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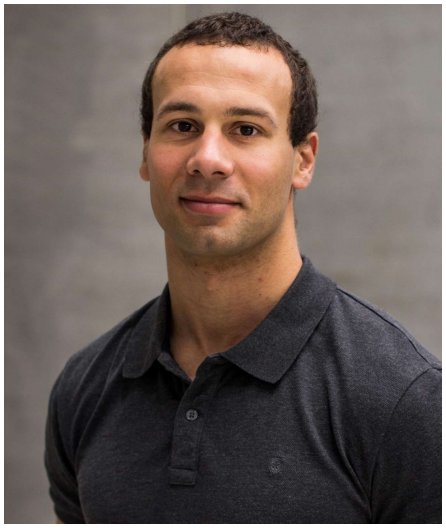
What Metrics Does the Building Energy Performance Community Use to Compare Dynamic Models?

Authors:
Hicham Johra
Markus Schaffer
Gaurav Chaudhary
Hussain Syed Kazmi
Jérôme Le Dréau
Steffen Petersen



Hicham Johra
Associate Professor
AALBORG UNIVERSITY
DENMARK

Motivations

- Comparing, validating and assessing the accuracy of dynamic models is crucial
- Dynamic simulation outputs are often in the form of time series
- Comparison methods and metrics for qualitative and quantitative analysis of these building model output time series are thus needed

Motivations

- Large reviews and discussions around comparison metrics and model key performance indicators exist in some research communities
- However, no such systematic review can be found for the field of indoor environment and energy in buildings
- Conclusions on the adequacy of a comparison metric can vary with the characteristics of the evaluated time series: sampling rate, amplitude, frequency spectrum, unit scale, value distribution, etc

Objectives

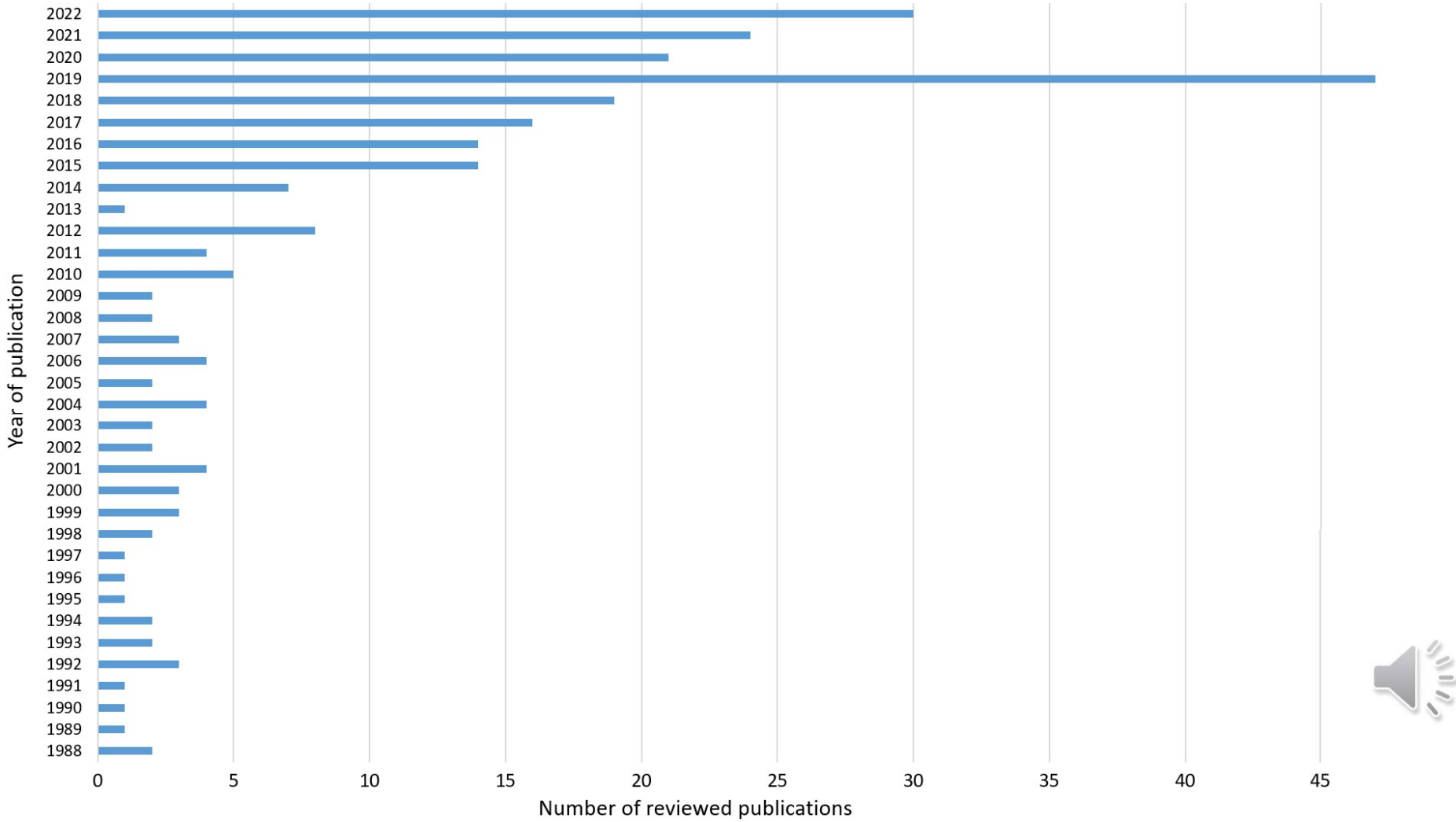
- Give an overview of what comparison methods and metrics are used in the building community to analyse simulation results (time series) of dynamic building models
- Discuss the issues of some common metrics
- Provide a unified definition and notation for the 48 metrics found in the review process

Methodology

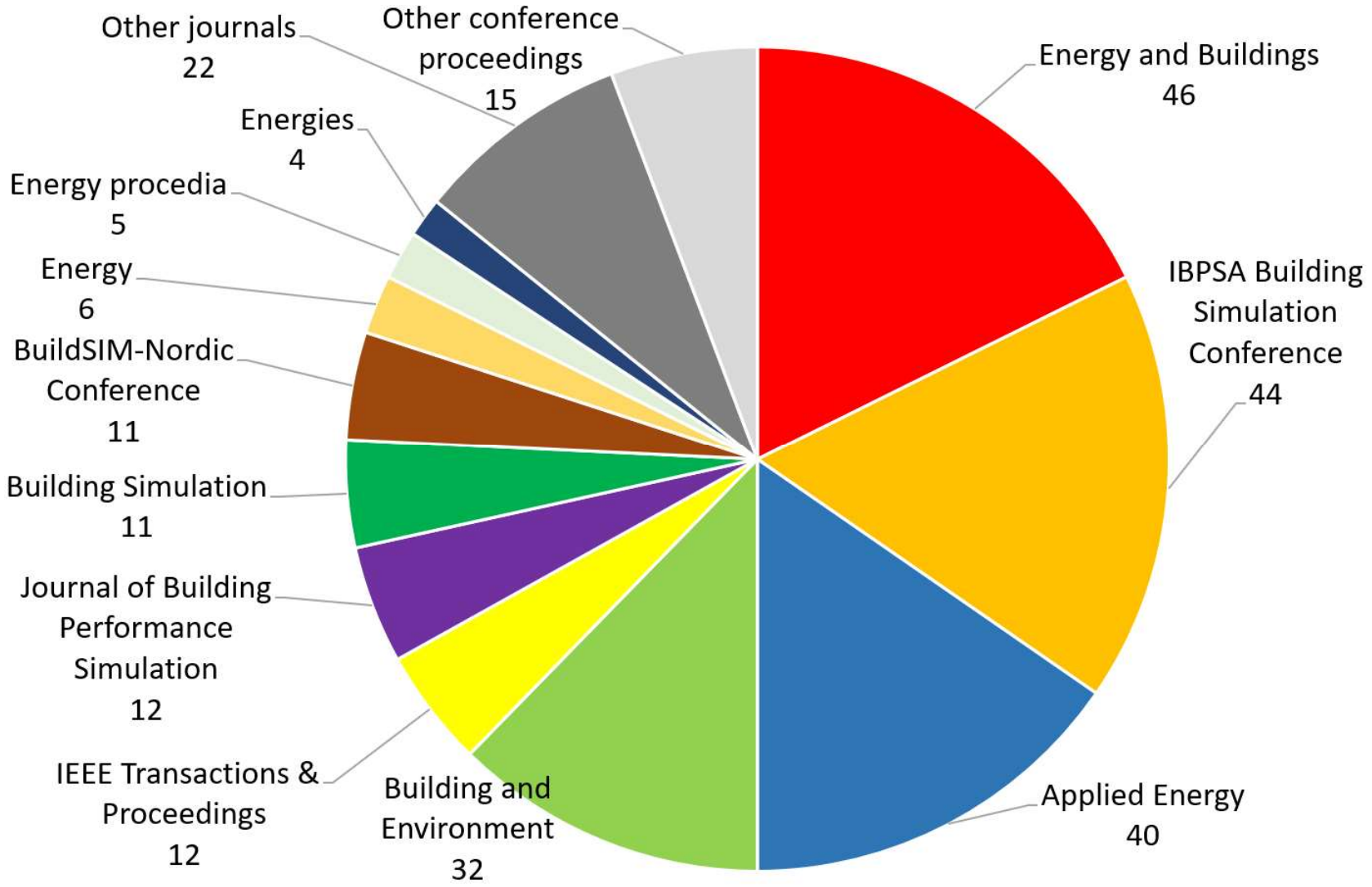
- Review of 259 papers about numerical modelling of building energy demand and indoor environment

- Systematic search for metrics and figures comparing the time series output of models for comparison or validation purposes

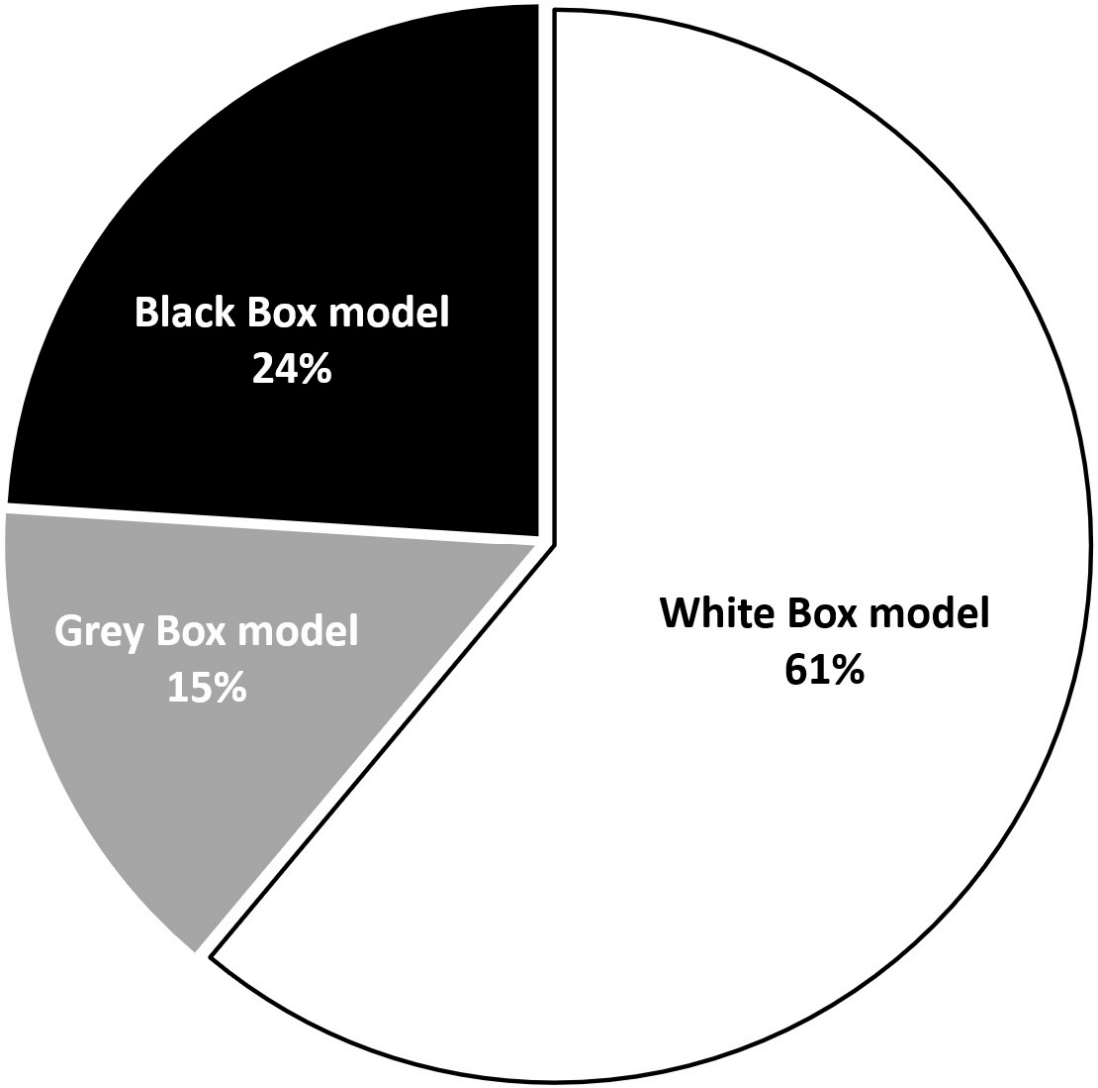
Methodology



Methodology



Trends in building modelling



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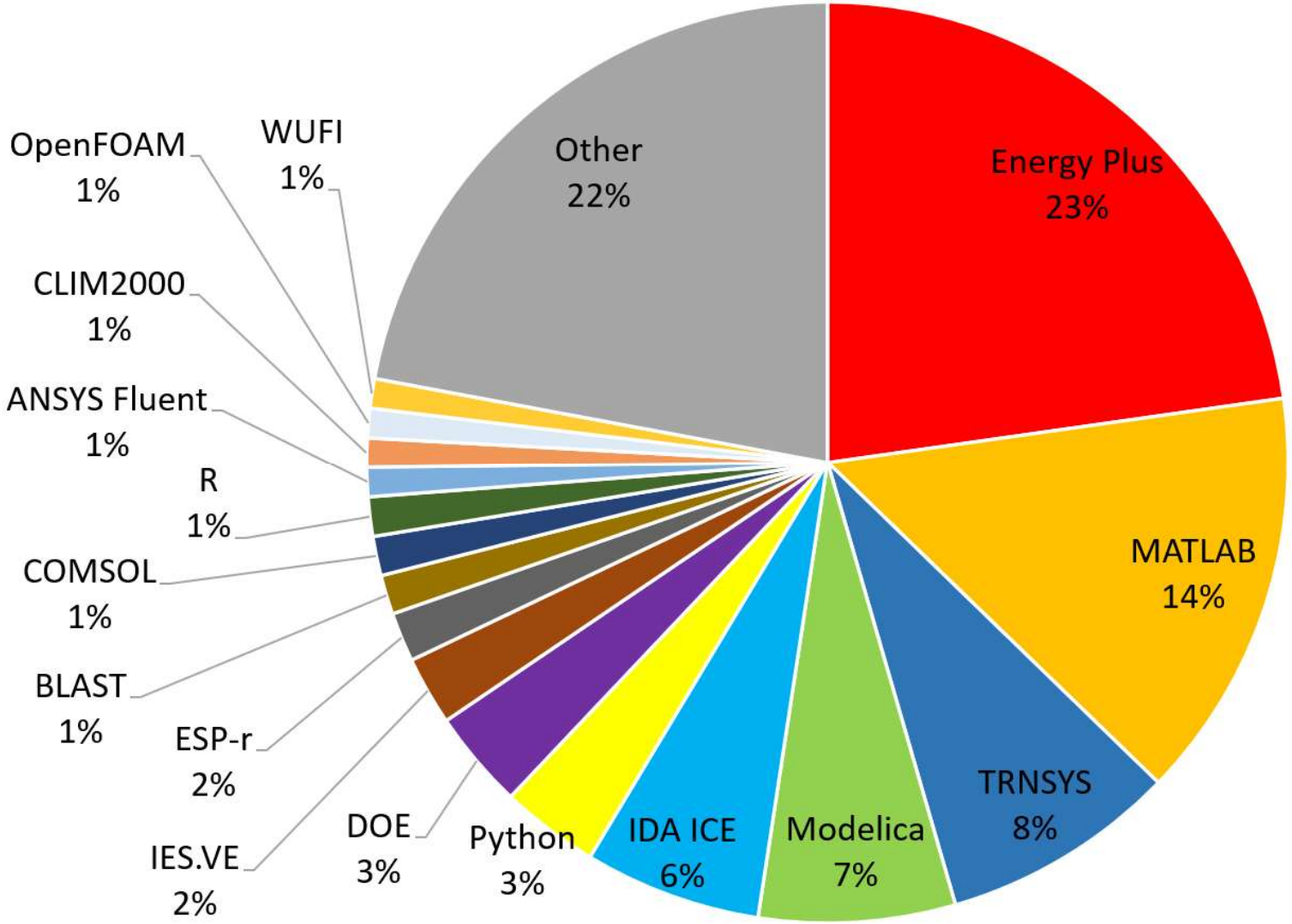
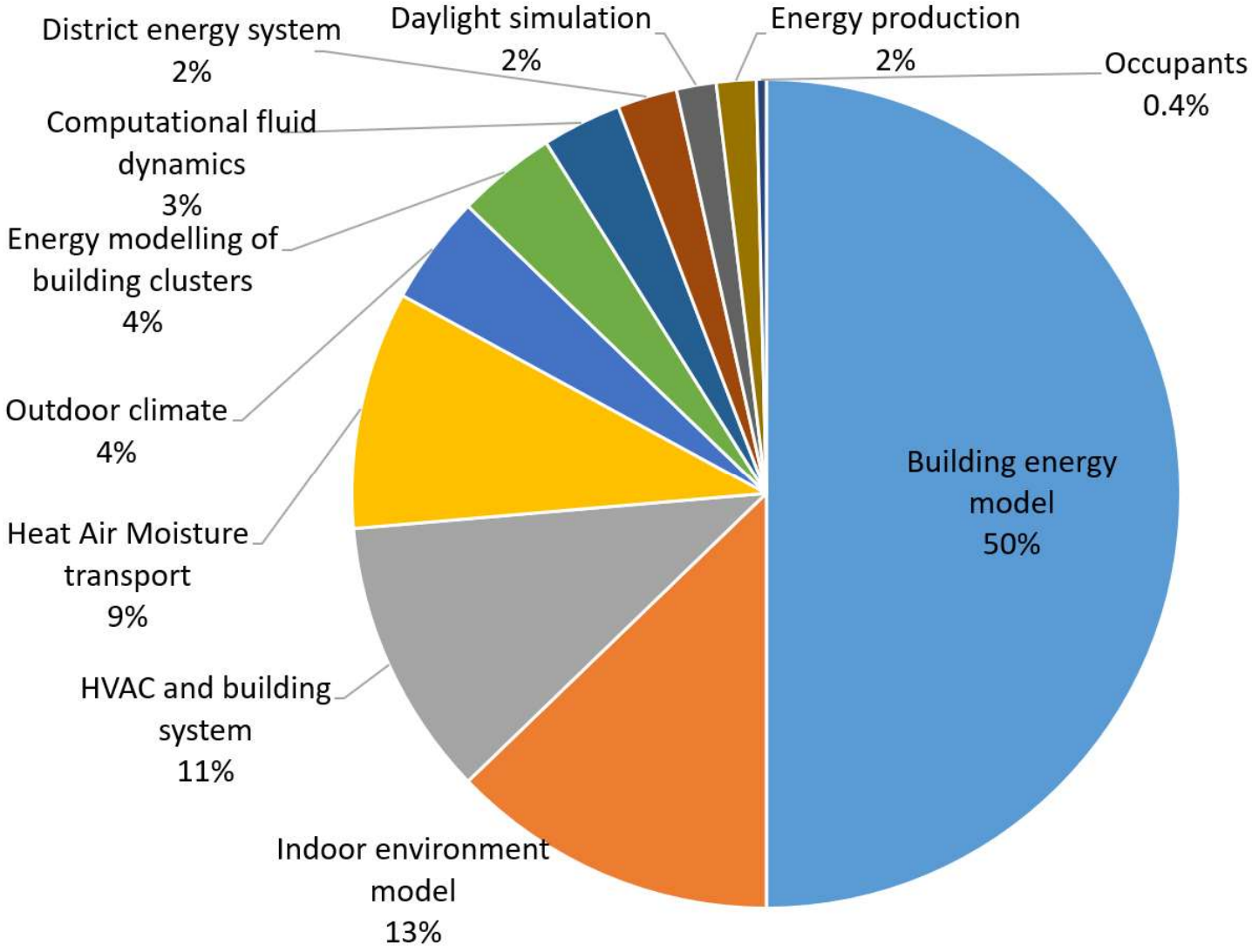
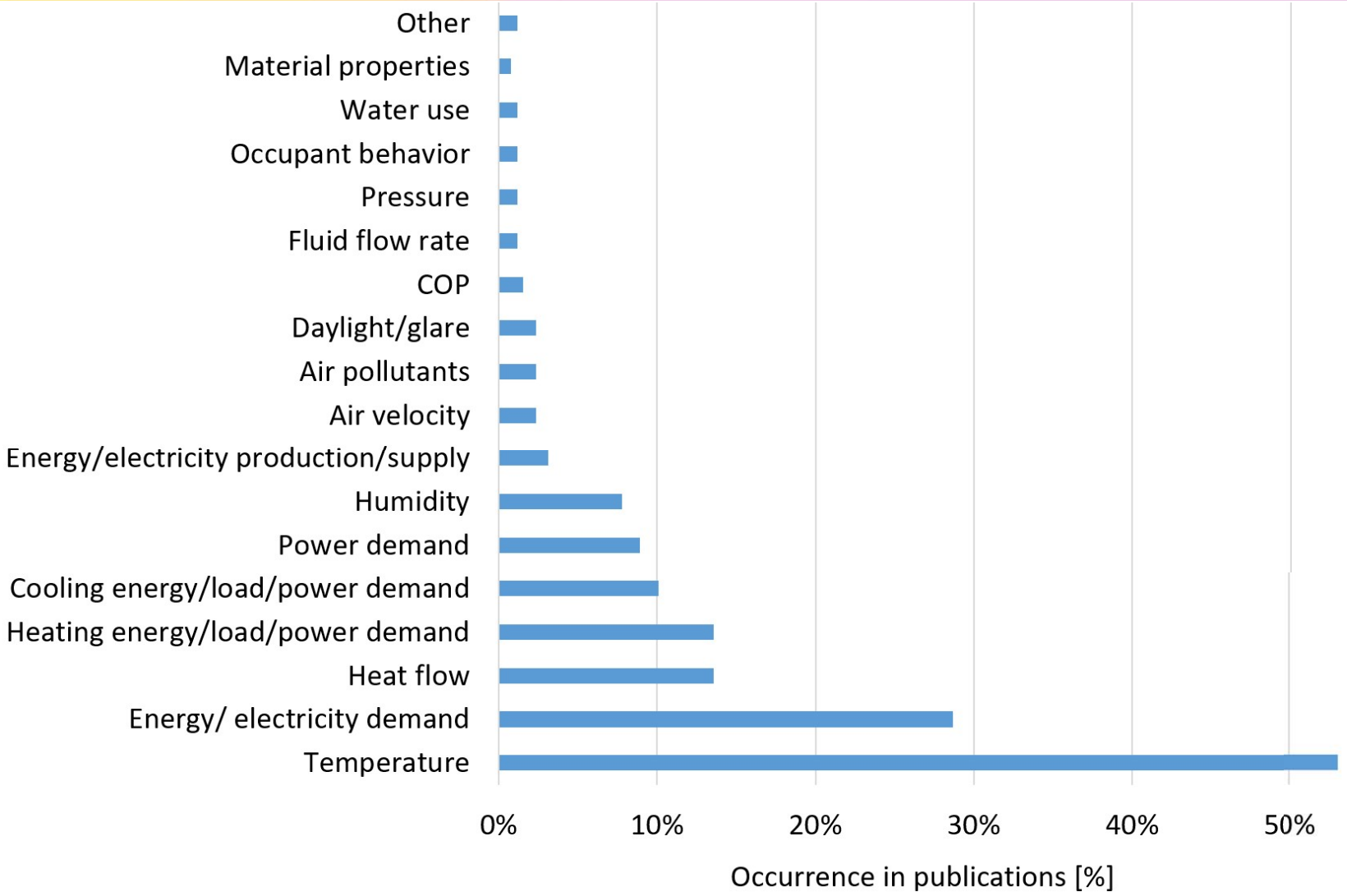


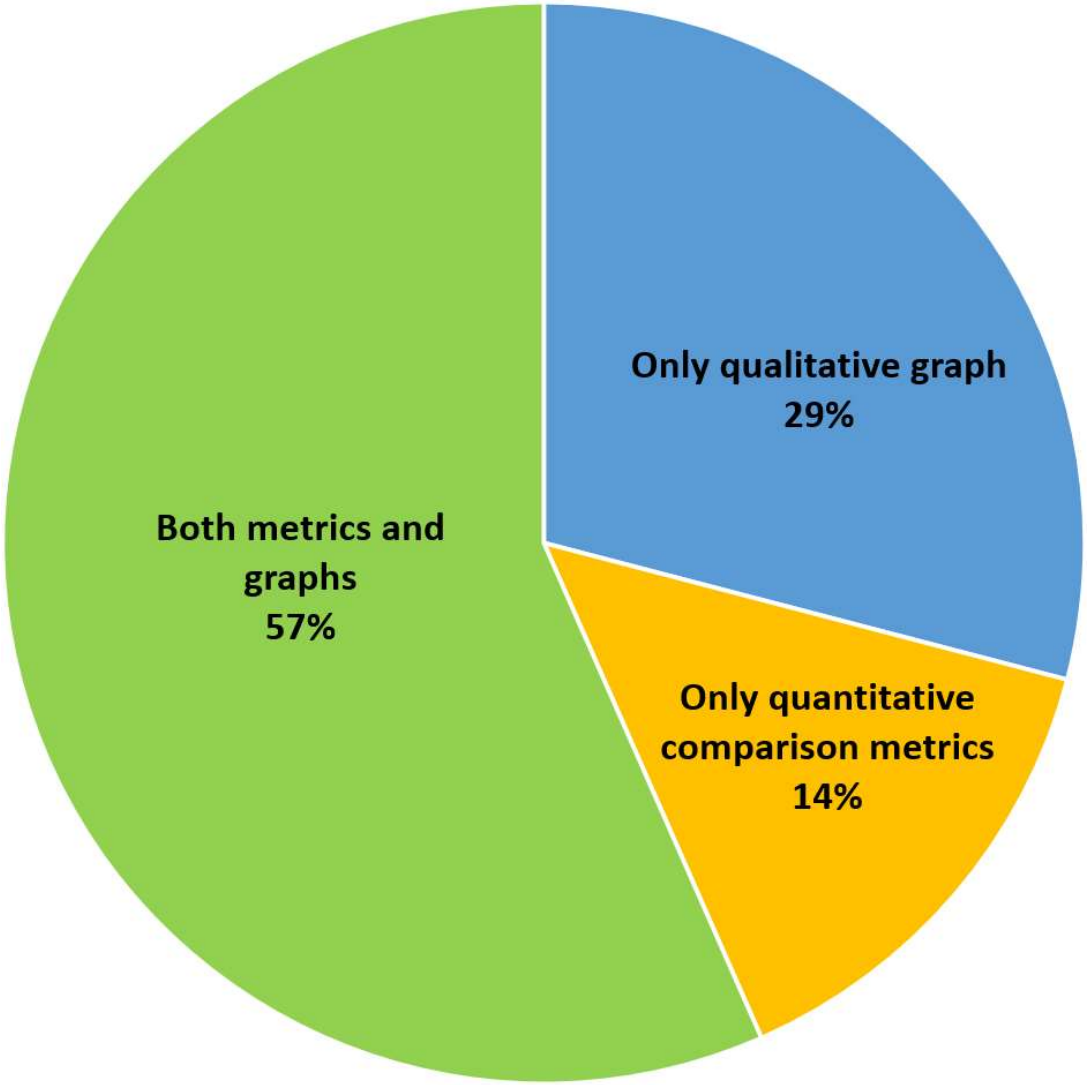
Trends in building modelling



Trends in building modelling



Comparison of time series



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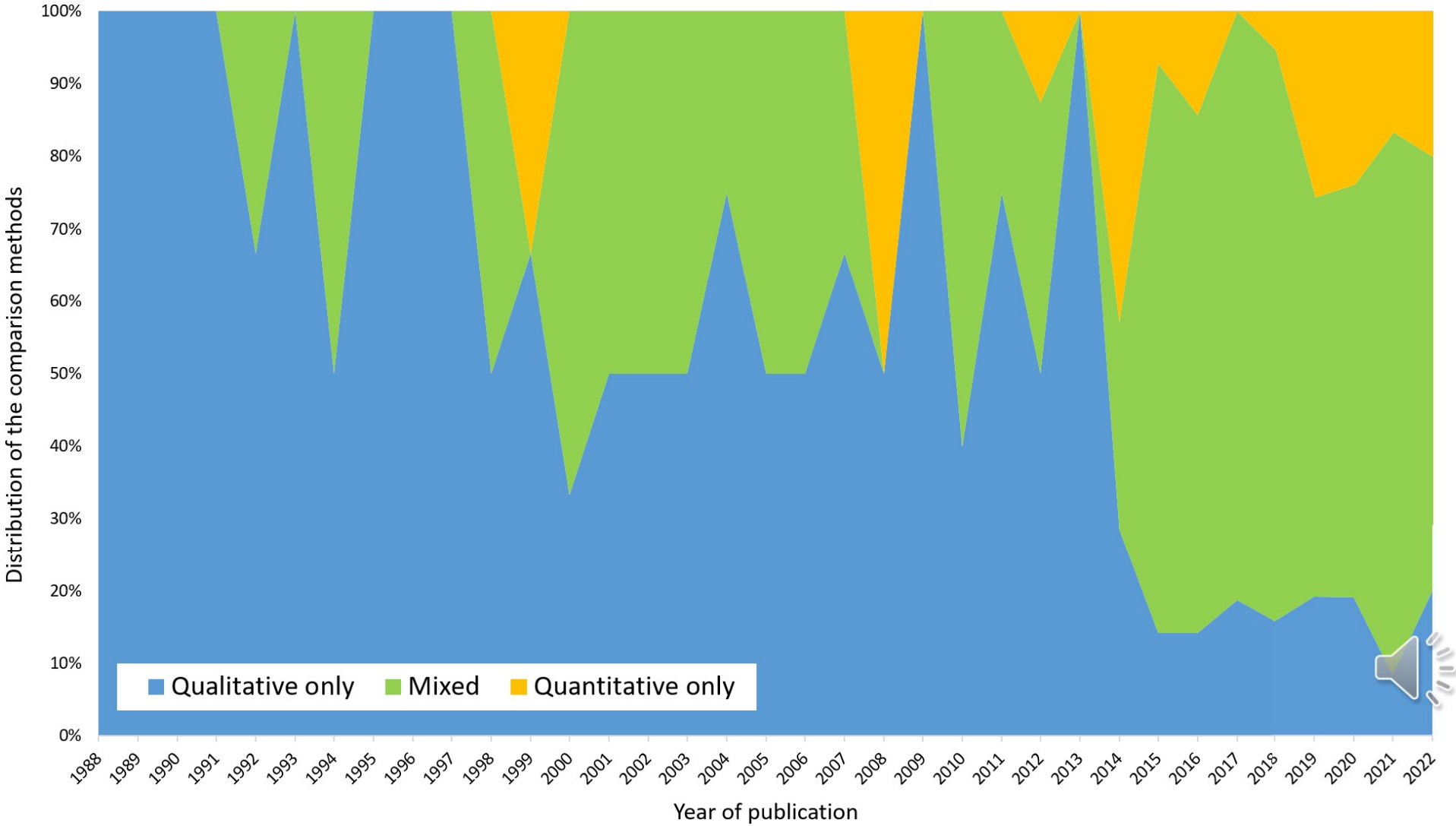

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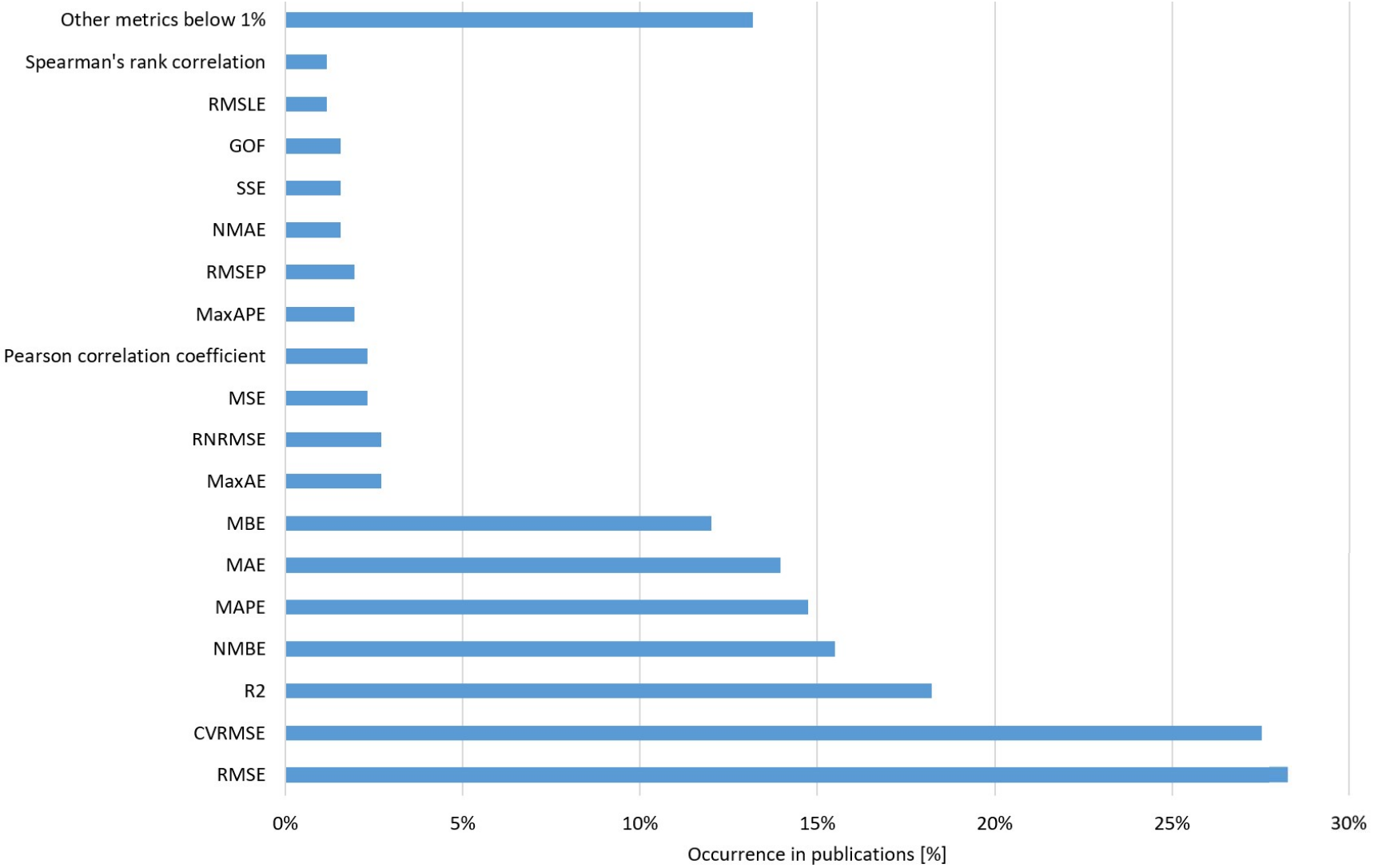


Discussions

- Large influence of recent guidelines (e.g., ASHRAE 14) on the adoption of MBE, NMBE, RMSE and CVRMSE
- These guidelines also suggest thresholds for model validity
- It clearly improves the simulation performance reporting and comparison between different studies
- However, these common metrics can present some issues

Discussions

MBE and NMBE:

- Global bias of the model
- Prone to cancellation or compensation effects
- Can lead to low MBE or NMBE despite large local discrepancies
- Squared difference-based or absolute value-based metrics do not have this problem

Discussions

Normalised metrics:

- Normalised metrics should be preferred: e.g., CVRMSE
- Necessary for model comparison on datasets of different sizes or unit scale
- Some confusion in the naming and definition of normalised metrics

Discussions

Normalised metrics:

- Normalisation by the total mean average of the entire dataset: bias towards periods of high magnitudes
- Can be problematic for time series with strong seasonality like heating/cooling demand

Discussions

Metric robustness:

- Some metrics are very sensitive to values close to the 0 of the time series unit scale
- Some metrics (e.g., MAPE) are mathematically undefined when the quantity is 0
- Very problematic for time series of building energy demand

Discussions

Metric robustness:

- Some metrics are very sensitive to outliers (e.g., CVRMSE)
- Can cause over-penalization: problematic for global model validation
- RMSE of log error (RMSLE) is less sensitive to large outliers but is asymmetrical: penalises more under-estimations than over-estimations

Discussions

Metric definition and implementation:

- *n-1* or *n* samples in the computation of comparison metrics?
- Various definitions and implementations of R^2, coefficient of determination

Conclusions

- Many different comparison metrics with various definitions, implementations and flaws causing mistakes or misunderstandings
- Quantitative comparison metrics must be reported in studies
- Qualitative comparison with time series graphical visualization should also be included with different time scales
- Normalized metrics are preferred over absolute metrics for quantitative comparison

Conclusions

- The equation of the metrics should always be provided along with the evaluation period, and information on the data treatment for zero-values
- For error evaluation, CVRMSE, RMSE, MAPE and MAE are commonly used
- For bias evaluation, NMBE and MBE are commonly used
- Elastic distance metrics (e.g., Dynamic Time Warping or Frechet distance) should be considered for further analysis of time series with possible time-shifting

Conclusions

A unified and coherent definition and notation for the 48 reviewed metrics:

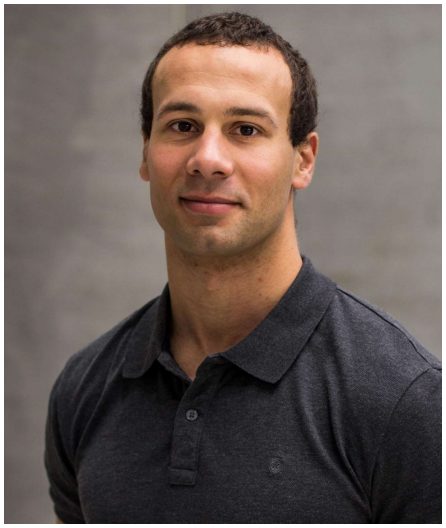
Johra, H., Schaffer, M., Chaudhary, G., Syed Kazmi, H., Le Dréau, J., & Petersen, S. (2023). *Coherent description of 48 metrics to compare, validate and assess accuracy of building energy models and indoor environment simulations*. DCE Technical Reports No. 314. https://doi.org/10.54337/aau533917780

Future work

- Continue testing and analysing comparison metrics for energy in building and indoor environment modelling applications
- Study common mistakes and pitfalls in the use of these metrics
- Make some recommendations for the comparison of building models with those metrics
- Looking into probability-based metrics for forecasting models

Thank you for your attention!

Please contact me if you have any questions



Hicham Johra
Associate Professor

AALBORG UNIVERSITY
DENMARK

Email: hj@build.aau.dk
LinkedIn ➔ ➔ ➔ ➔ ➔