

Model Failure or Data Corruption? Exploring Inconsistencies in Building Energy Ratings with Self-Supervised Contrastive Learning

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Background



Fig.1 Building Energy Rating (BER) Levels

- Building energy efficiency assessment plays a pivotal role in guiding decisions for both retrofitting existing buildings and designing new ones.
- Building Energy Rating (BER) are the cornerstone metric in shaping various policies for guiding the public to address energy poverty and steer climate action.
- Ensuring the reliability of the BER results is crucial for upholding the integrity of energy efficiency assessments.

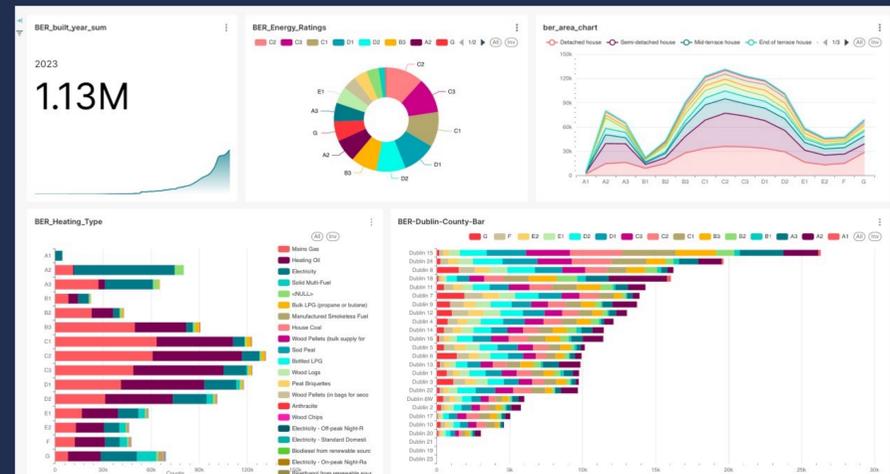


Fig.2 Dashboard for the Energy Performance Certificates (EPC) dataset¹

Identifying *inconsistencies* in Building Energy Ratings with **CLEAR**, a self-supervised Contrastive Learning for Energy Assessment Rating evaluation

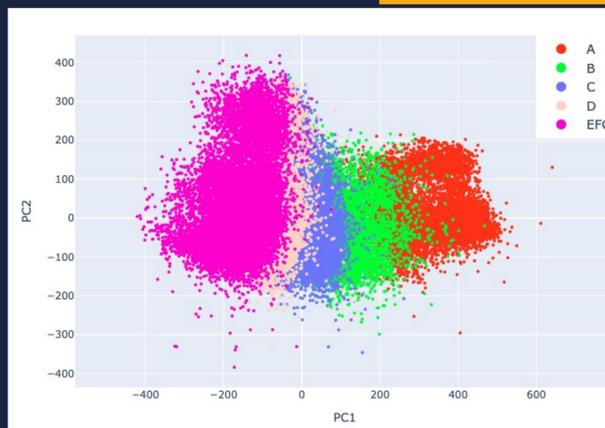


Fig.3 Principal Component Analysis with 5 Coarse BER Levels

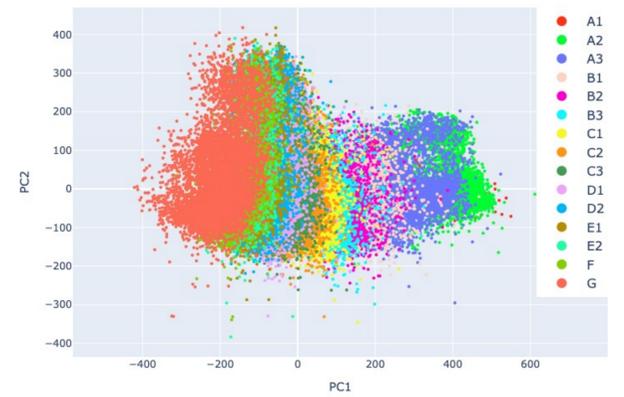


Fig.4 Principal Component Analysis with 15 Fine-grained BER Levels

Observations

Significant performance drop when predicting fine-grained rating level categories:

- Table 1 displays the performance drops observed in both the Random Forest model and the MLP (multi-layer perceptron) deep learning model.
- Fig. 5 shows the confusion matrix for MLP predictions, which reveals the poor performance for adjacent BER level predictions.

BER Levels	Performance Measure	Random Forest	MLP
A1, A2, ..., E1, E2, F, G	Accuracy (%)	62.8	69.5
	Macro F1 (%)	63.1	63.9
A, B, C, D, EFG	Accuracy (%)	76.1	88.6
	Macro F1 (%)	75.8	88.9

Table 1 Performance Comparison of Models for BER Prediction with Different Level Granularity

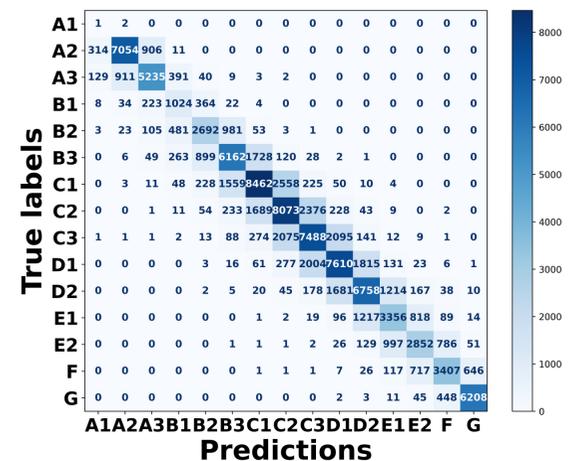


Fig.5 Confusion Matrix for BER Predictions with 15 BER Levels

Approach: CLEAR

1. Self-supervised contrastive learning via SCARF²:

- Generate positive pairs with contrastive learning by randomly selecting and corrupting a subset of features.
- Generate negative pairs by contrasting the selected buildings with other records in a batch.
- Extract the latent representation of each building with SCARF's encoder.

Findings

Data Corruption in the Inconsistent BER Rating Records:

- Visually identify rating inconsistencies by observing groups of close representations with different BER rating levels in the compressed PCA space
- Table 2 showcases a group of 10 similar buildings by calculating the top 9 closest representations to the first referencing building in the latent space.
- These buildings share very similar feature values, but their ratings range from 'A3' to 'D1'. Substantial abnormal values in lighting and water storage in Table 2 highlight potential data corruption in their measurements.
- Table 3 presents another group of similar buildings with ratings ranging from 'A3' to 'C3'.

The buildings rated as A3 and D1 display very similar values in their features.

Energy Rating	Uvalue Wall	Uvalue Roof	Uvalue Floor	Uvalue Door	MainSpace Heating Fuel	HSMain System Efficiency	NoOf Open Flues	Water Storage Volume	LowEnergy Lighting Percent
A3	0.22	0.0	0.25	0.0	Electricity	100.0	0.0	0.0	0.0
B3	0.34	0.0	0.16	0.0	Electricity	100.0	0.0	0.0	0.0
B2	0.23	0.22	0.0	1.2	Electricity	100.0	0.0	0.0	0.0
D1	0.27	0.22	0.25	2.68	Electricity	100.0	0.0	0.0	0.0
C3	0.27	0.13	0.25	3.0	Electricity	100.0	0.0	0.0	0.0
A3	0.2	0.16	0.0	0.0	Electricity	100.0	0.0	0.0	0.0
C3	0.25	0.0	0.27	1.36	Electricity	100.0	0.0	0.0	0.0
D2	0.52	0.13	0.27	1.36	Electricity	100.0	0.0	0.0	0.0
D1	0.22	0.2	0.0	0.0	Electricity	100.0	0.0	0.0	0.0
C1	0.26	0.0	0.0	1.36	Electricity	100.0	0.0	0.0	0.0

U-Values of zero are irrational. Water storage volume indicates thermal loss, but 32% of this feature is incomplete.

Similar features, very different energy ratings

Energy Rating	Uvalue Wall	Uvalue Roof	Uvalue Floor	Uvalue Door	MainSpace Heating Fuel	HSMain System Efficiency	NoOf Open Flues	Water Storage Volume	LowEnergy Lighting Percent
C1	0.37	0.26	0.26	3.0	Electricity	320.0	0.0	140.0	0.0
C2	0.37	0.16	0.34	3.0	Electricity	300.0	0.0	170.0	5.0
B3	0.21	0.15	0.18	2.6	Electricity	250.0	0.0	170.0	0.0
B3	0.37	0.16	0.34	4.37	Electricity	250.0	0.0	170.0	7.0
A3	0.37	0.13	0.34	3.0	Electricity	420.0	0.0	200.0	25.0
C1	0.37	0.25	0.34	3.0	Electricity	250.0	1.0	262.0	19.0
C2	0.37	0.13	0.31	3.0	Electricity	250.0	0.0	170.0	0.0
C3	0.37	0.13	0.34	3.0	Electricity	250.0	0.0	170.0	0.0
A3	0.37	0.13	0.34	3.0	Electricity	407.0	0.0	175.0	100.0
A3	0.37	0.13	0.34	3.0	Electricity	407.0	0.0	175.0	100.0

Similar U-Values

Table 2. Buildings with BER ranging from A3 to D1

Table 3. Buildings with BER ranging from A3 to C3

References

- the EPC Dataset: <https://ndber.seai.ie/BERResearchTool/ber/search.aspx>
- Dara Bahri et al. Scarf: Self-supervised contrastive learning using random feature corruption. In ICLR, 2021.