

Development of a CityGML infrastructure for the implementation of an energy demand method with different data sources



Introduction

Energy related simulations require providing decision support on research questions such as improving the efficiency of energy use or forecasts of energy demand in the future. Energy system models capable of describing future energy systems require a spatial representation in order to reflect the local context and the boundary conditions (Bahu, 2013). CityGML is an open XML data model for the representation and exchange of virtual 3D City models (Kolbe, 2009). It complements existing standards and has not been frequently used in energy related research. CityGML can be seen as a new standard, as it aims for reaching a common definition of sharing basic entities, attributes and relations of 3D city models (OGC, 2012). For optimal usage new methodologies and infrastructure have to be developed which are presented below.

Infrastructure developments

Set up of database environment for energy simulation model:

- PostgreSQL (DBMS) + PostGIS (DBMS extension)
- 3D City DB (Application)
- GIS interface (connecting spatial information with spatial objects)
- aEneas (developed python tool)

aEneas (stands for Energy Assessment) is the developed expert tool which connects to the DBMS and runs all calculations needed for the energy assessment.

Workflow

The study case data first gets converted in to a CityGML version that is readable by the 3DCityDB Importer/Exporter tool. Different software is used to perform the conversion. After this initial step multiple spatial data sources get connected over GIS system to the data of the study cases. When all information is stored into the DBMS, the in python developed tool Eneas is run to calculate an energy assessment. Results are then saved back into the DBMS.

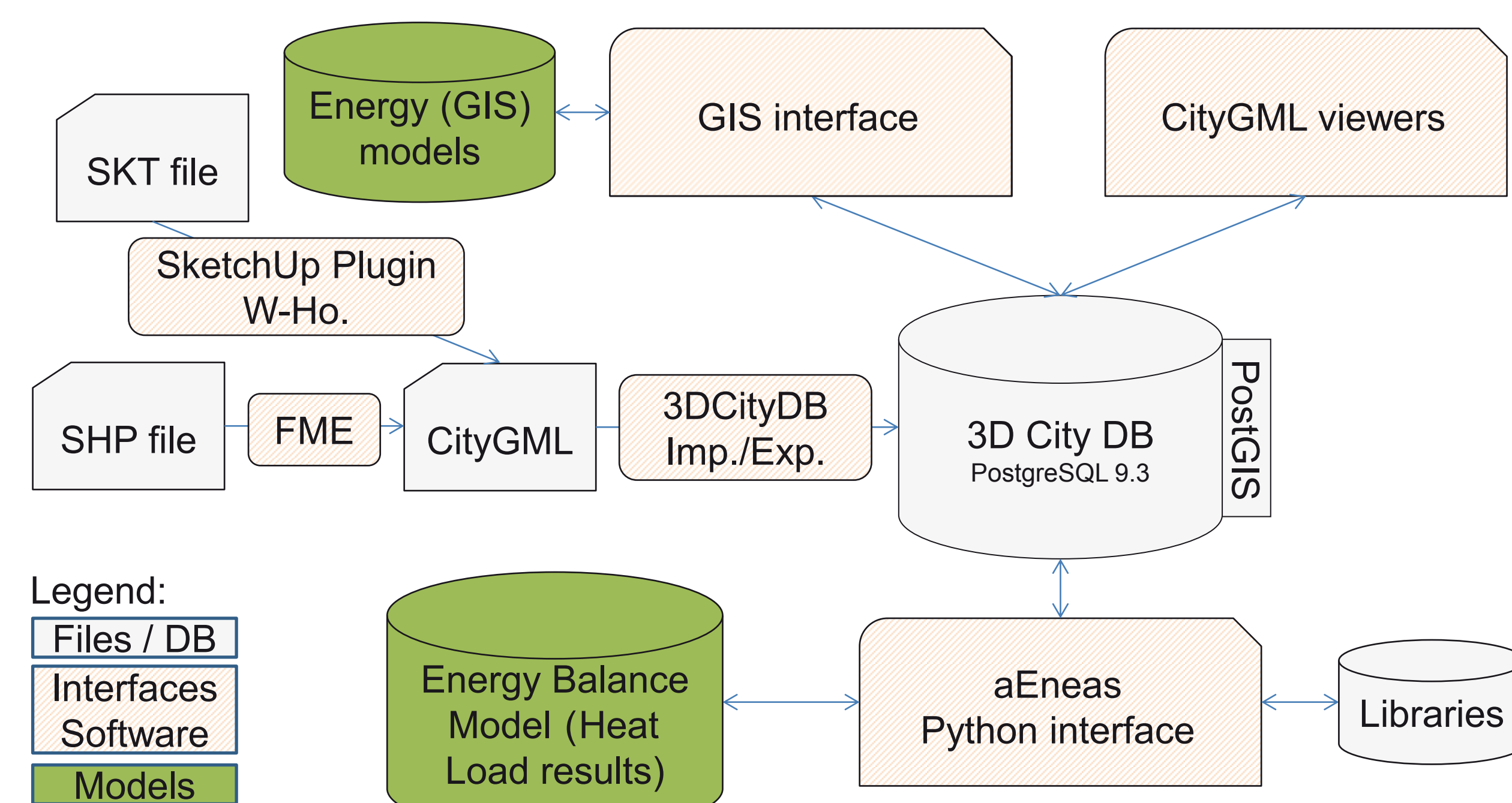


Fig.1: Specifications and workflow of ORDBMS (object-relational database management system). It stores geometry objects, geo-localized data and can perform spatial calculations (queries) on the data of a 3D city model.

Spatial Functions Development

In Python functions were developed for calculating surface area and volume of LoD2 building models. This had to done because PostGIS does not provide 3D functions as required.

Area (Fig. 3) is calculated with linear algebra over the perpendicular vector using the cross product (Fig. 2). Volume is calculated by splitting up the object into two parts, the body (footprint area * height) and the roof. The roof afterwards is split up into convex parts (Fig. 4) and calculated with the help of an open source library, called pyhull. The results were checked and proved to be correct by using linear algebra, calculating the volume of the convex objects by splitting them up into pyramids.

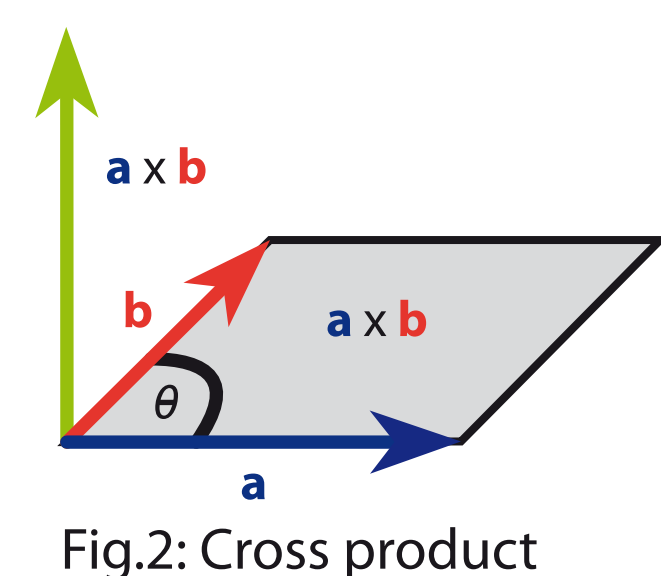


Fig.2: Cross product

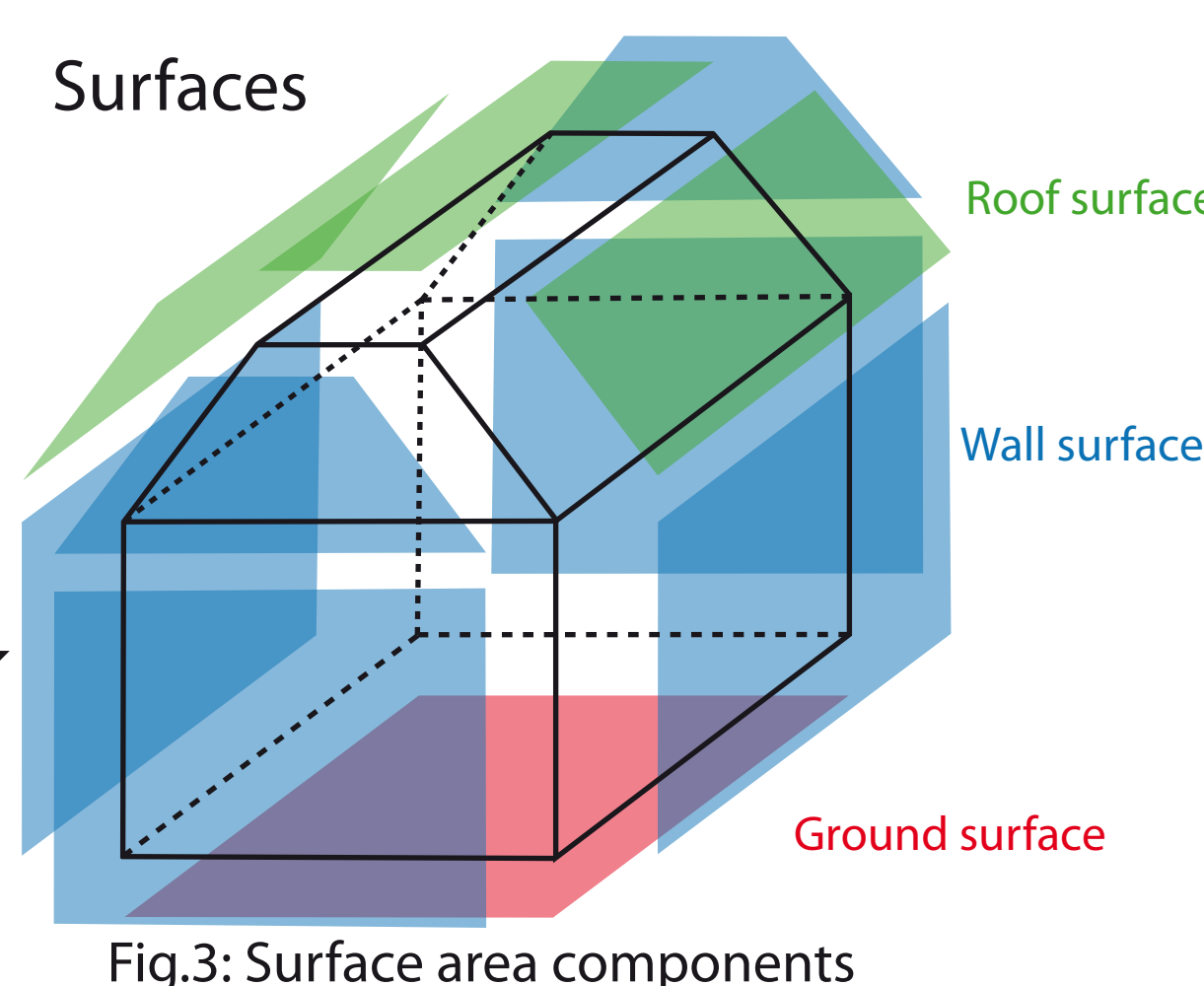


Fig.3: Surface area components

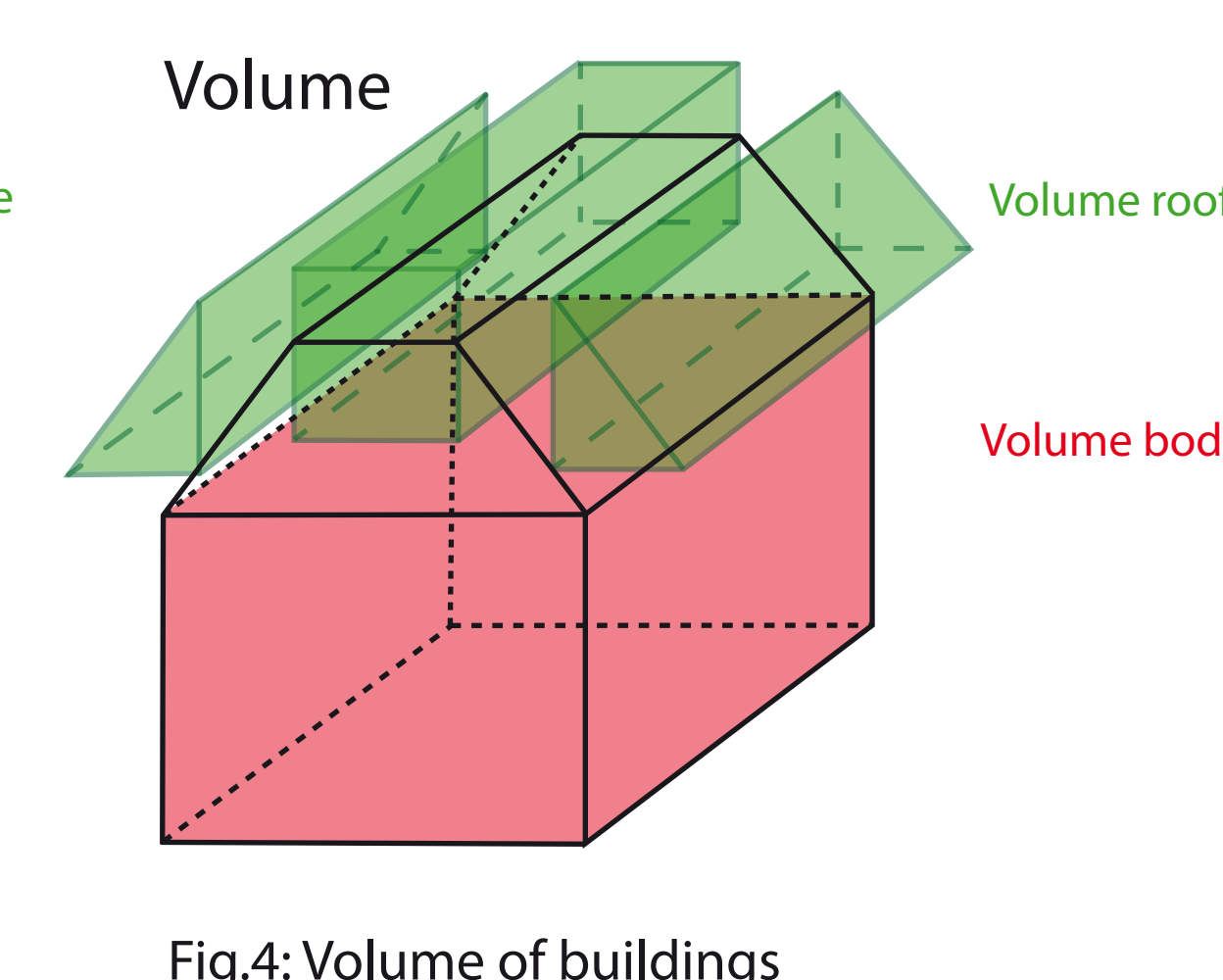


Fig.4: Volume of buildings

Energy Balance Model

The Energy Balance Model calculates the heat loss from the LoD2 building model in the database where different values are determined, such as building volume & surface areas (Fig. 4 & 3). In combination with U-values for the different surface types and other factors, the transmission- and ventilation heat loss is calculated (Formula 1). The results are then multiplied with a determined Heating Degree Days (Formula 2) for calculating the required annual energy demand for heating buildings (Formula 3).

$$\text{Heat loss} = \sum (A_i * U_i * f_T) + (V_A * n_A * C_{Air}) = W / K \quad (1)$$

A_i : Component surface area
 U_i : U-value of surface component
 f_T : Factor for temperature zone
 V_A : Air volume
 n_A : Energy-efficient air exchange in heating load case
 C_{Air} : Heat capacity of air

$$\text{HDD}_a = \sum_{i=1}^{12} [D_M * (T_i - T_o)] = Kd \quad (2)$$

D_M : Number of days a month
 T_i : Inside temperature of building
 T_o : Average outside temperature

$$\text{Annual energy demand}_{\text{bui}} = \text{Demand}_{\text{bui}} * \text{HDD}_a * \frac{1}{1000} = \text{kWh} \quad (3)$$

Conclusion

The study has shown that the developed infrastructure proved to be flexible and adaptive to the requirements set by energy models. We were able to successfully implement the energy balance model as well as the assessment of the results. The successful coupling of the DBMS and energy models enables modeling at different spatial scales and allowed us to use previously unavailable spatial information coming from DTM analysis, building texture and spatial queries directly in the models. The proposed interface allowed us to use all the advantages that geo-localized information brings to energy models in a flexible and stable manner.

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References

- T. Kolbe, 3D Geo-Information Science, 2009
- J.-M. Bahu*, A. Koch, E. Kremers, S.M. Murshed, Towards a 3d spatial urban energy modelling approach, 2013, ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume II-2/W1, ISPRS 8th 3DGeoInfo Conference & WG II/2 Workshop, 27 – 29 November 2013, Istanbul, Turkey
- A. Stadler, Claus Nagel, Gerhard König, Thomas H. Kolbe, Making interoperability persistent: A 3D geo database based on CityGML, 2009
- Institut Wohnen und Umwelt GmbH, Deutsche Gebäudetypologie Systematik und Datensätze, 2005
- Open Geospatial Consortium, OGC City Geography Markup Language (CityGML) Encoding Standard, 2012
- Westfälische Hochschule, CityGML-Toolchain Editor 1.8, 2013
- pyhull 1.4.3 documentation, <https://pythonhosted.org/pyhull/>, last visit: 10.06.2014

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