

Sustainability recommendation system for process-oriented building design alternatives under multi-objective scenarios

Xia Chen, Philipp Geyer

Leibniz University Hannover, Germany

xia.chen@iek.uni-hannover.de

<https://www.iek.uni-hannover.de/de/ngs>

Introduction

“Evolutionary algorithms are a great tool for exploring the dark corners of design space.”

- MIT Technology Review, 2005

Sustainable building design is a complex, multidimensional challenge: It requires **balancing**:



Energy
Performance



Environmental
Impacts



Life Cycle
Costs



Challenge

- Current requirement for interpretable design space exploration across multidisciplinary domains.
- Existing tools are limited by dependence on designers' prior knowledge and computational bottlenecks.
- A need for a system that can provide rapid feedback, handle trade-offs, and adapt to various building engineering evaluations.

Sustainability recommendation system

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🏠 Building Parameters

TOTAL_FLOOR_AREA (m²)

120.00

0.10300.00

FLOOR_HEIGHT (m)

4.26

2.0010.00

NUMBER_HABITABLE_ROOMS

7

125

BUILT_FORM

Detached

GLAZED_AREA

Less Than Typical

MAINHEAT_DESCRIPTION

Air source heat pump, radiators, ele...

MECHANICAL_VENTILATION

mechanical, extract only

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mechanical, extract only

Machine Assistance for Building Performance Assessment

This Demo derives from the EU Directive on the energy performance of buildings, which aims to provide transparency on building energy efficiency through energy certificates. It also proposes ways to improve this efficiency.

The system leverages a dataset comprising 19,725,379 samples of official Building [Energy Performance Certificates](#) records from England and Wales. Through this, the framework offers insights and suggestions related to:

- Energy Performance 🔌
- Environmental Impact 🌍
- Operational Cost 💰

To get started:

1 Select your building type.

House / Maisonette 🏠

2 Confirm your design stage (Level-of-Detail).

LOD1 (Geometry/System)

3 Choose your known building parameters.

Known inputs:

4 Enter your parameters on the left.

System status: Complete input received, running **Prediction** mechanism.

BUILT_FORM	TOTAL_FLOOR_AREA	FLOOR_HEIGHT	GLAZED_AREA	NUMBER_HABITABLE_ROOMS	MAINHEAT_DESCRIPTION
Detached	120	4.26	Less Than Typical	7	Air source heat pump, radiators, electric

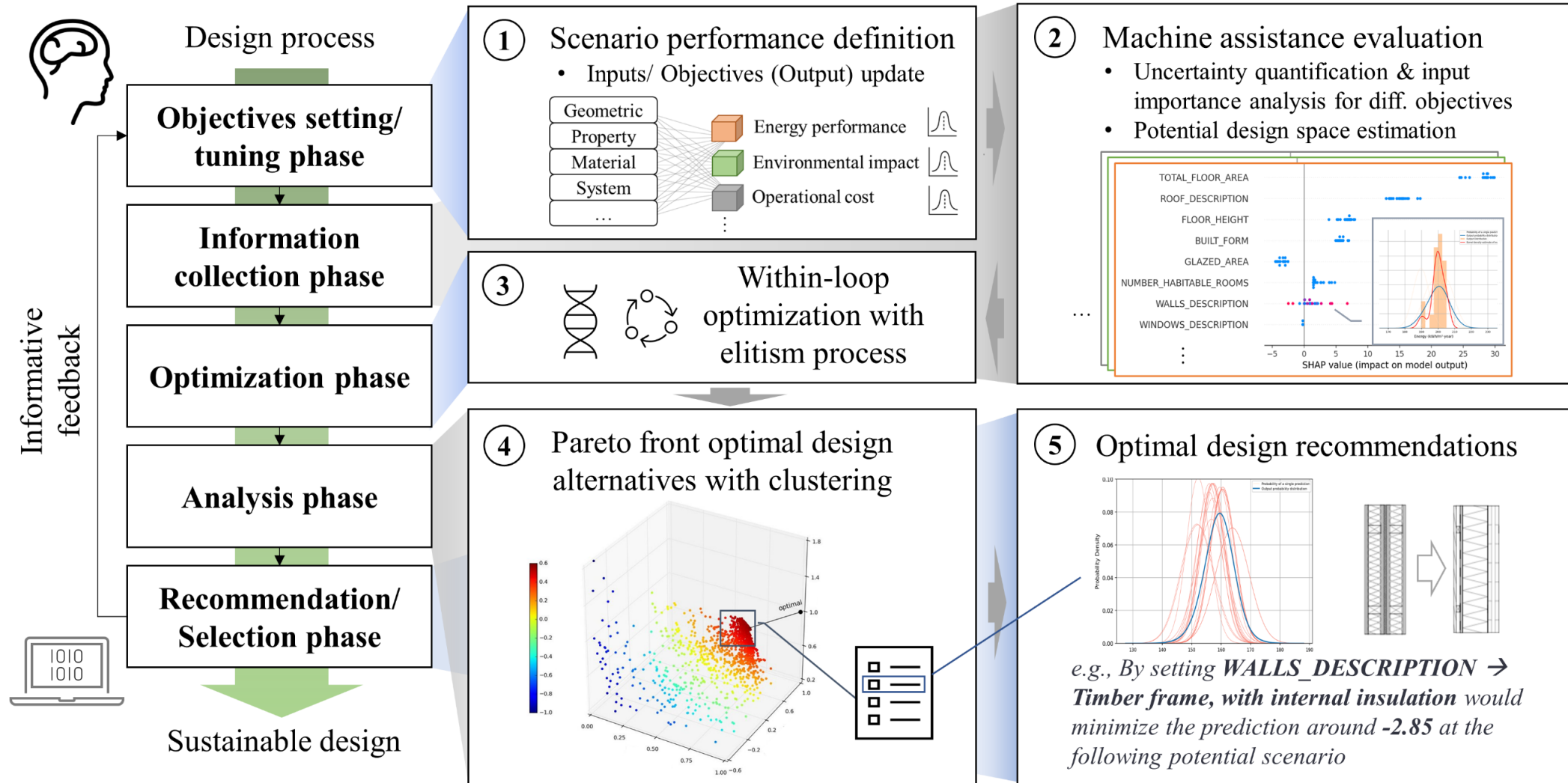
Analysis Result

Energy:

CO₂:

Cost:

Proposed Solution



- Chen, X., & Geyer, P. (2022). Machine assistance in energy-efficient building design: A predictive framework toward dynamic interaction with human decision-making under uncertainty. *Applied Energy*, 307, 118240.

Assistance in a case study

Energy Performance of Buildings Data: England and Wales, 19,725,379 samples with dwellings' detail across most UK regions and connects to the *domestic EPC (Energy performance certificate)*

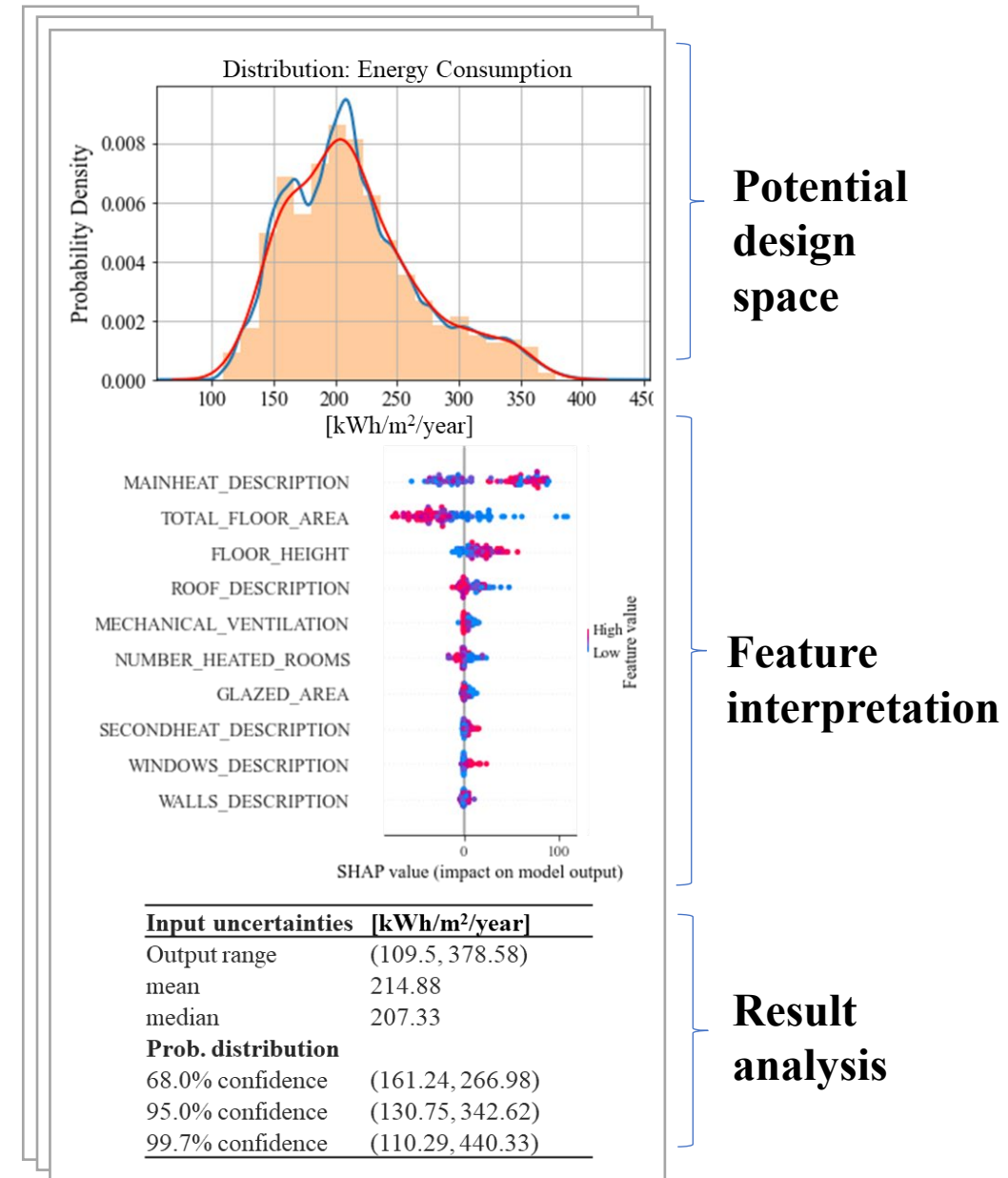
Input features in categories (Potential design space):

- *Geometry*
- *Component material property*
- *Energy system*

Outputs:

- *Energy Consumption* in kWh/m²/year,
- *Environmental Impact* by CO₂ Emission equivalent in kg/m²/year.
- *Operational Cost* in £/m²/year.

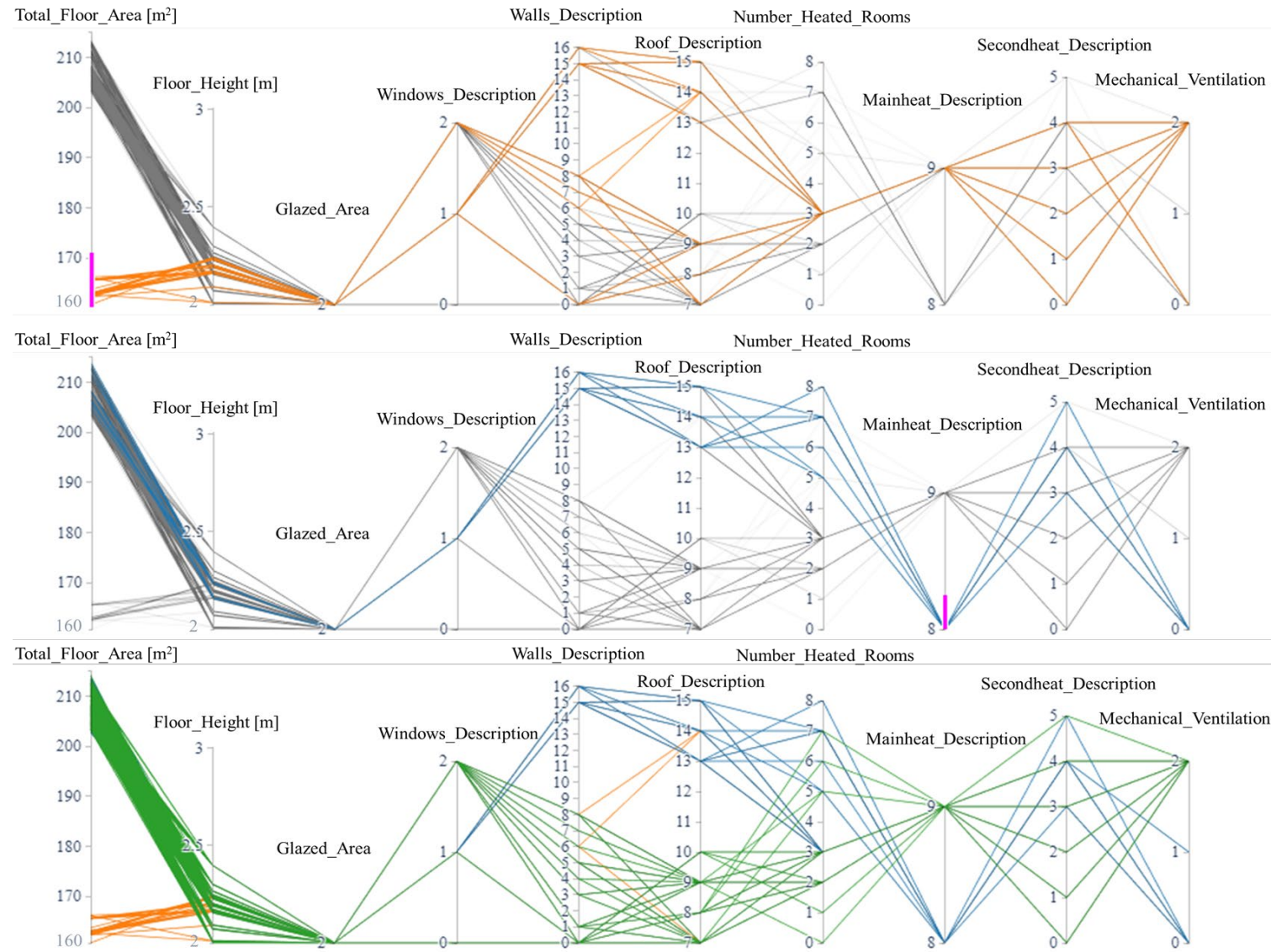
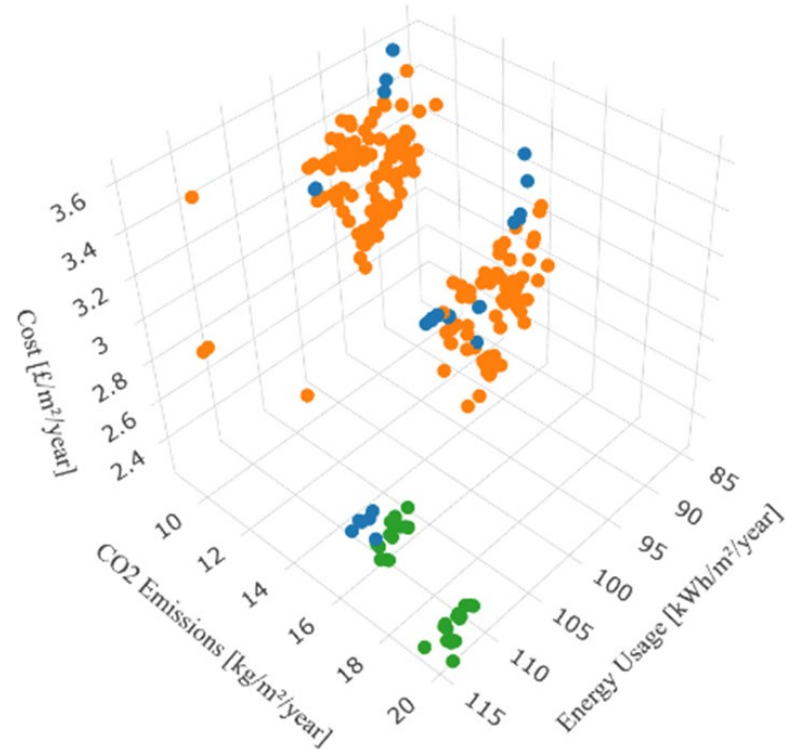
Design Scenario: A flat building with detached built form between 150-250 m²



Machine Assistance evaluation

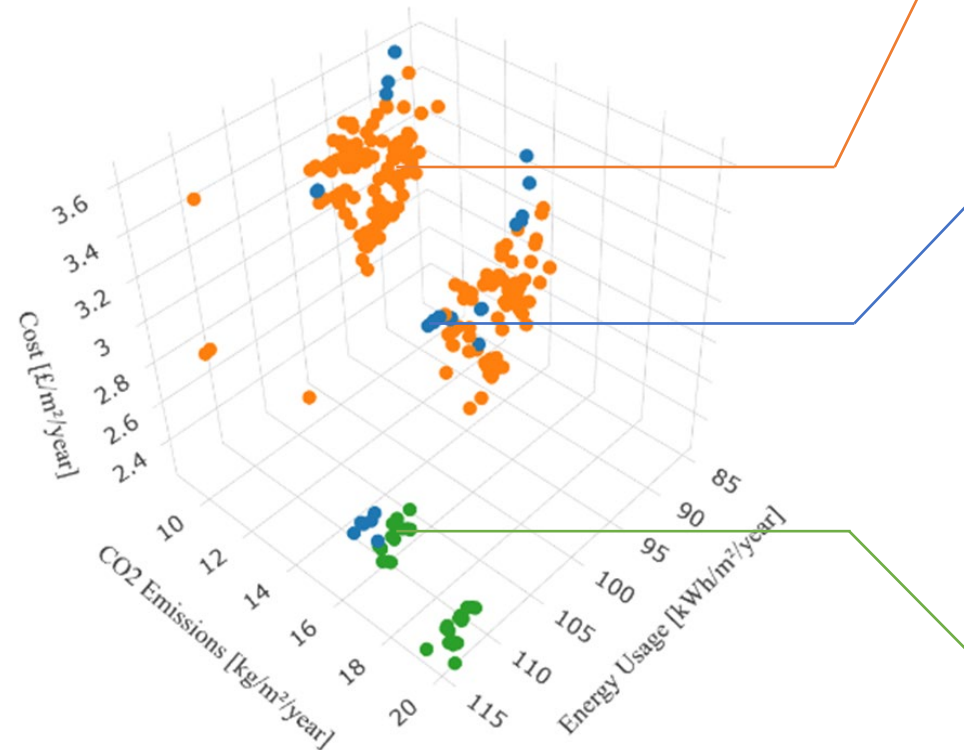
Optimization and Clustering Analysis

- **NSGA-II**: iterative elitism process to determine Pareto-optimal solutions
- **DBSCAN**: unsupervised clustering on optimal inputs set to discover design patterns.



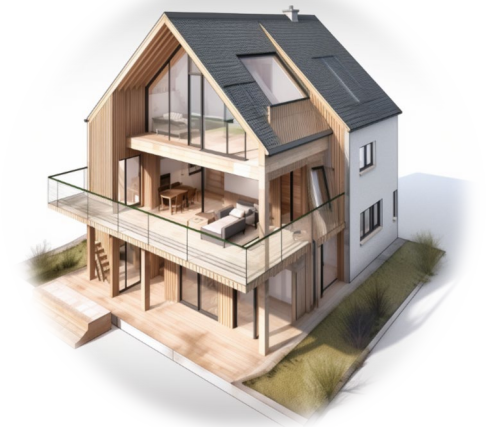
Results and Recommendations

- **General patterns:** relatively low floor height (around 2.3 m), normal glazed area (10%-20% based on RdSAP), and triple/double glazing windows.



Orange cluster

- **165 m², three-room-heated.**
- Insulated **timber frame** walls.
- Main heating system: community scheme with main gas.
- Mechanical ventilation for extract.



Blue cluster

- **210 m², 5-8 heated rooms.**
- **Fully triple-glazed windows.**
- Insulated **timber frame** walls.
- Main heating system: combined heat and power community scheme.
- Natural ventilation.

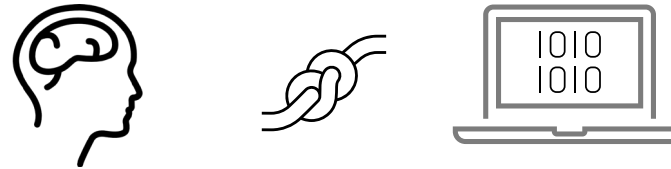


Green cluster

- **210 m², three-room-heated.**
- Insulated **cavity or granite walls.**
- Main heating system: combined heat and power community scheme.
- Nature ventilation.



Key takeaways



Sustainability Recommendation System: An innovative approach that supports sustainable building design by assisting designers in making informed decisions and optimizing design solutions.

1. **Flexibility in Design Space Exploration by Surrogate Models**
2. **Rapid Feedback & Interaction with On-going Design Process**
3. **Effective Trade-off Analysis and Pattern Discovery as Recommendations.**

Thank you!
Questions?

Demo address:

<https://designaid-for2363.streamlit.app/>



Me