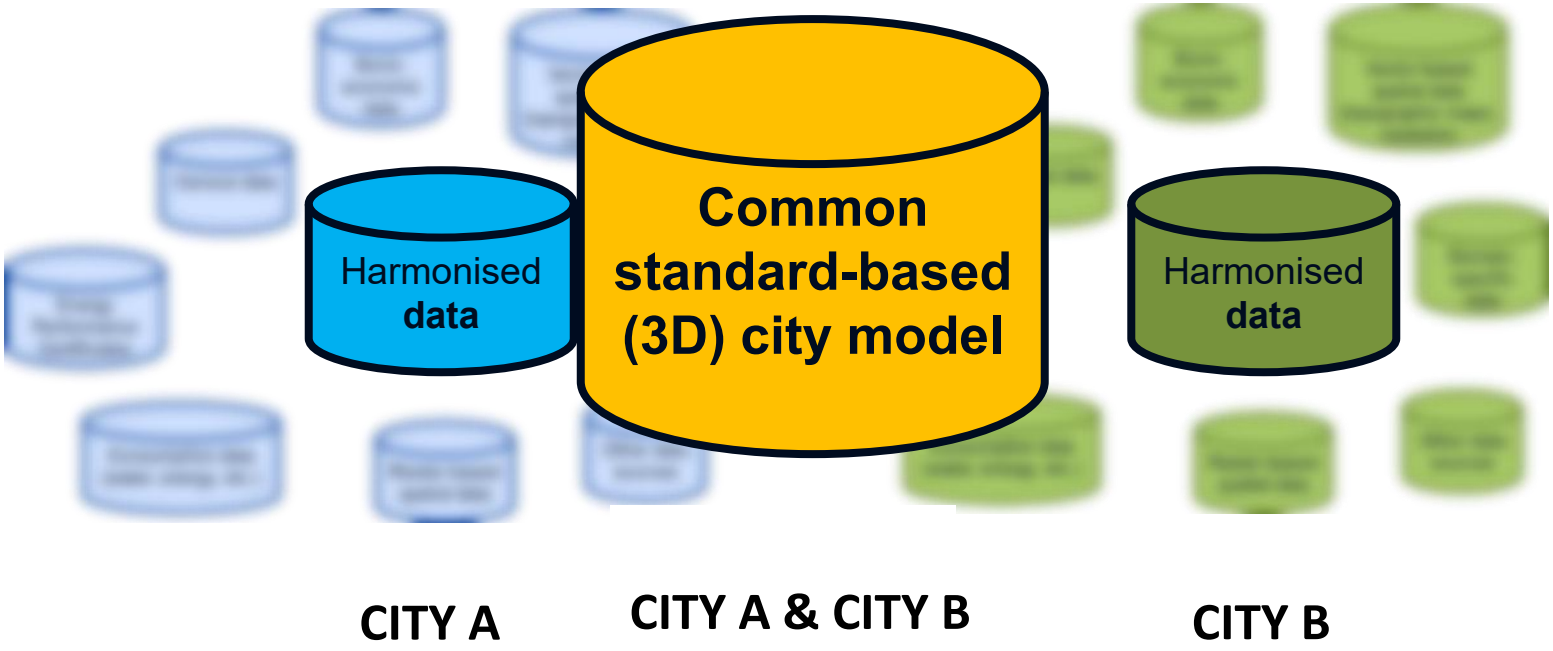
Conclusions



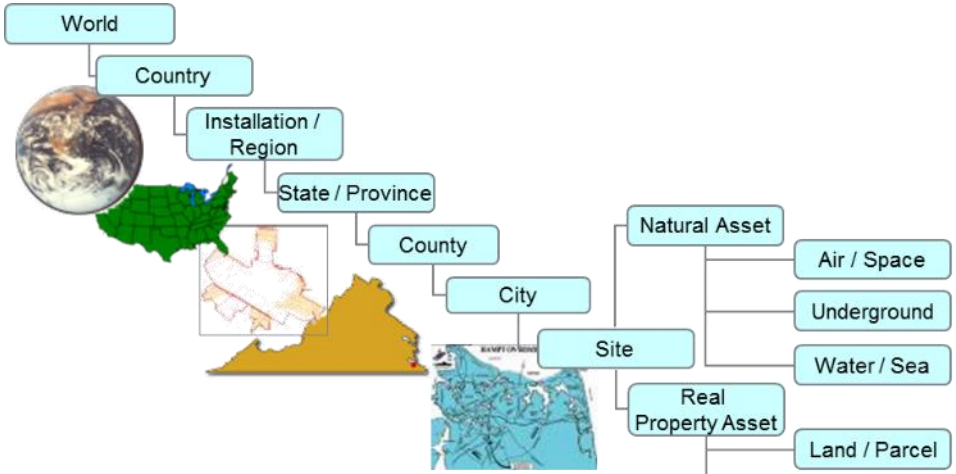
What about standards?

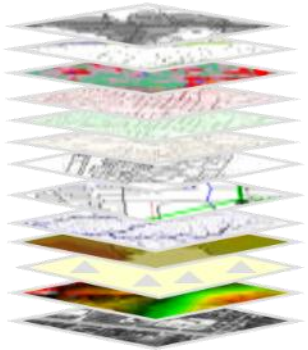
3D city models

Energy ADE

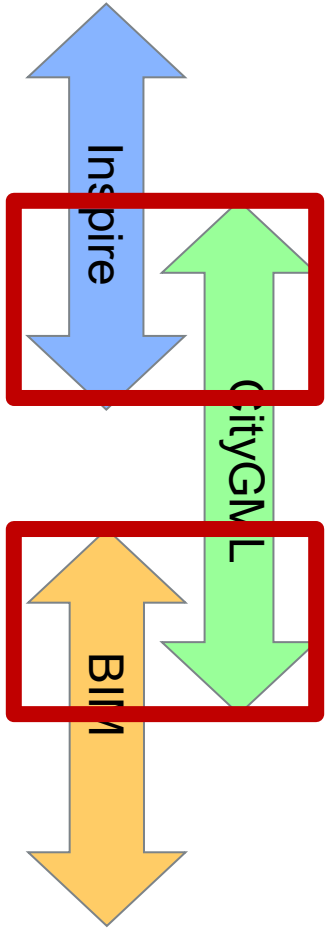
Utility Network ADE (glimpse)

Conclusions





Territorial scales



CityGML: City Geography Markup Language

3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

- **Information model** for 3D city models at urban and regional scale (**OGC standard**)
- Comprises **thematic areas** for buildings, terrain, traffic, tunnel, bridges, vegetation, etc.
- Includes multi **level-of-detail 3D geometry**, topology, semantics and appearance
- **Extendible** to other application domains

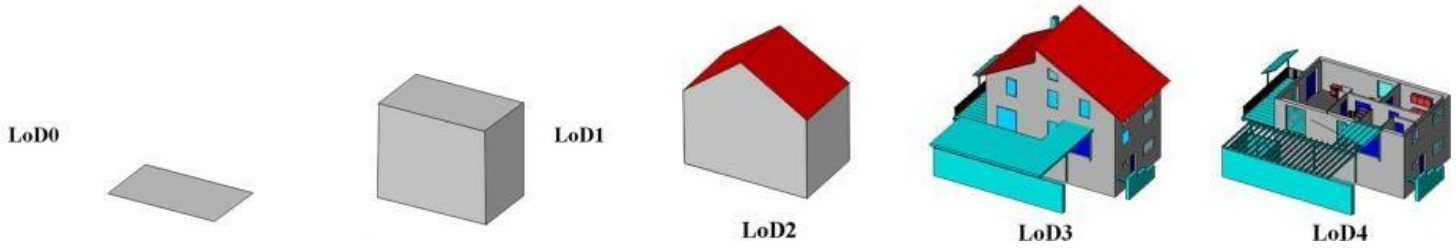


Image source: CityGML 2.0 encoding standard specifications

TU Delft 3Dgeoinfo

3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

Image source: Kolbe et al., 2009

TU Delft 3Dgeoinfo

3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

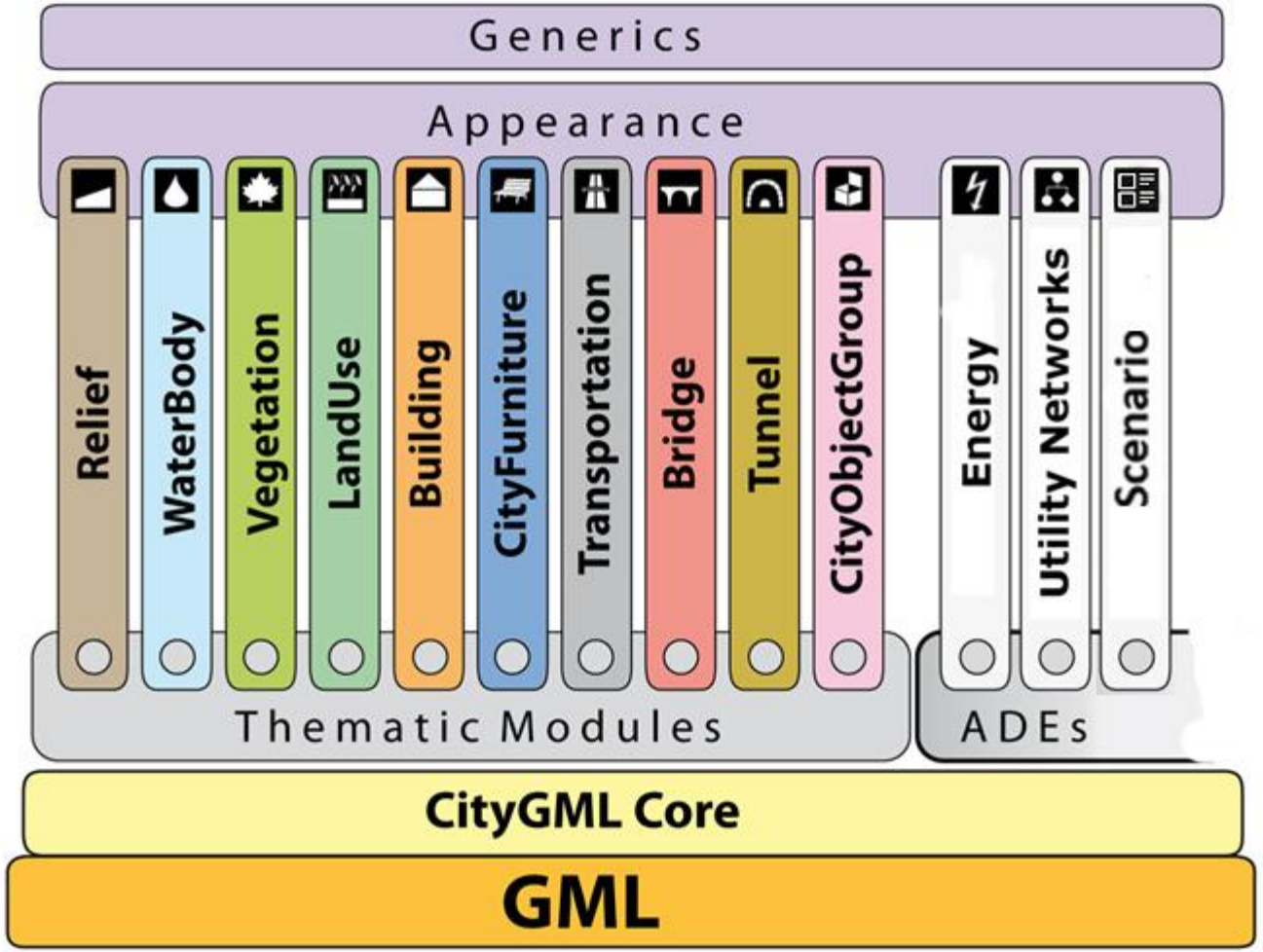


Image source: virtualcitySYSTEMS

Semantic 3D City models as information hub

3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

Semantic 3D city models help **reducing complexity** and facilitating cooperation and **exchange of information** among city departments, companies, cities and citizens, etc.

What about standards for energy?

3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

- BIM:
  - Availability of some standards (*gbXML, IFC*)
  - In general, the focus is the *new* building/object

buildingSMART

- INSPIRE:
  - *Data Specification on Buildings*: Lack or too few attributes/classes usable for energy simulations

INSPIRE Infrastructure for Spatial Information in Europe

- CityGML
  - A bit better than INSPIRE, but still not enough
  - But: **extensibility through *ADEs*** (Application Domain Extensions)

CityGML

What about standards for energy?

3D city models

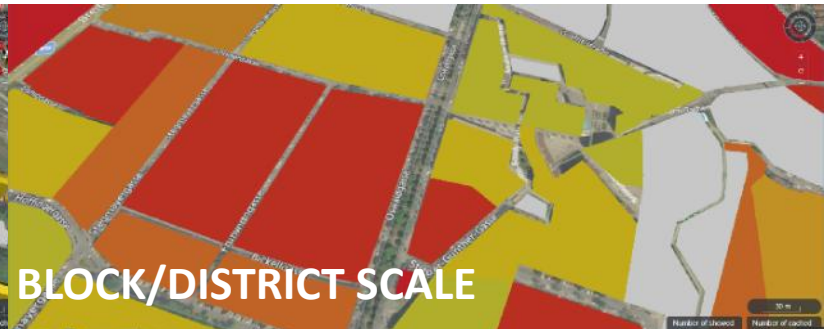
Energy ADE

Utility Network ADE (glimpse)

Conclusions

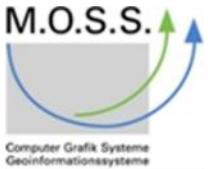
CityGML Energy ADE

- Eases data interoperability for Urban Energy Modelling
  - Among heterogeneous software tools
  - Among heterogeneous stakeholders
- Defines (and stores) energy-related data in a standard, open, urban data model
  - Allow for multi-scale energy modelling (different time & spatial resolutions)
  - From “single” building up to whole district/city
  - Both top-down and (preferably) bottom-up approaches
- Fosters and stems from multidisciplinary cooperation among CityGML users, data producers, software vendors, …, and scientists



Energy ADE

- International consortium started in 2014
  - Ca. 20 institutions, 11+ countries (as of 2018)



3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

Energy ADE

3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

- Open, consensus-based development
  - GitHub: https://github.com/cstb/citygml-energy
  - Wiki: http://en.wiki.energy.sig3d.org

- Open, on-going series of workshops (twice per year)
  - 1st: May 2014 in Stuttgart @ HFT (v. 0.4)
  - 2nd: October 2014 in Karlsruhe @ EIFER
  - …
  - …
  - 9th: June 2018 in Aachen @ RWTH (**version 1.0**)
  - **10th: December 2019 in Delft @ TU Delft**

Energy ADE

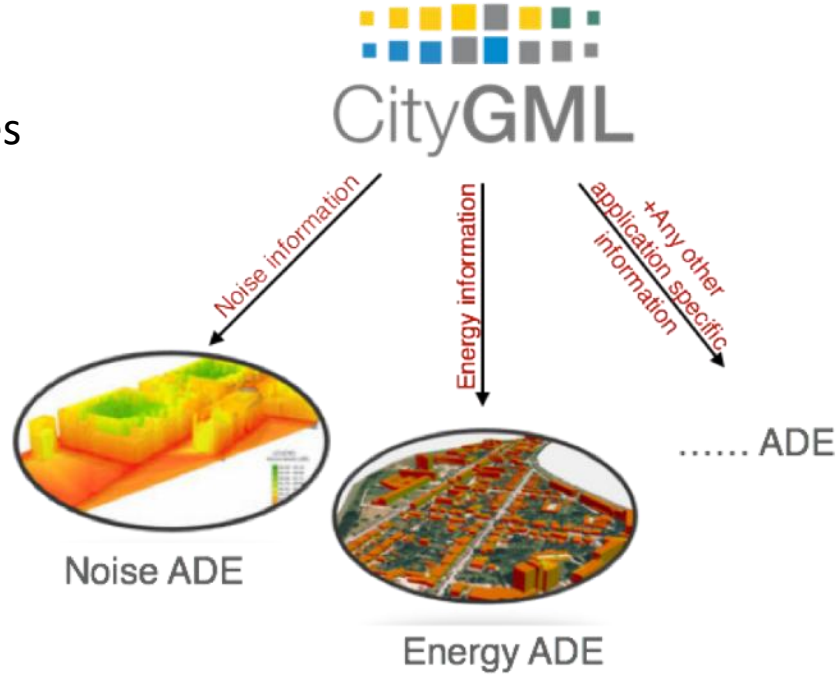
3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

- Extension to the CityGML 2.0 standard
- Exploits the CityGML Application Domain Extension (ADE) mechanism to
  - Extends existing classes
  - Adds new classes and attributes
- Modelled in UML
- Available as XSD schema
- Modular structure



https://www.citygml.org/ade/

Energy ADE

3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

Modular structure:

- Core module
  - Shared classes, enumerations and codelists
- Building Physics module
  - Thermal zones, thermal boundaries
- Material and Construction module
- Occupant's Behaviour module
  - Building usage, occupants, appliances, …
- Energy Systems module
- Supporting Classes
  - Weather data, time series, etc.

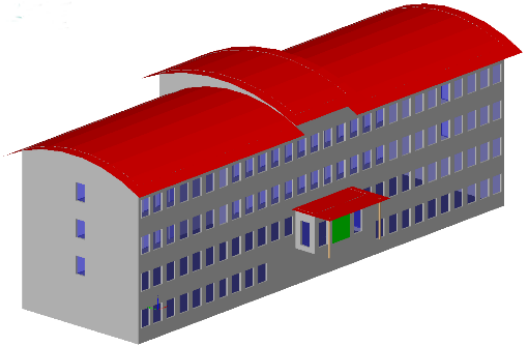
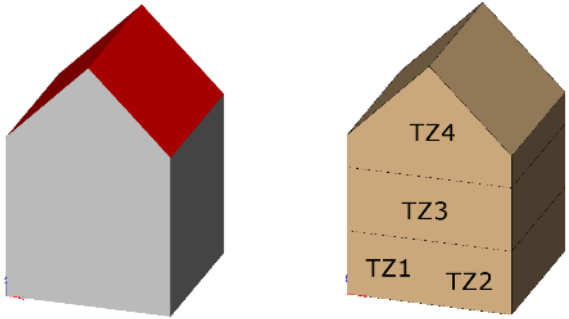


Image source: Courtesy of KIT



Partitioning of a building into thermal zones (example)

Agugiaro, G., Benner, J., Cipriano, P., Nouvel, R., 2018
The Energy Application Domain Extension for CityGML: Enhancing interoperability for urban energy simulations.
Open Geospatial Data, Software and Standards 2018 3:2

CityGML + Energy ADE

3D city models

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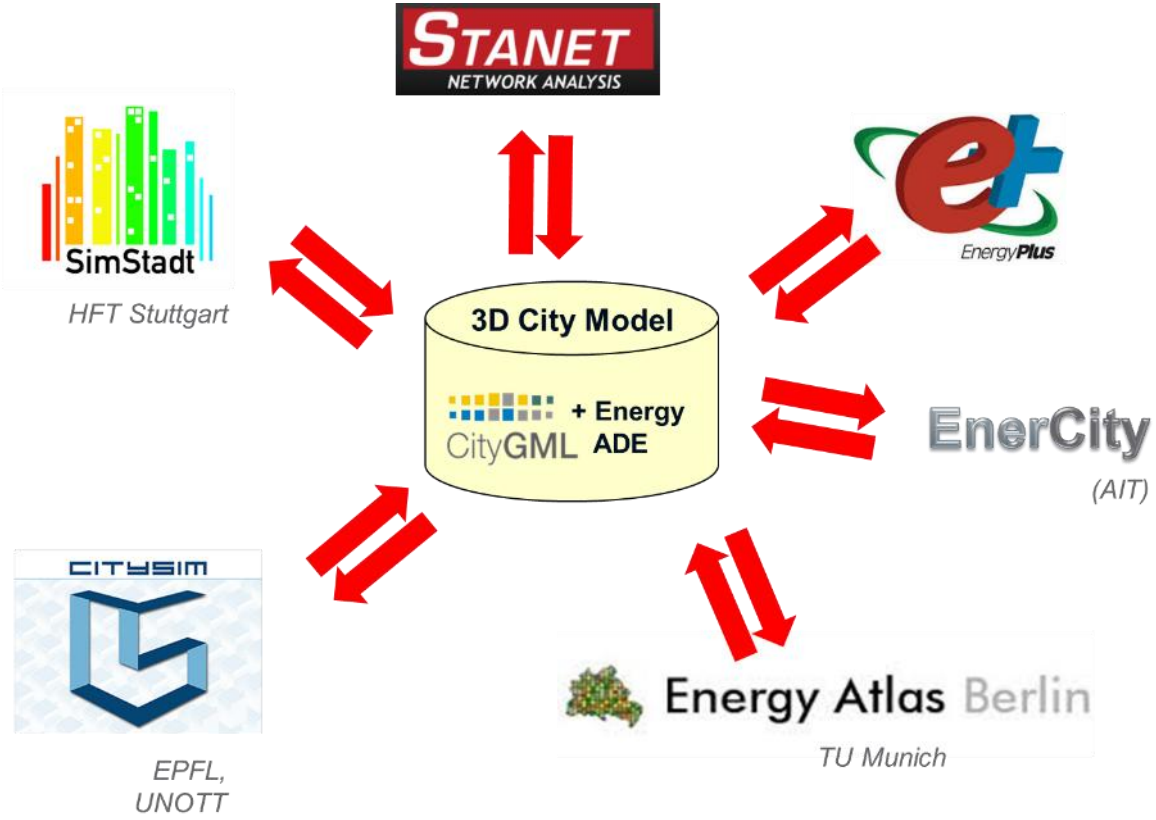
Utility Network ADE (glimpse)

Conclusions



Energy ADE: some experiences

Vienna: Estimate energy demand based on energy balance method (norm-based, yearly and monthly values) + scenarios

3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

Energy ADE: some experiences

3D city models

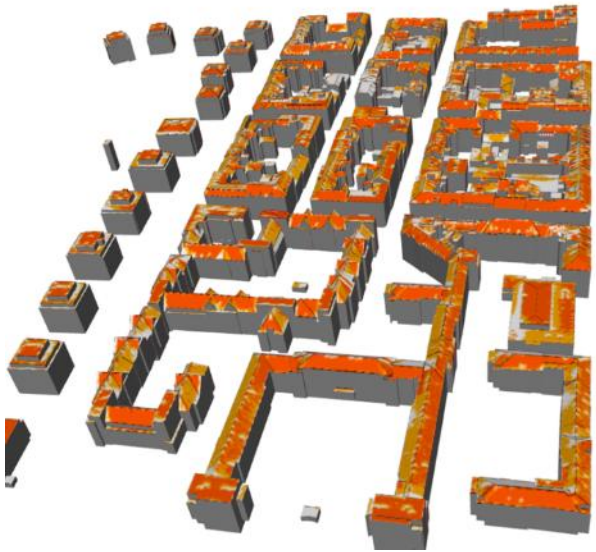
Energy ADE

Utility Network ADE (glimpse)

Conclusions

Vienna: Evaluate how to harmonise and integrate existing datasets

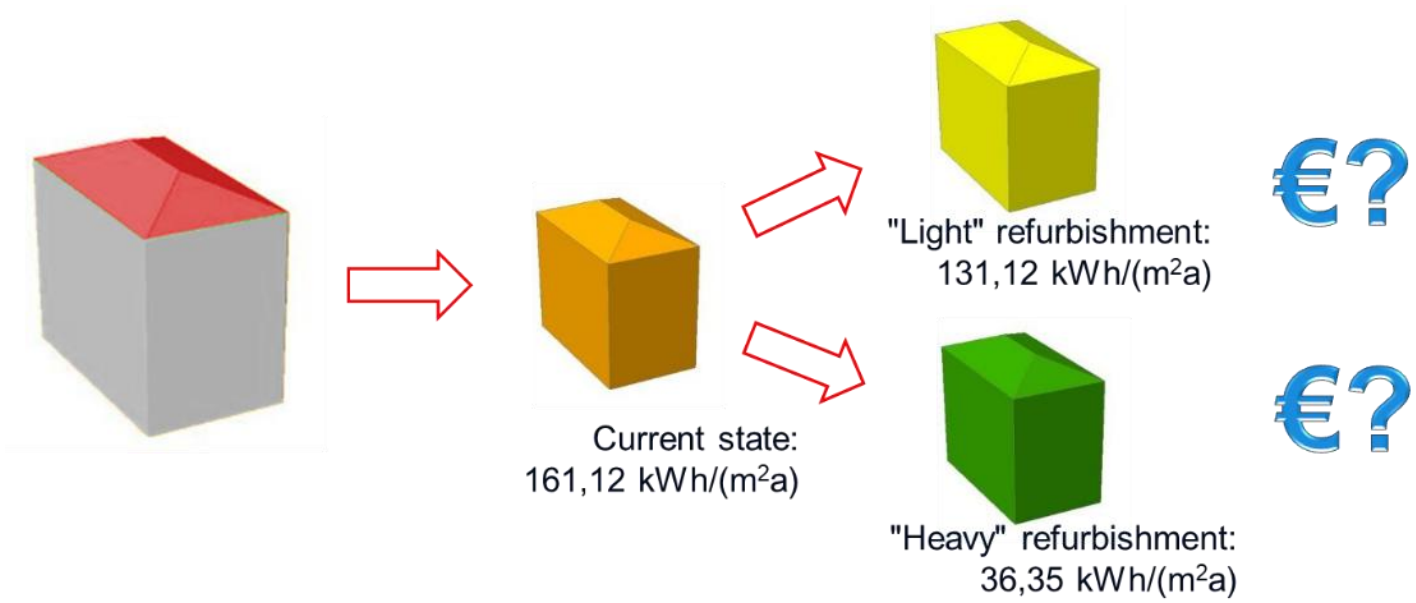
- Detailed info of buildings (usage, net floor area, number of floors, etc.)
- Residents per building
- Installed thermal and PV systems
- Solar cadastre
- Vienna heating cadastre
- Refurbishments of public housing buildings
- Energy performance certificates (WIP)



Agugiaro, G., 2016
Enabling "energy-awareness" in the semantic 3D city model of Vienna.
Remote Sens. Spatial Inf. Sci., IV-4/W1, pp. 81-88, doi:10.5194/isprs-annals-IV-4-W1-81-201

Energy ADE: some experiences

- Definition of refurbishment scenarios
- Comparison with regards to national and European legislation
- Cost-benefit analysis up to block/district scale



3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

Energy ADE: some tools

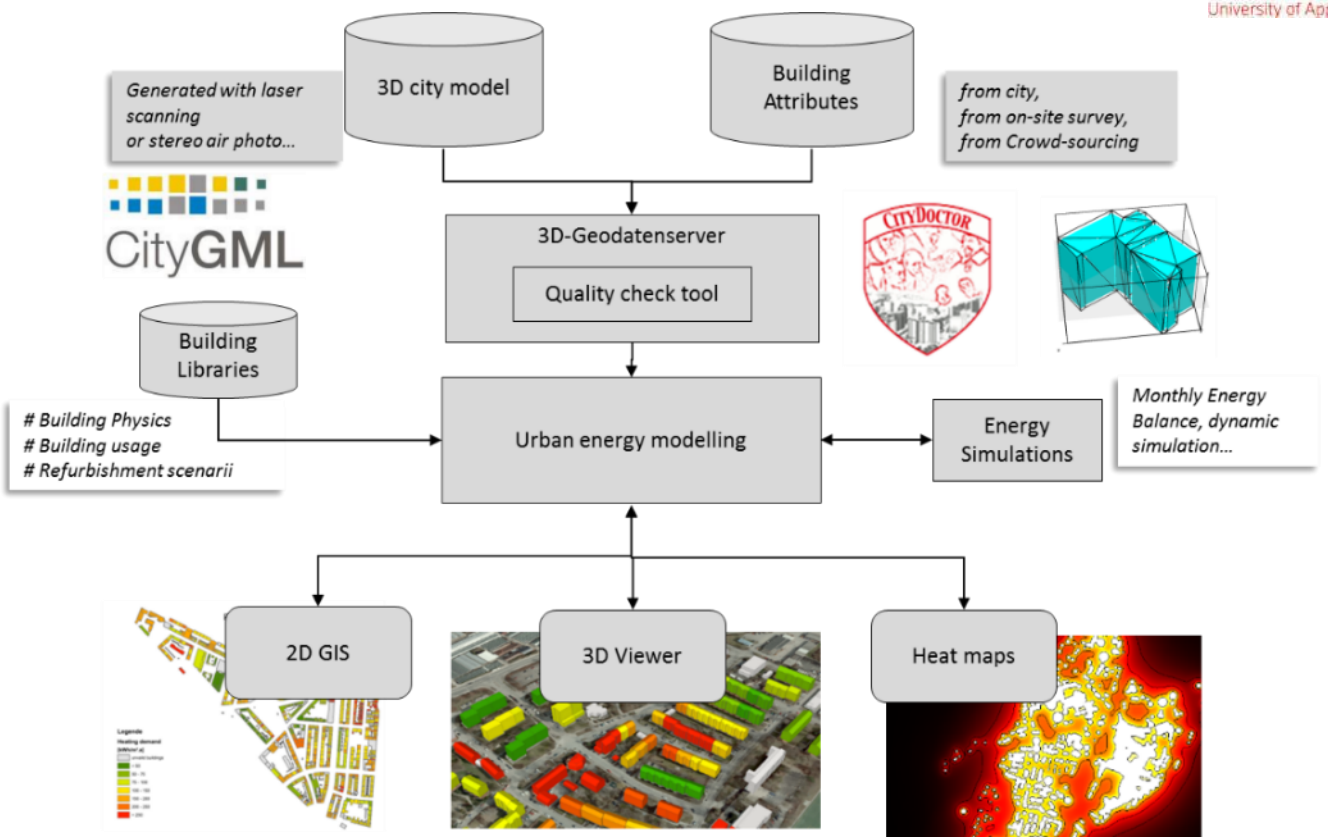
3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

Simstadt platform



Energy ADE: some tools

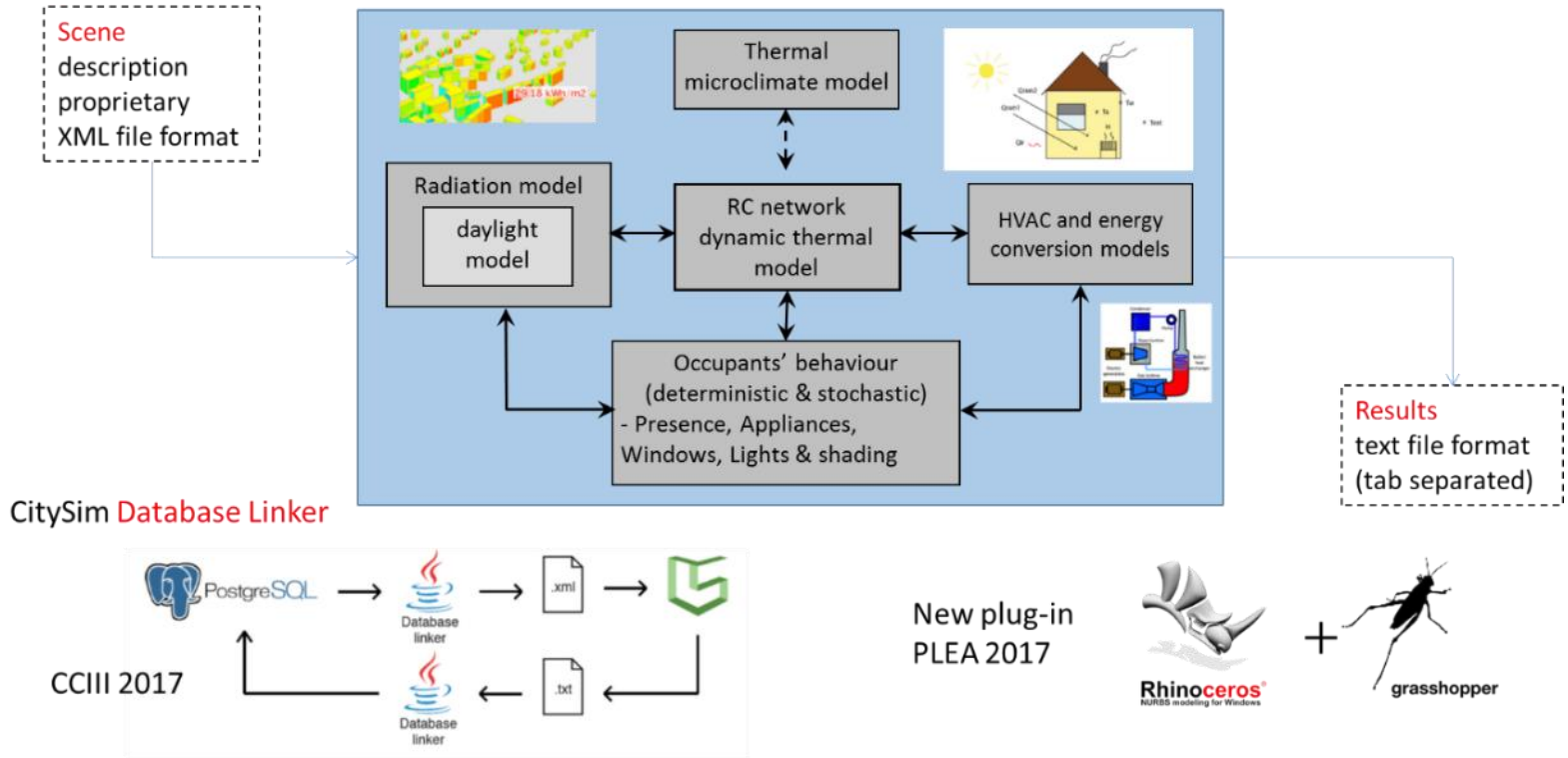
3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

CitySim Solver + CitySim Pro



Energy ADE: some tools

3D city models

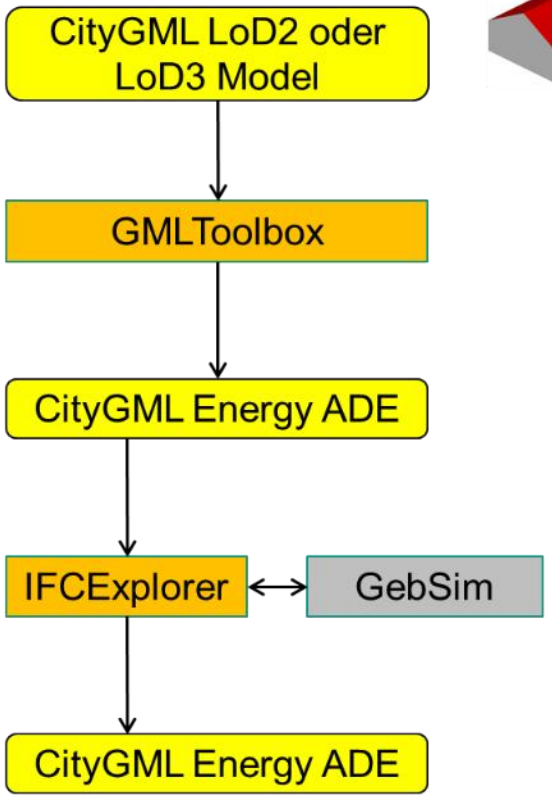
Energy ADE

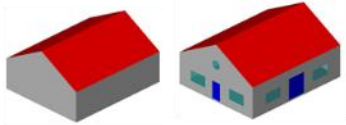
Utility Network ADE (glimpse)

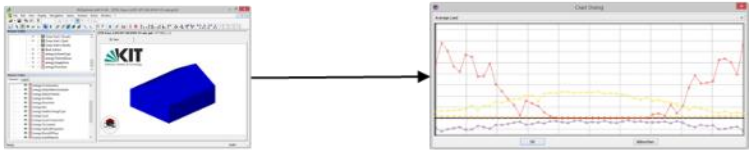
Conclusions

KIT workflow and toolset

Karlsruher Institut für Technologie







Energy ADE: some tools

3D city models

Energy ADE

Utility Network ADE (glimpse)

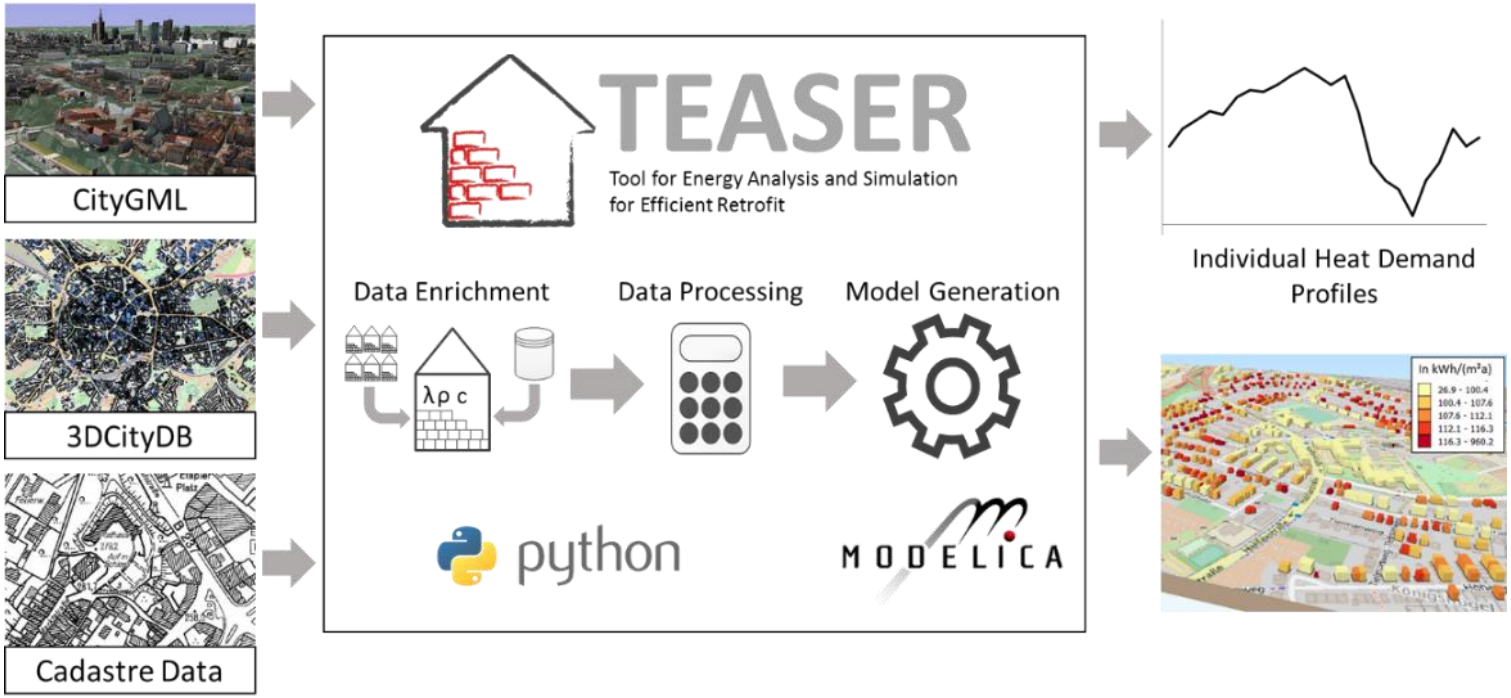
Conclusions

TEASER

EBC | Institute for Energy Efficient Buildings and Indoor Climate

E.ON Energy Research Center

RWTH AACHEN UNIVERSITY



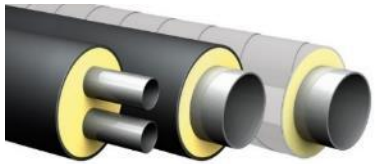
3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

City-wide energy “chain”



Production

- Fossils
- Renewables
- Industrial processes
- Nuclear

Distribution

- Electrical
- Gas
- District Heating & cooling
- Waste water
- Steam
- Oil

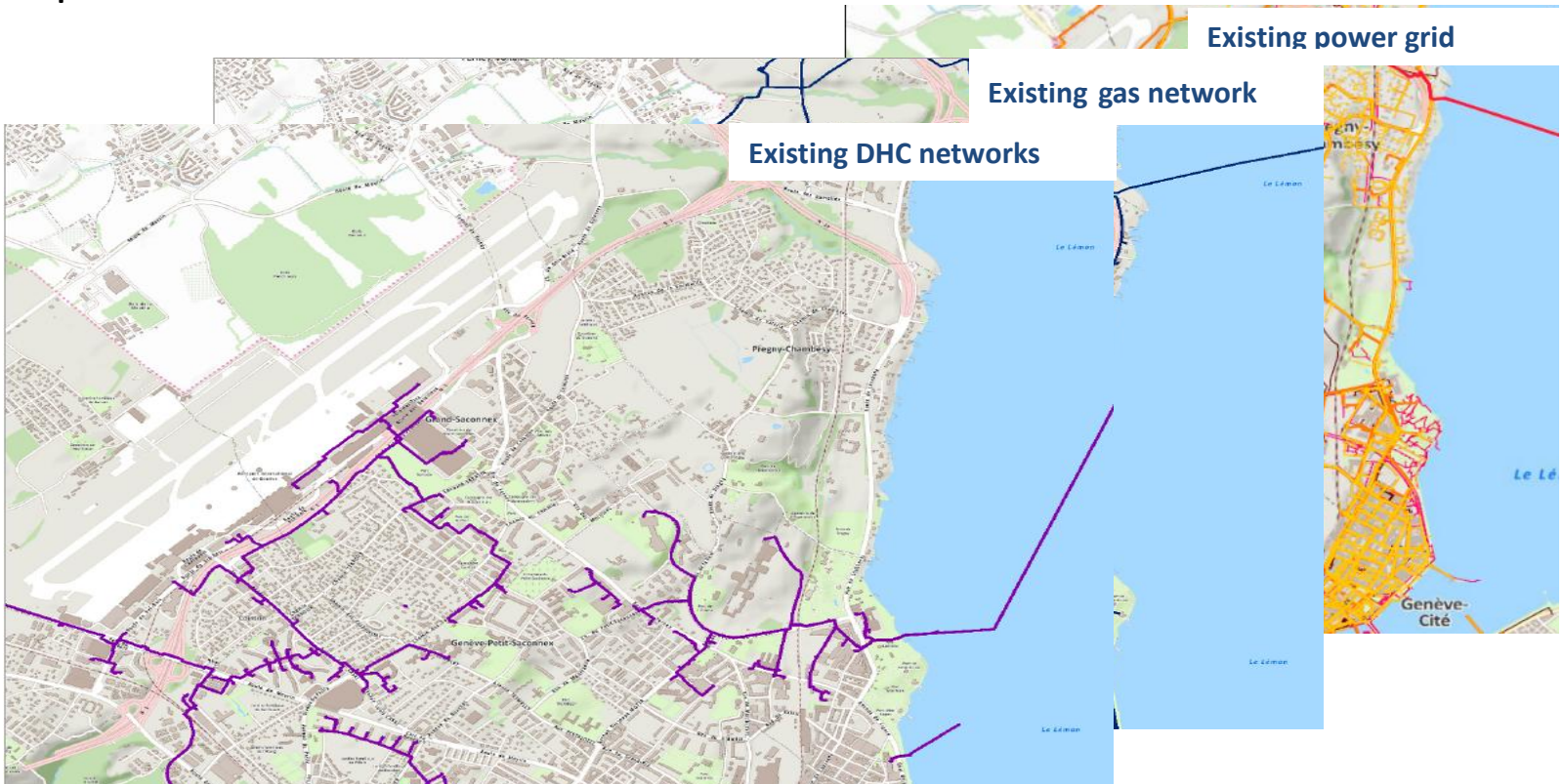
Consumption

- Housing
- Industrial
- Tertiary

Slide courtesy of A. Nichersu, EIFER

What about networks?

Energy networks in cities are still planned, built, operated and optimized in silo-like fashion



3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

Utility Network ADE

3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

- Extends CityGML and defines standardised entities needed for utility networks (district heating, gas, power grid, telecommunications)

- Goal: tackle interoperability issues among heterogeneous network data models

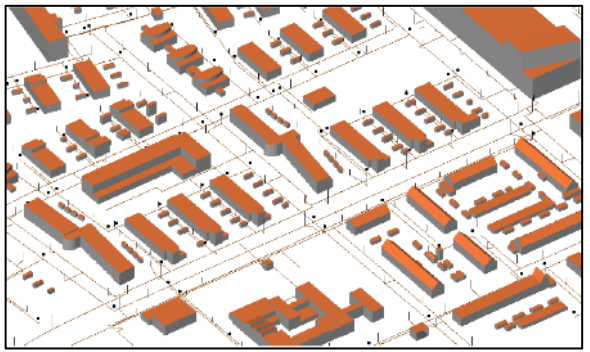
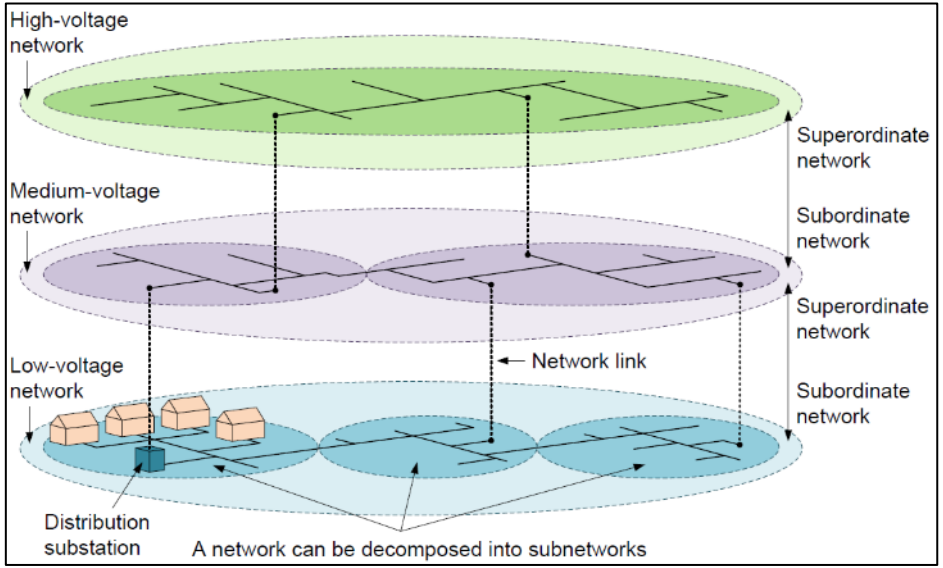


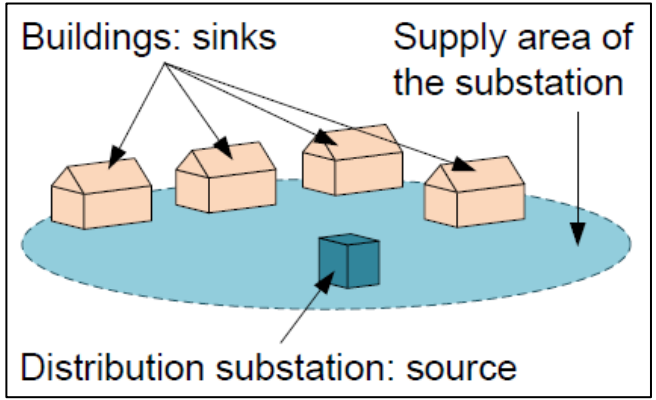
Image source: Den Duijn (2018)

- Still in development, but already freely available
  - Apache 2.0 license
  - GitHub: https://github.com/TatjanaKutzner/CityGML-UtilityNetwork-ADE

Utility Network ADE

- Allows for integrated representation of networks:
  - Hierarchical structure of networks
  - Definition of different supply areas (also with missing topology)





Images source: Kutzner et al., 2016

Utility Network ADE

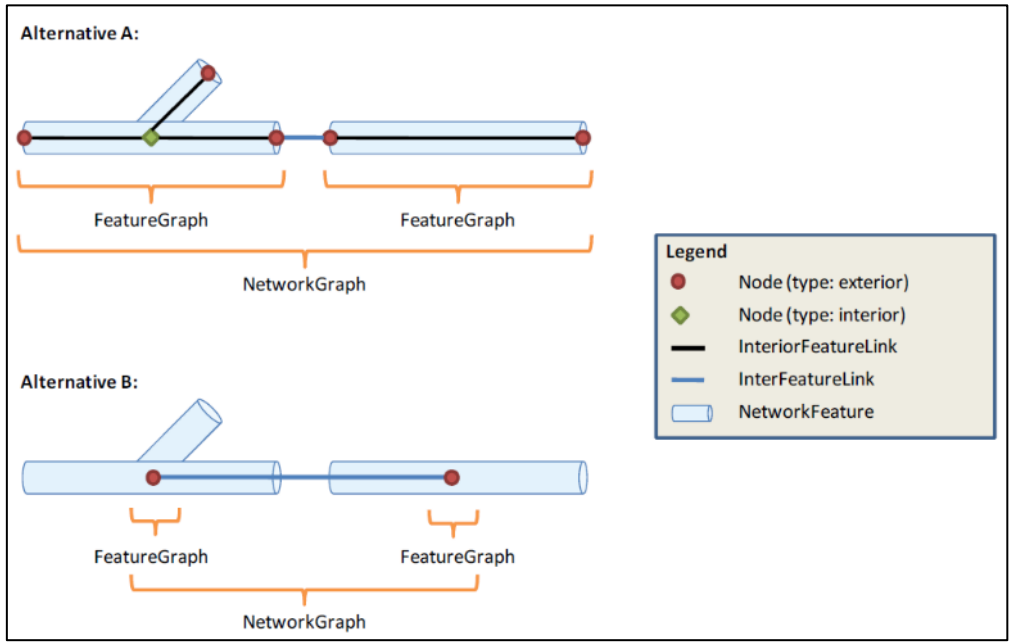
3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

- Allows for integrated representation of networks:
  - Hierarchical structure of networks
  - Definition of different supply areas (also with missing topology)
  - Topological (graph-based) AND topographical representation



Images source: Becker et al. 2012

Utility Network ADE

3D city models

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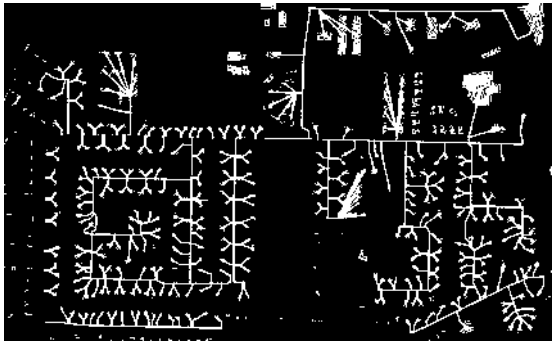
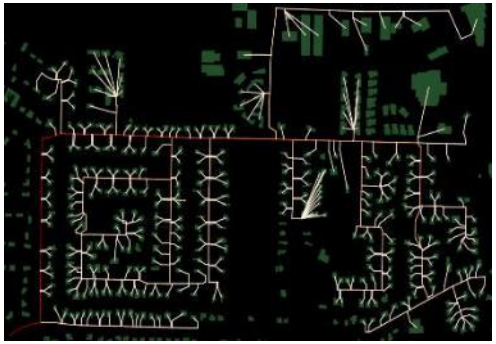
Utility Network ADE (glimpse)

Conclusions

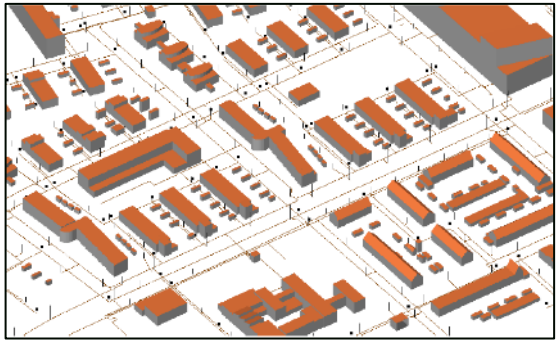
Examples

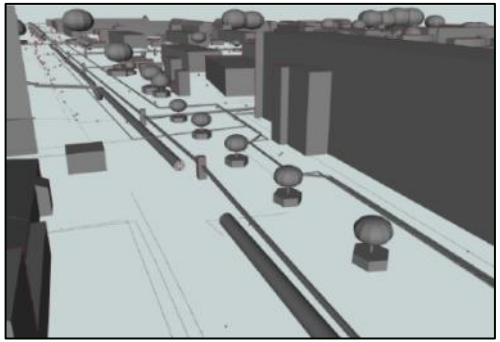




I. Boates (2018): Electricity and freshwater networks

Boates, I., Agugiaro, G., Nichersu, A., 2018,
Network modelling and semantic 3D city models: testing the maturity of the Utility Network ADE for CityGML with a water network test case.
ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., IV-4, pp. 13-20





X. den Duijn (2018): Electricity and sewer networks

Den Duijn, X., Agugiaro, G., Zlatanova, S., 2018
Modelling below- and above-ground utility network features with the CityGML Utility Network ADE: experiences from Rotterdam.
ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., IV-4/W7, pp. 43-50

Conclusions

3D city models

Energy ADE

Utility Network ADE (glimpse)

Conclusions

- Standard-based semantic **3D city models** represent a powerful and useful **information hub** for city-wide applications
  - Tools can be developed to help answer questions for urban planning at city scale, but with a granularity which reaches down to the single building
  - Data integration is always time-consuming, so: **Do once, use many**!

- **Energy ADE** greatly improves the modelling capabilities of CityGML wrt. energy-related topics
  - So far, only existing open data model for urban energy modelling "*between BIM and INSPIRE scales*"
  - Open, has reached version 1.0
  - Number of tools is growing
  - Feel free to join the consortium!

Image courtesy of A. Nichersu, EIFER

Thank you for your attention!

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