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

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Content

Introduction

- Energy simulation models for buildings
  - Energy management, ensure energy efficieny
  - 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 – Workflow

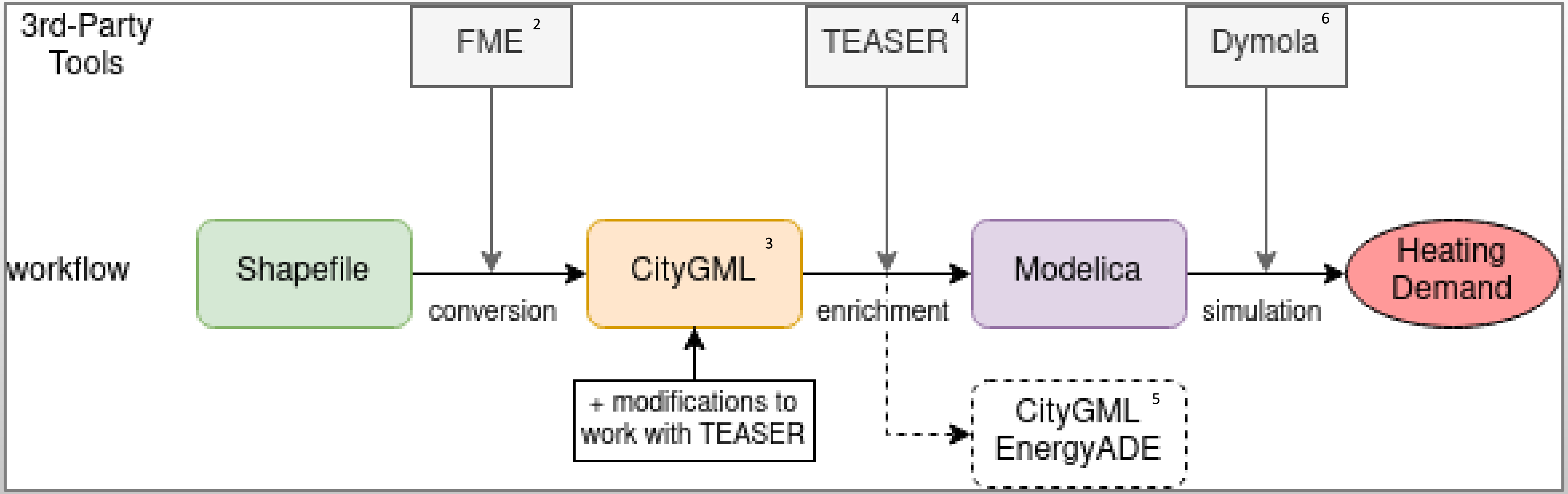


Fig. 1: Overview pipeline SHP2SIM

[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: Agugiaro, 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

```python

def main():
    '''Demonstrates the workflow of the pipeline shp2sim.'''

    project_name = 'Inffeldgasse'
    data_dir = pathlib.Path(__file__).parent / 'building_data'

    #transform 2D shp into 3D CityGML-file
    shpfile = data_dir / 'shp' / 'campus_inffeld_basis.shp'
    gmlfile = data_dir / 'gml' / 'campus_inffeld.gml'
    shptocitygml(shpfile, gmlfile)

    #alter CityGML file
    gmlfile_teaser = data_dir / 'gml' / 'campus_inffeld_modified.gml'
    gml_file_teaser_buildingfunc = data_dir / 'gml' / 'campus_inffeld_modified_buildingfunctions.gml'
    prepare_gml_for_teaser(gmlfile)
    add_bldg_function(gmlfile_teaser)

    #enrichment of CityGML-file with TEASER
    weatherfile = data_dir / 'AUT_Graz_Univ.mos'
    modelica_dir = data_dir / 'modelica'
    enrich_citygml(project_name, gml_file_teaser_buildingfunc, weatherfile, modelica_dir)

    #simulation of Modelica model
    simulation_results = data_dir / 'simulation_results'
    run_simulation('Inffeldgasse', modelica_dir, simulation_results, ['Inffeldgasse11_1', 'Inffeldgasse11_2'])
```

Conversion

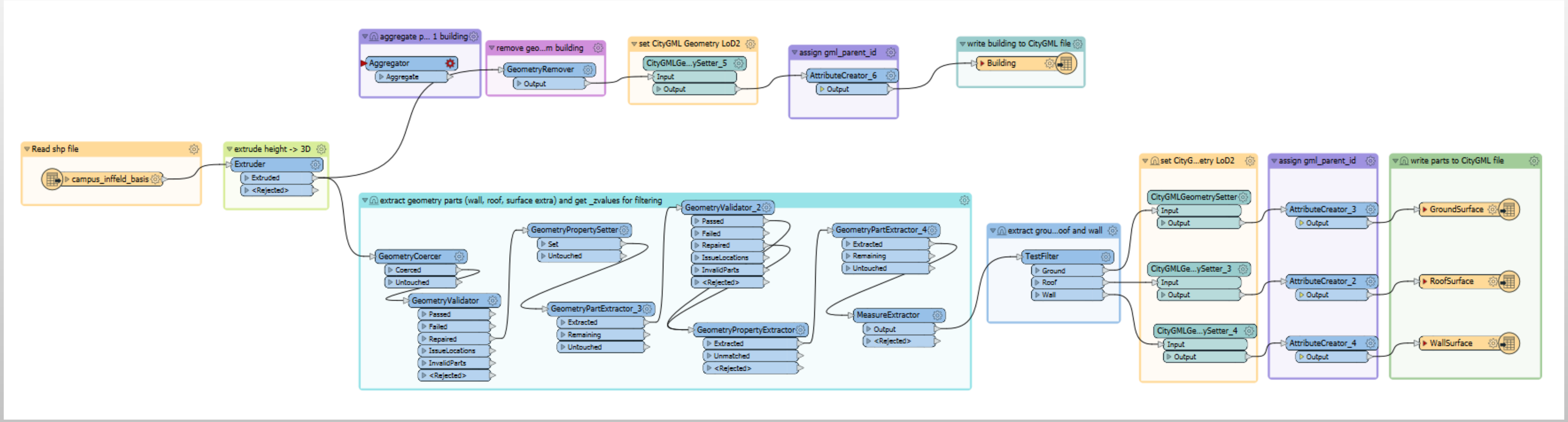
Modifications

Enrichment

Simulation

Methodology

Conversion: FME Workbench



Methodology

Enrichment: TEASER [4]

TEASER [7]

- 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

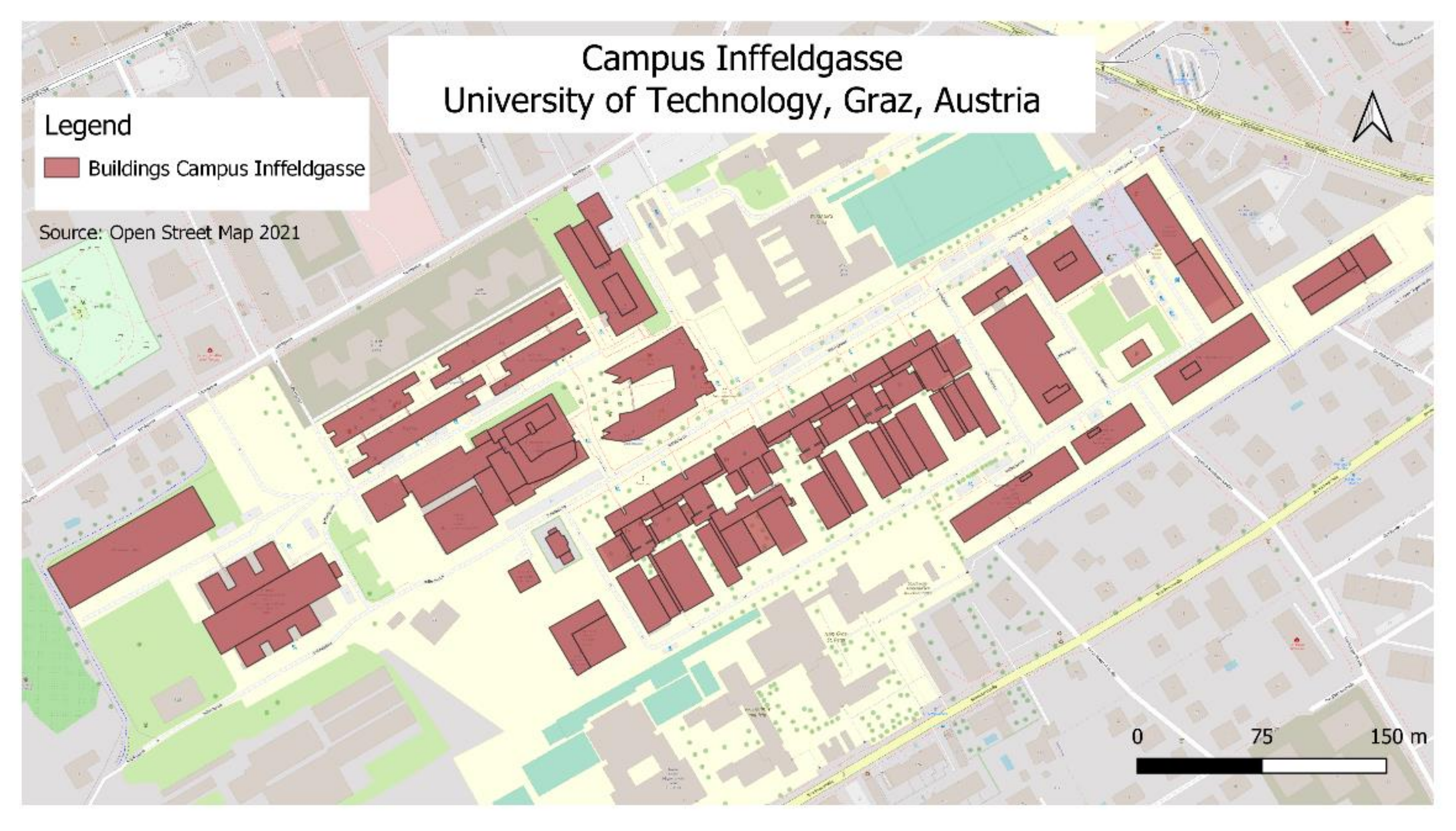


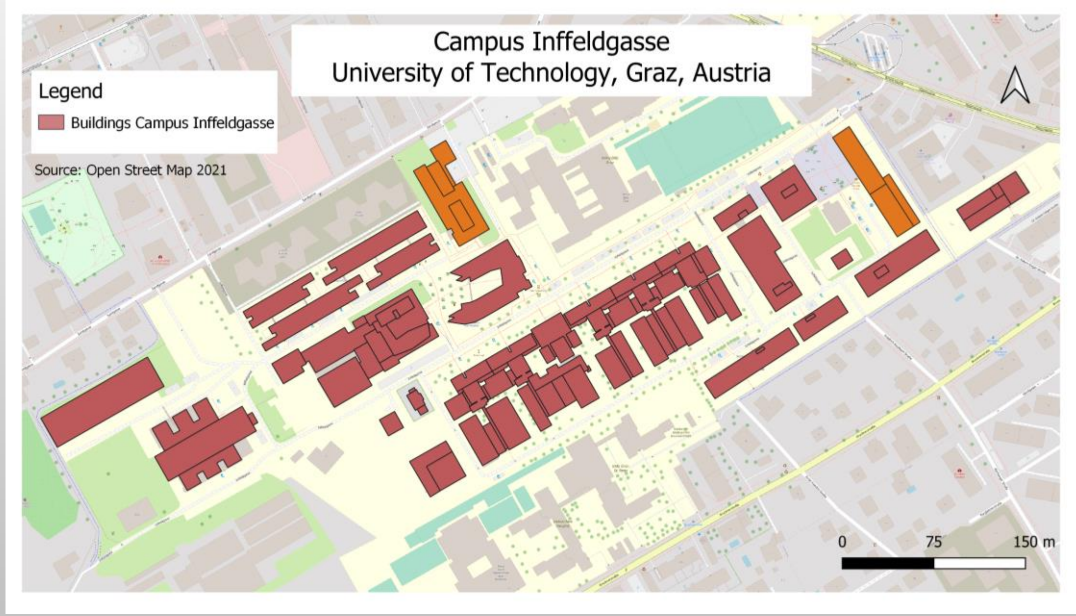
Fig. 2: Case study area Campus Inffeldgasse

<u>Data for Use Case</u>

- 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]
- Measured Data
  - Heatload of each of 2 builidngs
  - 2019

Table 1: Share of zones in case study buildings

%	Office	Floor	Labora-tory	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

[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

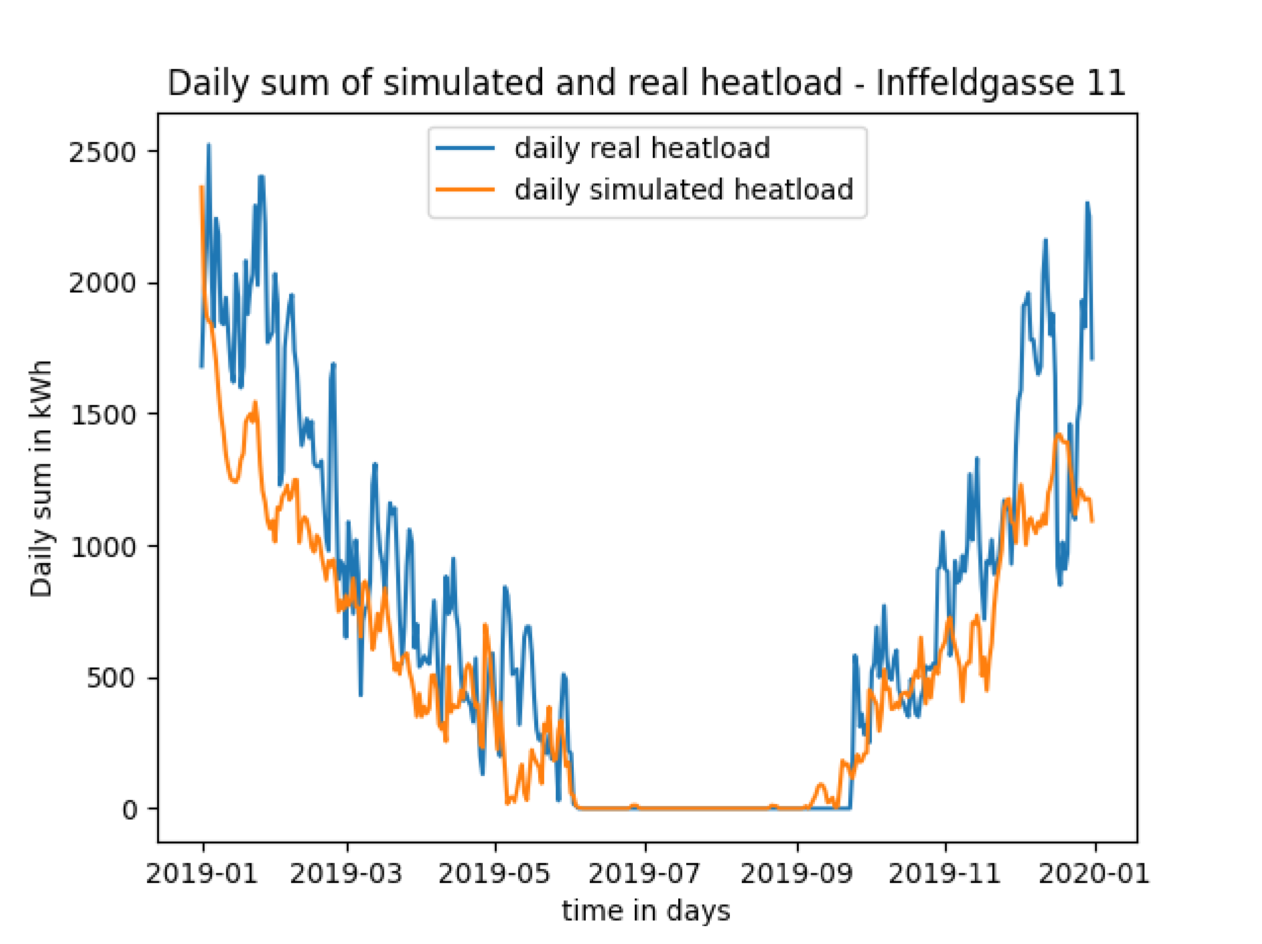


Fig. 3: Daily simulated and measured heat load for Inffeldgasse 11

Use Case – Inffeldgasse 11

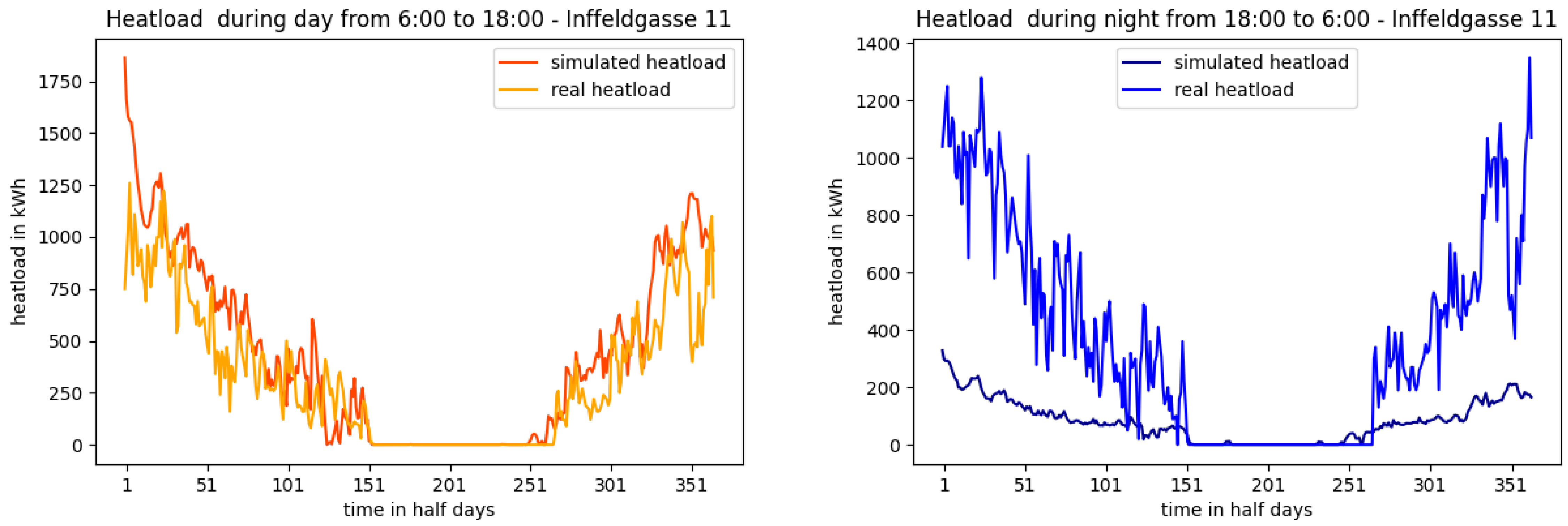


Fig. 4: Simulated and measured heat load for Inffeldgasse 11 during day and night

Use Case – Inffeldgasse 12

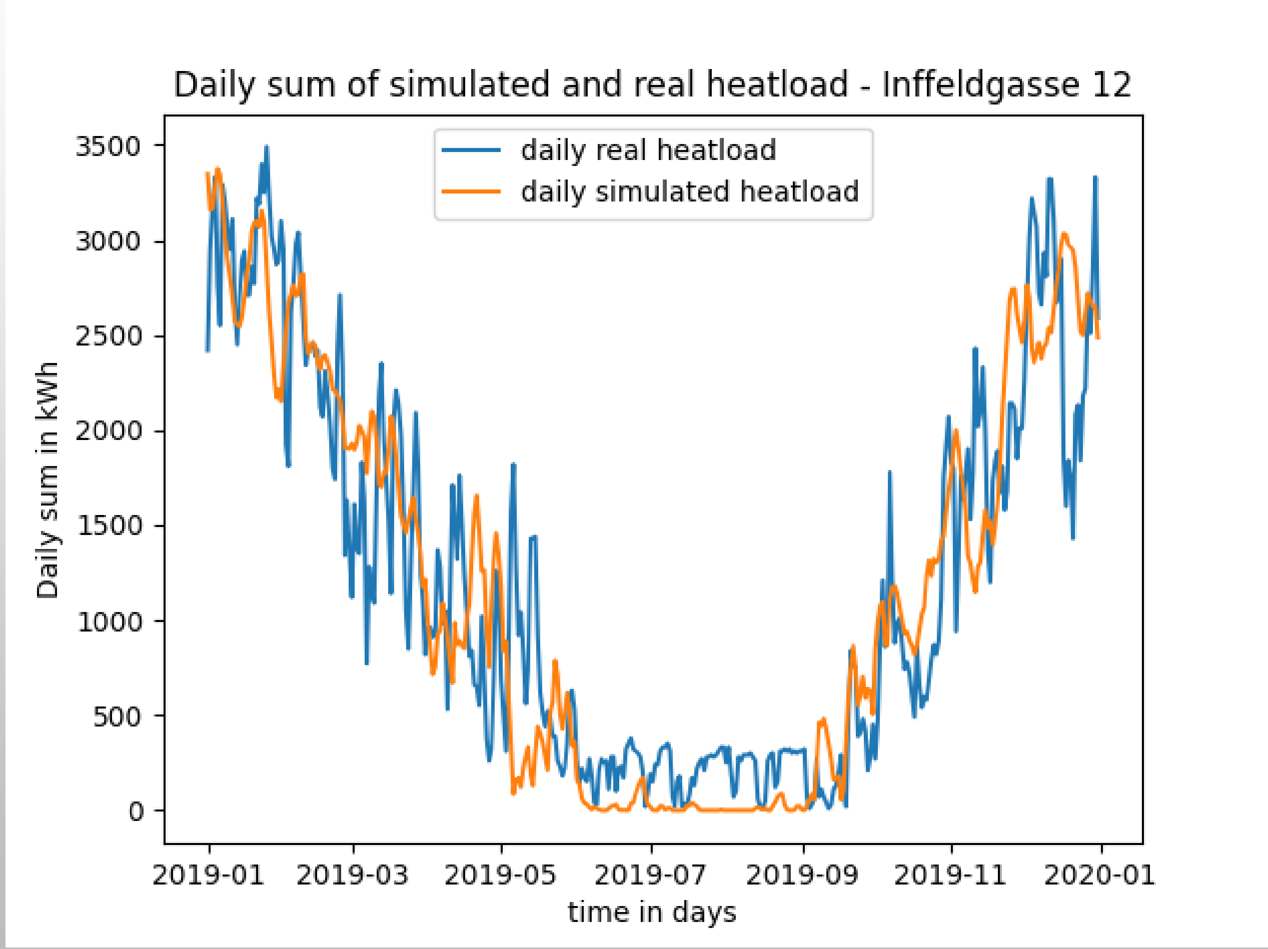


Fig. 5: Daily simulated and measured heat load for Inffeldgasse 12

Use Case – Inffeldgasse 12

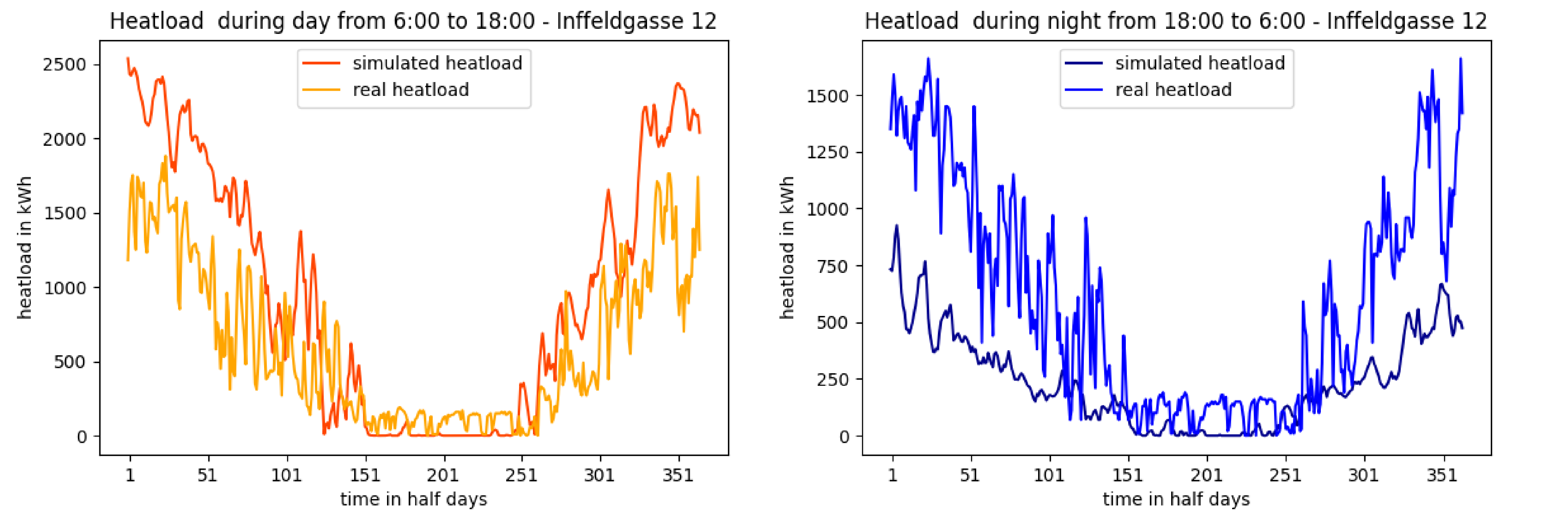


Fig. 6: Simulated and measured heat load for Inffeldgasse 12 during day and night

Conclusion

SHP2SIM: Python Pipeline for building energy simulation models

- Disctrict 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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