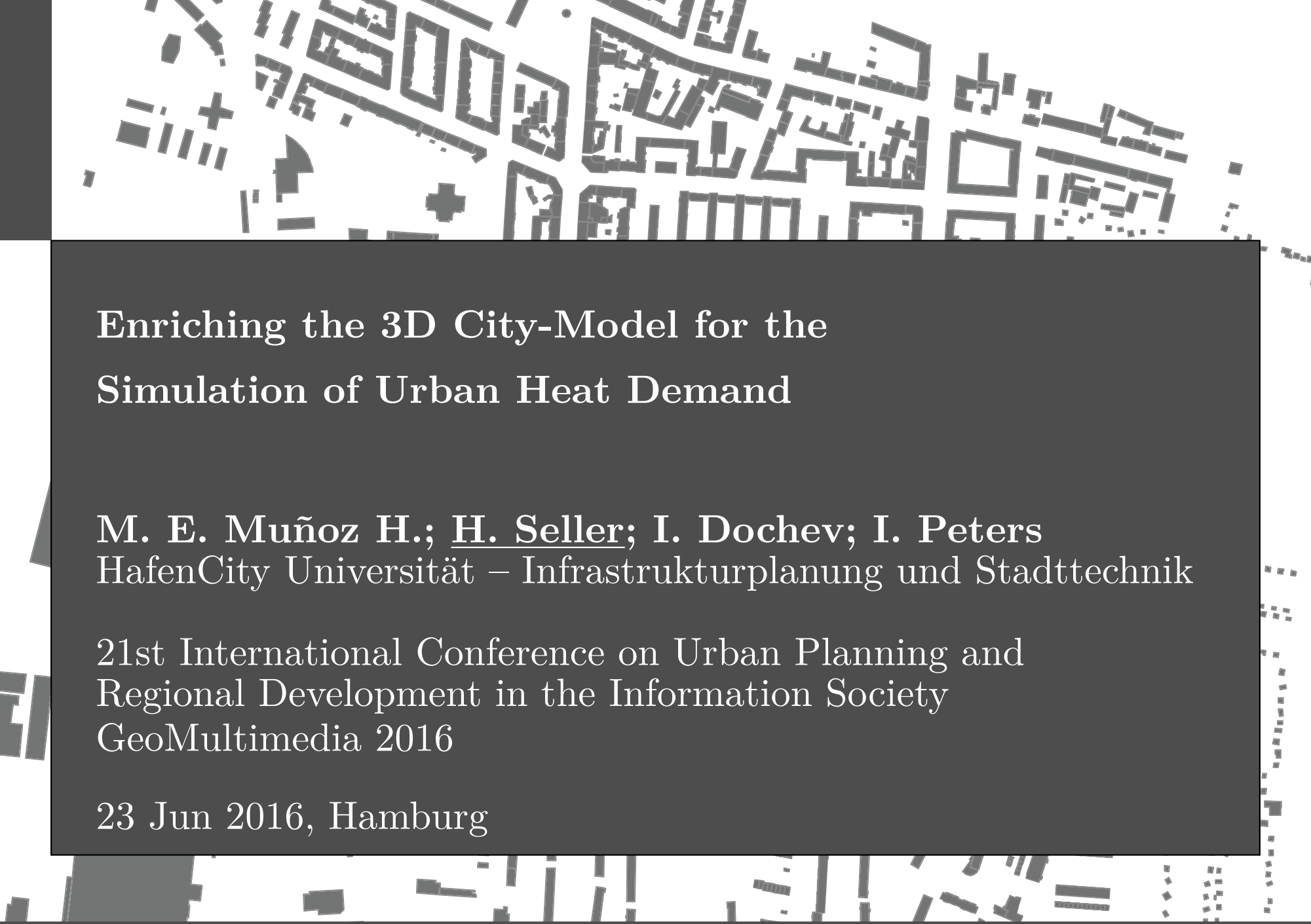

Enriching the 3D City-Model for the Simulation of Urban Heat Demand

M. E. Muñoz H.; H. Seller; I. Dochev; I. Peters
HafenCity Universität – Infrastrukturplanung und Stadttechnik

21st International Conference on Urban Planning and Regional Development in the Information Society
GeoMultimedia 2016

23 Jun 2016, Hamburg

Outline

Outline

Introduction (1/3)

1. We describe the process of enriching the Hamburg 3D City model (3D-Stadtmodell) with energy relevant attributes for the simulation of heat demand.
2. We make use of the energy application domain extension (ADE) to store the energy relevant data in a standardized format.
3. For the enrichment process we classify the residential building stock into building types.
4. And classify the non residential sector by use.
5. With the enriched 3D city model we perform a monthly heat demand estimation of a selected neighbourhood in Hamburg.

Introduction (2/3)

We develop a python command line interpreter that is able to:

1. download CityGML data from different locations;
2. process the data and retrieve relevant information;
3. compute heat demand for the residential and non residential sector
4. save the data as different data formats, including CityGML with Energy ADE relevant attributes; and

Possible uses of this approach are:

1. identification of hot spots in the city,
2. creation of base data sets for the simulation of retrofit scenarios, and
3. creation of temporal heat density maps.

Introduction (3/3)

1. A simple set of python scripts to process geo-spatial data for the computation of heat demand.
2. The enrichment process is a simple read and write operation.
3. In between the data input and data output we define a set of templates for the construction of CityGML files.
4. Direct download of data predefine on a JSON configuration file.

Definition of data sources

We define sources of data as a simple JSON notation.

Listing 1: Configuration structure of data loacation and attributes on the data-sets

```
{"hamburg": {
    "2015": {
        "lod": "1",
        "bbox": [["587611.770", "5975921.492"],
                 ["466355.917", "5917209.548"]],
        "type": "zip",
        "url": "http://daten-hamburg.de/geo...zip",
        "attributes":[
            "function",
            "measuredHeight",
            "storeysAboveGround",
            ...
            "tridicon_Dachform"]}}}
```

We can call this data just by its name `hamburg`.

Outline

Using Templates (1/2)

- This approach has the advantage of been very flexible because the files are created only based on the predefine templates.
- The disadvantage of this method is that the tool is not aware of errors implemented in the template.
- Internally the tool will populate a template with predefine variables retrieved from either the downloaded data of from other sources joint to the data.

For the example presented on this paper we define 3 templates:

1. A header template, containing the header information of the xml file including all the namespace definitions;
2. A description of the generated file, including the bounding box of the geometry features; and
3. A template describing a building element;

Using Templates (2/2)

- The first step is to create some pieces of xml code with pre-define variables on them.
- The template can be arbitrarily defined, decoupling so, the development of the tool to any development of CityGML schema or any other xml schema.

Listing 2 shows an extract of the building template. On this template we define a singe variable: $sqm. The value of this variable will be populated by the computed heated floor area by the tool. On Listing 3 we define five variables. In this case we populate this template with the computed heat demand of each building.

Template example (1/2) — Heated Area

Listing 2: Template for energy heated area

```
<!-- Energy heated area -->
<energy:floorArea>
    <energy:FloorArea>
        <energy:type>EnergyReferenceArea</energy:type>
        <energy:value uom="m2">$sqm</energy:value>
    </energy:FloorArea>
</energy:floorArea>
```

Template example (2/2) — Heat Demand

Listing 3: Template for computed heat demand

```
<!-- Computed energy demand -->
<energy:energyDemands>
    <energy:EnergyDemand>
        <energy:endUse>SpaceHeating</energy:endUse>
        <energy:energyAmount>
            <energy:RegularTimeSeries>
                <energy:id>$heatid</energy:id>
                <energy:temporalExtent>TMY</energy:tempora
                <energy:timeInterval unit="$timeintervalunit">
                    $timeinterval
                </energy:timeInterval>
                <energy:values uom="$uom">
                    $heatdemand
                </energy:values>
```

Code for populating the heading template

Listing 4: Example code used for the population of the XML heading template

```
#(1) import the python template module
from string import Template
#(2) open and read the template
file_in = open("head.xml")
src = Template(file_in.read())
#(3) define the document data
d={"citygml": "2.0",
   "energyade": "0.7.0",
   "name": "Example file created with energyade.py"}
#(4) do the substitution on the template
result = src.substitute(d)
print(result)
```

Listing 4 shows how easy it is to populate a template with predefines variables.

The command line interpreter

- Using the python command line interpreter to call the functions or run scripts.
- Each defined command is documented directly at the source code.
- Quick development.
- Large palette of powerful libraries (pandas, fiona, shapely, sklearn, pysal, geoalchemy, etc. . .)

```
[EM@ citygml4py]$ python energyade.py
running with lxml.etree


    Simple command line interface for Energy-ADE CityGML enriching model.

    @author: M. Esteban Munoz H.


eade > help

doc_header
----------
_load            connect           join            pause          set
_relative_load   delete_attribute  l               print_city     set_bbox
add_attribute    download          li              py             shell
add_bbox_clip    ed                list            r              shortcuts
clip             edit              list_cities     run            show
cmdenvironment   get_geometry      load            save           simplify
compute_bbox     hi                make_bbox_clip  save_clip      validate
compute_heat     history           map             save_geometry

undoc_header
------------
EOF  eof  exit  help  q  quit

eade >
```

Example Script (1/2)

Listing 5: Example script to compute the heat demand of a defined urban area with downloaded data for the city of hamburg

```
download hamburg
delete_attribute all
add_attribute function measuredHeight storeysAboveGround
add_bbox_clip data/output/2016-02-16T04:26:22.145116-clip.
get_geometry all
clip all
join data/bja.csv bja baw
simplify all
compute_heat Year static Hamburg
save_geometry GeoJSON csv CityGML shp
validate xsd/energy.xsd
```

Example Script (2/2)

1. Listing 5 shows the script used to estimate the heat demand of the urban area presented on this paper.
2. Code line 5 adds the attributes to keep from the downloaded data-set
3. This bounding box can be define with an upper left and a lower right coordinates or with a spatial file.
4. The tool has a small option to enrich the input data through the use of data store on csv files.
5. command: `simplify all`, code line 15, performs a geometrical simplification of the buildings.
6. The computation of heat demand occurs on code line 18.

Geometrical Simplification

1. A simplification of the building geometry allows us to perform faster heat demand computations.
2. Another advantage is the projection of the defined building stock into the future.
3. Kim, Plessis, Hubert, and Roux (2014) show that a simplification of the building geometry decreases the performance of the model by less than 1% of total annual heat demand but are able to perform the same simulation 700 times faster than taking a complex geometry into account.
4. An algorithm considering the neighbouring buildings into account for a geometry simplification is described on (Muñoz H., 2016).

Building classification

1. With the enriched data, through the csv file join, we classify the building stock into building typologies.
2. The default building typology define in the tool is the IWU typology (Diefenbach, Cischinsky, Rodenfels, & Clausnitzer, 2010; Loga, Diefenbach, & Born, 2011).

Table: IWU-de building typology matrix for Germany

	< 1859	1860–1918	1919–1948	1949–1957	1958–1968	1969–1978	1979–1983	1984–1994	1995–2001	2002–2009
EFH	183	180	164	181	146	155	118	132	110	88
RH		153	137	156	106	127	127	98	78	86
KMH	190	143	168	156	129	134	118	122	92	79
GMH		127	144	142	131	117				
HH					114	113				

source: (Loga et al., 2011) Specific Heat demand (spez. Wärmebedarfskennzahl) [kWh/m^2a]

Outline

Specific Heat Demand of Urban Areas (1/2)

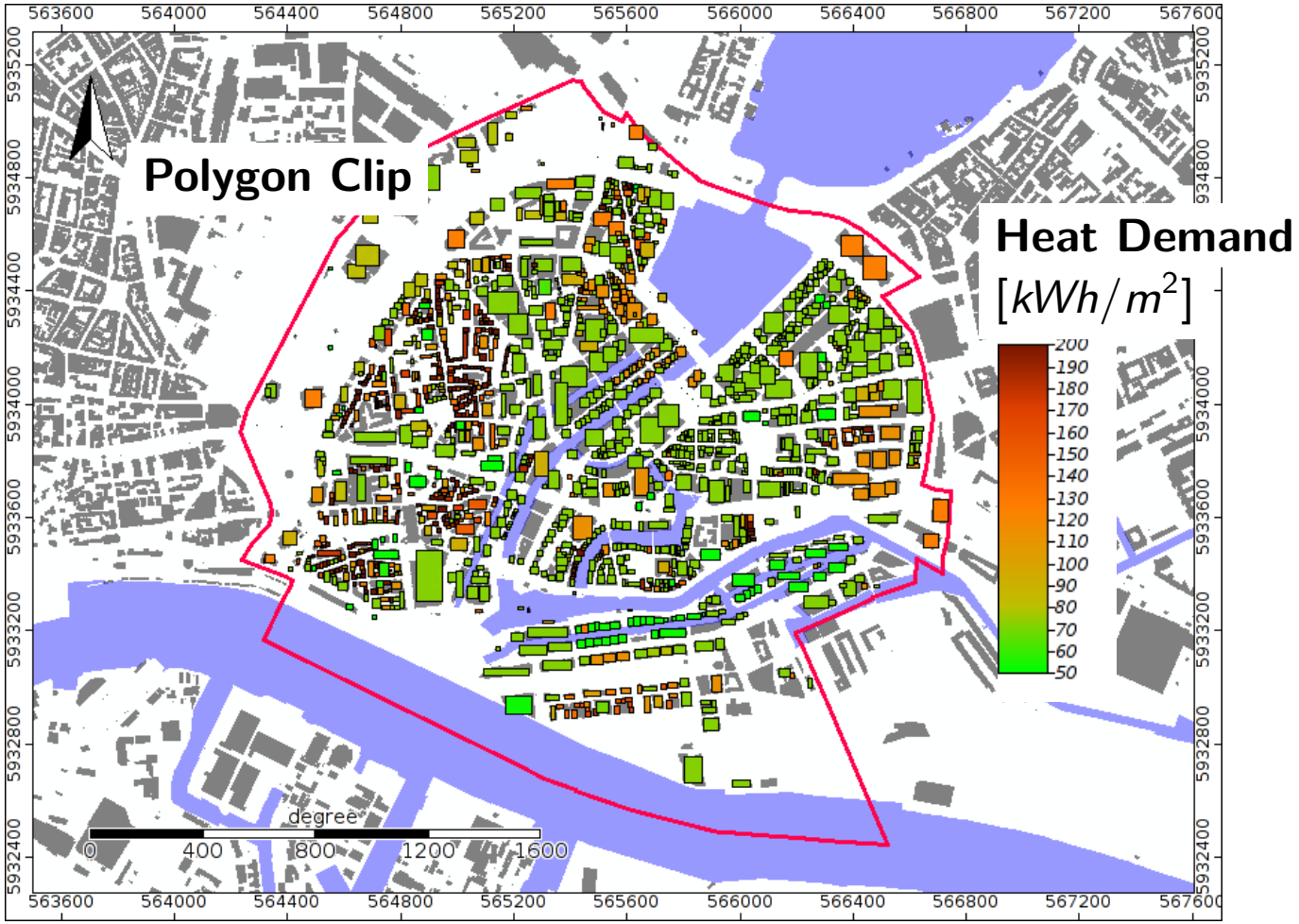

Figure: Specific heat demand for selected urban area

Specific Heat Demand of Urban Areas (2/2)

1. On the figure we can see the simplified geometry of the individual buildings.
2. The pink line surrounding the computed elements is the geometry used to clip the input data set.
3. On the figure we can identify some agglomerations of residential buildings with higher specific heat demand.
4. We still need to quantify the loss in accuracy induced by the simplification of the building geometry.
5. The big advantage of using a template system as opposed to a hard coded data structure is its ability to cope with a rapid changing system.

References

Diefenbach, N., Cischinsky, H., Rodenfels, M., & Clausnitzer, K.-D. (2010). *Datenbasis gebäudebestand: Datenerhebung zur energetischen qualität und zu den modernisierungstrends im deutschen wohngebäudebestand* (1. ed.). Darmstadt: Institut Wohnen und Umwelt (IWU) and Bremer Energie Institut (BEI).

Kim, E.-J., Plessis, G., Hubert, J.-L., & Roux, J.-J. (2014). Urban energy simulation: Simplification and reduction of building envelope models. *Energy and Buildings*, *84*, 193 - 202. doi: http://dx.doi.org/10.1016/j.enbuild.2014.07.066

References (Continued)

Loga, T., Diefenbach, N., & Born, R. (2011). *Deutsche Gebäudetypologie: Beispielhafte Maßnahmen zur Verbesserung der Energieeffizienz von typischen Wohngebäuden.*

Muñoz H., M. E. (2016). Construction of building typologies from a regional material catalog: Assessment of urban heat demand and the environmental impact of retrofit policies. *Management of Environmental Quality - An international journal*, *–in Press–*.