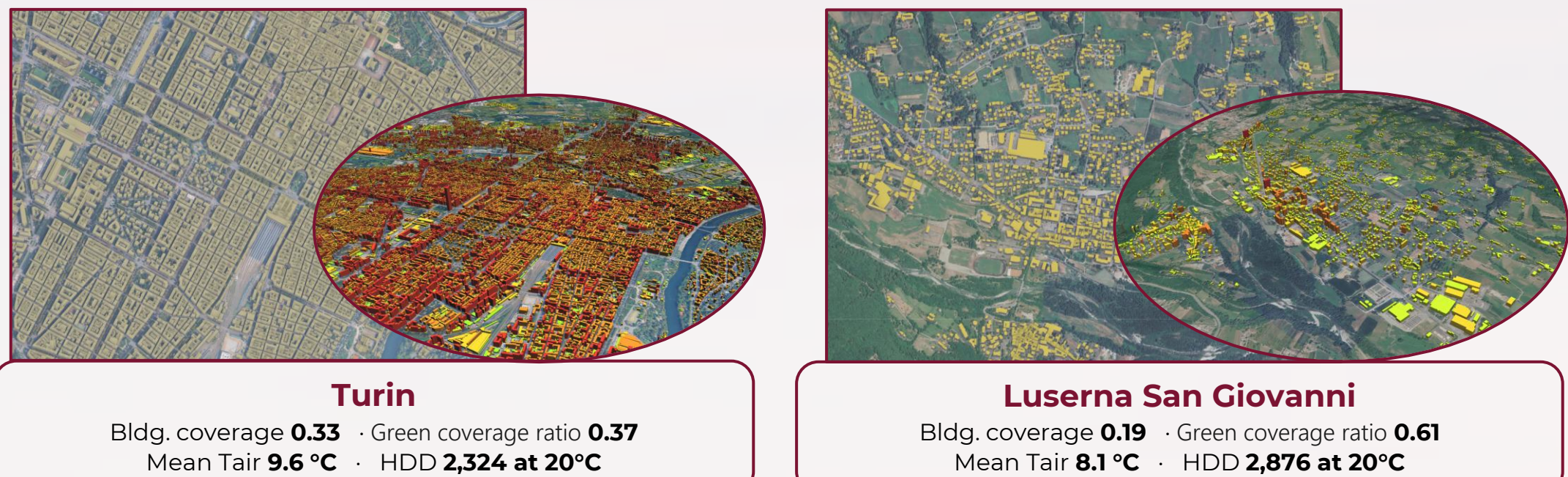


An Urban Building Energy Multi-Modeling Powered by Local Climate Conditions.

R. Roshan Kharrat; A. Montazeri; X. Zhou; G. Mutani*

Context

Urban Building Energy Models support district- and city-scale energy analysis. However, their accuracy depends on model inputs i.e., local climate condition, urban morphology, solar exposure, wind effects, and infiltration. Detailed tools such as EnergyPlus are accurate but costly at a large scale, while simplified UBEMs are faster but less detailed. To compare different energy simulation approaches, two case-studies were analyzed in Piedmont, Italy: Turin (high-density city) and Luserna San Giovanni (low-density mountain city).



Background & Objectives

Why urban building energy models (UBEM)?

- ~40%** of global final energy is used in buildings
- Cities** are central targets for decarbonization strategies
- UBEMs** simulate energy at district and urban scale
- UBEMs support the evaluation of building energy demand at the district and city scale.
- Detailed tools such as EnergyPlus provide high-resolution results but are computationally expensive for large urban applications.
- Simplified process-driven models are faster; However, their physical assumptions, like solar exposure, local air temperature, air infiltration rates, must be improved to reduce prediction errors.

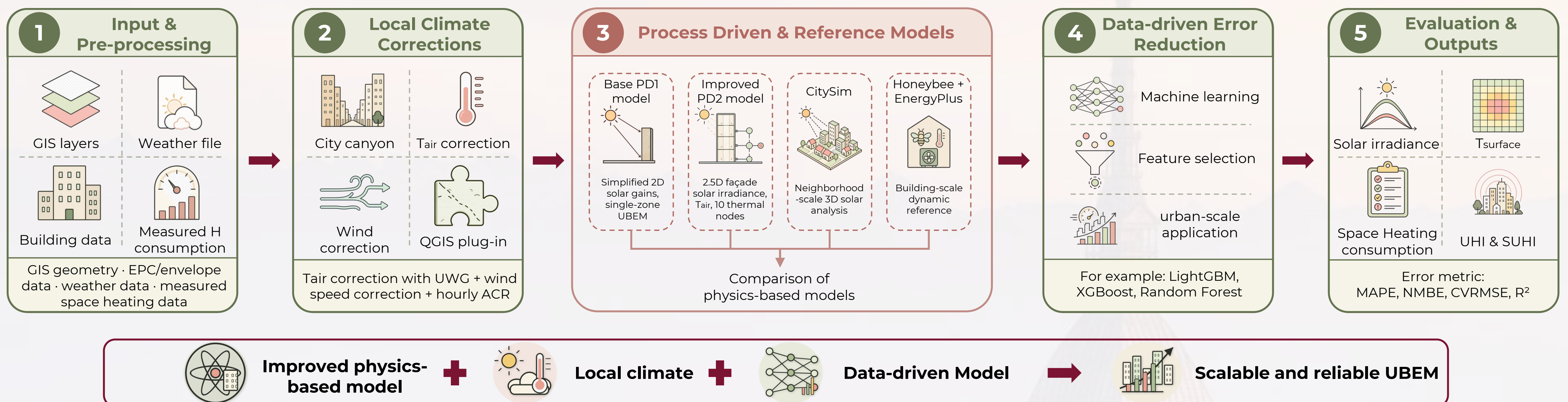
Objectives

- Develop an improved process-driven UBEM with orientation-dependent solar irradiance.
- Benchmark initial vs. improved models against CitySim Pro, EnergyPlus and Honeybee.
- Test all models in two urban contexts: Turin (high-density) and Luserna (low-density).
- Assess whether better solar simulation improves heating accuracy vs. measured data.

Methodology

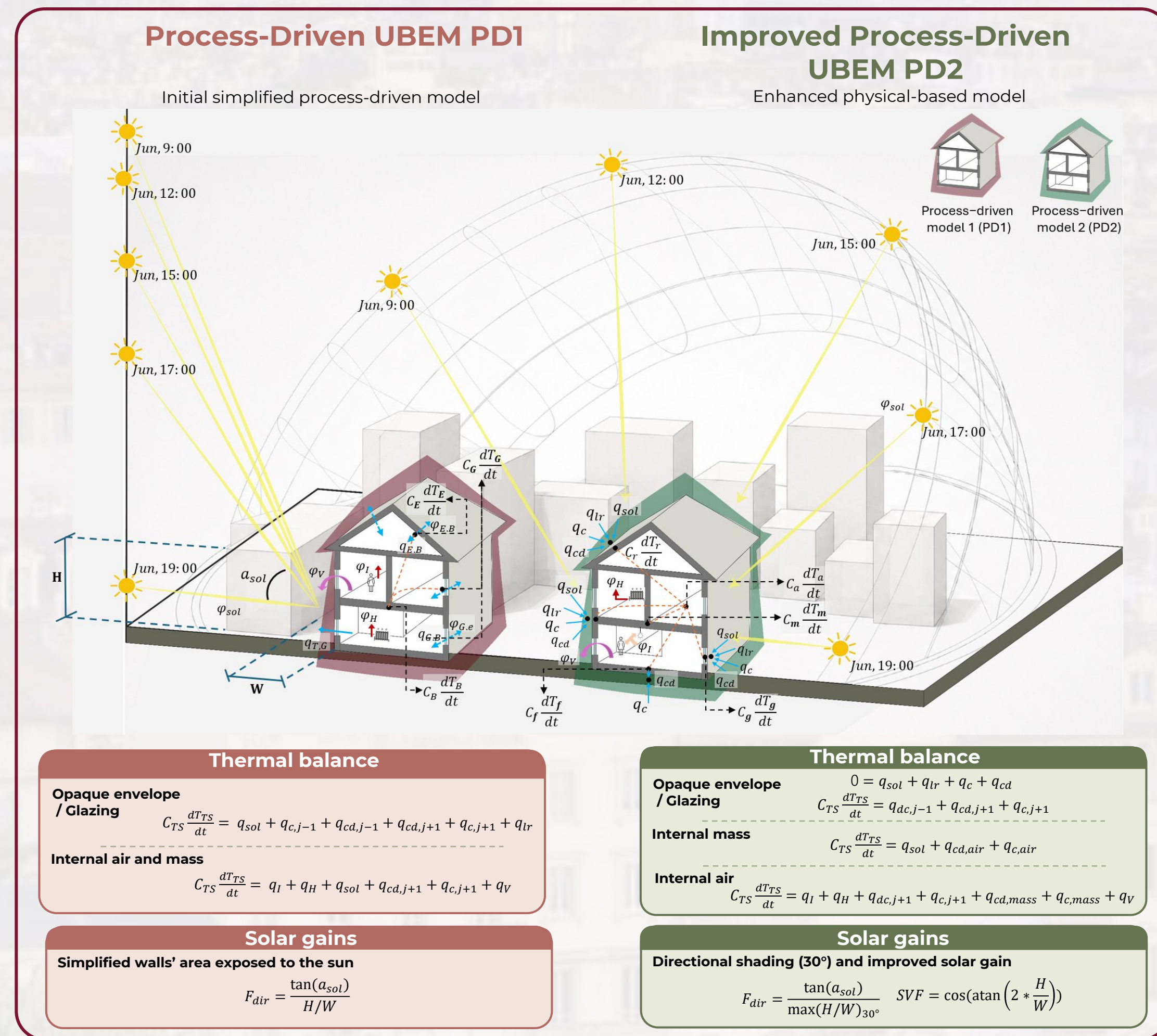
The methodology combines GIS-based data preparation, local climate condition correction, surface oriented solar analysis, physics-based energy modeling, data-driven error reduction, and model evaluation. Building geometry and envelope physical characteristics, weather data, urban morphology, and measured heating consumption are pre-processed. Local climate conditions are refined using UWG. Four models are compared: Initial process-driven (PD1), improved process-driven (PD2), CitySim Pro, and Honeybee/EnergyPlus.

Outputs are evaluated using solar irradiance, surface temperature, heating consumption, and error metrics such as MAPE, RMSE, and NMBE.



Process-Driven Model Comparison

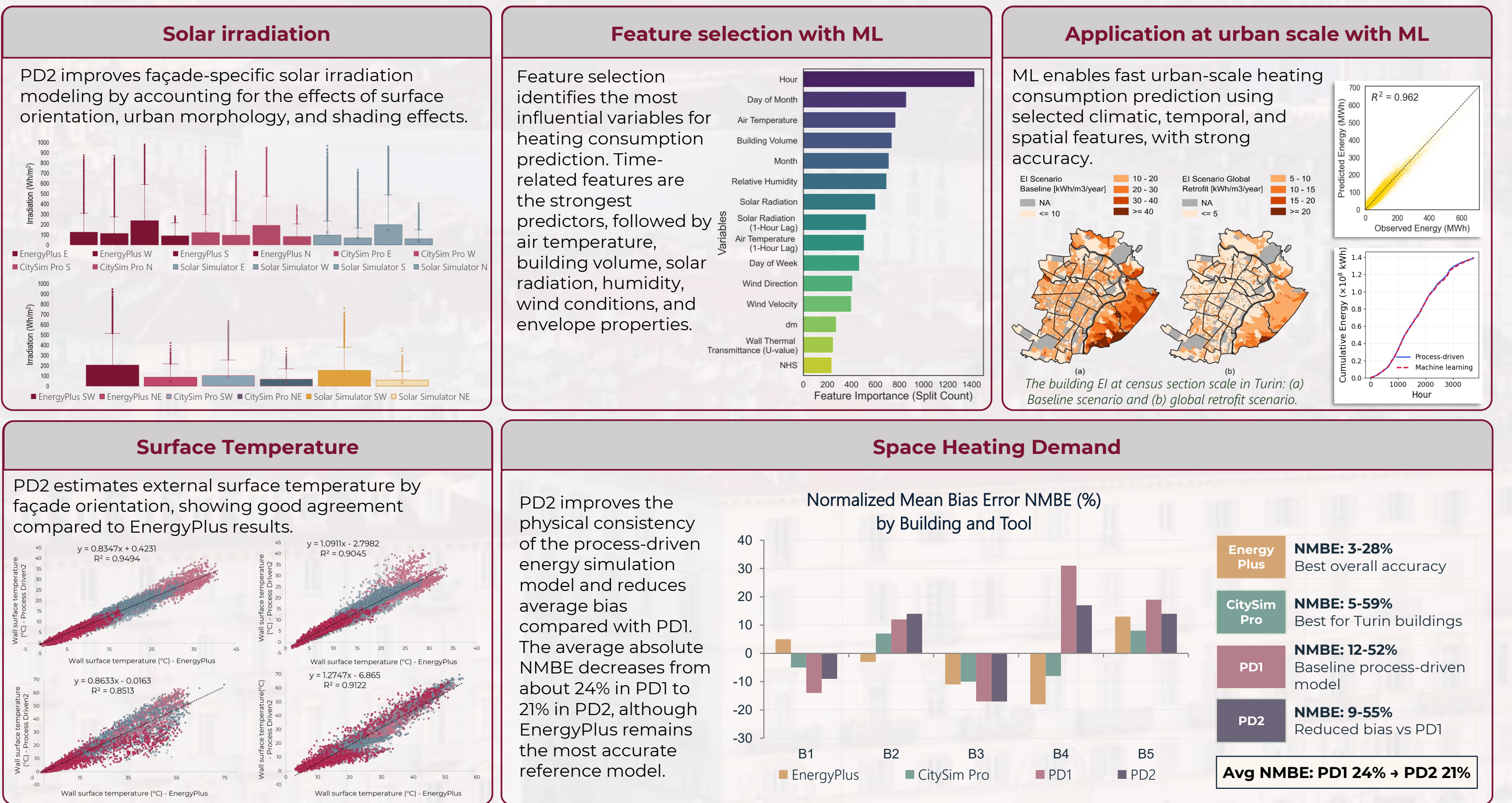
PD1 models building thermal behavior utilizing aggregated component thermal capacitances and simplified external boundary conditions. PD2 refines this framework by explicitly calculating surface specific solar radiation, the exterior surface energy balance, and incorporating detailed components thermal inertia.



Results and Discussion

The results show that PD2 improves the physical representation of façade-specific solar irradiation and external surface temperature, supporting a more reliable evaluation of building heat exchanges. Additionally, it improves energy consumption prediction.

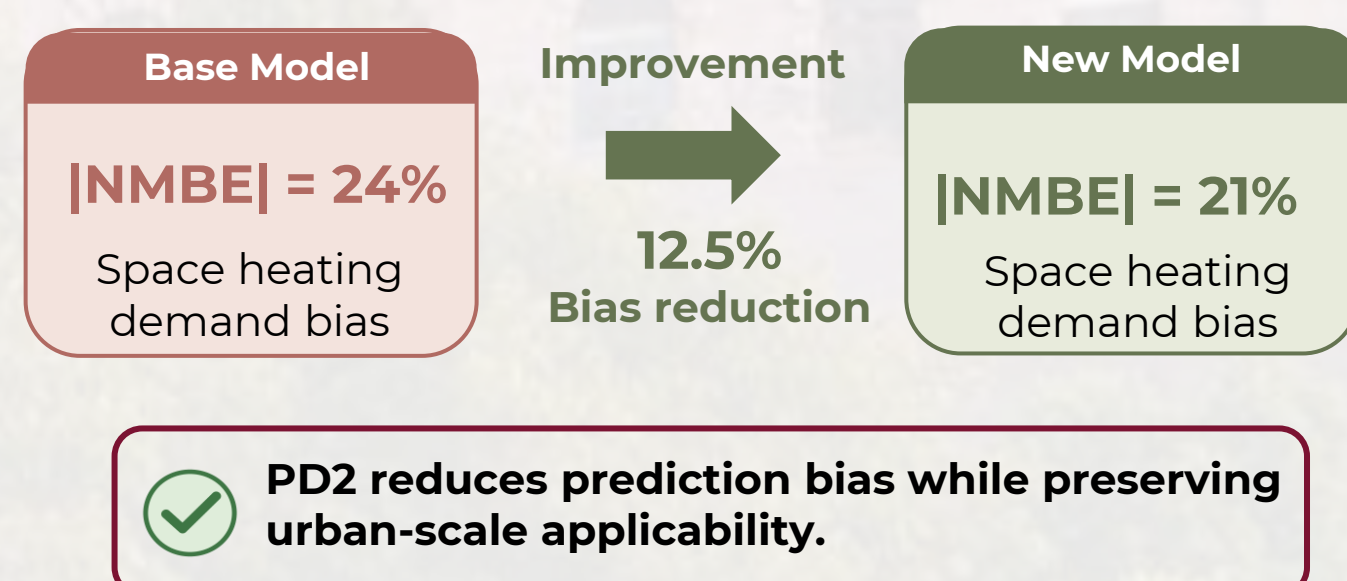
In parallel, machine-learning methods identify the most influential variables and enable faster urban-scale heating consumption prediction, thereby reducing errors in simplified UBEM workflows.



Conclusion

The proposed framework integrates local climate condition correction, façade-oriented solar radiation analysis, improved process-driven modeling compared to reference energy simulation tools, and data-driven feature selection and generalization power to support development of more reliable Urban Building Energy Modeling application. PD2 better accounts for surface orientation, shading effects, urban morphology, envelope heat exchange, and local boundary conditions while still maintaining the computational efficiency required for urban-scale studies. The comparison between PD1 and PD2 shows that the improved process-driven model enhances the physical representation of façade-specific solar irradiation, external surface temperature, and space heating consumption prediction. In addition, machine-learning methods support the workflow by identifying the most influential variables affecting heating consumption prediction, including temporal, climatic, spatial, and building-related features.

This enables faster application to larger building stocks and reduces the need for detailed dynamic simulation of every individual building. Overall, the proposed approach improves model reliability, supports error reduction, and provides a scalable pathway for urban energy assessment and future climate-sensitive planning.



Future Work

- Improve modeling of occupancy patterns and heating system operation schedules with ML
- Refine infiltration and ventilation characterization for each building type and urban context
- Extend methodology to larger building stocks and additional urban morphologies
- Integrate future climate scenarios to assess the robustness of UBEM predictions under climate-changing future scenarios.

References

- Energy consumption models at urban scale to measure energy resilience — Mutani et al., 2020.
- Automatic and Rapid Calibration of Urban Building Energy Models by Learning from Energy Performance Database — Chen et al., 2020
- Review of Urban Building Energy Modeling Approaches, Methods and Tools — Ali et al., 2021
- Urban Building Energy Modeling: A Systematic Review of Challenges and Opportunities — Kong et al., 2023
- Accelerating Urban Building Energy Modeling — Le Hong & Wolk, 2024
- From Building Energy Modeling to Urban Building Energy Modeling — Salvalai et al., 2024
- Urban Building Energy Models: Results from Research, Potential Policy Strategies and Didactic Activities — De Carli, 2026, AIGE/IIETA International Conference
- Multi-dimensional Urban Building Energy Modeling for Understanding and Addressing Energy Poverty — Montazeri et al., 2025.