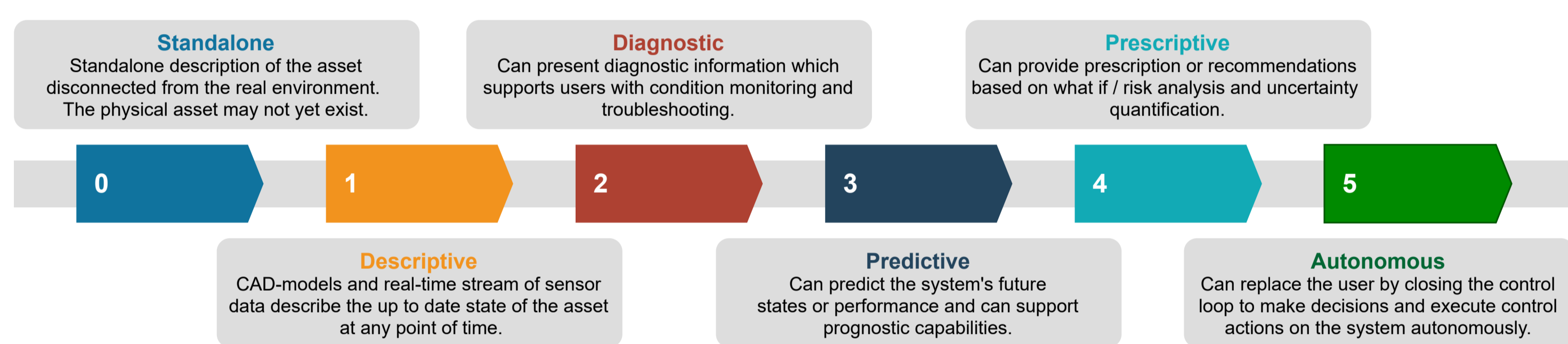
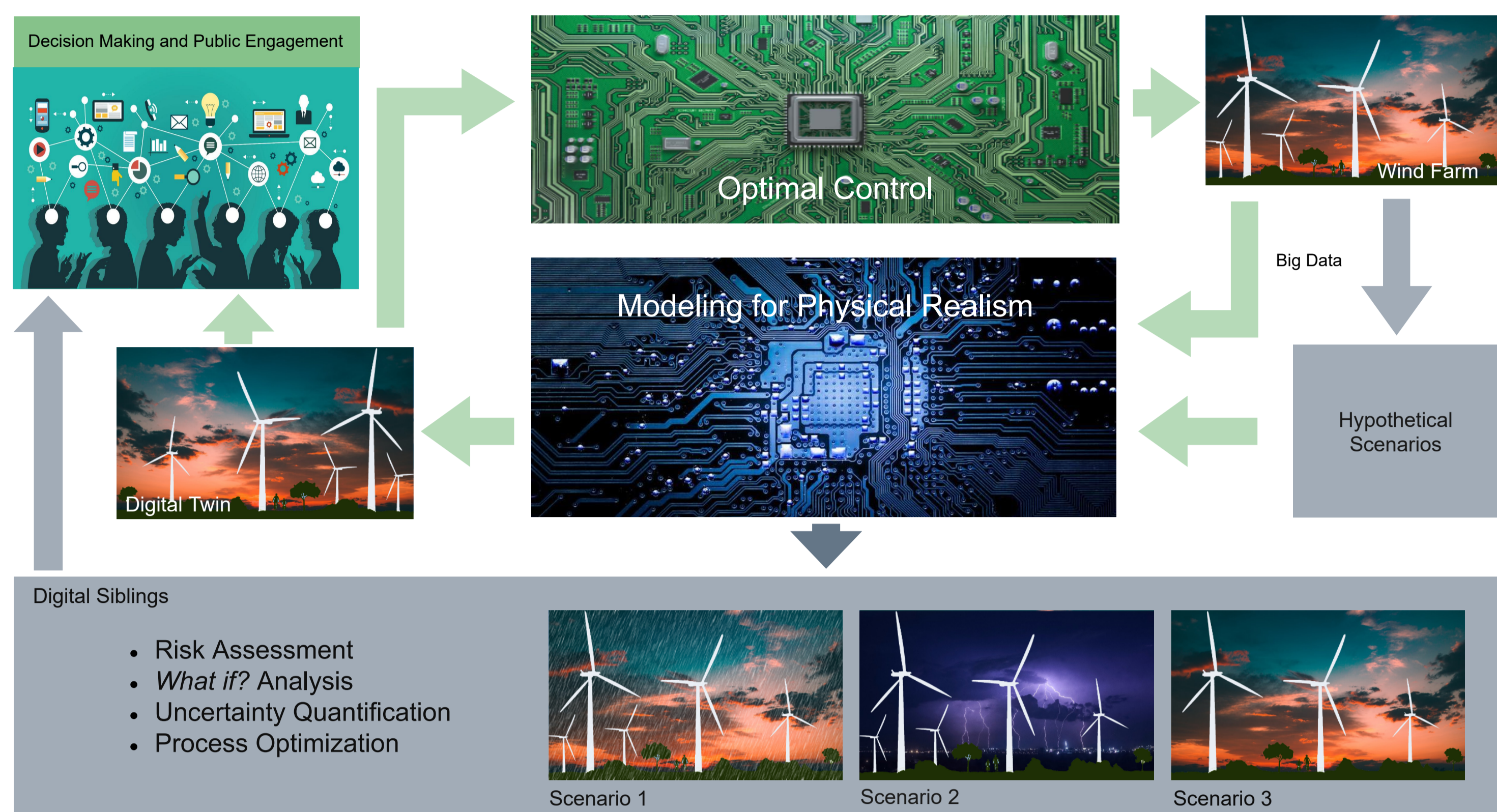
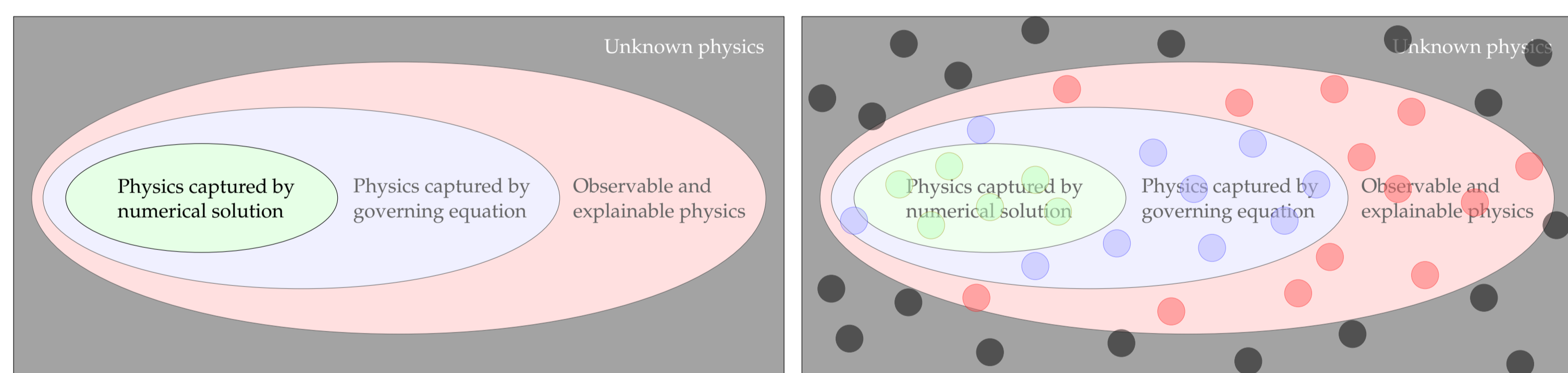


Objective: Enabling deployment of predictive digital twins (DTs) for real-time forecasting, monitoring, control and optimization.



Accurate predictive modelling is paramount!

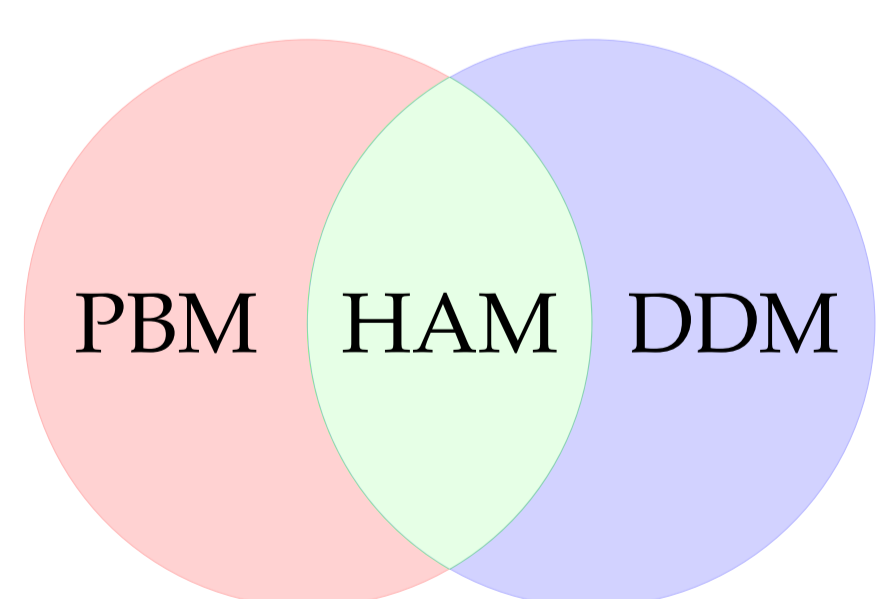
Physics-based modelling (PBM) and data-driven modelling (DDM) have been the dominant modelling paradigms.



PBM: + uses known first-principles
- does not model all physics

DDM: + data manifests *all* physics
- lacks the robustness of PBM

Hybrid Analysis and Modelling (HAM) combines PBM and DDM to keep their strengths and limit their weaknesses [2].



	PBM	HAM	DDM
Generalizability	😊	😊	😞
Trustworthiness	😊	😊	😞
Computational efficiency	😞	😊	😊
Self-adaption	😞	😊	😊

References

- [1] S. S. Blakseth, A. Rasheed, T. Kvamsdal, and O. San. Deep neural network enabled corrective source term approach to hybrid analysis and modeling. 2021. arXiv:2105.11521.
- [2] O. San, A. Rasheed, and T. Kvamsdal. Hybrid analysis and modeling, eclecticism, and multifidelity computing toward digital twin revolution. *GAMM-Mitteilungen*, 2021;44:e202100007.

Solution: CoSTA — a novel HAM approach

For any dynamical system, the Corrective Source Term Approach (CoSTA) augments a PBM of the system with a deep neural network (DNN)-generated corrective source term [1].

$$\mathcal{L}_{\theta} u = f + \hat{\sigma}_{NN}$$

CoSTA

Experiments on 2D Transient Heat Diffusion

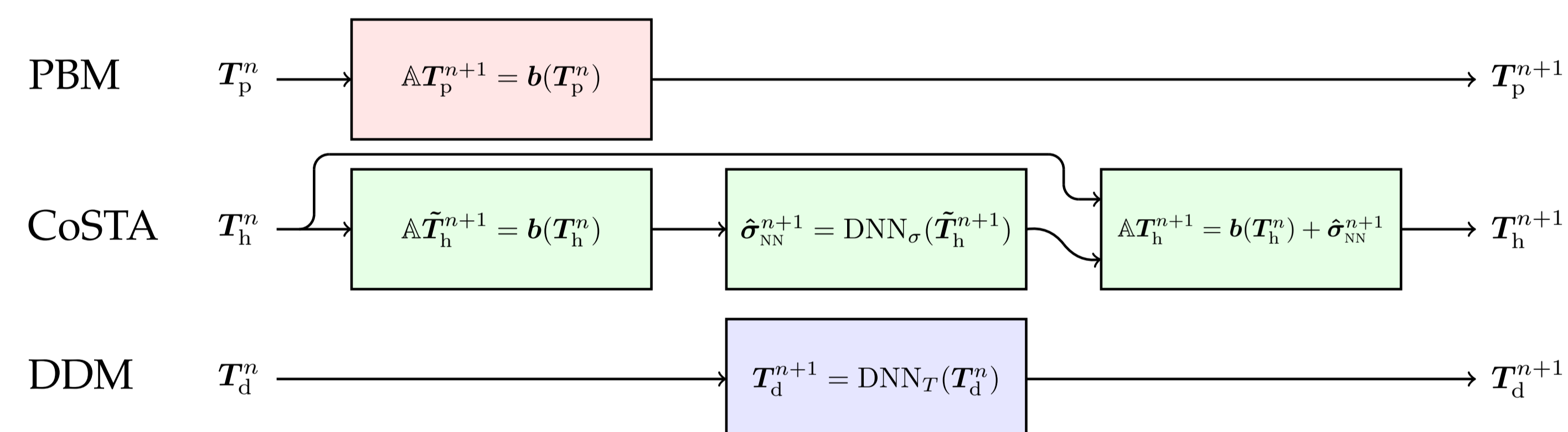
Why model heat diffusion?

1. Heat diffusion drives temperature changes.
2. Temperature can be measured easily and non-intrusively.
3. Temperature data is often used in condition monitoring.

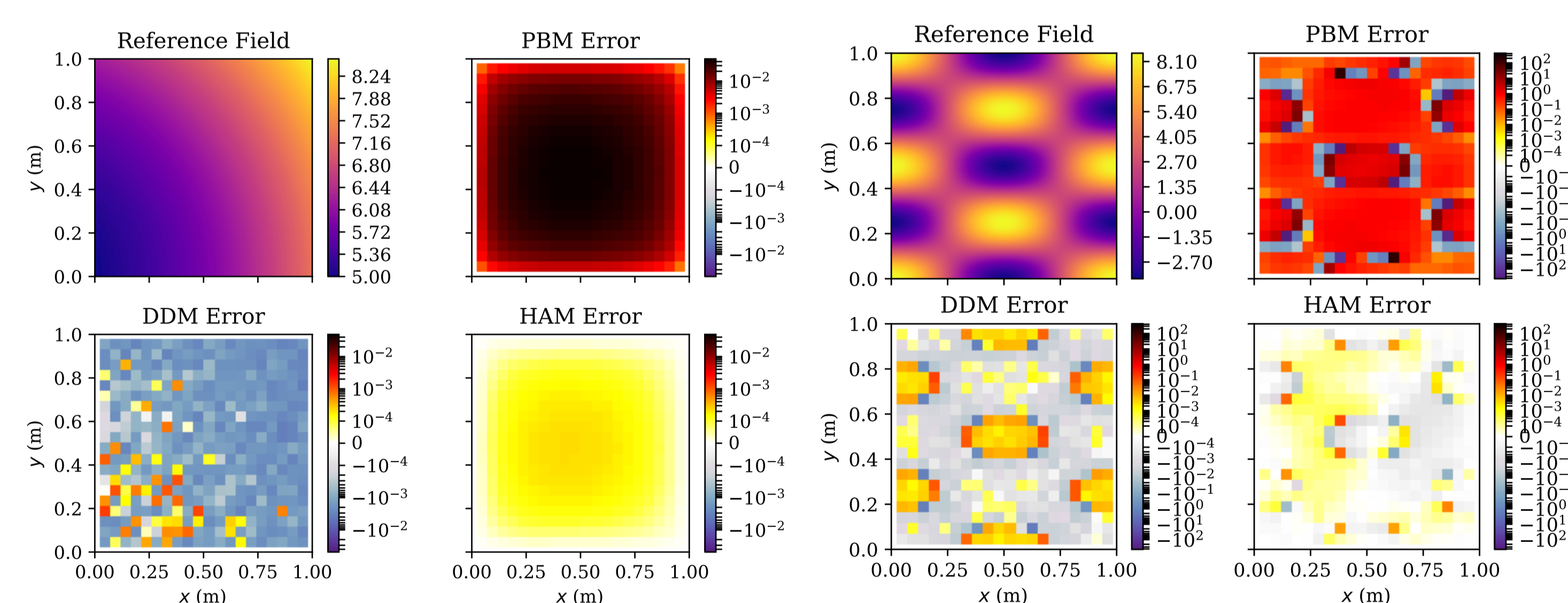
The systems we modelled

1. 2DP: A system with unknown uniform heating.
2. 2Dk: A system with unknown periodic thermal conductivity.

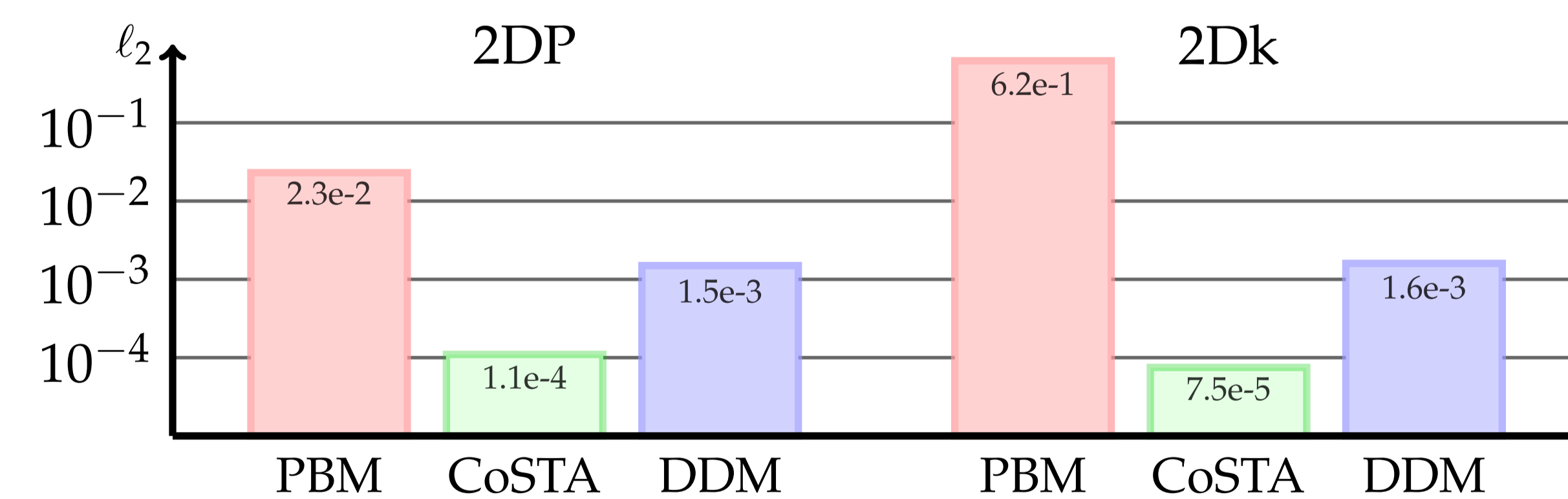
The models we compared



Results



The errors of the predicted temperature fields are illustrated above for the systems 2DP (left) and 2Dk (right). Relative ℓ_2 -norms of these errors are illustrated below.



Highlights

CoSTA is over one order of magnitude more accurate than stand-alone PBM and DDM in our experiments.

CoSTA facilitates physics-based interpretation of the DDM component \implies Increased applicability of DDM.

CoSTA can leverage novel developments within both PBM and DDM due to its modular framework.