

Flexibility provision by decentralized energy and resource systems

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Motivation



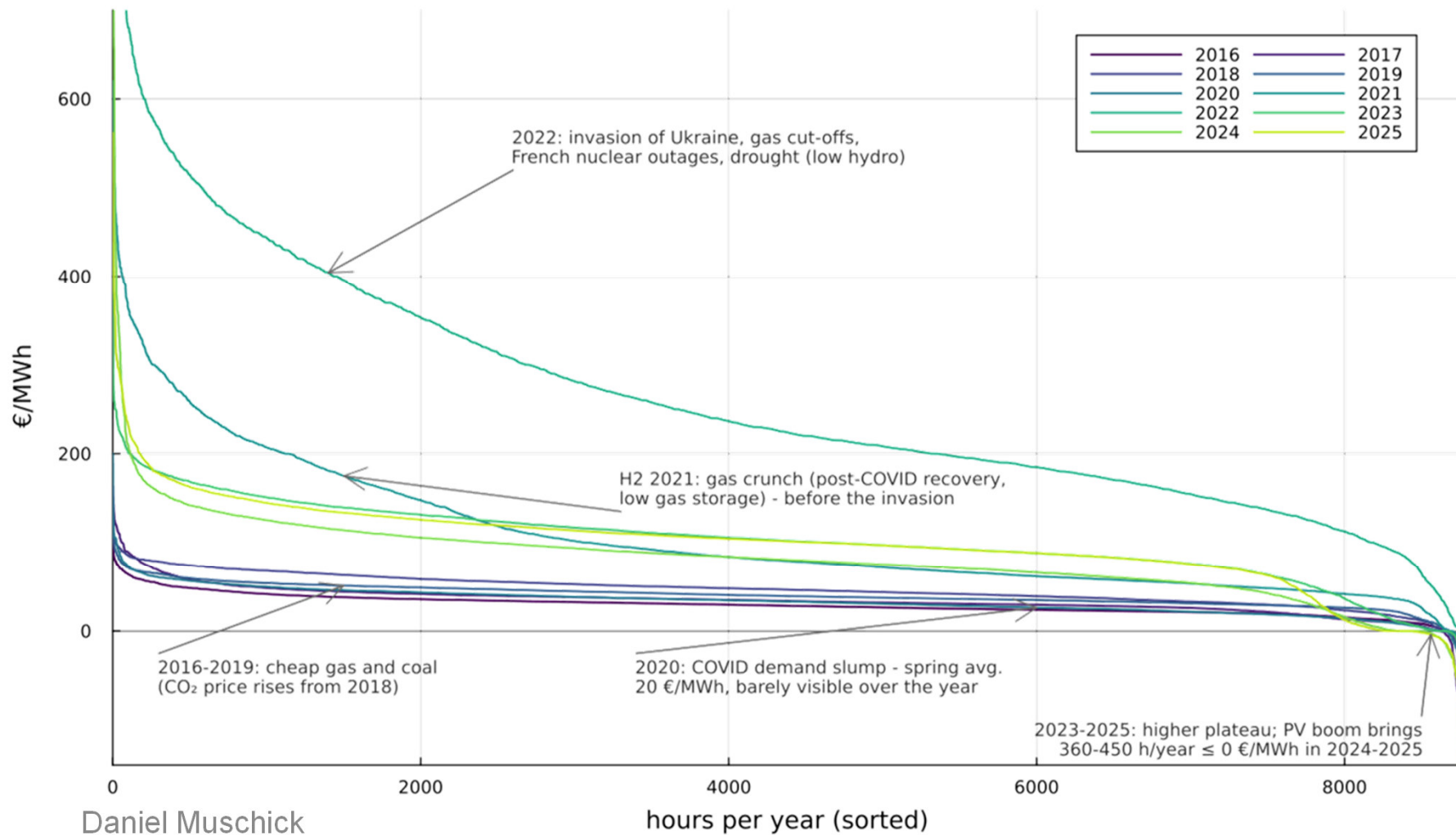
**Variable & decentralized
generation from
renewables**

**Electrification & sector
coupling: Challenges to
grid infrastructure**

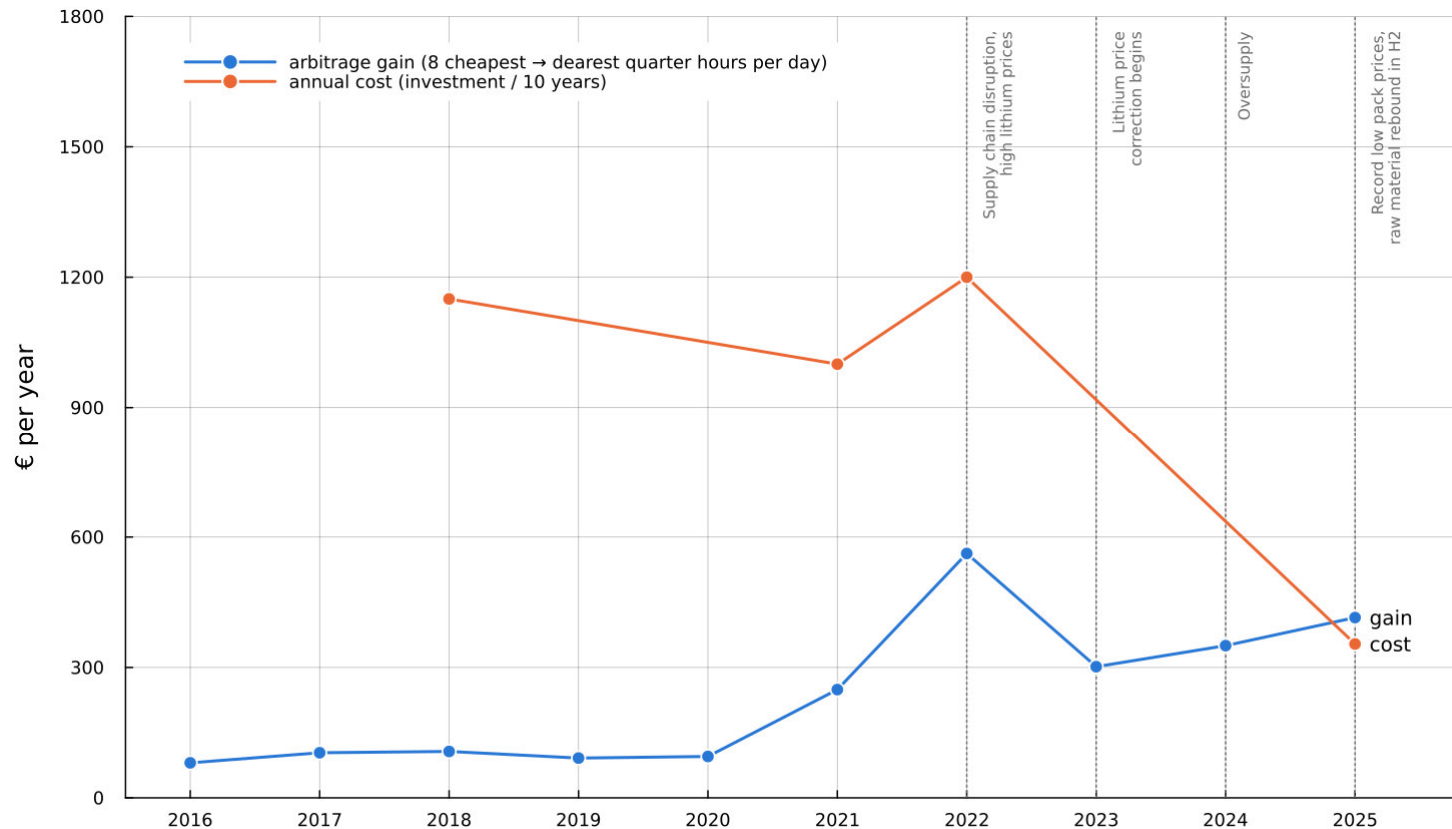
**Decentralized
flexibility as both a
necessity and a
business model**

**Requires intelligent &
predictive control**

Price duration curves as history lessons



Batteries to the rescue?



Plot based on information on <https://bslbatt.com/blogs/current-average-energy-storage-cost-2025> and publications by Jan Figgenger

- Battery prices have fallen
- **But:** Sector coupling enables using existing and new flexibilities without increased dependence on, e.g., China
- Increasing share of renewables **requires** us to use flexibility to limit required investment costs

Who can offer flexibility?

**Single family
homes**



**Office
buildings**



**Energy
communities**



**EV charging
infrastructure**

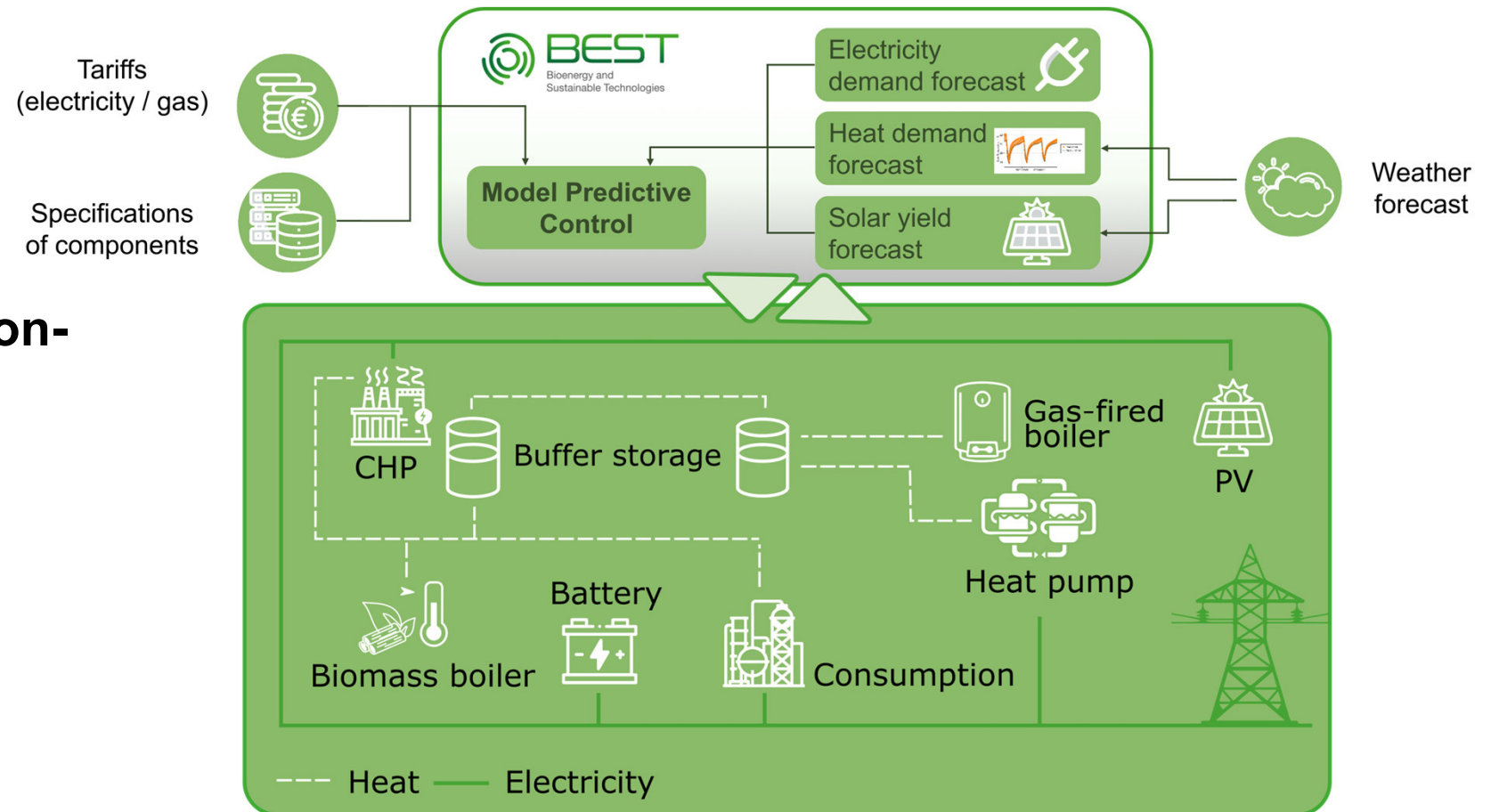


**District heating
energy hubs &
industry**



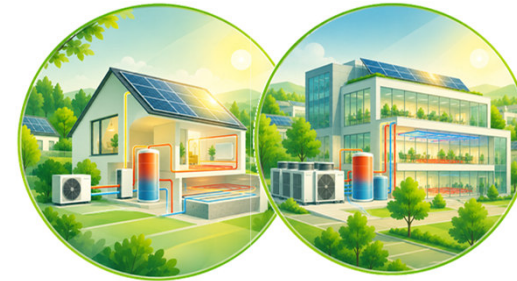
Handling flexibility from heat pumps, CHPs and EVs benefits from predictive control

BEST's Energy Management System Framework

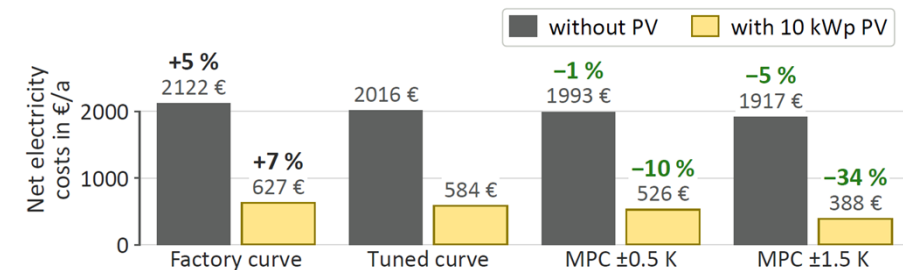


- **Optimization-based**
- **Predictive**
- **Modular**

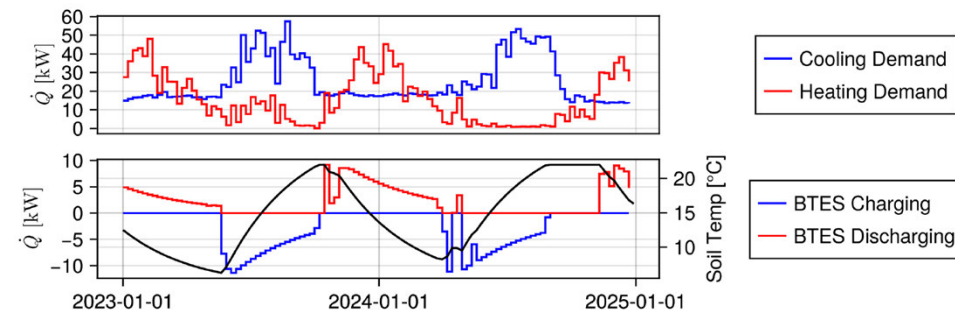
Example Heating / Cooling with Heat Pumps



- **Where does flexibility come from?**
 - Thermal energy storage (TES)
 - Building mass
- **What are the challenges?**
 - Energy system and hydraulics models
 - Estimate thermal dynamics of the building and ensuring comfort while shifting energy demand
 - Scaling to many thermal zones
 - Integrating long-term storage (borehole TES)
- **Our solutions:**
 - 3-state models per zone automatically identified via Unscented Kalman Filter
 - Thermal controllers interact with energy hub optimization directly or via cost curves
 - Coordination of long-term and short-term optimization using Benders Decomposition



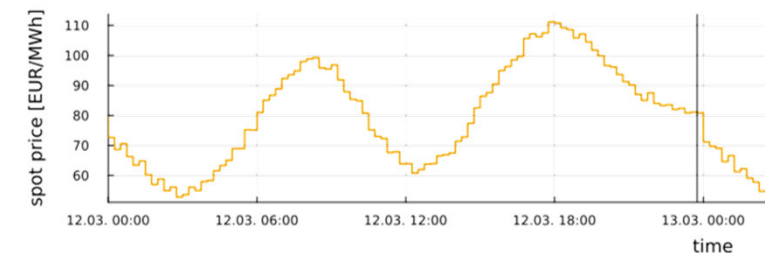
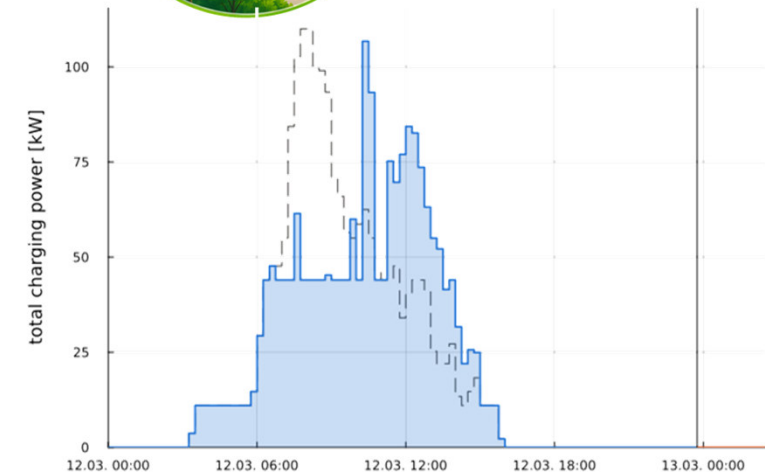
See poster: *Building as Storage: Predictive Temperature Control for Single-Family Homes* by A. Moser



From *Cooperative Optimization-based Control of Heating Systems with Seasonal Storage* by J. Fuchsberger & V. Kaisermayer

Example Electric Vehicle Charging Infrastructure

- **Where does flexibility come from?**
 - Limit charging power to defer load
 - Future: Bi-directional charging (V2G)
 - Local batteries
- **What are the challenges?**
 - Extreme uncertainty of charging sessions
 - Tradeoff between deferred and curtailed demand
 - Taking advantage of larger numbers requires aggregation / disaggregation methods
- **Our solutions:**
 - Probabilistic models for charging session forecasts conditioned over charging park occupancy
 - Agent-based distributed demand response algorithm and virtual battery approximation of flexibility potential



Simulation study based on real data leading to **~5% reduction** in electricity costs.

Conclusions

- **Using flexibility is both a necessity and a business opportunity across all sectors**
 - Energy transition cannot work without storage = flexibility
 - Batteries are growing cheaper, but increase our dependence on foreign countries for raw materials
 - Sector coupling and aggregation enable both existing and new flexibilities and open electricity markets to many applications
 - Increased complexity benefits from smart, predictive supervisory control!

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