

SHP2SIM: A Python Pipeline for Modelica based District and Urban Scale Energy Simulations

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Introduction

- Energy simulation models for buildings
 - Energy management, ensure energy efficiency
 - Control/design of smart energy systems
 - Estimate energy demand of buildings
- District/City Scale
 - high-number of buildings
 - Automated way for creation
- Input for building energy simulation models
 - Building geometries, construction detail, heating, occupancy, ... ¹
 - Required data available on limited extent ¹

¹ Malhotra, A., et al., (2022), Information modelling for urban building energy simulation—A taxonomic review. Building and Environment 208, <https://doi.org/10.1016/j.buildenv.2021.108552>.

Methodology

- **Python Pipeline SHP2SIM -> energy simulation models**
- Input: GIS data
- Output: Modelica simulation model

- Github: <https://github.com/tug-cps/shp2sim>

Methodology – Workflow

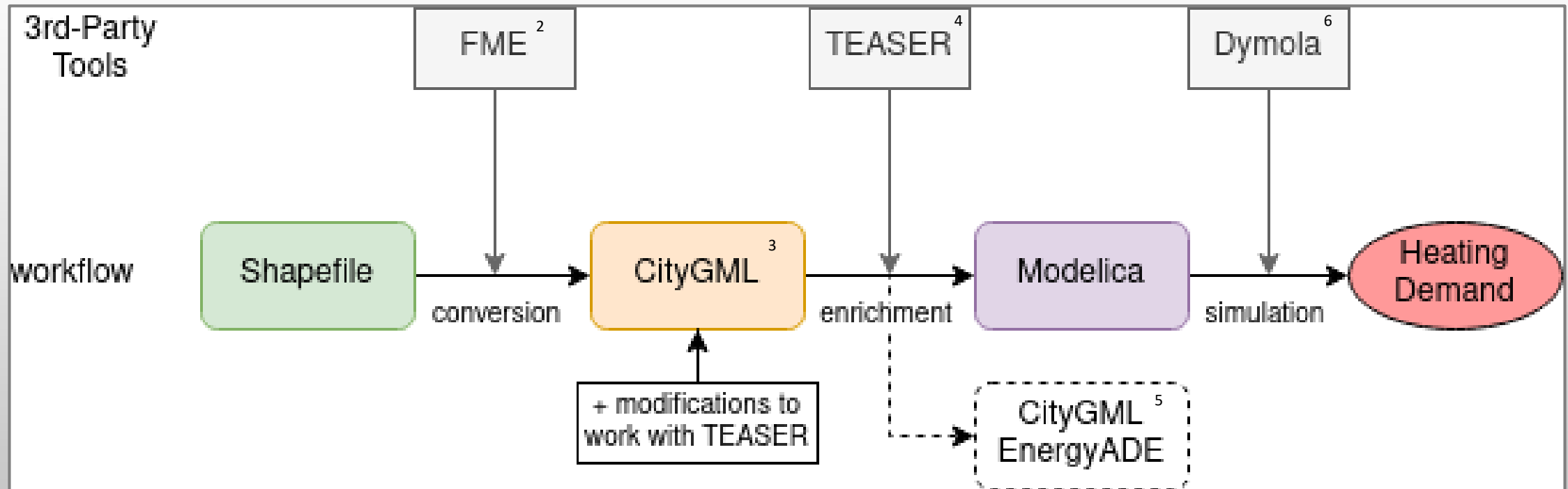


Fig. 1: Overview pipeline SHP2SIM

² FME: Safe Software, (2021), FME — The Simple Solution for Complex Integration. Retrieved from <https://www.safe.com/>, last access 06.02.2022.

³ CityGML: Gröger, G., Plümer, L., (2012), CityGML – Interoperable semantic 3D city models. ISPRS Journal of Photogrammetry and Remote Sensing Vol. 71, p.12-33. <https://doi.org/10.1016/j.isprsjprs.2012.04.004>.

⁴ TEASER: Remmen, P., et al., (2018), TEASER: an open tool for urban energy modelling of building stocks. Journal of Building Performance Simulation Vol. 11/1, p.84-98. <https://doi.org/10.1080/19401493.2017.1283539>.

⁵ EnergyADE: Aguiaro, G., et al., (2018), The Energy Application Domain Extension for CityGML: enhancing interoperability for urban energy simulations. Open geospatial data, softw. stand. 3, 2. <https://doi.org/10.1186/s40965-018-0042-y>.

⁶ Dymola: Dassault Systemes, (2021), Dymola Systems Engineering. Retrieved from <https://www.3ds.com/de/produkte-und-services/catia/produkte/dymola/>, last access 06.02.2022.

Methodology – Python Code Example

```
1
2 def main():
3     '''Demonstrates the workflow of the pipeline shp2sim.'''
4
5     project_name = 'Inffeldgasse'
6     data_dir = pathlib.Path(__file__).parent / 'building_data'
7
8     #transform 2D shp into 3D CityGML-file
9     shpfile = data_dir / 'shp' / 'campus_inffeld_basis.shp'
10    gmlfile = data_dir / 'gml' / 'campus_inffeld.gml'
11    shptocitygml(shpfile, gmlfile)
12
13    #alter CityGML file
14    gmlfile_teaser = data_dir / 'gml' / 'campus_inffeld_modified.gml'
15    gml file teaser buildingfunc = data_dir / 'gml' / 'campus_inffeld_modified_buildingfunctions.gml'
16    prepare_gml_for_teaser(gmlfile)
17    add_bldg_function(gmlfile_teaser)
18
19    #enrichment of CityGML-file with TEASER
20    weatherfile = data_dir / 'AUT_Graz_Univ.mos'
21    modelica_dir = data_dir / 'modelica'
22    enrich_citygml(project_name, gml_file_teaser_buildingfunc, weatherfile, modelica_dir)
23
24    #simulation of Modelica model
25    simulation_results = data_dir / 'simulation_results'
26    run_simulation('Inffeldgasse', modelica_dir, simulation_results, ['Inffeldgasse11_1', 'Inffeldgasse11_2'])
```

Conversion

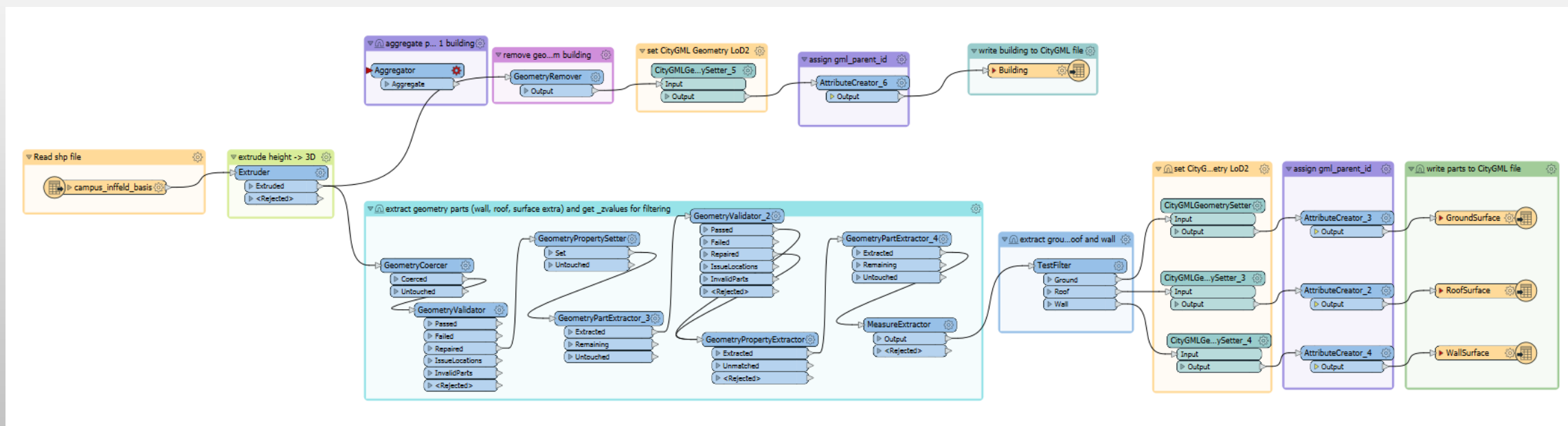
Modifications

Enrichment

Simulation

Methodology

Conversion: FME Workbench



Methodology

Enrichment: TEASER ⁴



- Open tool for urban energy modelling
- Based on archetype buildings

→ Enrichment of CityGML with energy data (CityGML EnergyADE)

→ Creation of modelica simulation model

Simulation: Dymola ⁶ / buildingspy ¹¹

- Simulation of modelica model

⁴ TEASER: Remmen, P., et al., (2018), TEASER: an open tool for urban energy modelling of building stocks. Journal of Building Performance Simulation Vol. 11/1, p.84-98. <https://doi.org/10.1080/19401493.2017.1283539>.

⁶ Dymola: Dassault Systemes, (2021), Dymola Systems Engineering. Retrieved from <https://www.3ds.com/de/produkte-und-services/catia/produkte/dymola/>, last access 06.02.2022.

⁷ Source: <http://rwth-ebc.github.io/TEASER/>

¹¹ Wetter, M., & USDOE, (2019), BuildingsPy [Computer software]. <https://www.osti.gov//servlets/purl/1569219>. <https://doi.org/10.11578/dc.20190430.2>.

Use Case

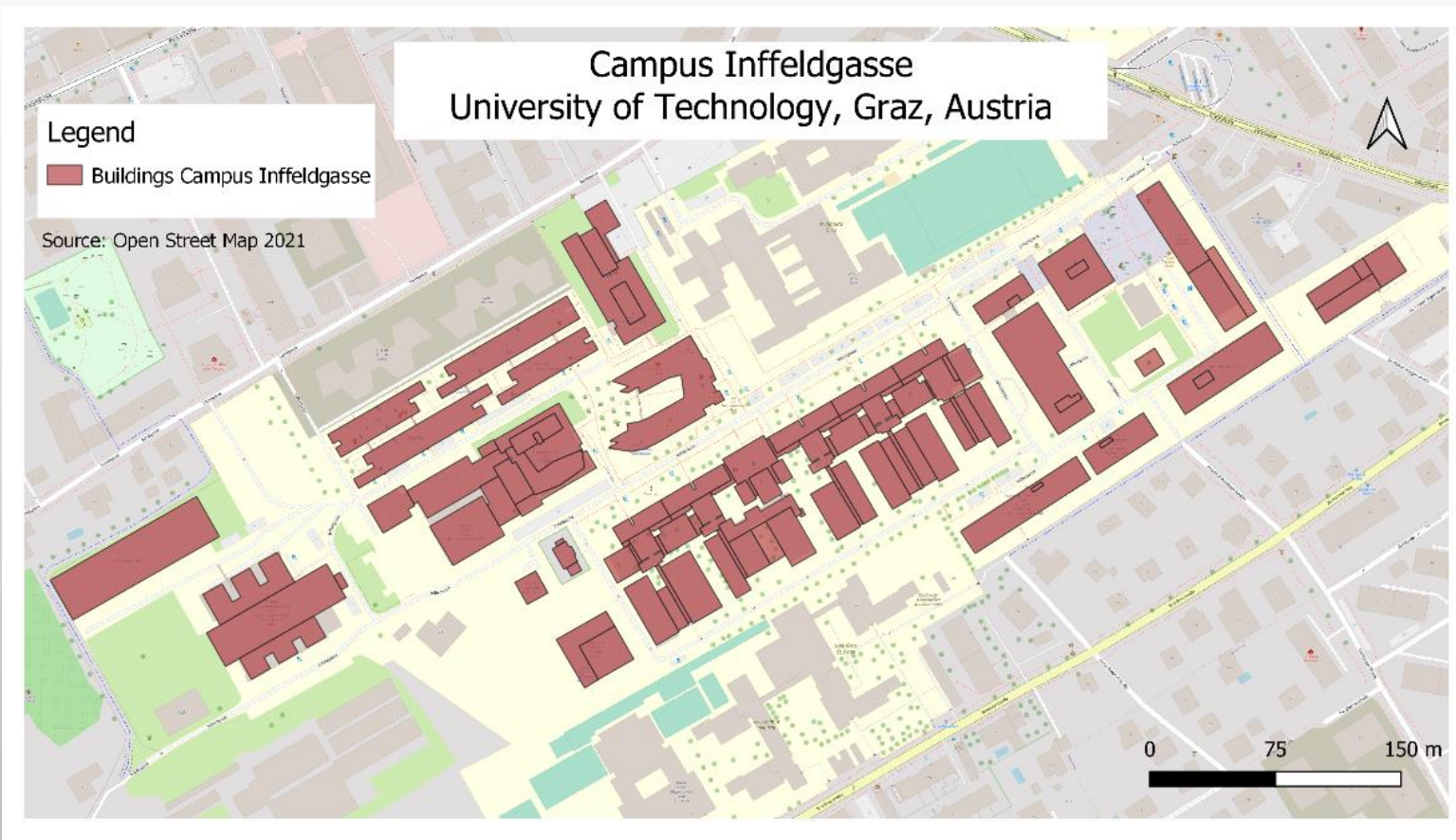


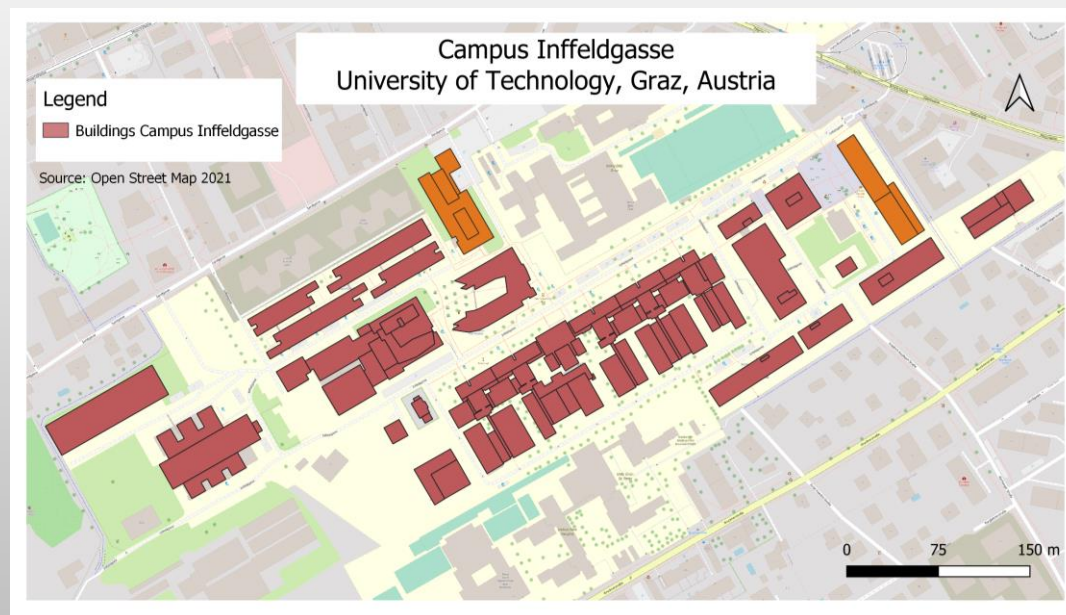
Fig. 2: Case study area Campus Inffeldgasse

Data for Use Case

- 27 buildings
- Footprints & building parts
- Attributes
 - Heights by digital terrain model
 - Storey heights
 - Year of construction

Use Case

- 2 buildings for comparison: Inffeldgasse 11 & Inffeldgasse 12



Inffeldgasse 11 ⁸



Inffeldgasse 12 ⁹

⁸ Photo by author, 03.04.2022

⁹ Photo by author, 03.04.2022

Use Case

- Inffeldgasse 11 & 12: Simulated heatload vs. Measured data

- Simulation

- Zones of buildings
- Weather data
 - Typical Meteorological Years (TMY) data ¹⁰
 - 2015 to 2019
- Simulated with buildingspy ¹¹

Table 1: Share of zones in case study buildings

%	Office	Floor	Laboratory	Storage	Meeting	Rest-room	ICT
Inffeldgasse 11	18.73	26.74	36.55	0.57	12.96	3.22	1.23
Inffeldgasse 12	32.8	26.93	25.77	2.28	5.61	2.94	3.67

- Measured Data

- Heatload of each of 2 buildings
- 2019

¹⁰ Lawrie, L., Crawley, D., (2019), Development of Global Typical Meteorological Years (TMYx). Retrieved from <http://climate.onebuilding.org>, last access: 05.02.2022.

¹¹ Wetter, M., & USDOE, (2019), BuildingsPy [Computer software]. <https://www.osti.gov/servlets/purl/1569219>. <https://doi.org/10.11578/dc.20190430.2>.

Use Case

Simulation results

- Yearly heatload for building
- Simulated vs. measured

Table 2: Simulated and measured heat load of case study buildings for one year

	Simulated heat load in kWh	Measured heat load 2019 in kWh	Difference in kWh	Deviation in %	Euclidian norm of hourly data in kWh
Inffeldgasse 11	189403	256880	67477	26.27	2138
Inffeldgasse 12	439812	446620	6808	1.52	10195

Use Case – Inffeldgasse 11

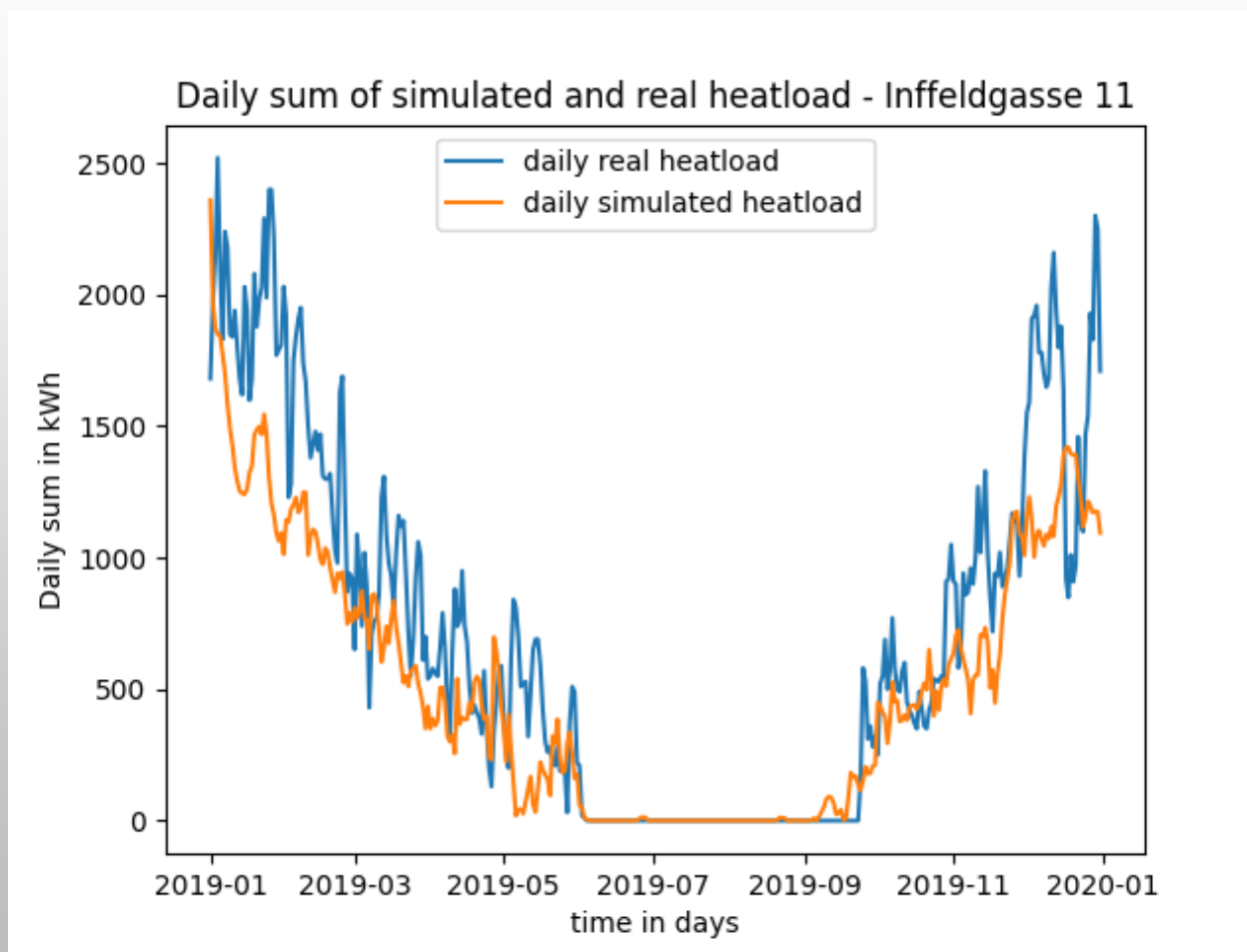


Fig. 3: Daily simulated and measured heat load for Inffeldgasse 11

Use Case – Inffeldgasse 11

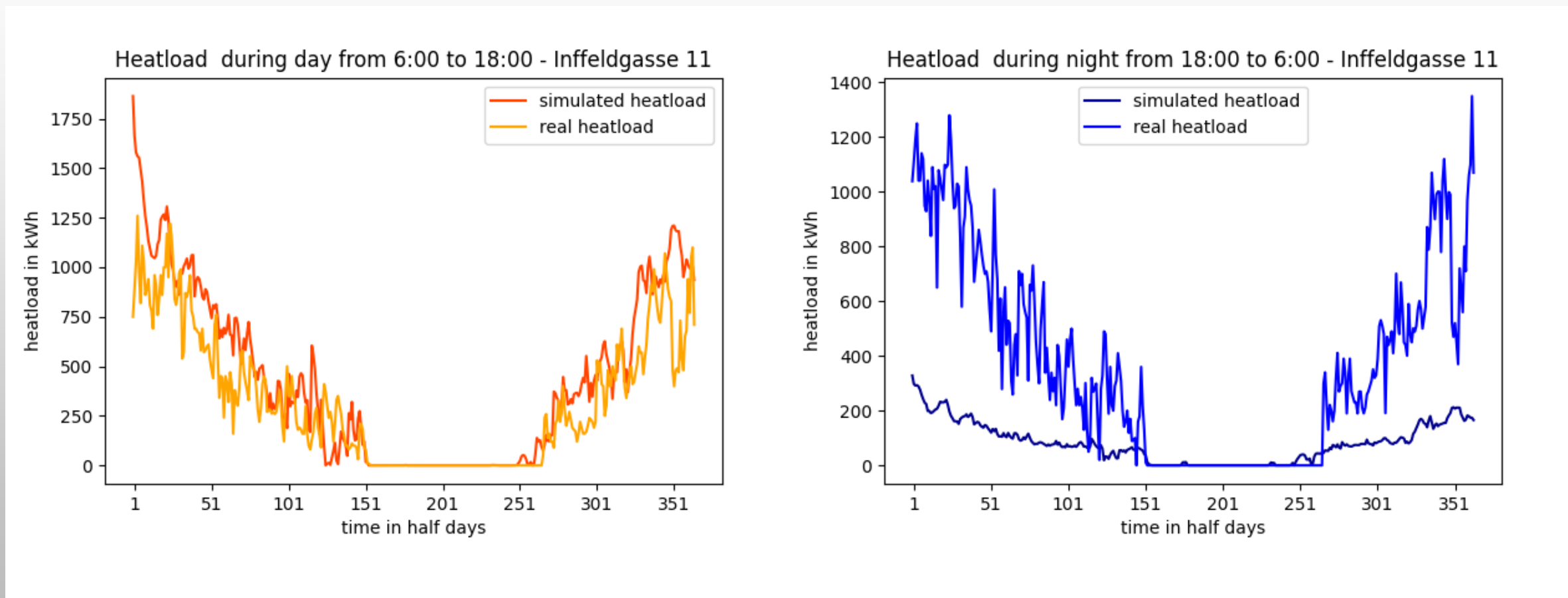


Fig. 4: Simulated and measured heat load for Inffeldgasse 11 during day and night

Use Case – Inffeldgasse 12

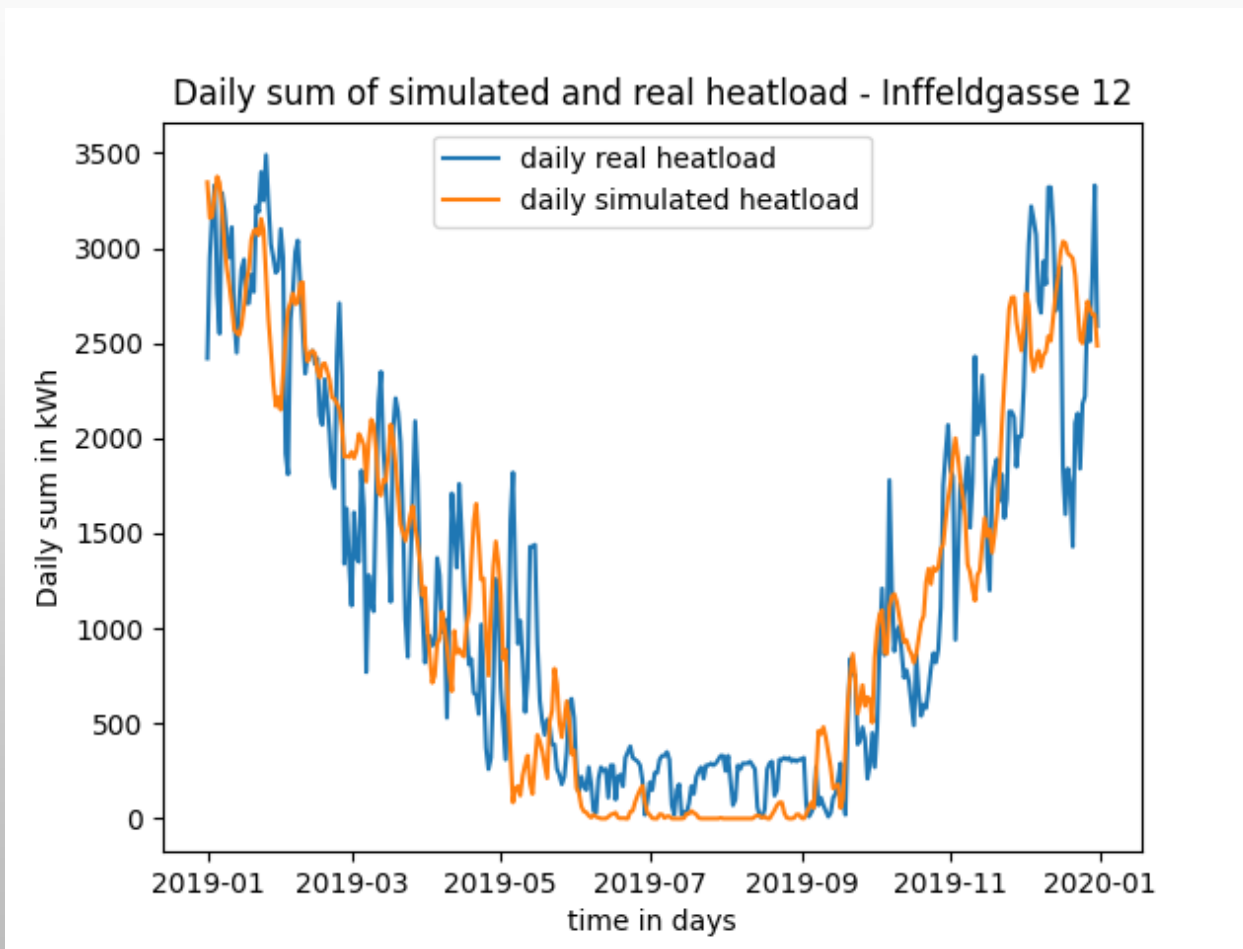


Fig. 5: Daily simulated and measured heat load for Inffeldgasse 12

Use Case – Inffeldgasse 12

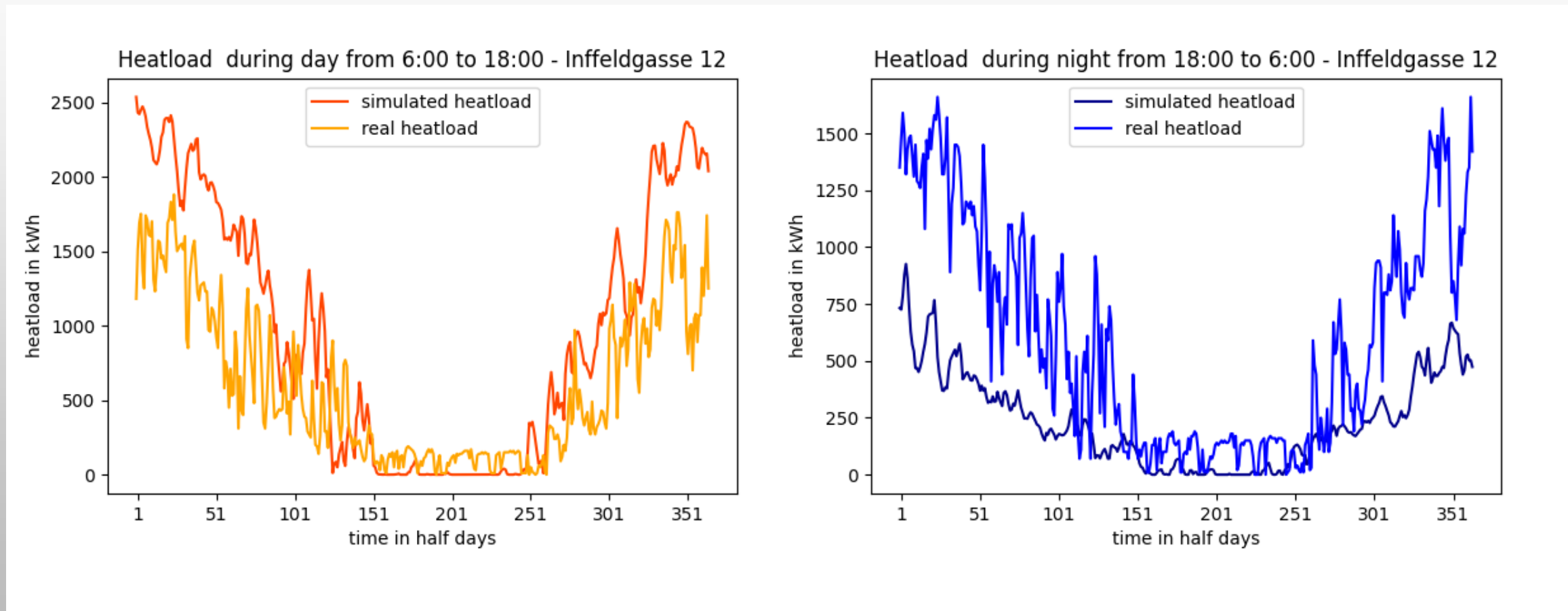


Fig. 6: Simulated and measured heat load for Inffeldgasse 12 during day and night

Conclusion

SHP2SIM: Python Pipeline for building energy simulation models

- District or city scale level
 - Automated, high-number of buildings
- Data input
 - Relatively little data input need
- Simulation models as output
 - generate results close to measured data

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