DELFT UNIVERSITY OF TECHNOLOGY

GEOMATICS THESIS

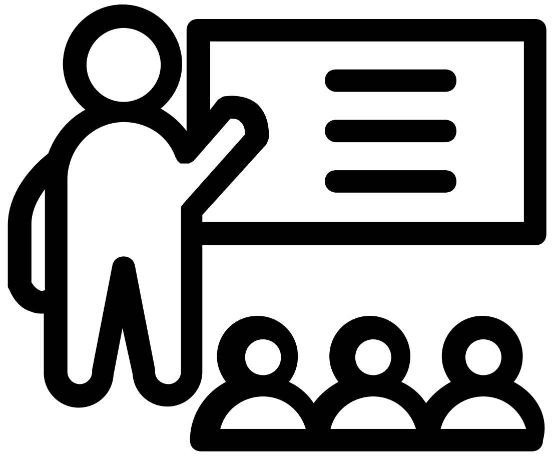
Implementing a Dutch building energy simulation tool

Model testing for Rijssen-Holten

BY: GABRIELA KOSTER

Motivation & Research Question

Intro duction



01

BACKGROUND

Reducing residential energy consumption is high on the political agenda
Strategies to reduce consumption is modeled through *Building Energy Simulation Tools*

02

PROBLEM

Modelling for single buildings is viable but it gets more complex at the urban level
Dutch buildings also need to follow the *BENG* standard as of January 1st, 2021

03

RELEVANCE

Development of a Dutch-specific BES tool based on the *NTA 8800*, while maintaining individual building granularity can help policy makers decision making process

Objectives

01

OBJECTIVES

Implementing a model for the city-scale analysis using *semantic 3D city models*

02

OBJECTIVES

Ensuring compliance with *BENG* standards and *NTA 8800* principles

03

OBJECTIVES

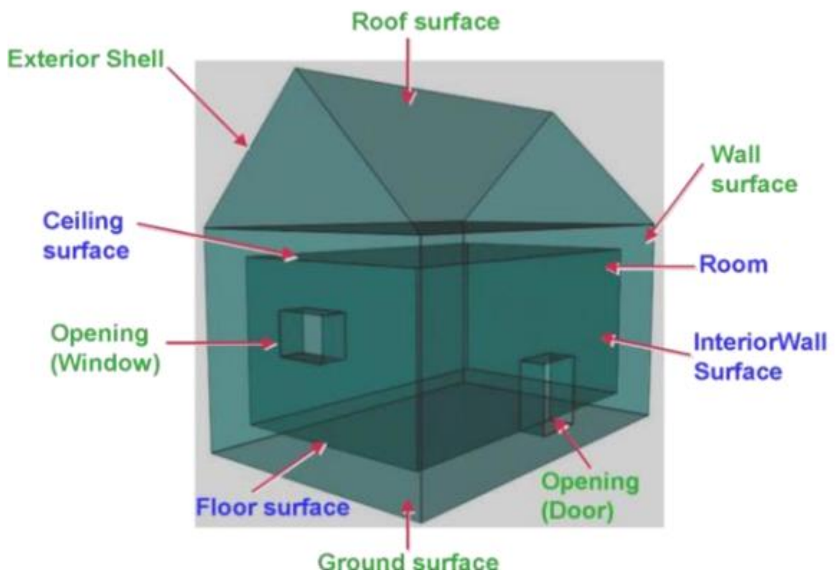
Validating model accuracy

Terminology

NTA 8800

NTA 8800 is the **Dutch norm** for determining the **energy performance** of buildings

Used for assessing the energy performance of the building stock for **Dutch regulation**



CityGML

Semantic 3D city model

3D city model is a **digital** representation of the urban environment, e.g. building objects, with **geometries**

Semantic 3D city model can also store **contextual** and **functional** meaning, e.g. a building object has a **wall surface** made out of **wood**

CityGML is a data model that can represent **semantic 3D city models**

Research Question

To what extent can a heat demand model be developed that adapts and implements the NTA 8800 to be coupled with CityGML-based semantic 3D city models?

Methodology

Research Roadmap

PHASE 1

Content Analysis

- Read the *NTA 8800*
- Outline the formulas for space heating demand
- Formulate a mind map to space heating demand calculation
- Data requirement & mapping

PHASE 2

Model Implementation

- Implement *NTA 8800* principles into a Python script
- Model testing with a semantic 3D city model

PHASE 3

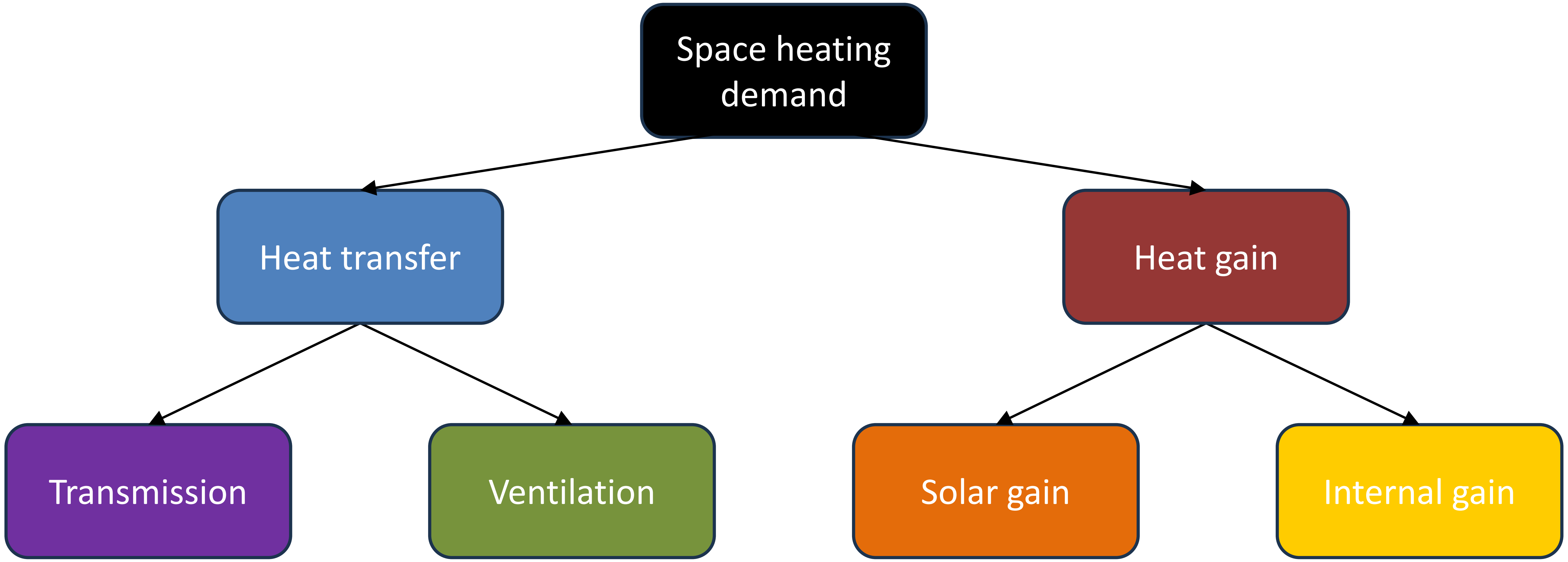
Results comparison

- CitySim Pro modelling
- Compare *NTA 8800* model results with CitySim results, energy performance indicators and CBS ground-truth

Content Analysis

PHASE 1

Concept Mapping:
Space Heating Demand Depends On



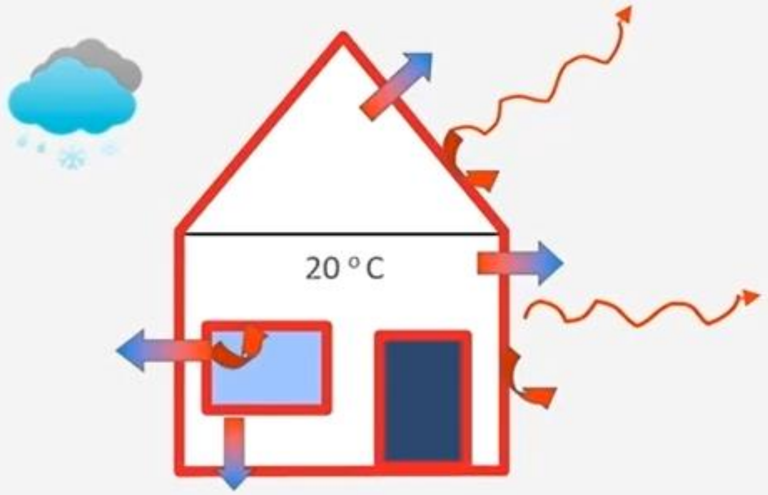
Concept Mapping:
Space Heating Demand Depends On

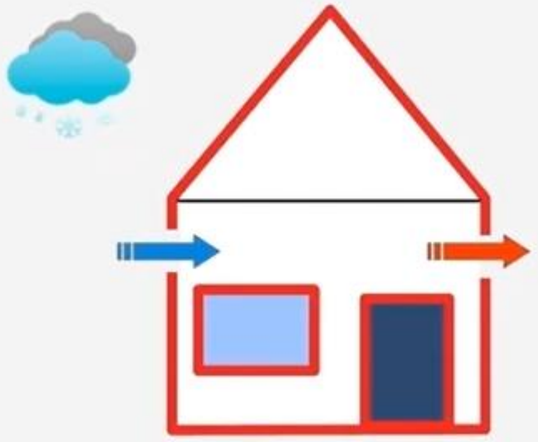
Transmission

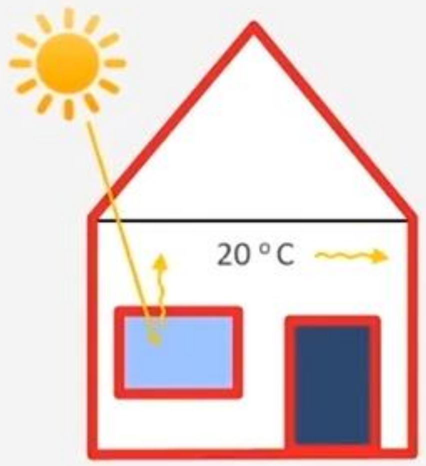
Ventilation

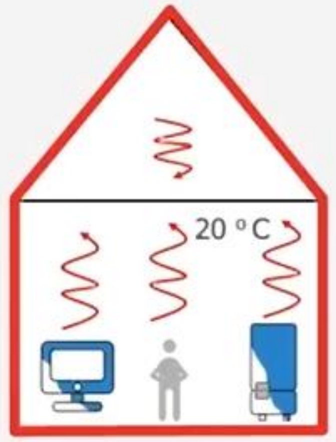
Solar gain

Internal gain





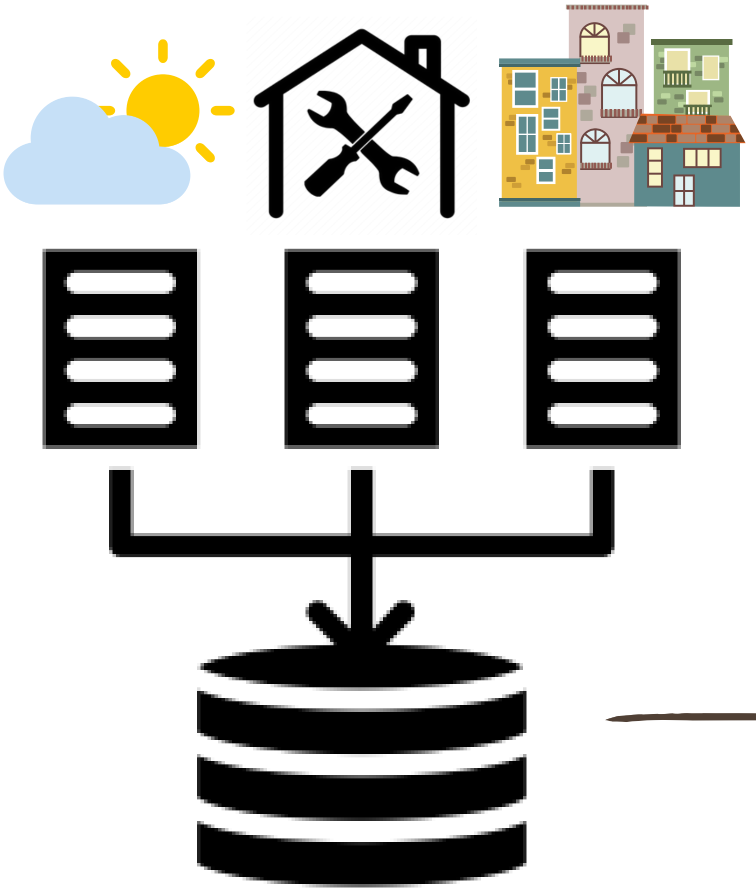




Model Implementation

PHASE 2

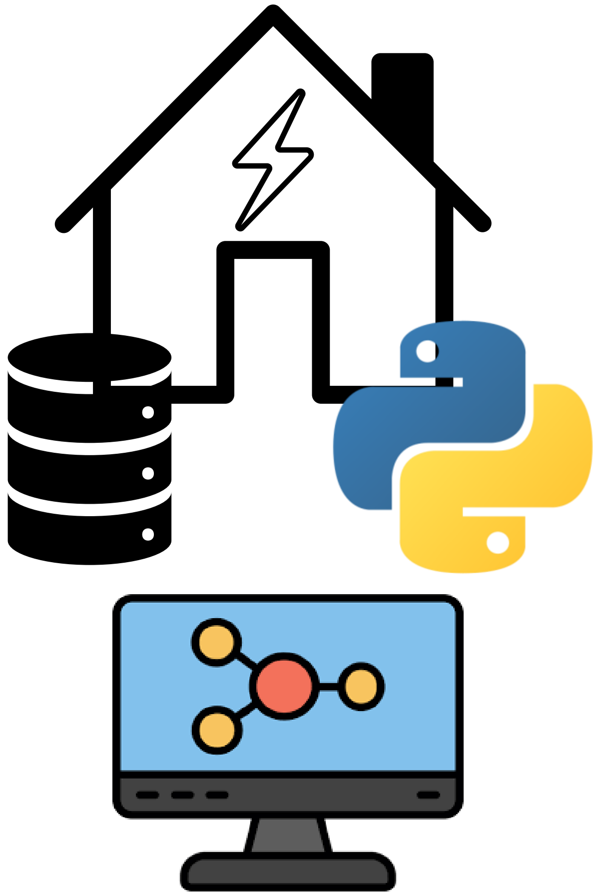
Model Implementation Steps



01 DATA REQUIREMENTS

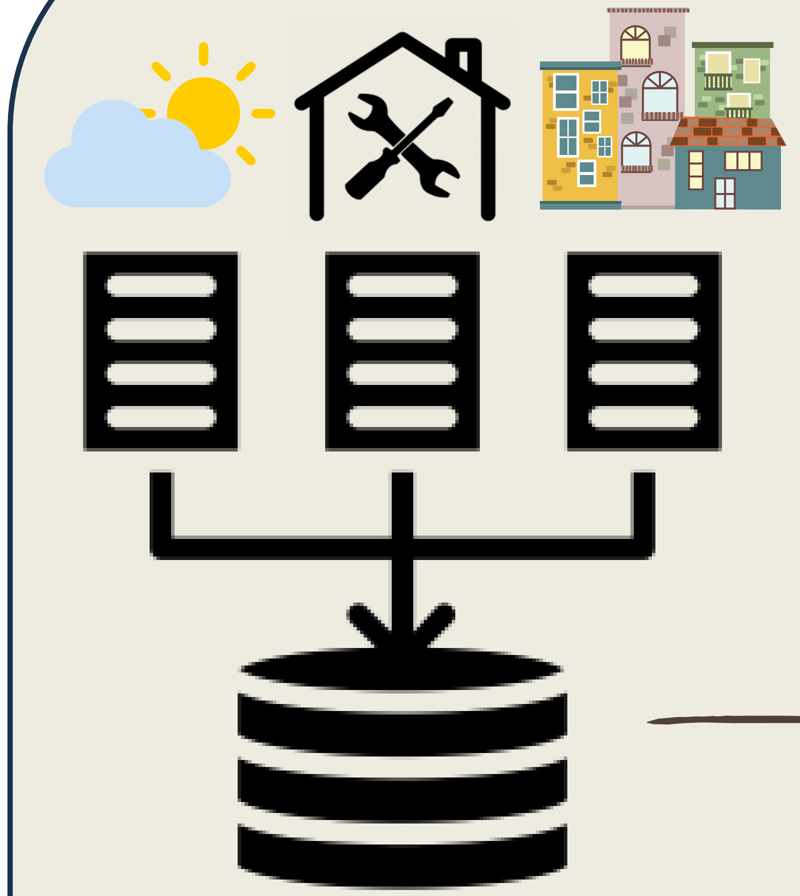
Based on the content analysis*

02 MODEL IMPLEMENTATION



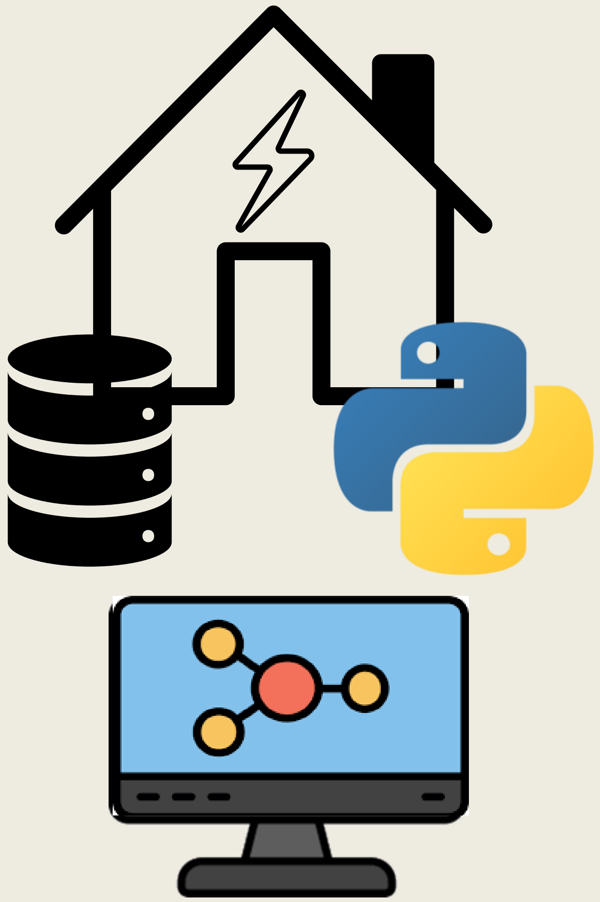
03 MODEL TESTING

Model Implementation



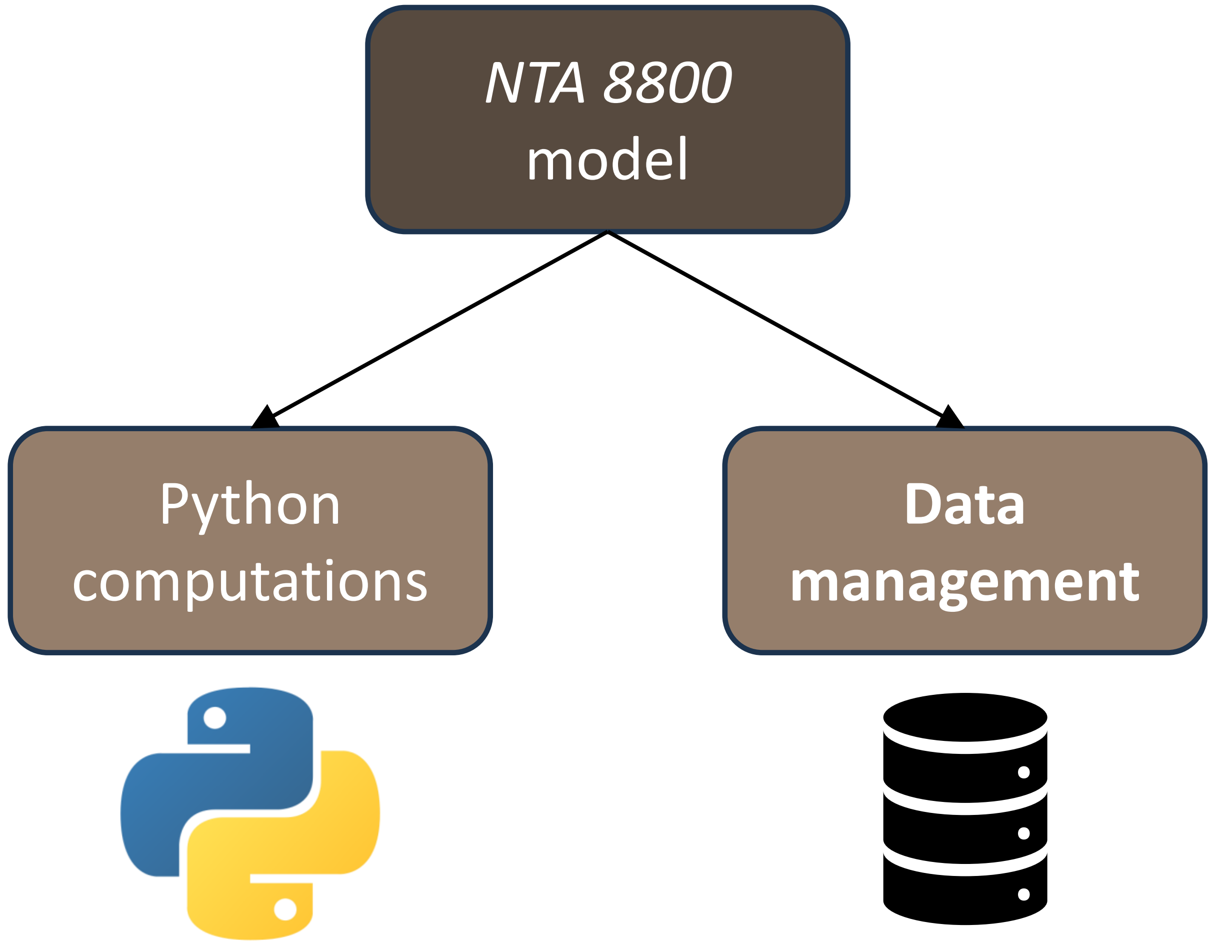
01 DATA REQUIREMENTS

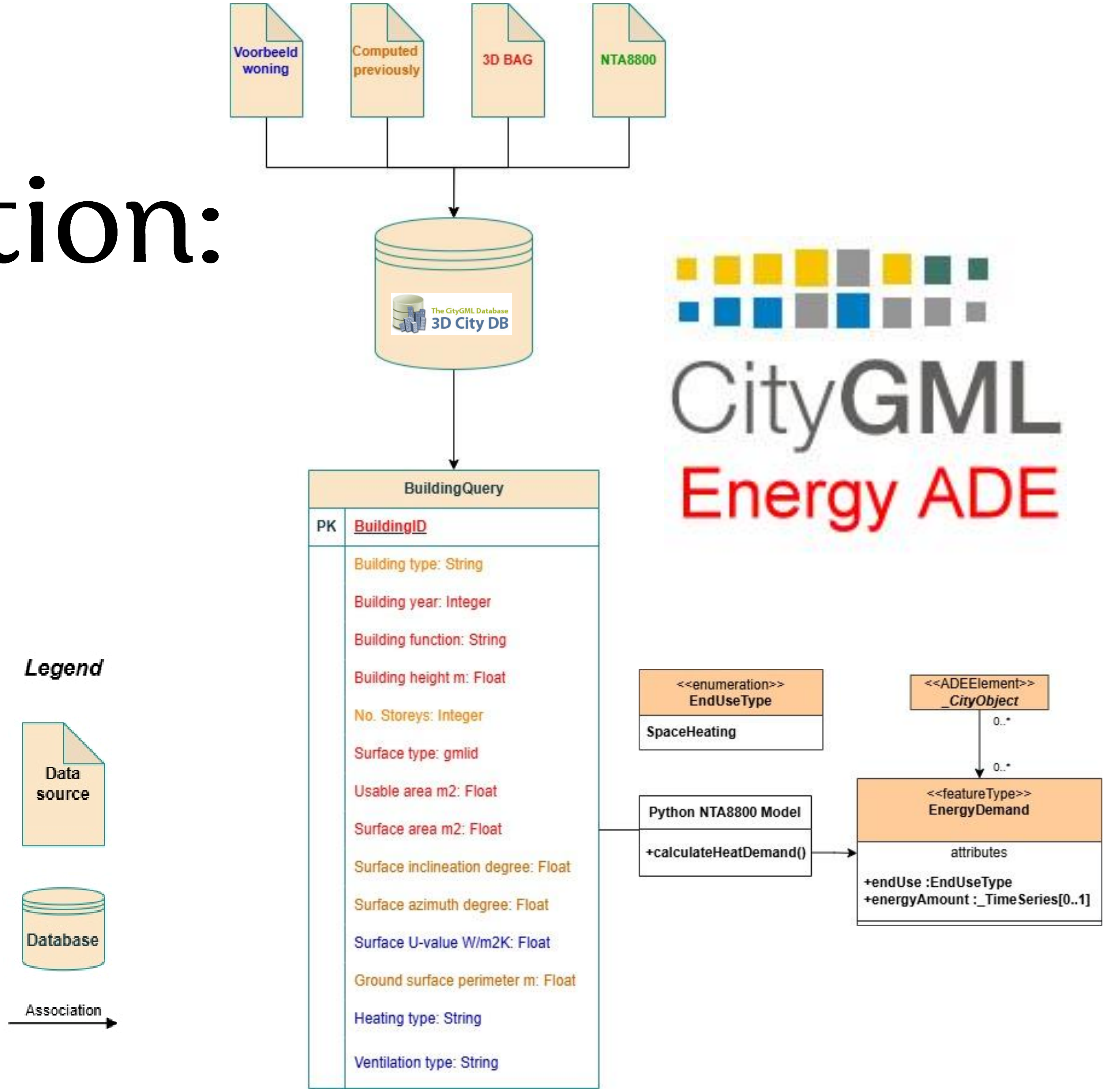
02 MODEL IMPLEMENTATION



03 MODEL TESTING

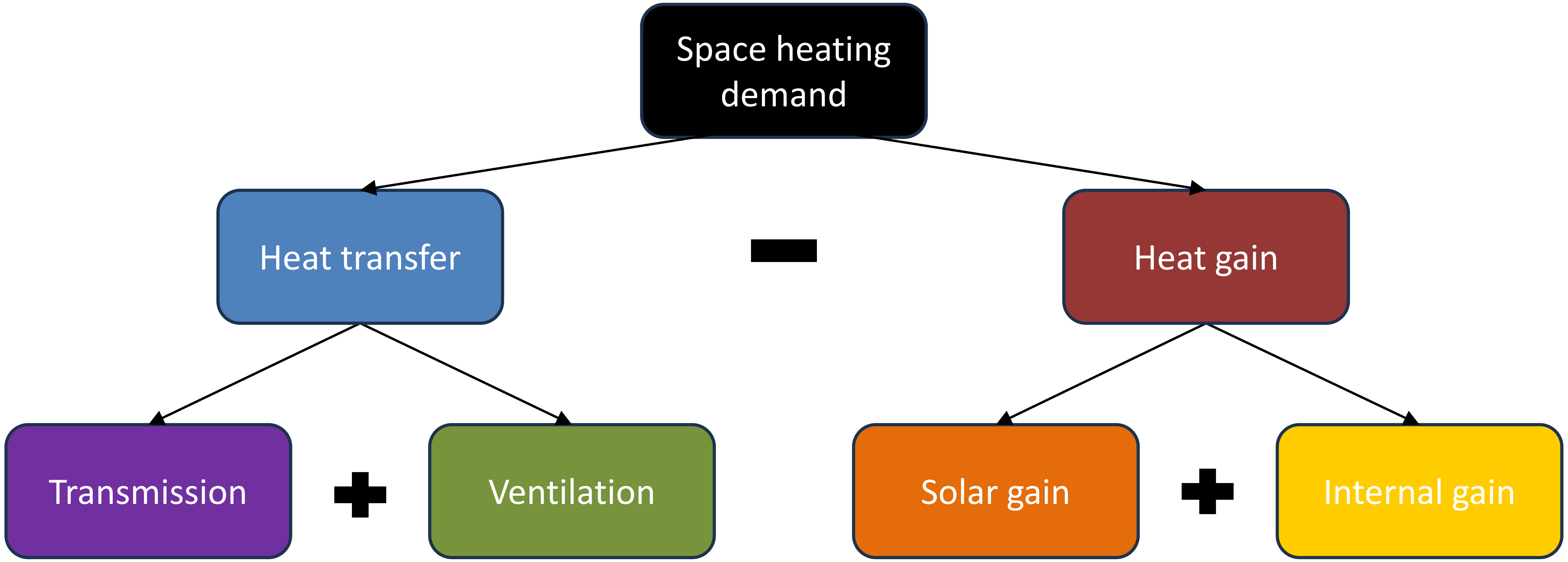
Model Implementation:
Data management





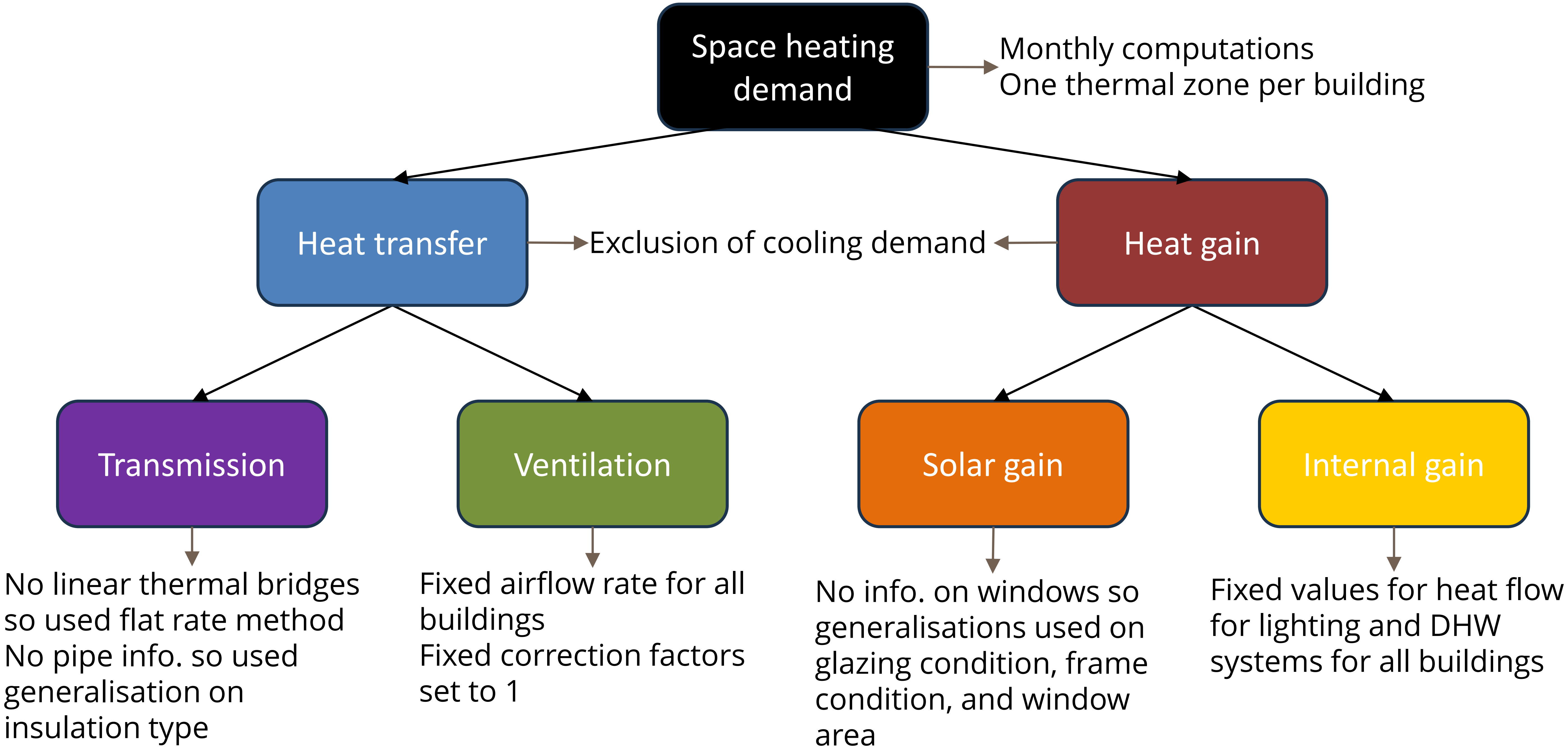
CityGML
Energy ADE

Model Implementation:
Python computations

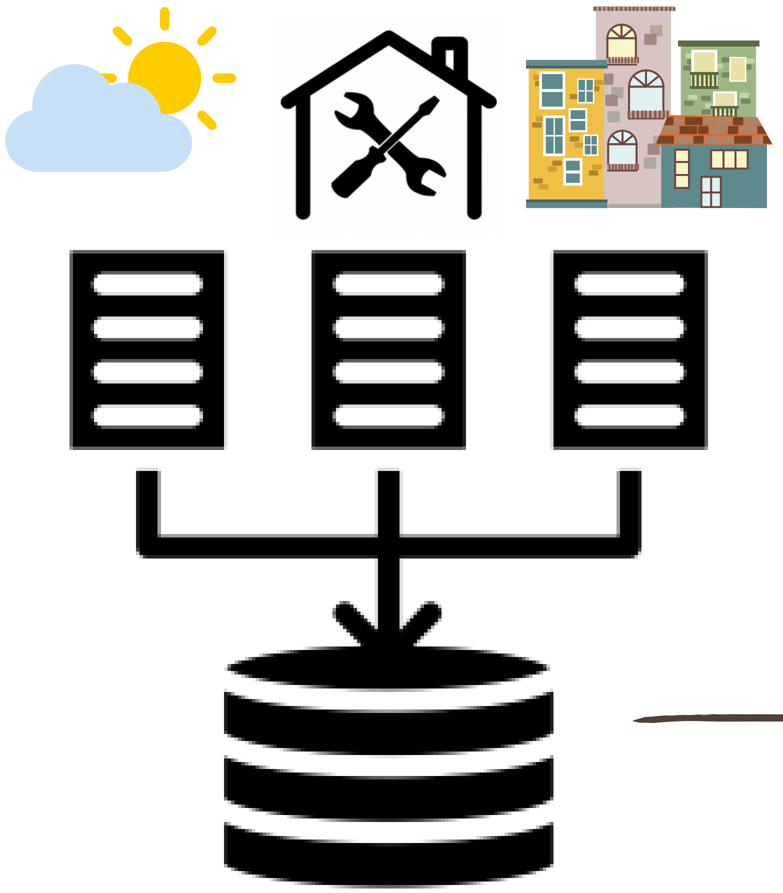


Model Implementation:

Assumptions

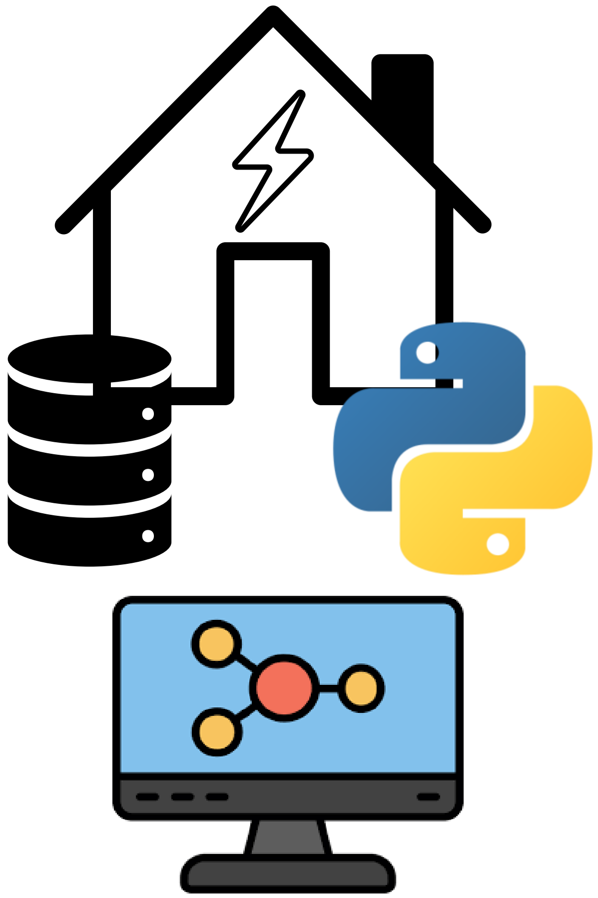


Model Testing



01 DATA REQUIREMENTS

02 MODEL IMPLEMENTATION



03 MODEL TESTING

Study Area: Rijssen-Holten

In Overijssel, the Netherlands

There are around 15,005 buildings in Rijssen-Holten

CityGML dataset contains 2588 building in Rijssen

Most enriched semantic 3D city model available

Test buildings:

ID 1742100000006518

Residential building

Built in 1965

Building type: semi-detached house

Perimeter: 26.14 m

Usable area: 90 m2

Energy label C

Test buildings:

ID 1742100000004574

Residential building

Built in 1923

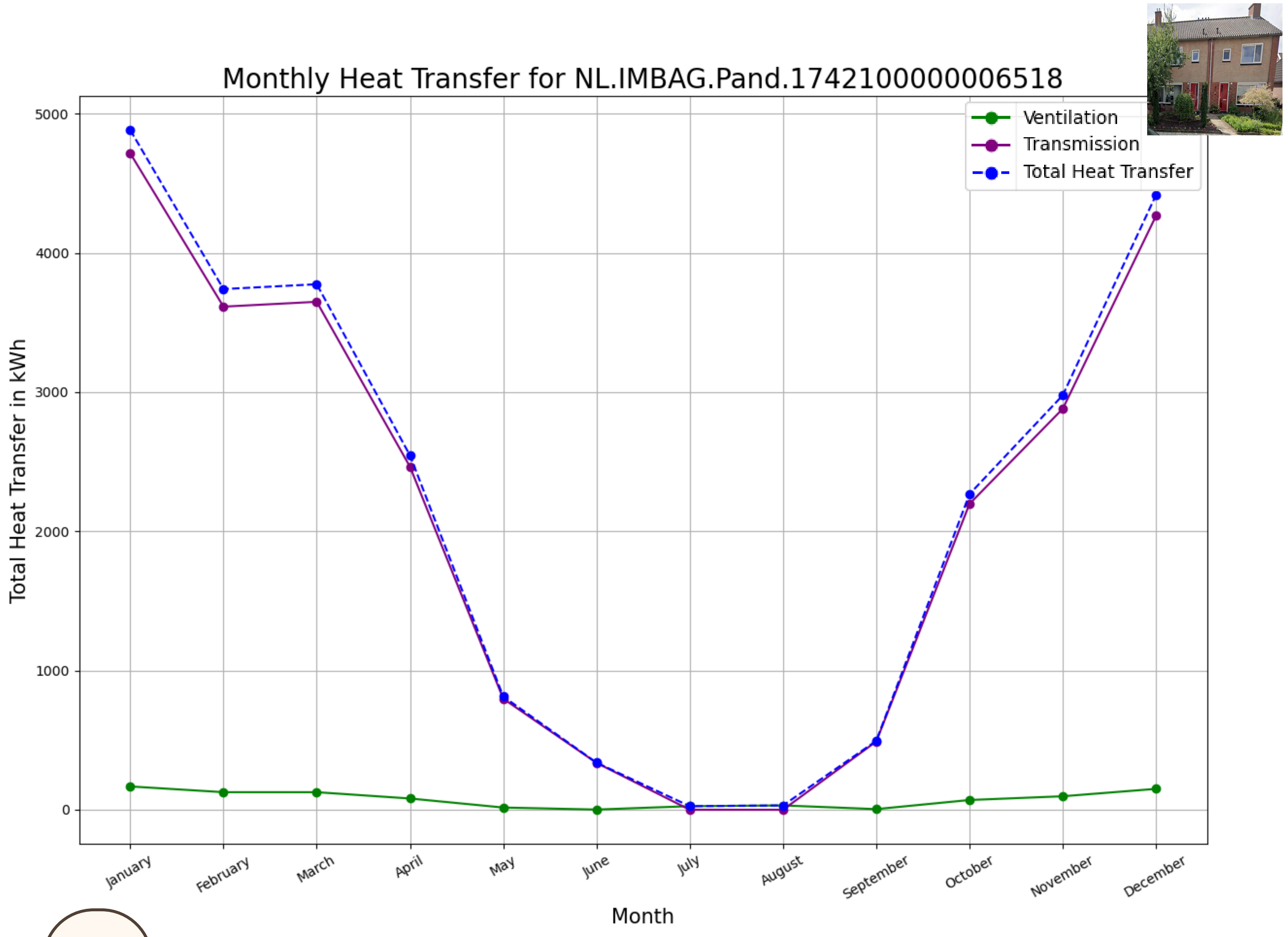
Building type: detached house

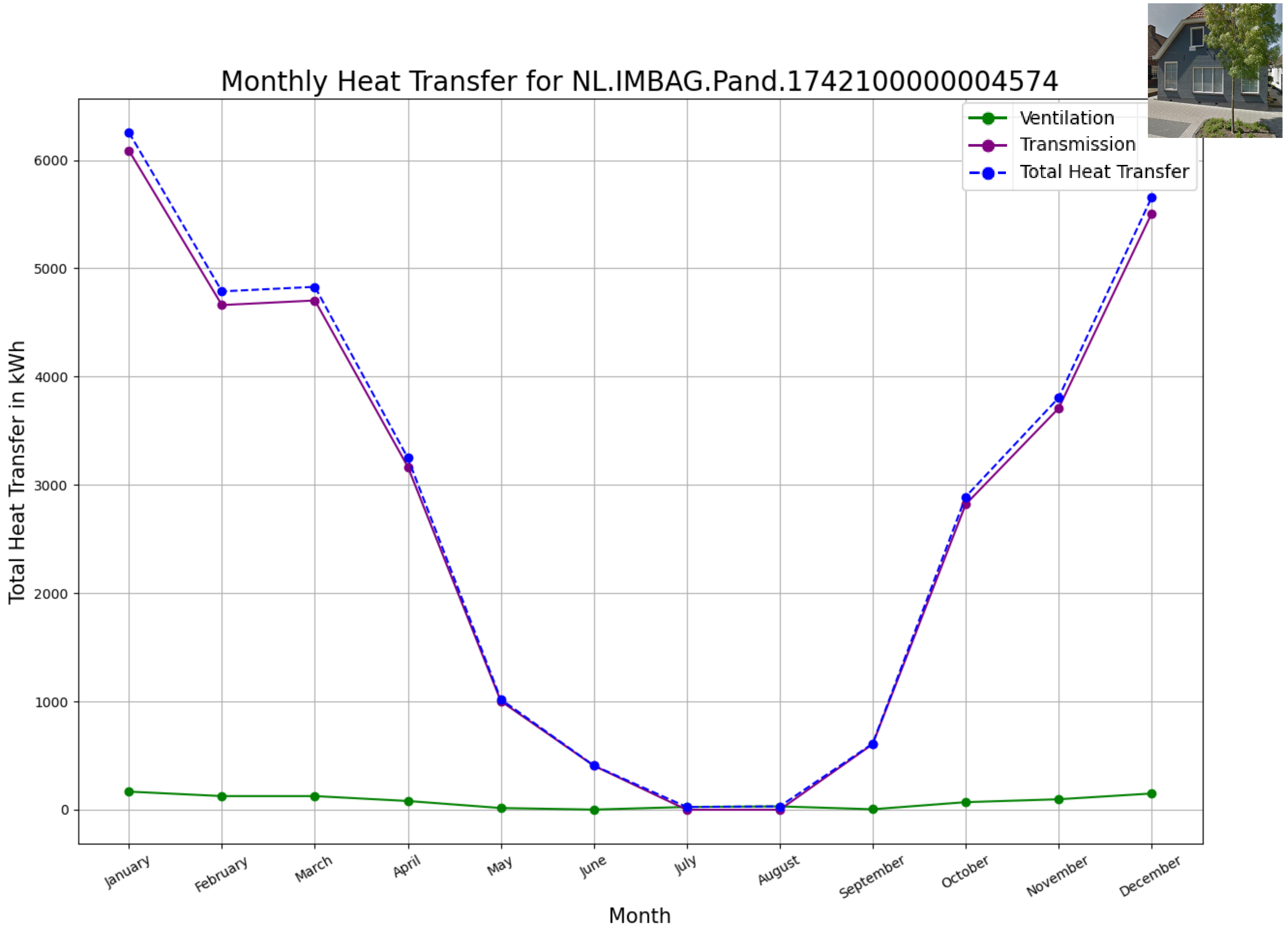
Perimeter: 34.45 m

Usable area: 144 m2

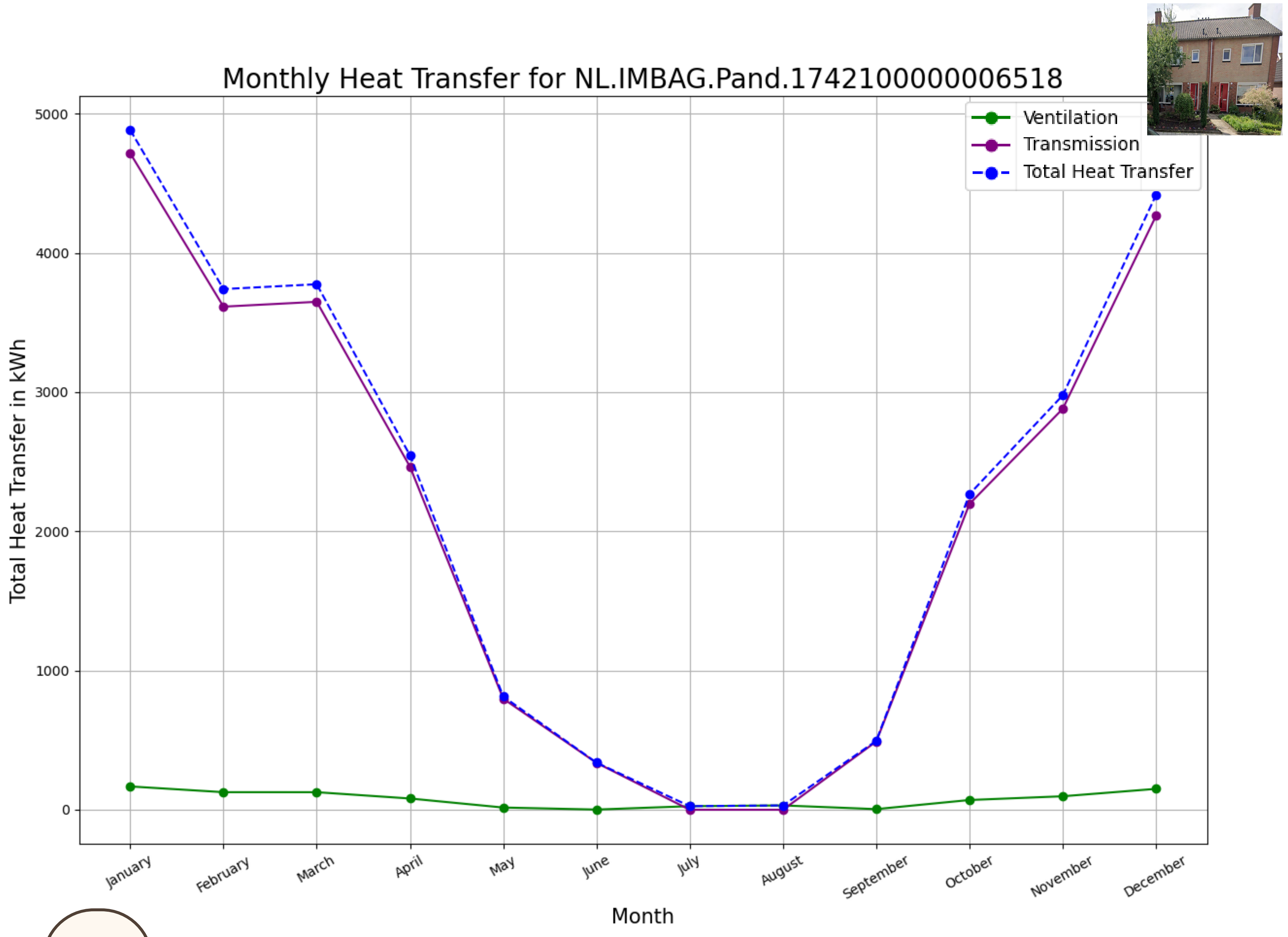
No energy label

Heat Transfer = Transmission + Ventilation

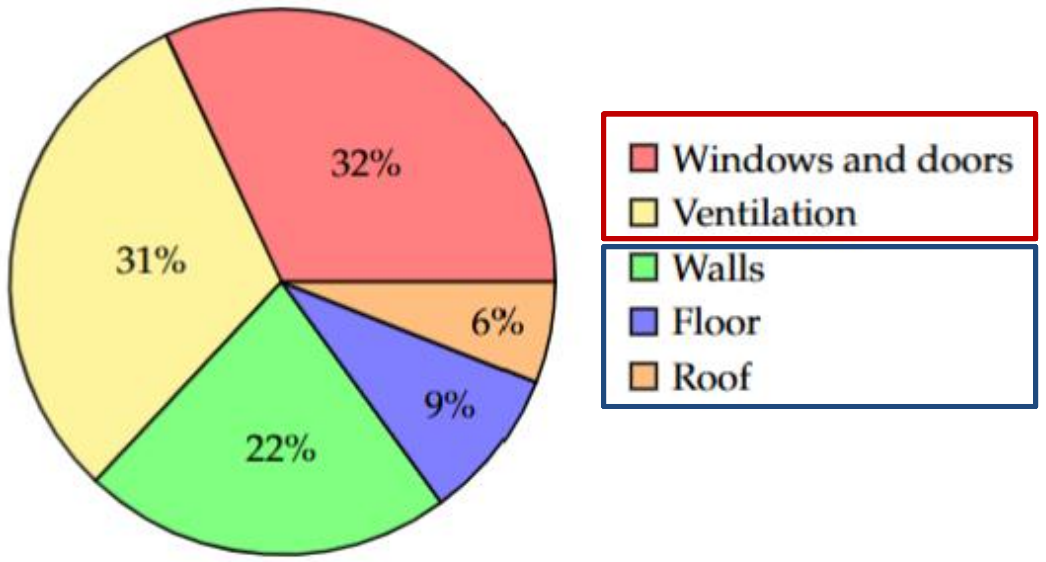




Heat Transfer Considerations



Heat Transfer Distributions



- Missing in model implementation
- Model's transmission consists of: Walls & roof: highest impact Floor: second largest, followed by heat transfer through pipes

NTA 8800 formulation

$$Q_{\text{ventilation}} = H_{\text{heat transfer coeff. for ventilation}} \cdot (\theta_{\text{indoor temperature}} - \theta_{\text{outdoor temperature}}) \cdot 0.001 \cdot \text{time} \quad (1)$$

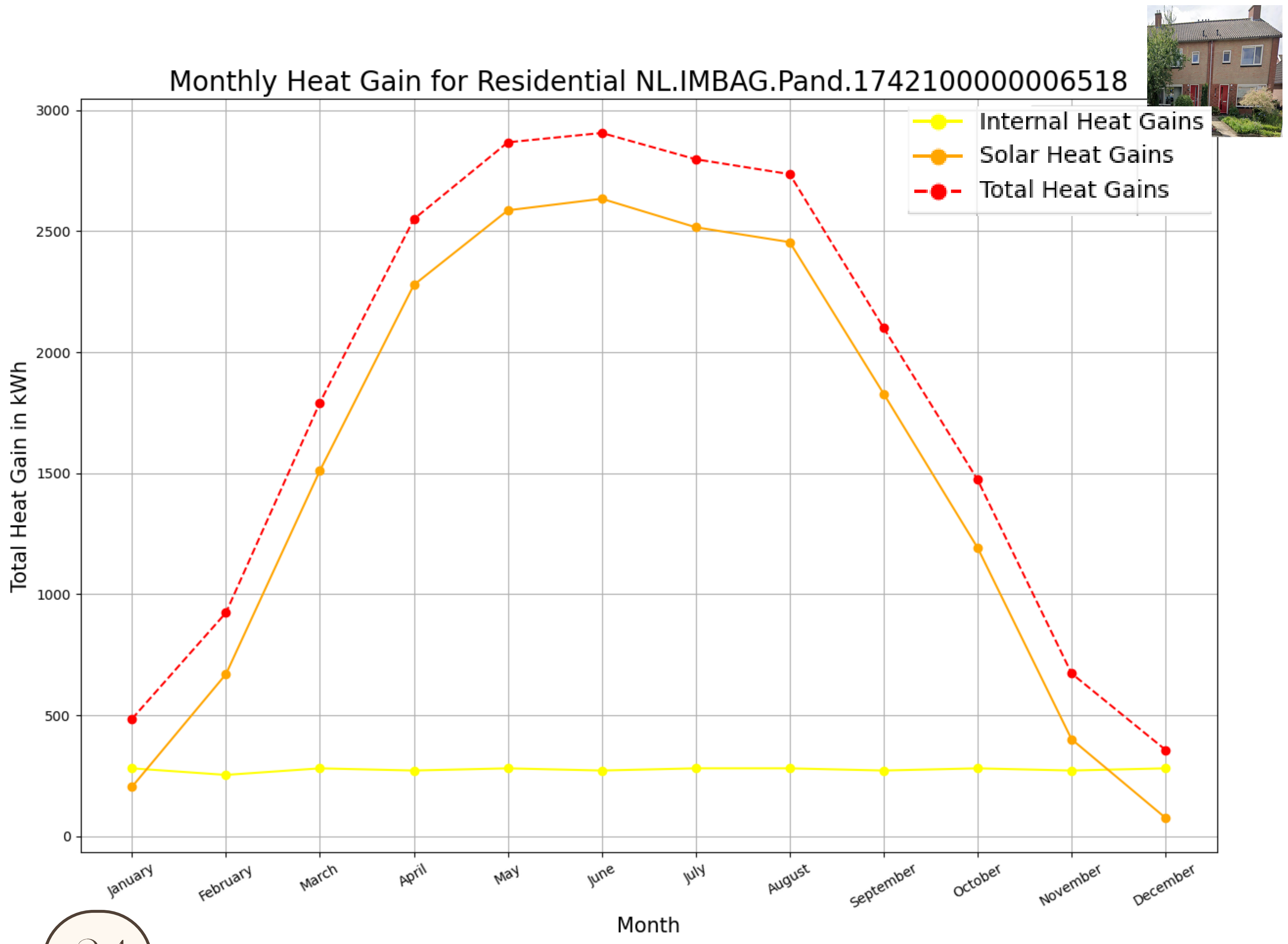
In which:

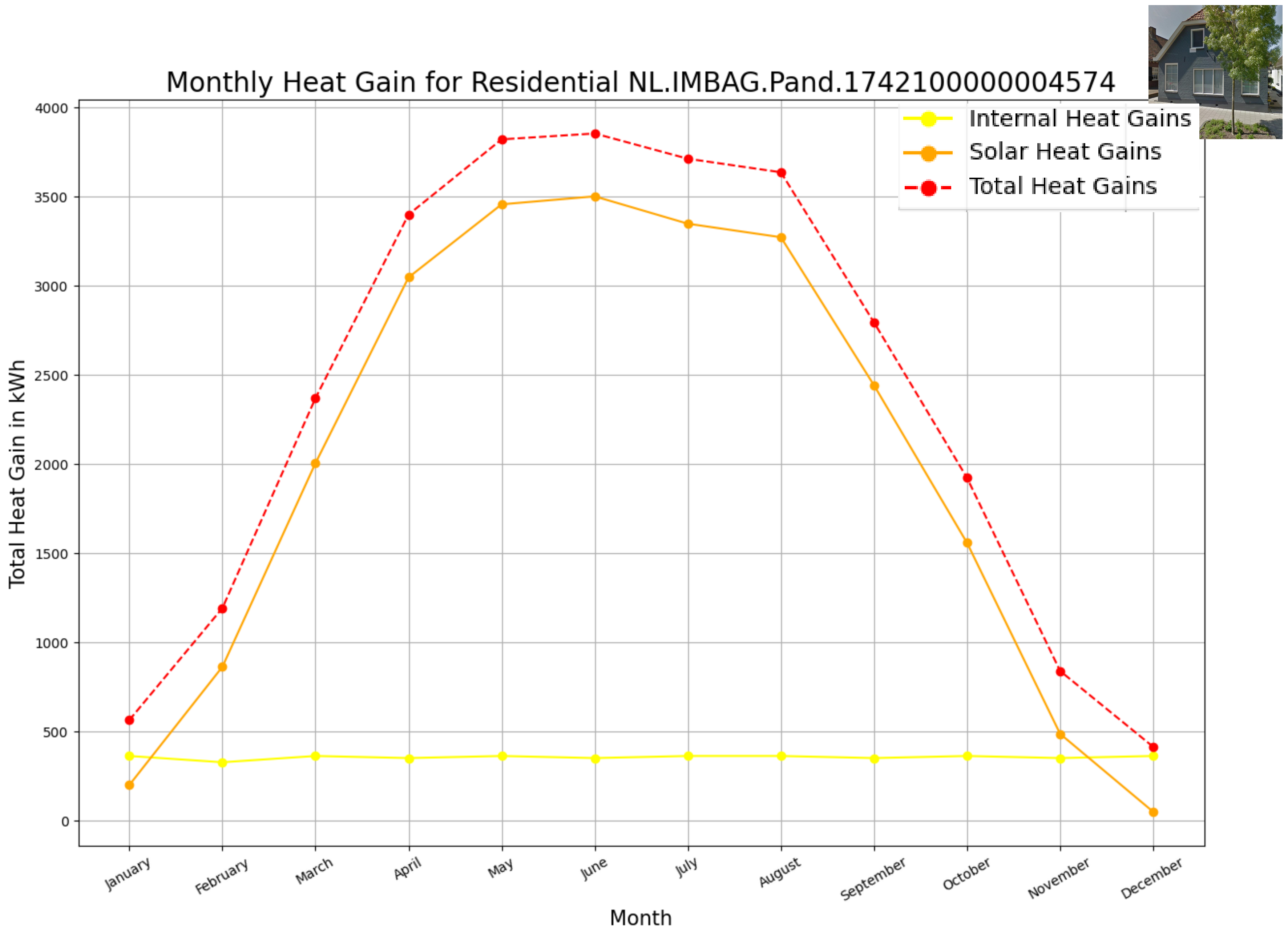
$$H_{\text{heat transfer coeff. for ventilation}} = \text{heat capacity of air} \cdot \frac{\sum(\text{airflow})}{3600} \quad (2)$$

Other formulations

$$Q_{ventilation} = 0.33 \times \text{no. air changes per hour} \times \text{building volume} \times \Delta\text{temperature diff.}$$

Heat Gain = Solar gain + Internal gain





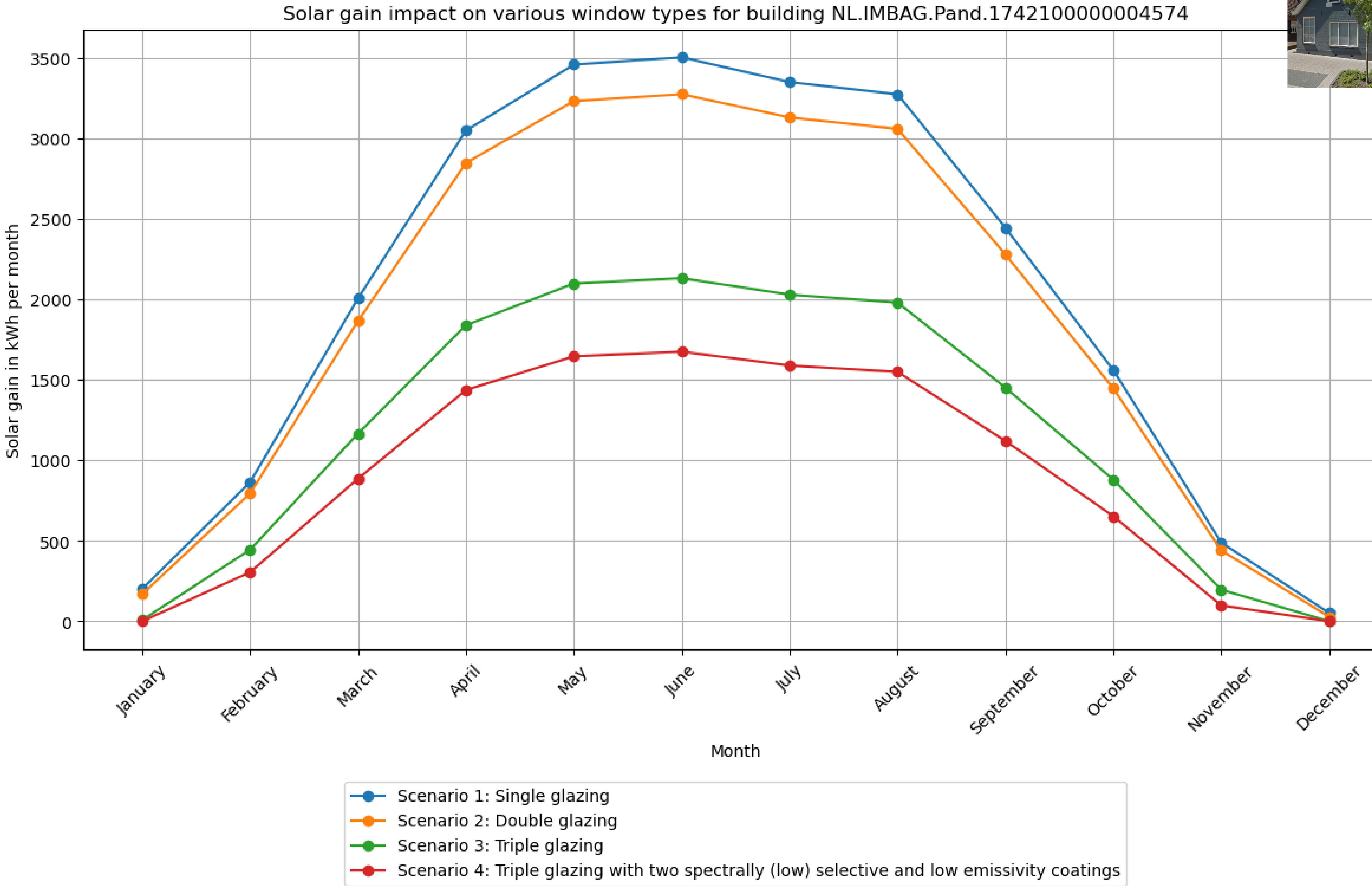
Solar Gain Scenarios

Minimal difference between single and double glazing in summer (7% difference)

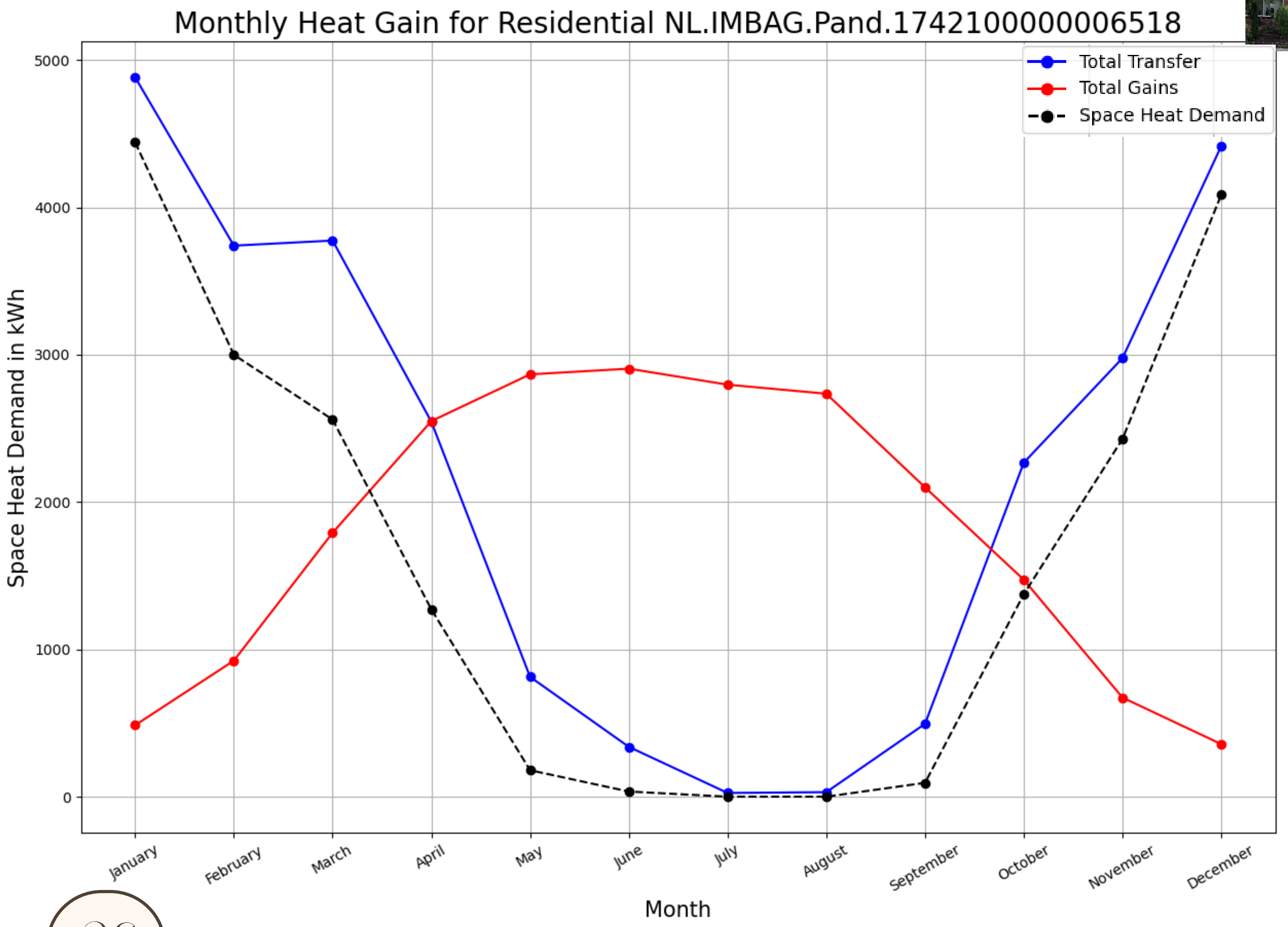
High impact of triple glazing on solar gain reduction (65%-110% difference)

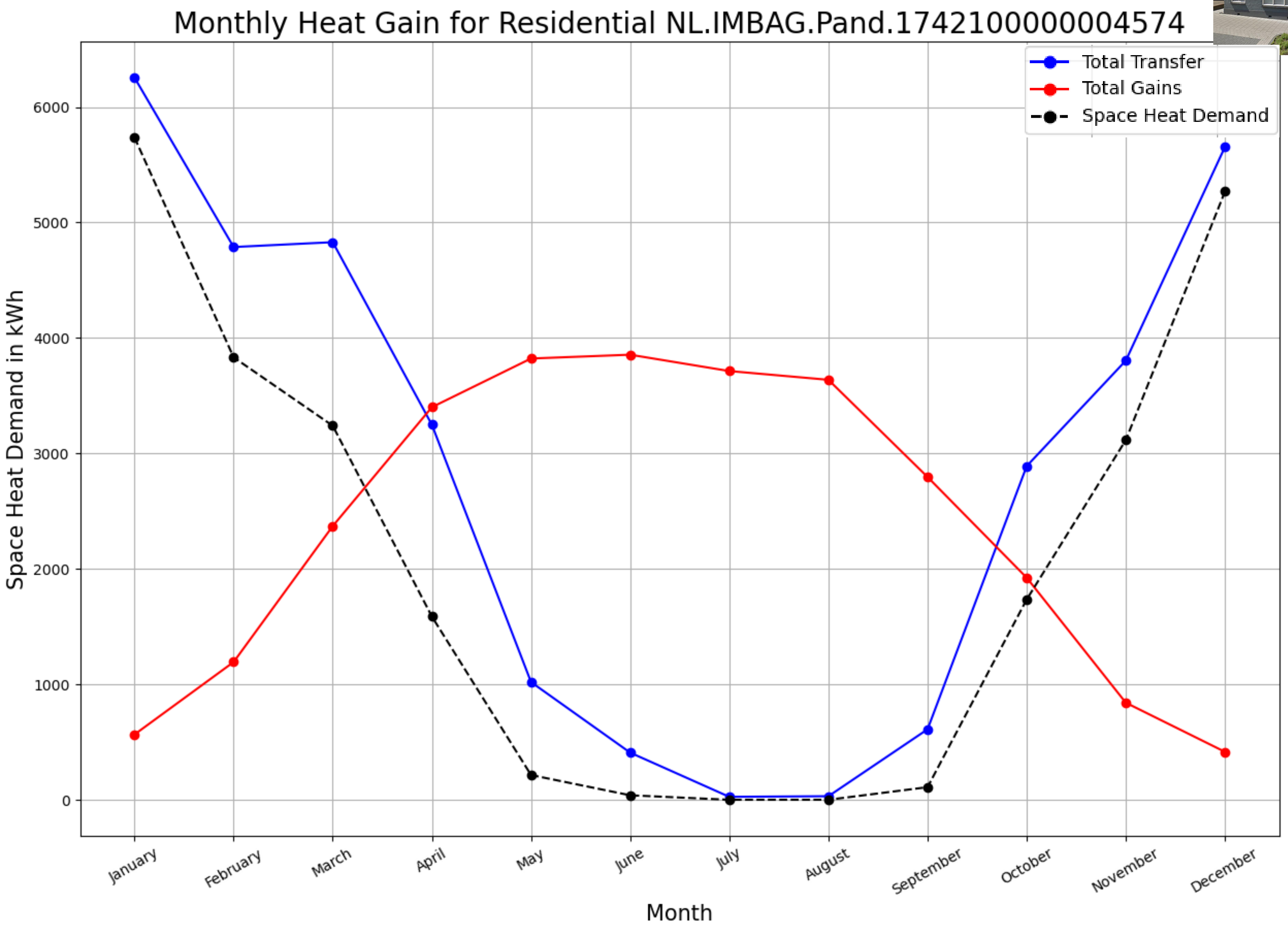
Triple glazing offers the best thermal performance, minimizing heat transfer

Single glazing beneficial in winter for reducing heating demand but causes overheating in summer



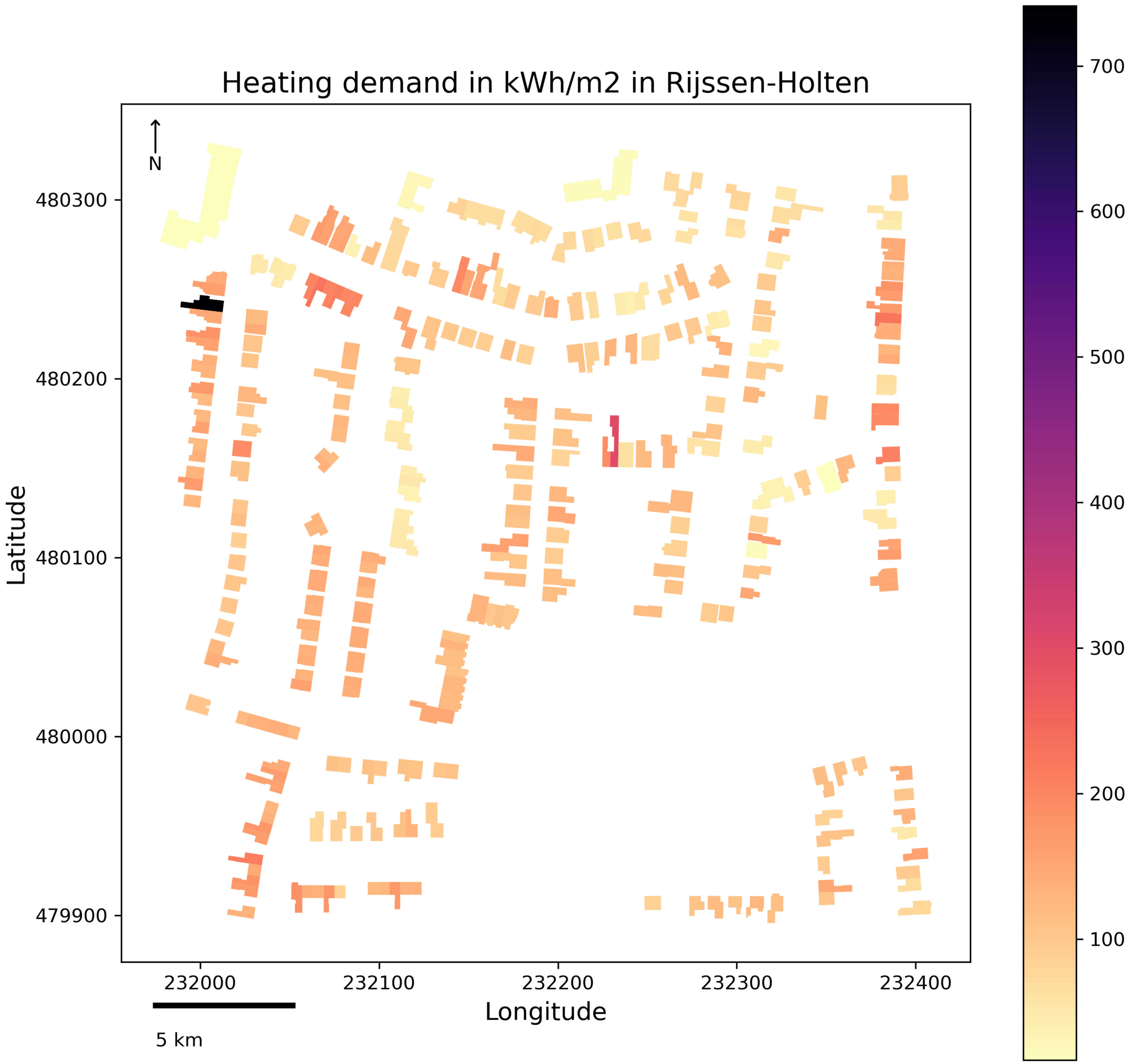
Space Heating Demand





Rijssen-Holten Space Heating Demand

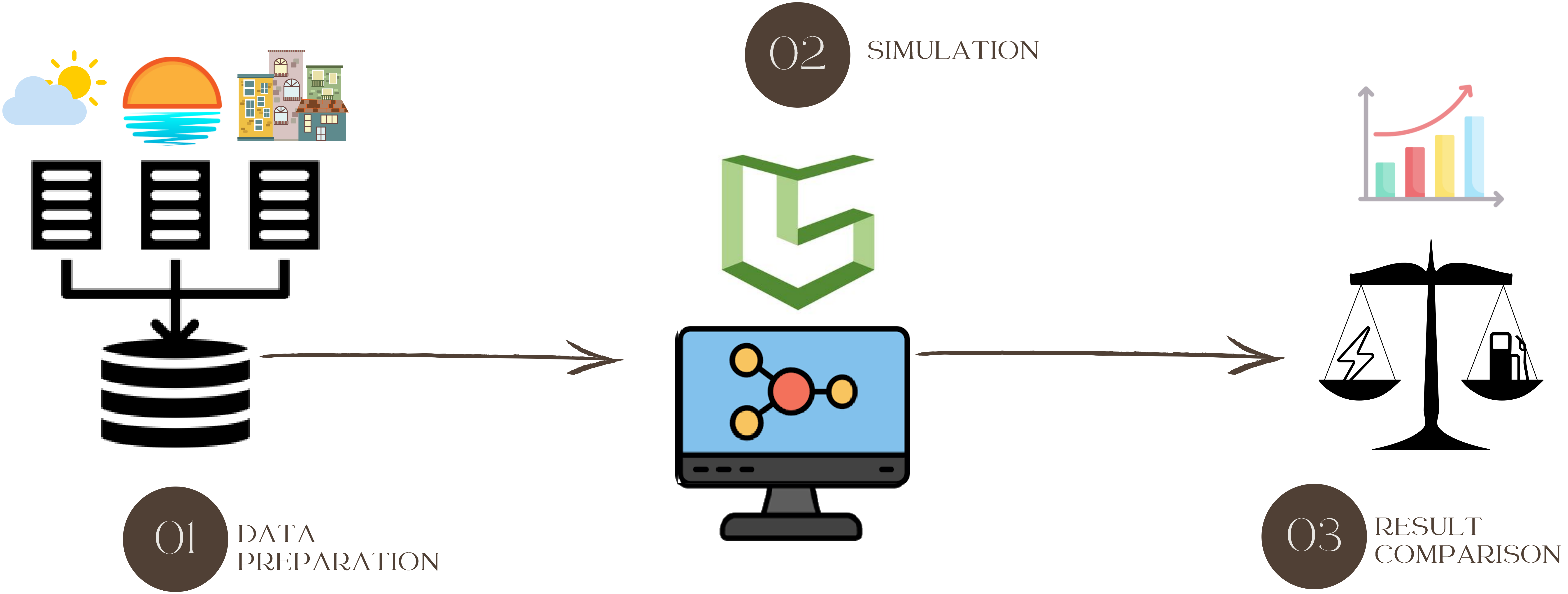
Descriptive statistics	Model results
Count	324
Mean	117.4
Min	16.8
Max	741.3



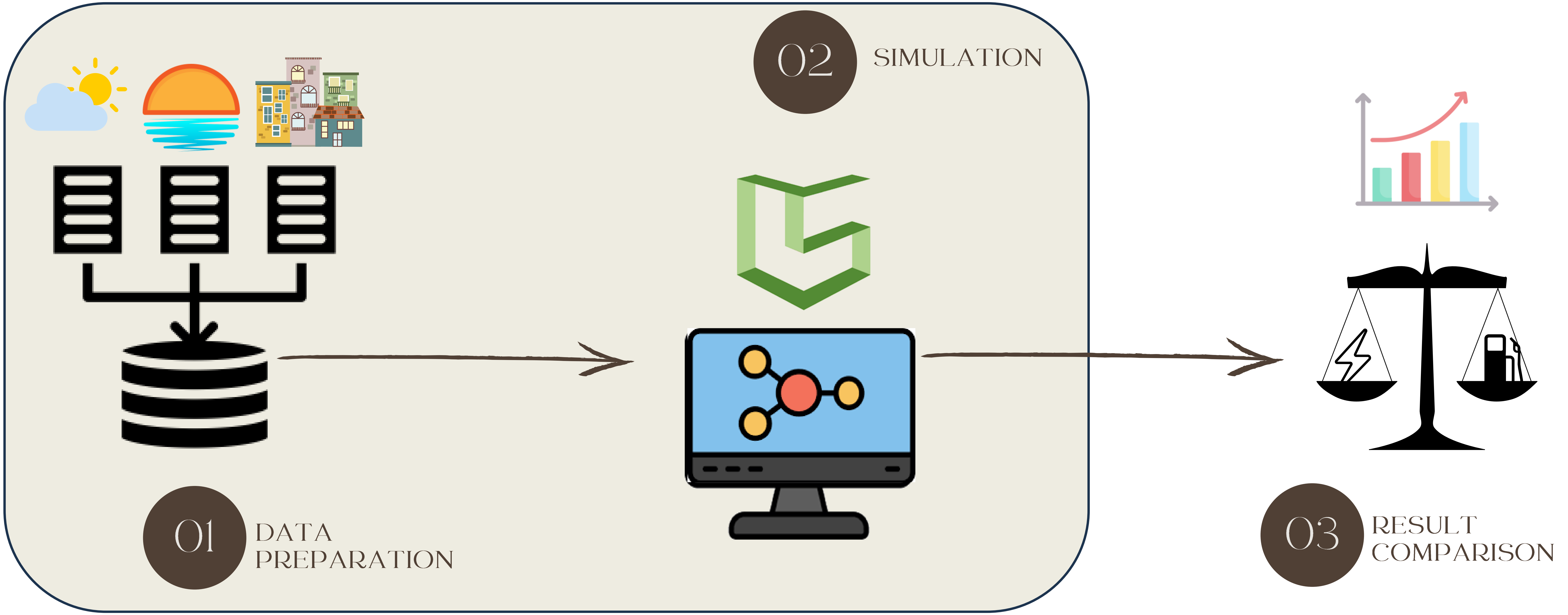
Result Comparison

PHASE 3

Model Validation Steps



Energy Simulation

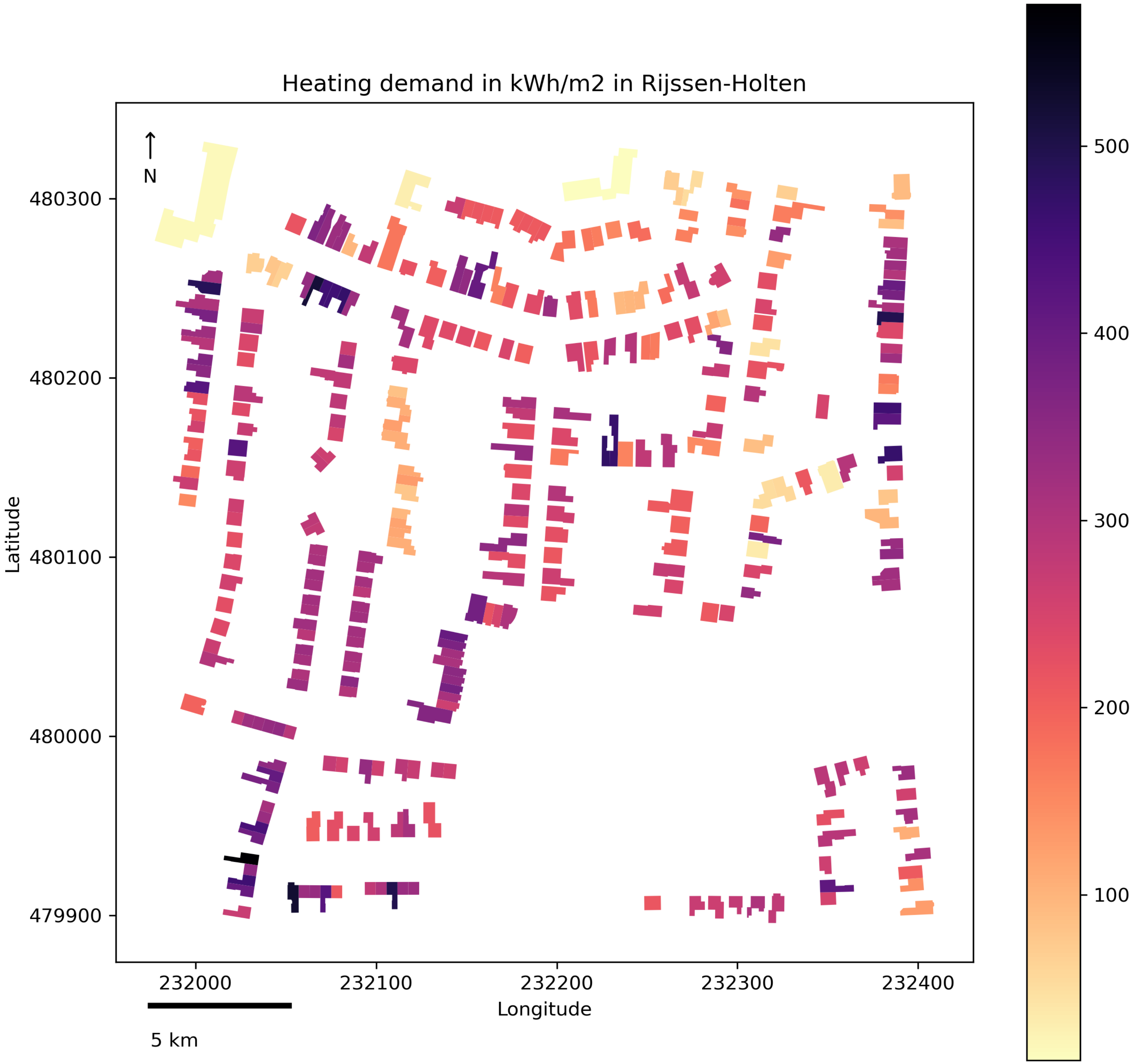


CitySim Pro Results

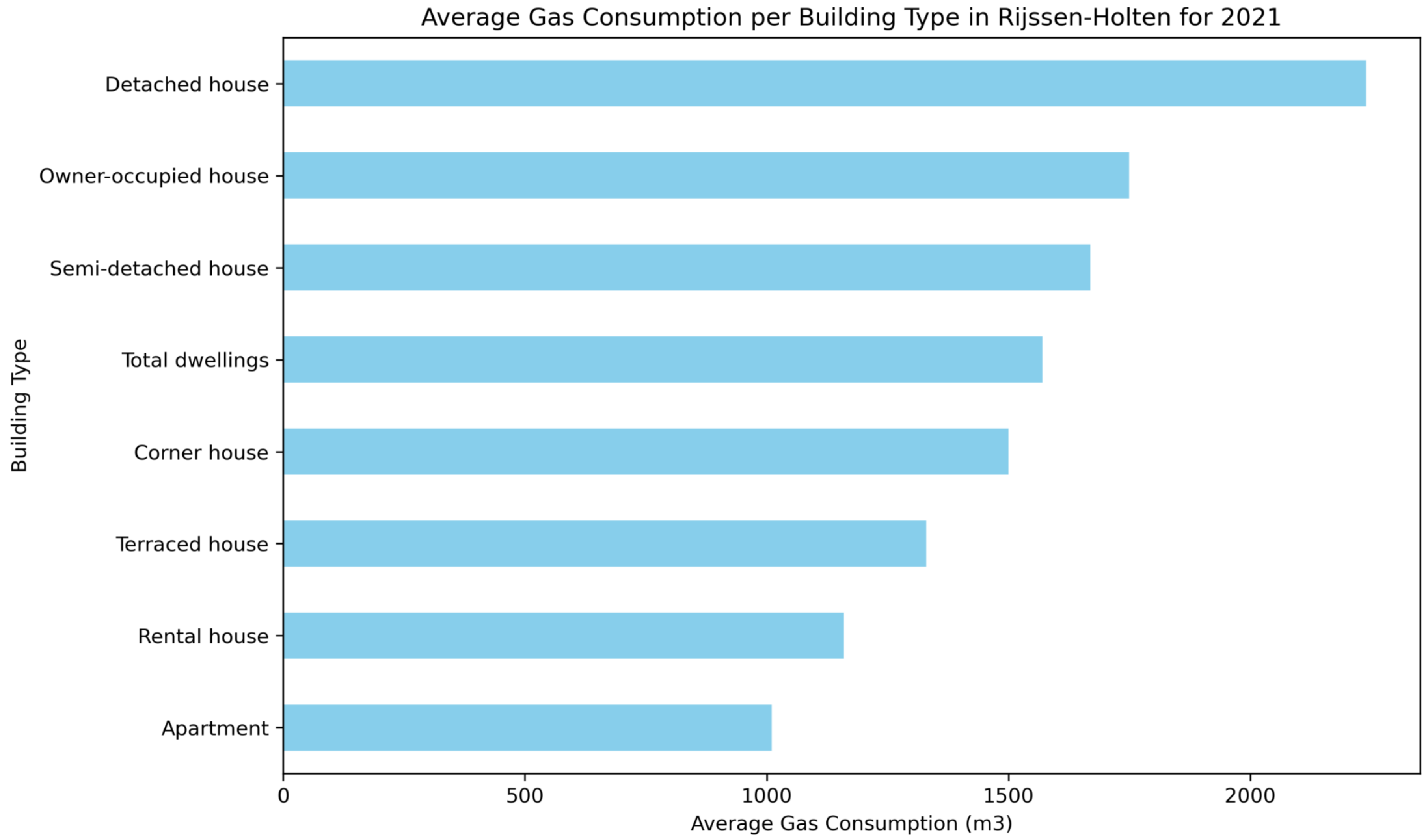
Input data:

- Horizon file (.HOR)
- Climate file (.CLI)
- CityGML building geometries from 3D BAG
- Building characteristics from TABULA existing state

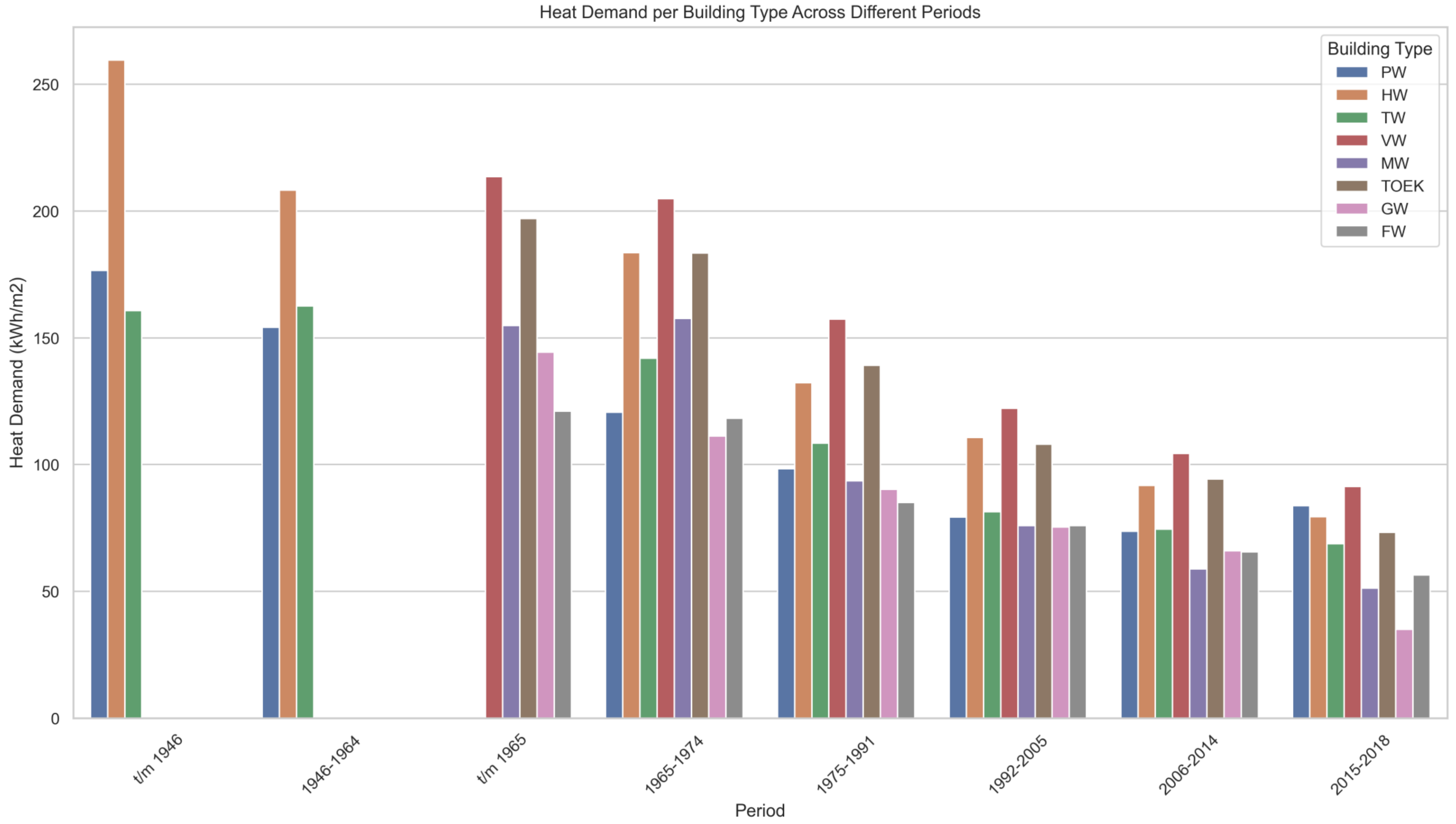
Descriptive statistics	Existing State
Count	324
Mean	260.7
Min	11.5
Max	575.7



Other collection for comparison

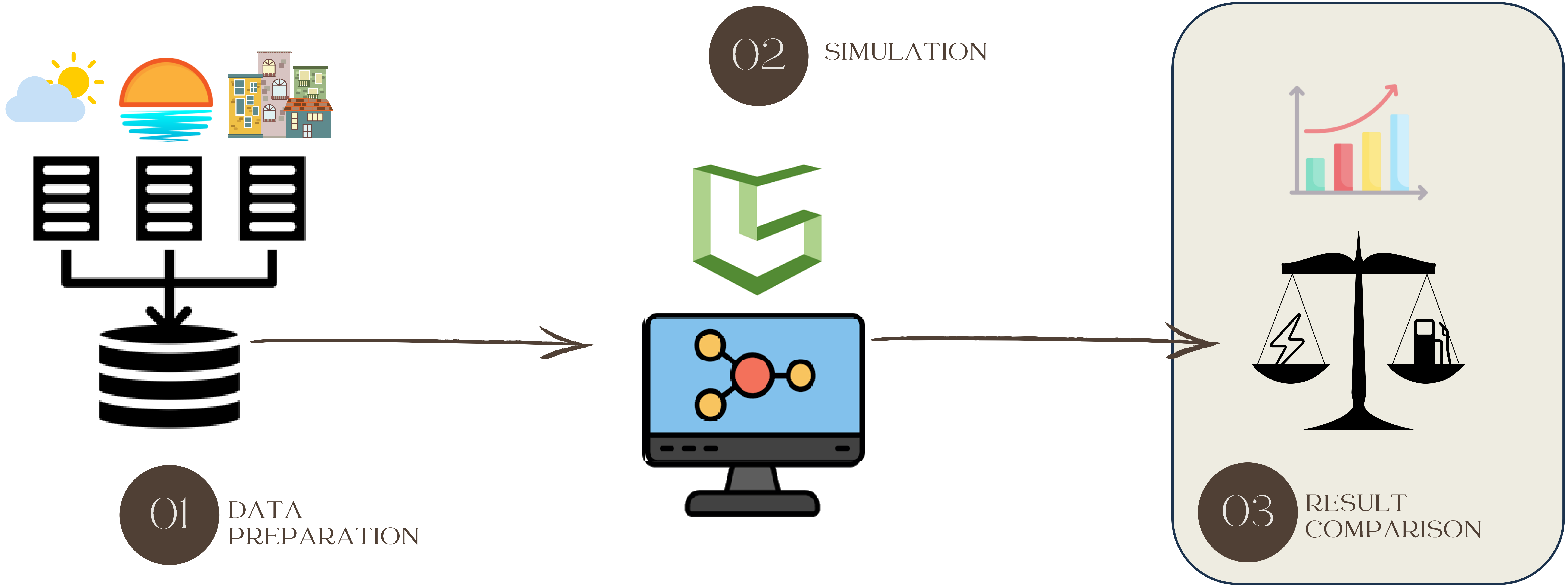


CBS gas consumption 2021 data per building type for Rijssen-Holten

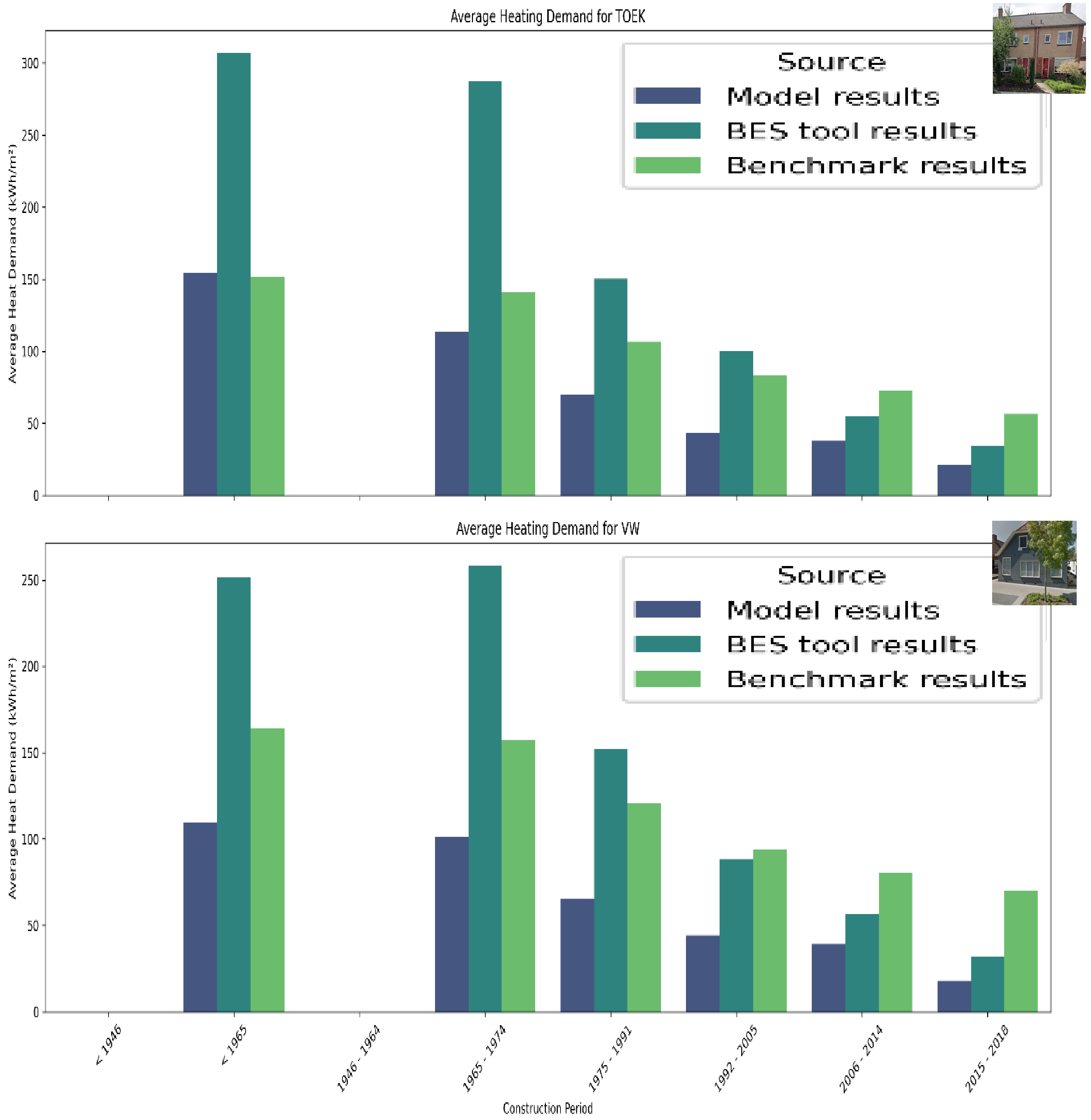


Voorbeeldwoning 2022 heat demand per building type and year

Results Comparison



Comparison



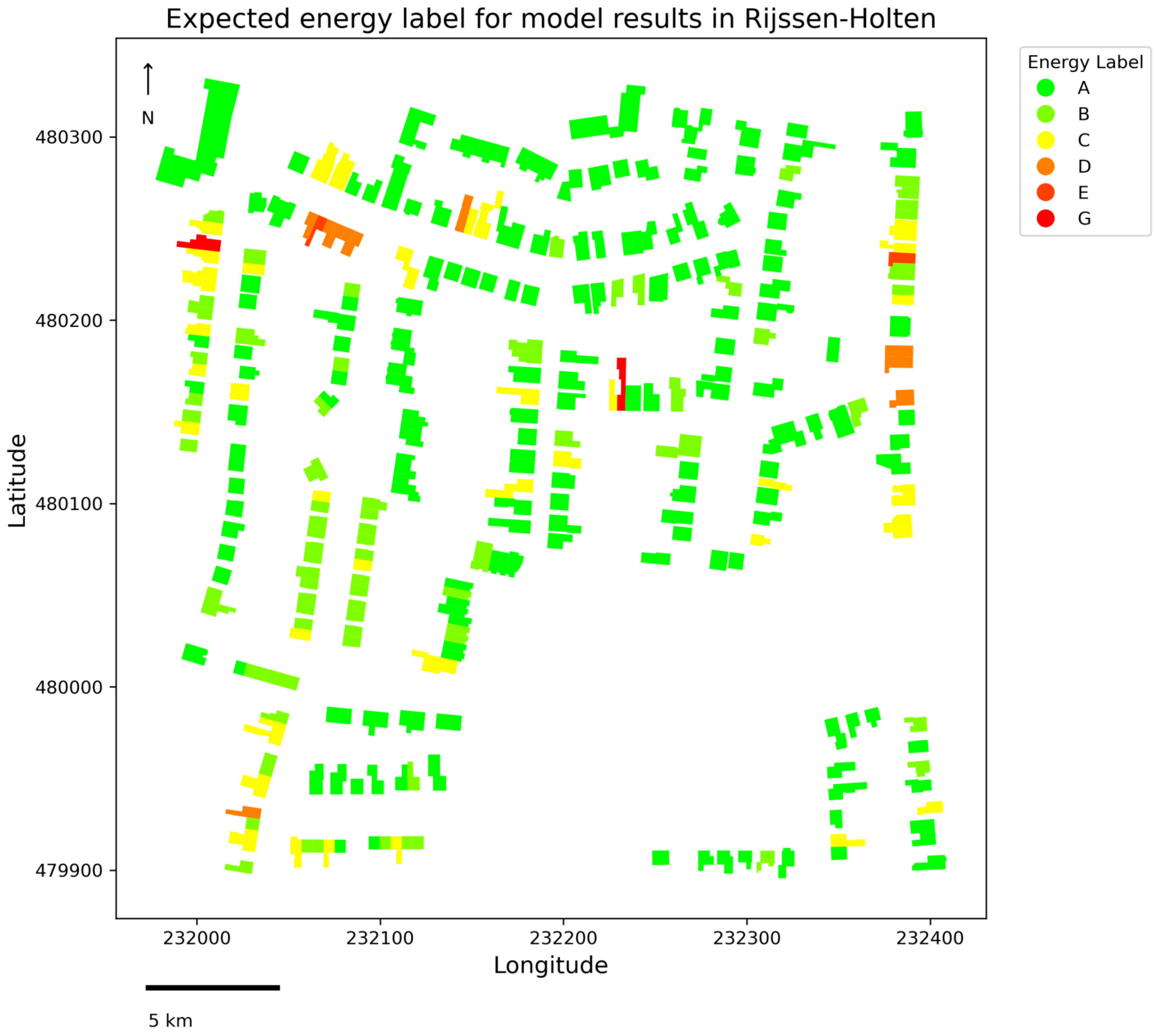
Using statistical metrics for entire Rijssen-Holten

Metric	CitySim Pro vs model values	CBS ground truth vs model values	Voorbeeldwoning benchmark vs model values
MAE	148.9	19886	39.8
RMSE	162.8	31862	63.5

For the two test buildings

Statistic	1742100000006518		1742100000004574	
Total space heating demand kWh/m^2/yr in the model	218.95	~27%	178.6	~43%
Total heating demand kWh/m^2/yr in *CitySim Pro*	278.6		254.8	

Energy Label



Predominantly classified buildings as energy label A (186 buildings) or B (78 buildings)

Estimated far lower energy label values

Model implementation suggests Rijssen-Holten's buildings perform better

Lower expected space heating demand results in model implementation

Final Remarks

Discussion

CURRENT SITUATION

The Dutch built environment is behind in reducing energy consumption

EU pressure to decarbonize

Need for structural adjustments in built environment

MODEL

Development of a space heating demand model following *NTA 8800*

Integration with CityGML-based semantic 3D city models

KEY INSIGHTS

Low and constant heat transfer through ventilation

Seasonal variation in heat transfer by transmission

Solar gain patterns as expected; varying impact of window quality on energy savings

Research Implications

VALIDATION

Model underestimated space heating demand

Similarities with benchmark estimates, deviations from historical data

Need for refinement and validation with diverse data sources

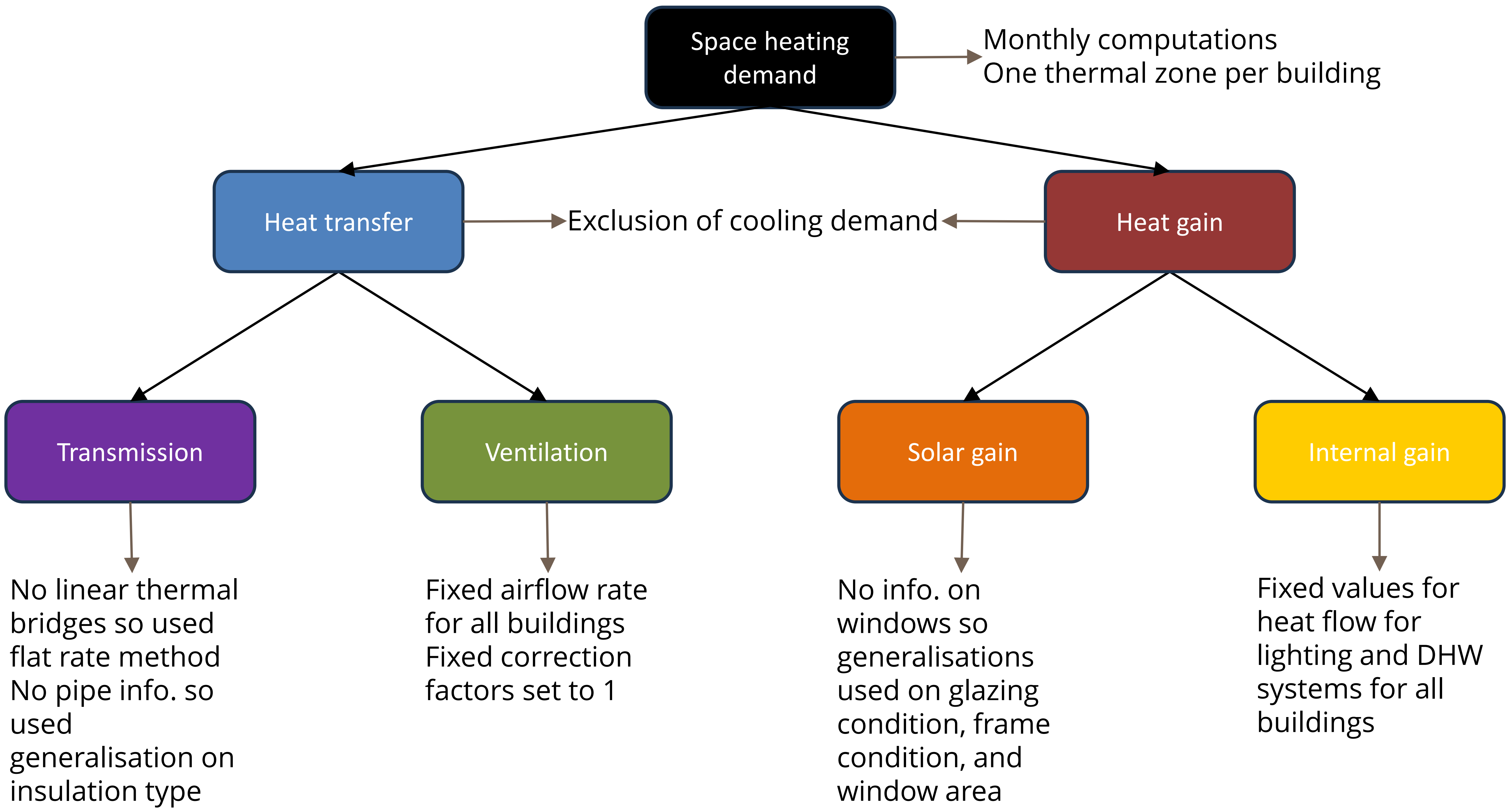
DISADVANTAGES

Simulates energy flows but should be cautioned due to limitations, predicts lower space heating demand than expected

ADVANTAGES

Can guide renovation strategies, e.g., improving window quality
Rapid computation (5 minutes for Rijssen-Holten)
Less sensitive to non-watertight geometries
Tailored for Dutch building regulation

Limitations & Future Research:



Possible improvements:

- Focus on refining model input data
- Test with a solar radiation model
- Developing a library of ventilation system typologies to addressing the variability in airflow rates
- Alternatively, implement ventilation loss formulation considering building volume
- Test impact of heat transfer through windows and doors

Conclusion

01

AIM & METHOD

Develop BES tool tailored to the **Dutch context** for **city scale analysis** for policymakers to estimate space heating demand

02

FINDINGS

NTA 8800 model predicts space heating demand **lower** than expected, potentially due to **missing components**

03

RECOMMENDATIONS

Incorporate the **heat transfer through windows and doors** and modify current **ventilation** implementation

Thank You For Your Attention