UNIVERSITY OF TWENTE.

COORDINATING MULTI-ENERGY SYSTEMS

GERWIN HOOGSTEEN, ENERGY OPEN 2019 GRONINGEN

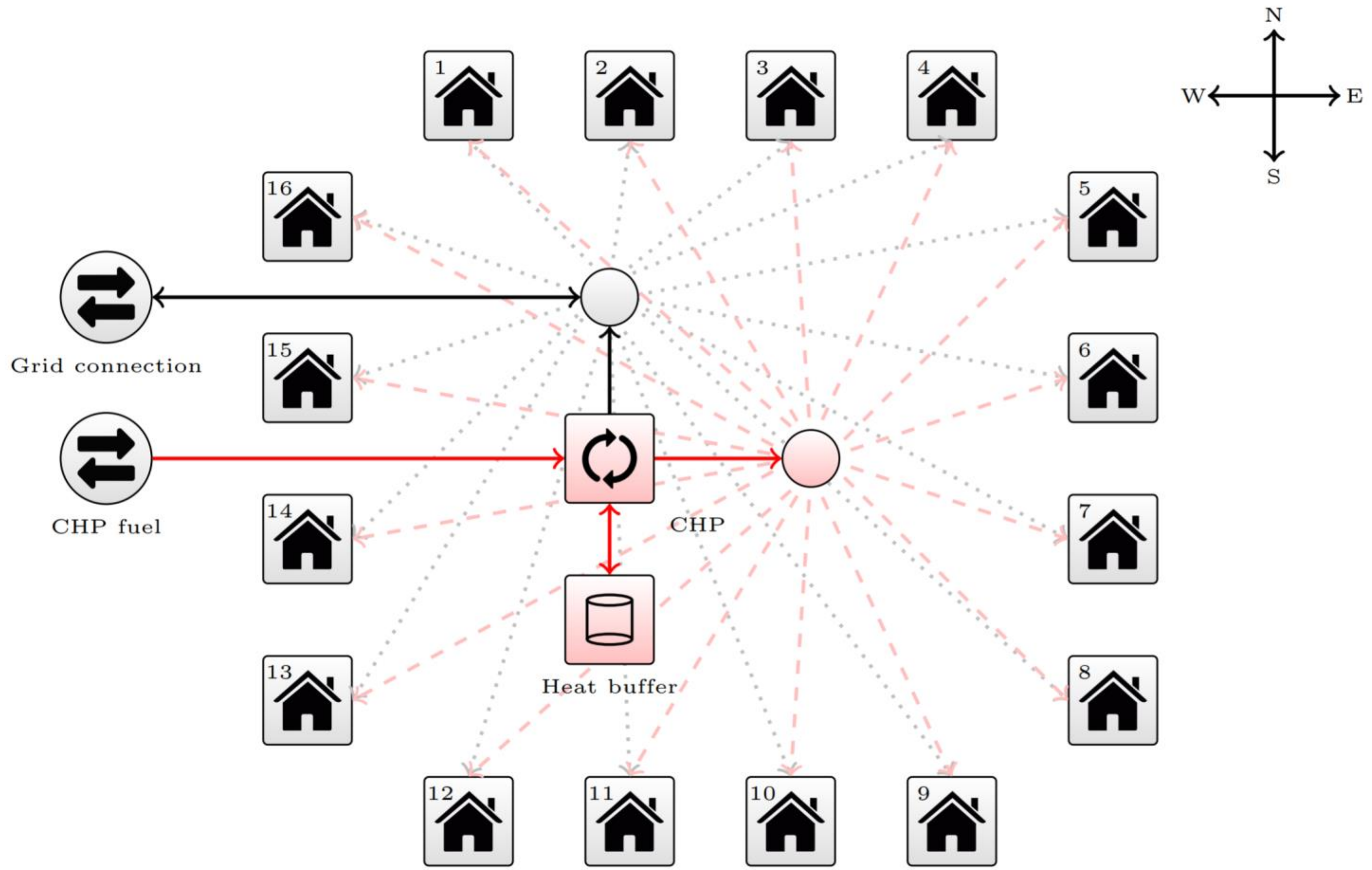
MULTI-ENERGY SYSTEMS COORDINATION

- Multi-energy systems required
  - Seasonal storage: Hydrogen, PCM, etc.
  - Heat and district heating grids
- Coupling with the electricity grid
  - Heat Pumps, Combined Heat and Power
  - Multi-energy system with dependencies
- Need for scalable coordination

Can Profile Steering be used to coordinate a multi-energy system?

16 HOUSES CASE

NEARLY AUTARKIC NEIGHBOURHOOD



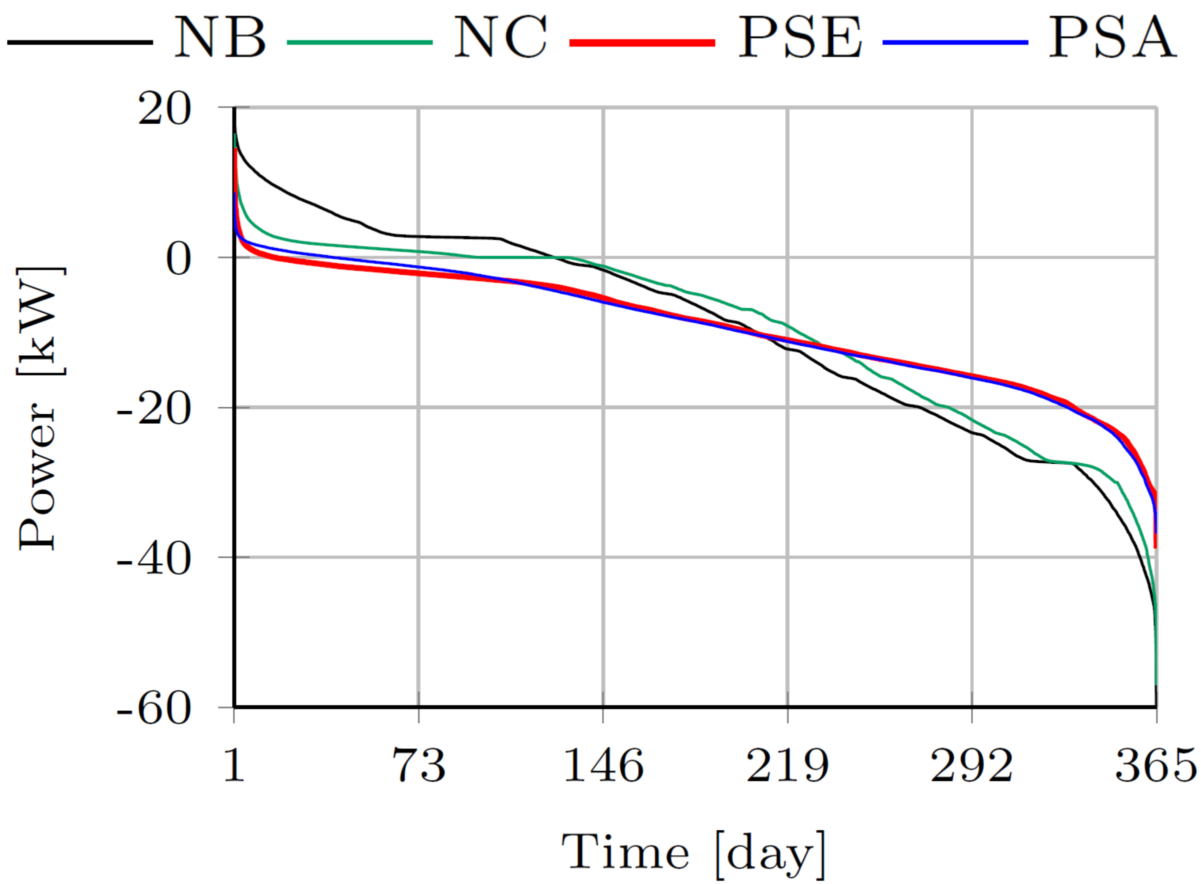
[1] Homan, Hoogsteen et al. “Maximizing the Degree of Autarky of a 16 House Neighbourhood by Locally Produced Energy and Smart Control” Published in Elsevier Sustainable Energy, Grids And Networks journal

16 HOUSES CASE
EQUIPMENT SIZING

Equipment	Electricity	Remarks
CHP	30 kWel 60 kWth	
Heat buffer	250 kWh	
Battery	64 kWh (4 kWh/house)	3.7 kW
PV	244 panels (14 per house)	50% South 25% East 25% West

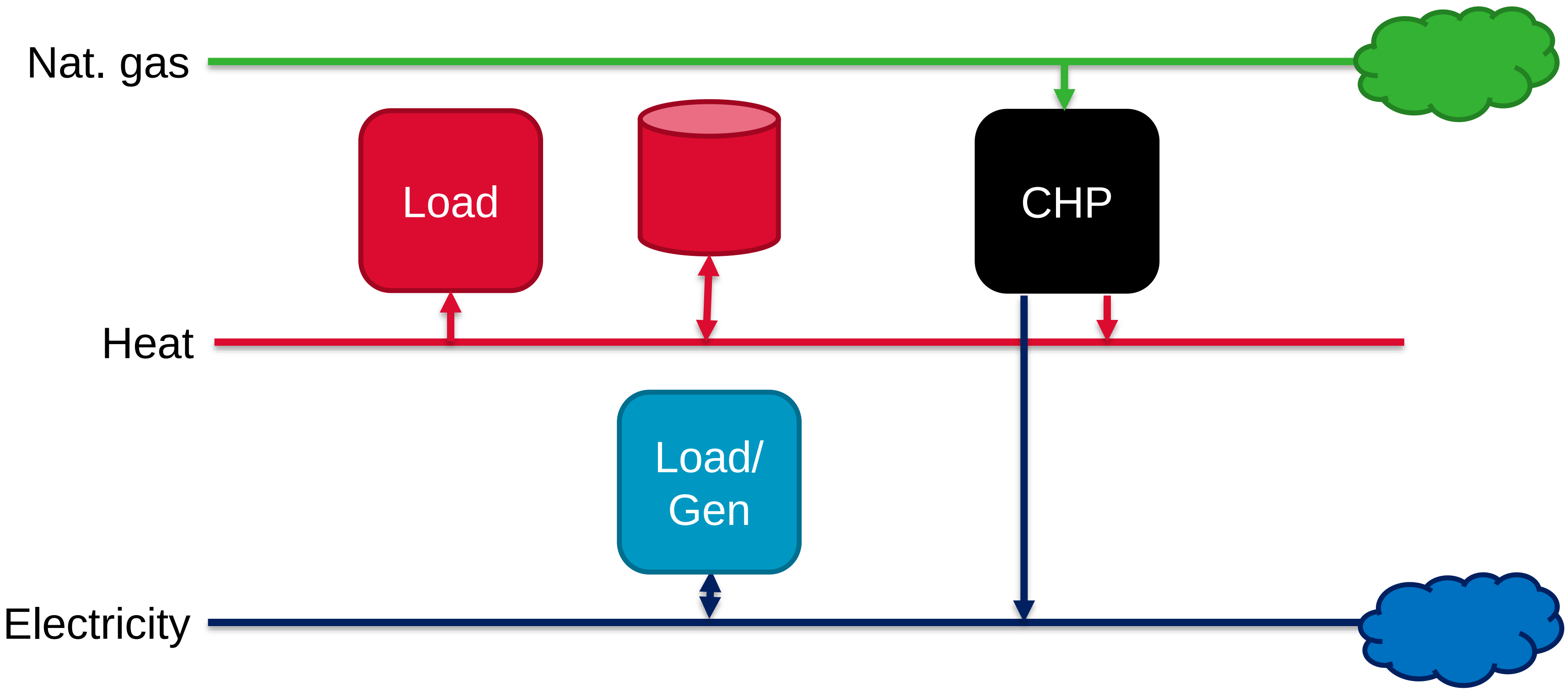
16 HOUSES CASE

… BUT SIGNIFICANT OVERPRODUCTION OF ELECTRICITY



16 HOUSES CASE

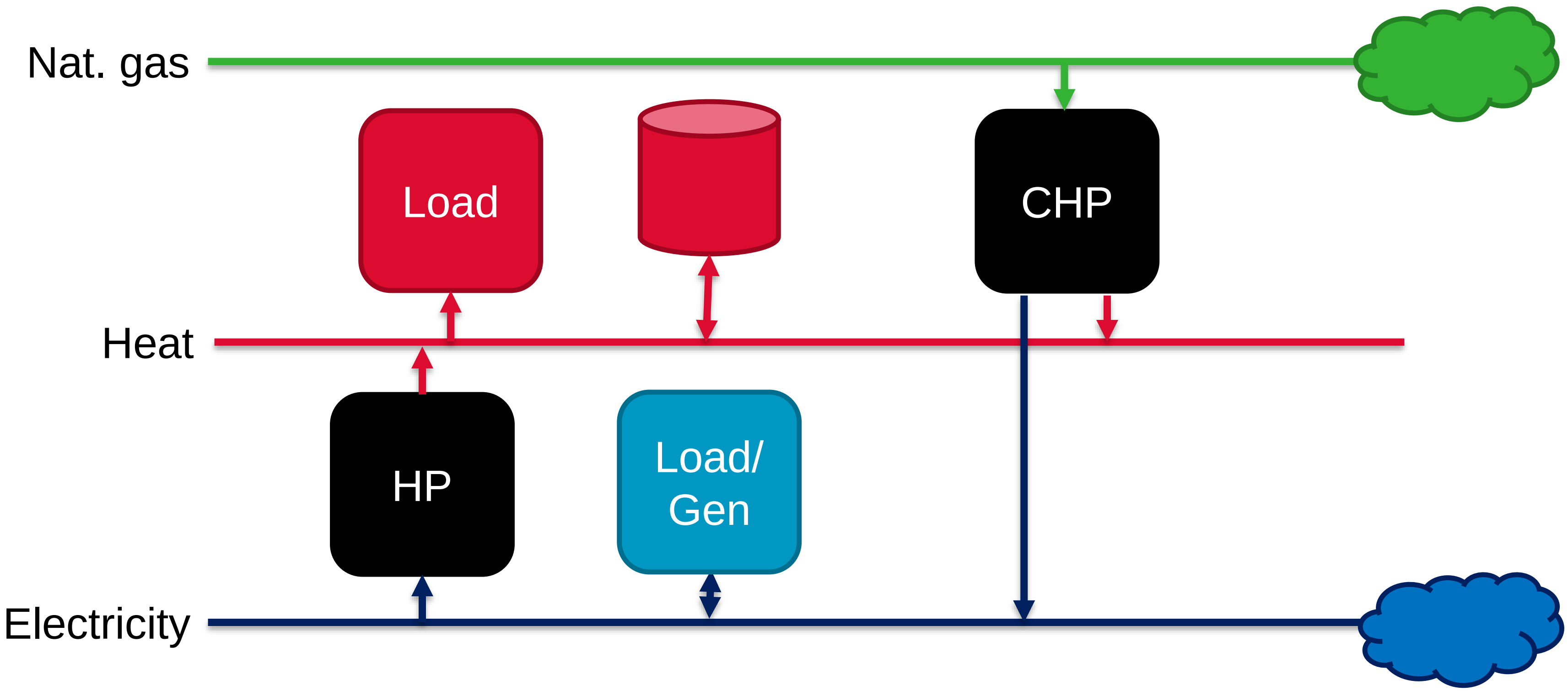
A POSSIBLE SOLUTION



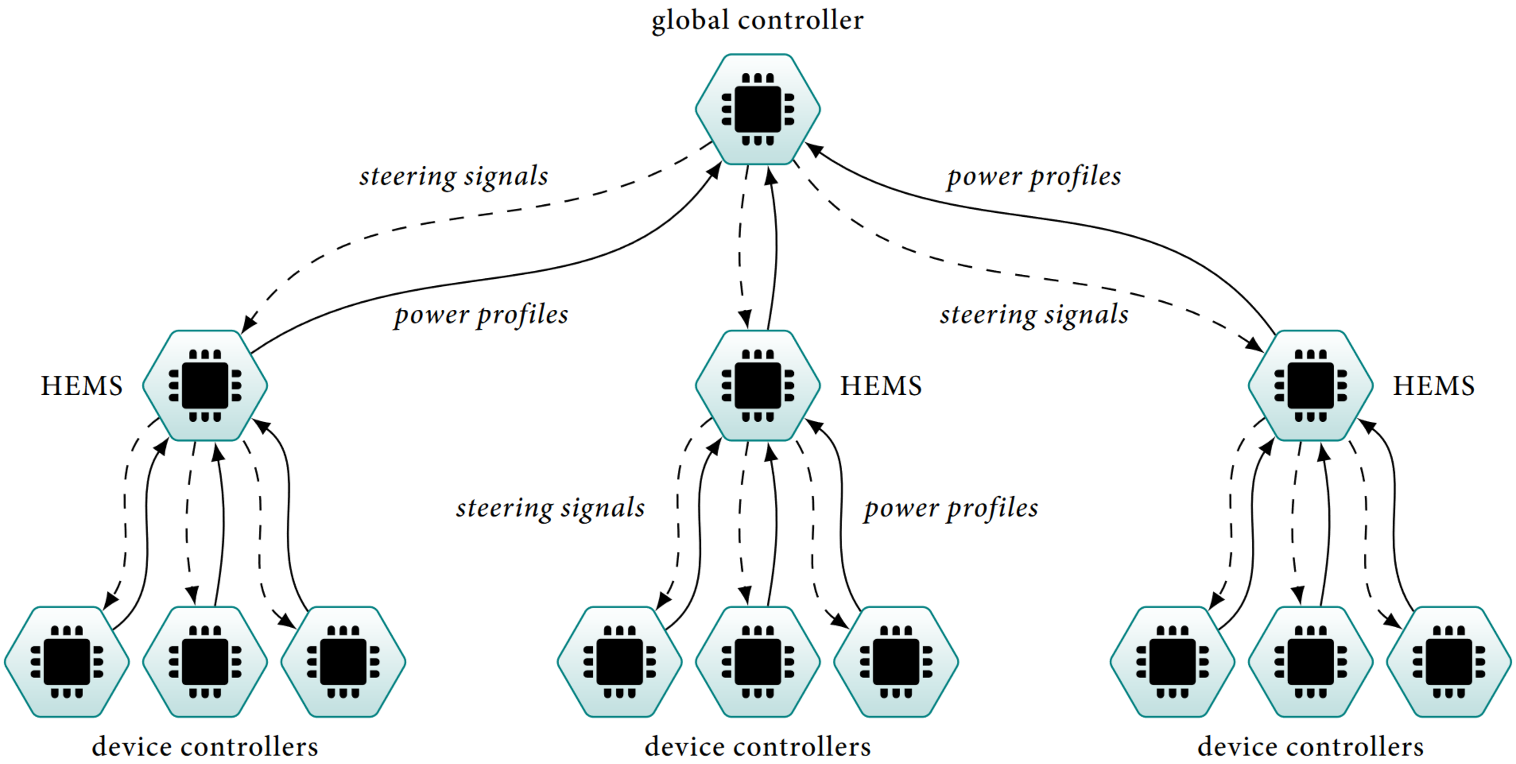
16 HOUSES CASE

A POSSIBLE SOLUTION

CHP + HP + Buffer act as a “battery” to the electricity grid!

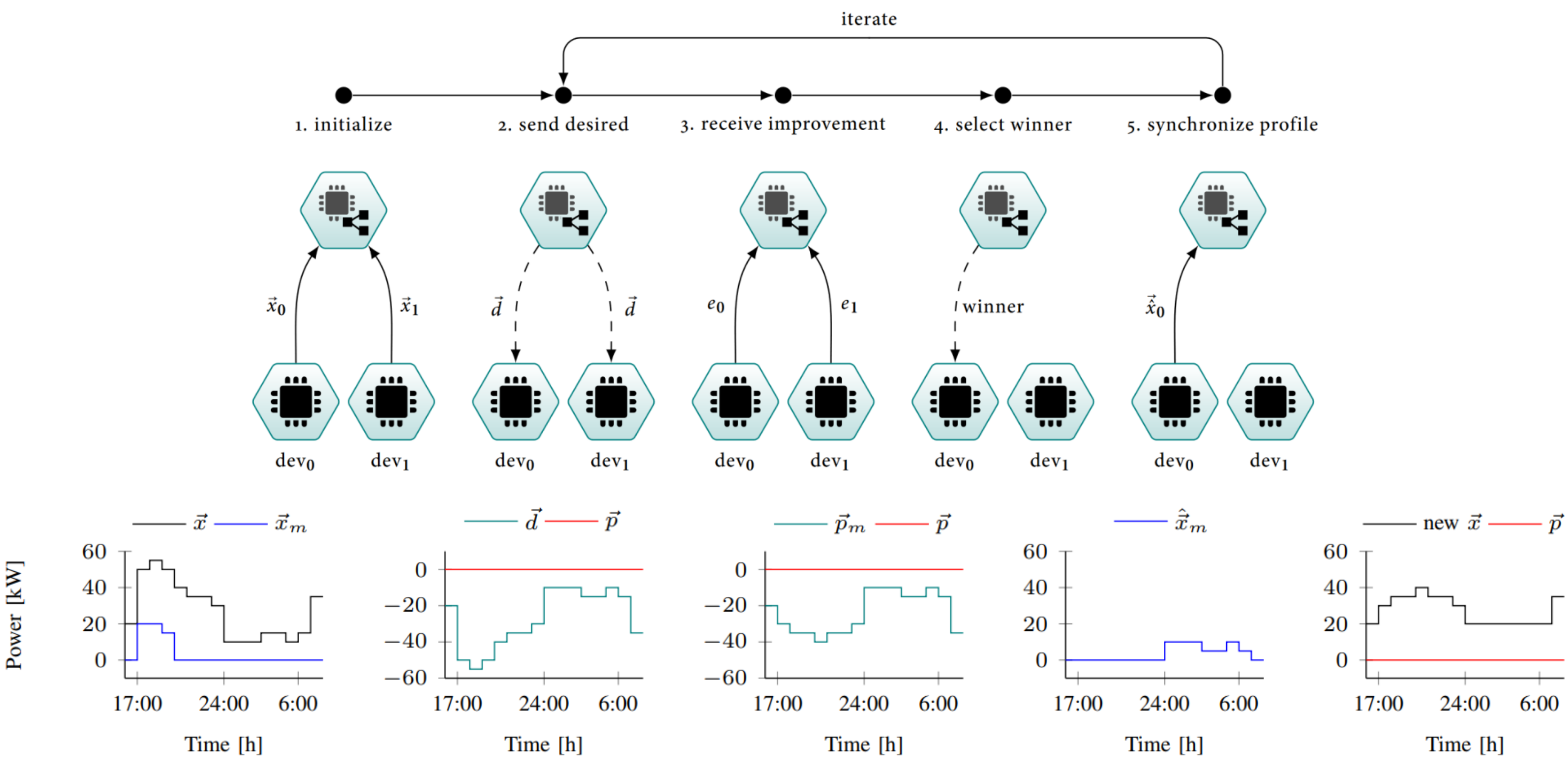


PROFILE STEERING
DISTRIBUTED OPTIMIZATION ALGORITHM



PROFILE STEERING

OBJECTIVE: $minimize\ ||x - p||_2$



(a) Initial profiles (b) Incentive (c) EV desired (d) EV candidate (e) Parent controller

PROFILE STEERING

MULTI ENERGY CARRIER STEERING

- **Multi-commodity PS:**
  - Matrices instead of vectors
  - Each column represents an energy carrier
  - Local device optimization algorithms can generate optimal response

- **Scalable PS:**
  - Send a fraction of the desired profile to children
  - Speed-up through accepting multiple profiles

- **Limits in PS:**
  - Energy exchange limits to certain nodes

PROFILE STEERING

HEURISTIC STEPS

- Create initial *planning*
  -
- **IF NOT** *planning* **IN** *bounds*:
  - Continue *PS planning* step with revised desired profile
    -
  - **IF (STILL) NOT** *planning* **IN** *bounds*:
    - **ALLOW** *discomfort* and continue *PS planning*
      -
    -
- **ELSE:**
  - Continue with a normal *PS planning*

PROFILE STEERING

HEURISTIC STEPS

- Create initial *planning*
  - *Heating system optimizes to balance all energy carriers*
- **IF NOT** *planning* **IN** *bounds*:
  - Continue *PS planning* step with revised desired profile
  - **IF (STILL) NOT** *planning* **IN** *bounds*:
    - **ALLOW** *discomfort* and continue *PS planning*
- **ELSE:**
  - Continue with a normal *PS planning*

PROFILE STEERING
HEURISTIC STEPS

- Create initial *planning*
  - *Heating system optimizes to balance all energy carriers*
- **IF NOT** *planning* **IN** *bounds*:
  - Continue *PS planning* step with revised desired profile
    - *Heating system tries to get within limits with positive improvement*
  - **IF (STILL) NOT** *planning* **IN** *bounds*:
    - **ALLOW** *discomfort* and continue *PS planning*
- **ELSE:**
  - Continue with a normal *PS planning*

PROFILE STEERING
HEURISTIC STEPS

- Create initial *planning*
  - *Heating system optimizes to balance all energy carriers*
- **IF NOT** *planning* **IN** *bounds*:
  - Continue *PS planning* step with revised desired profile
    - *Heating system tries to get within limits with positive improvement*
  - **IF (STILL) NOT** *planning* **IN** *bounds*:
    - **ALLOW** *discomfort* and continue *PS planning*
      - *Heating system forced towards feasible solution*
    - Minimize deviation from bounds instead of the desired profile
- **ELSE:**
  - Continue with a normal *PS planning*

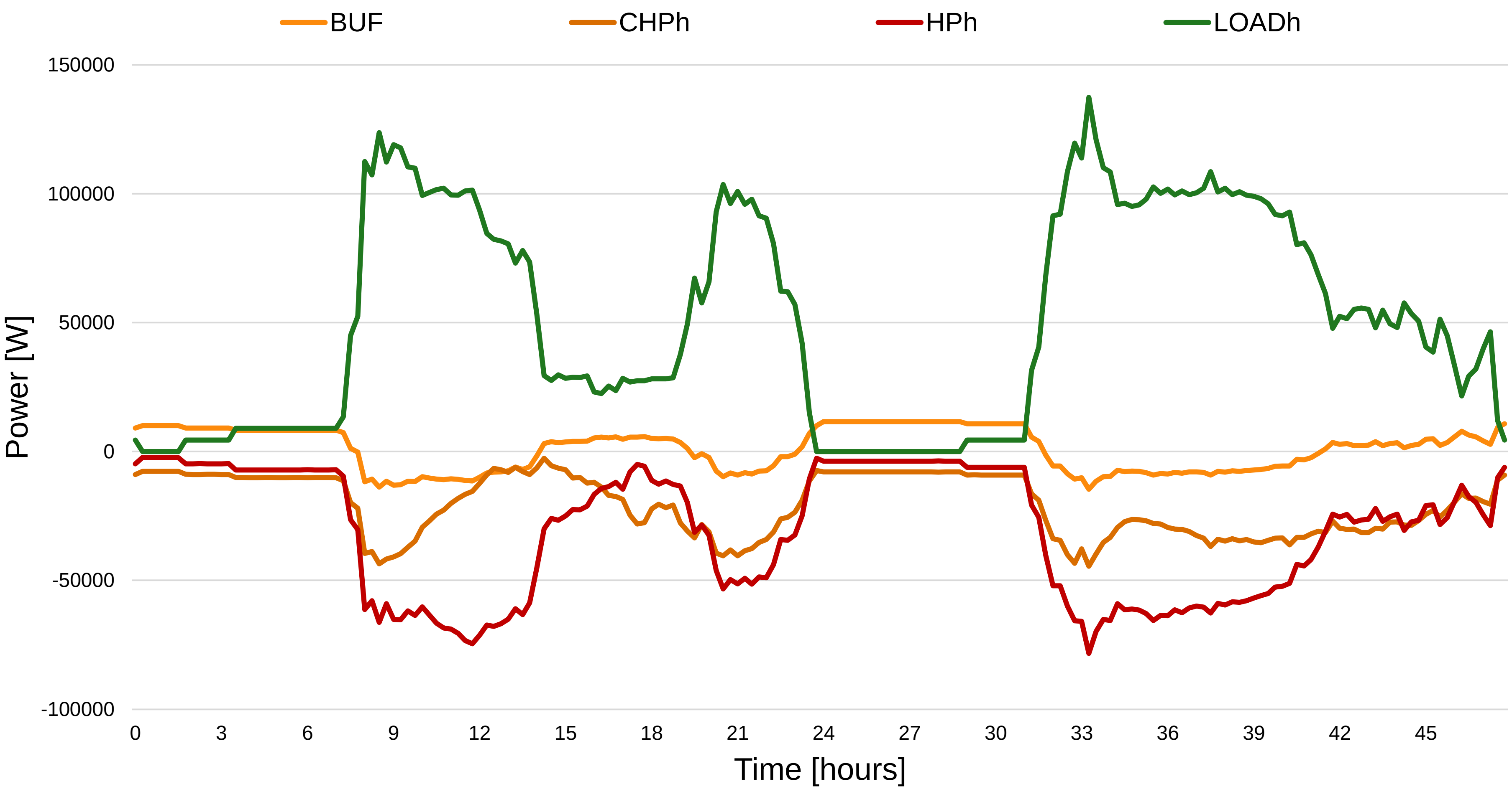
RESULTS

TESTDRIVE USING A CASE SIMILAR TO 16 HOUSES

	CHP	HP	BUF	BAT	CHP [kW] gas > heat + elec	HP [kW] elec > heat	BUF/BAT [kWh]
N					-	-	-
B					-	-	- / 64
CB					200 > 133 + 67	-	250 / -
CBB					200 > 133 + 67	-	250 / 64
CHB					100 > 67 + 33	50 > 200	250 / -
CHBB					100 > 67 + 33	50 > 200	250 / 64

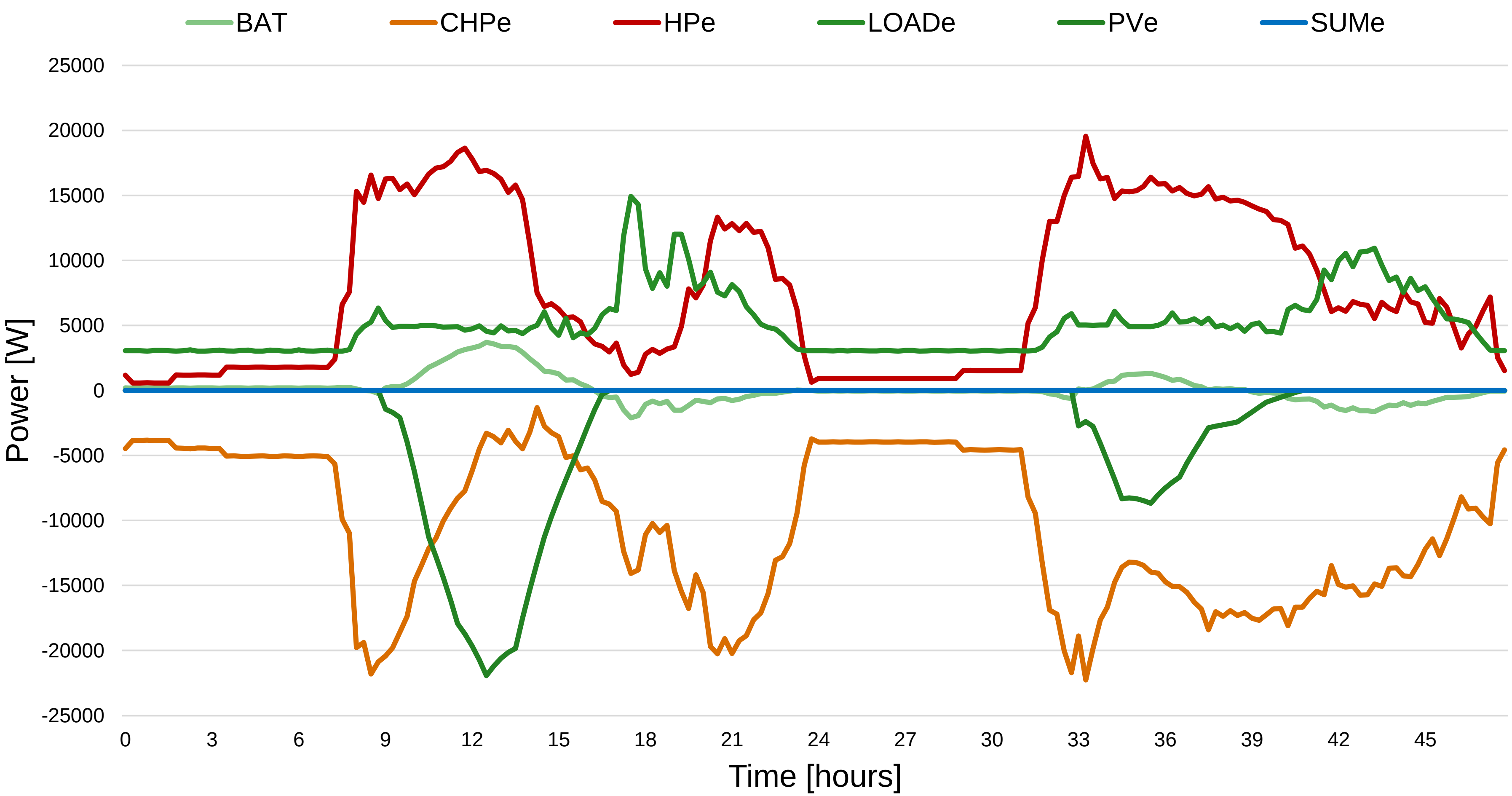
RESULTS

WINTER (HEAT)



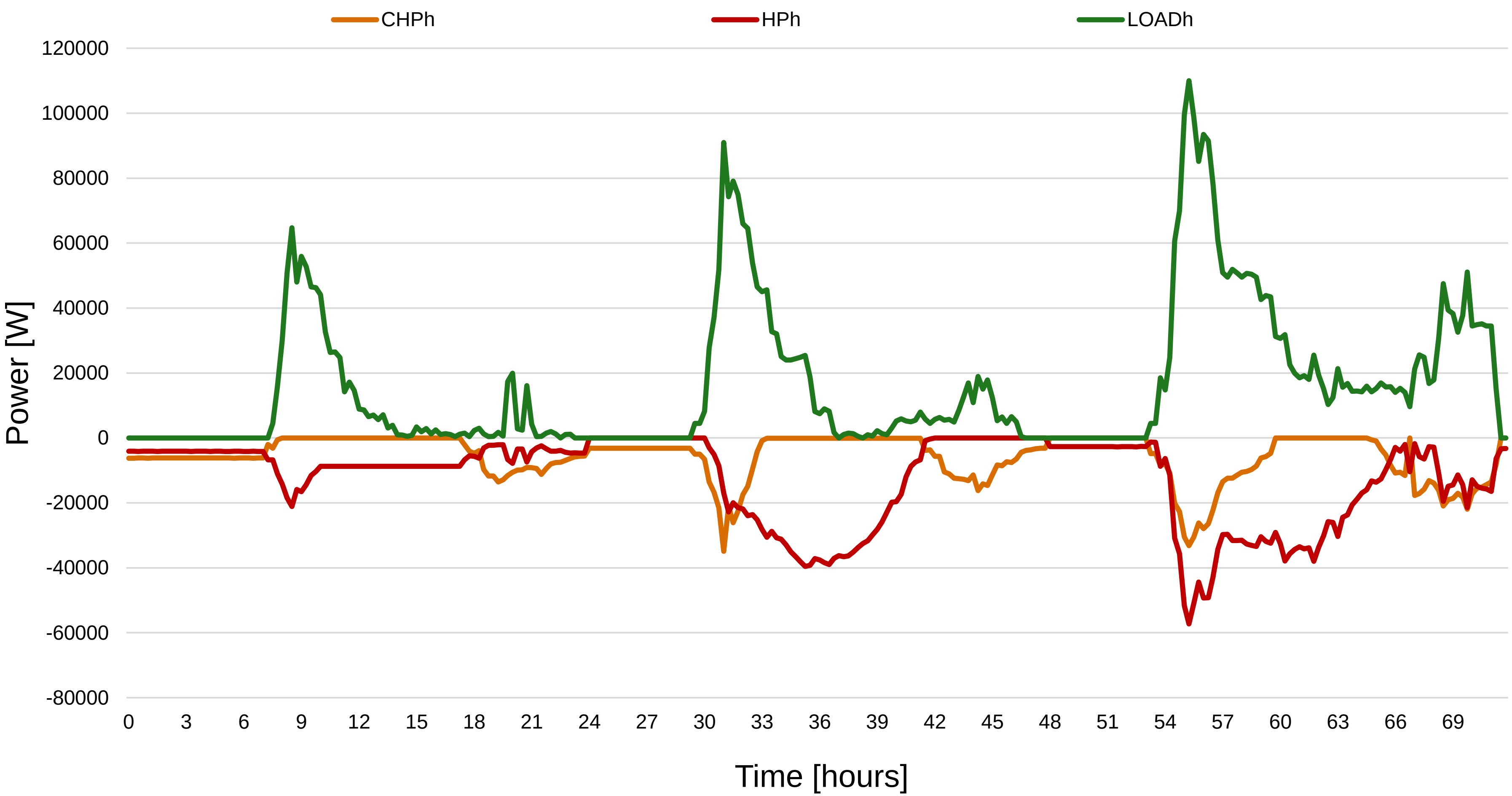
RESULTS

WINTER (ELECTRICITY)



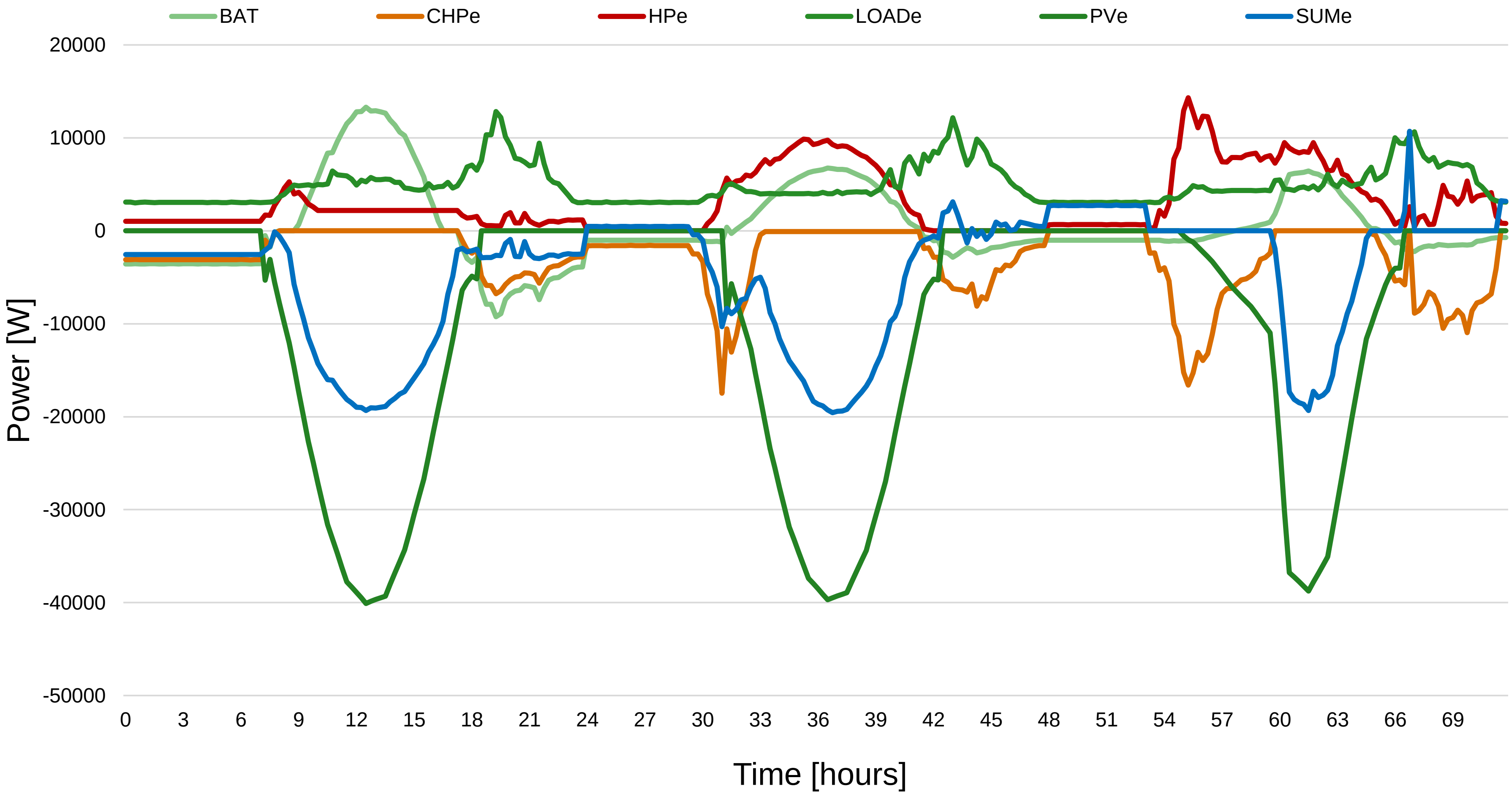
RESULTS

SPRING (HEAT)



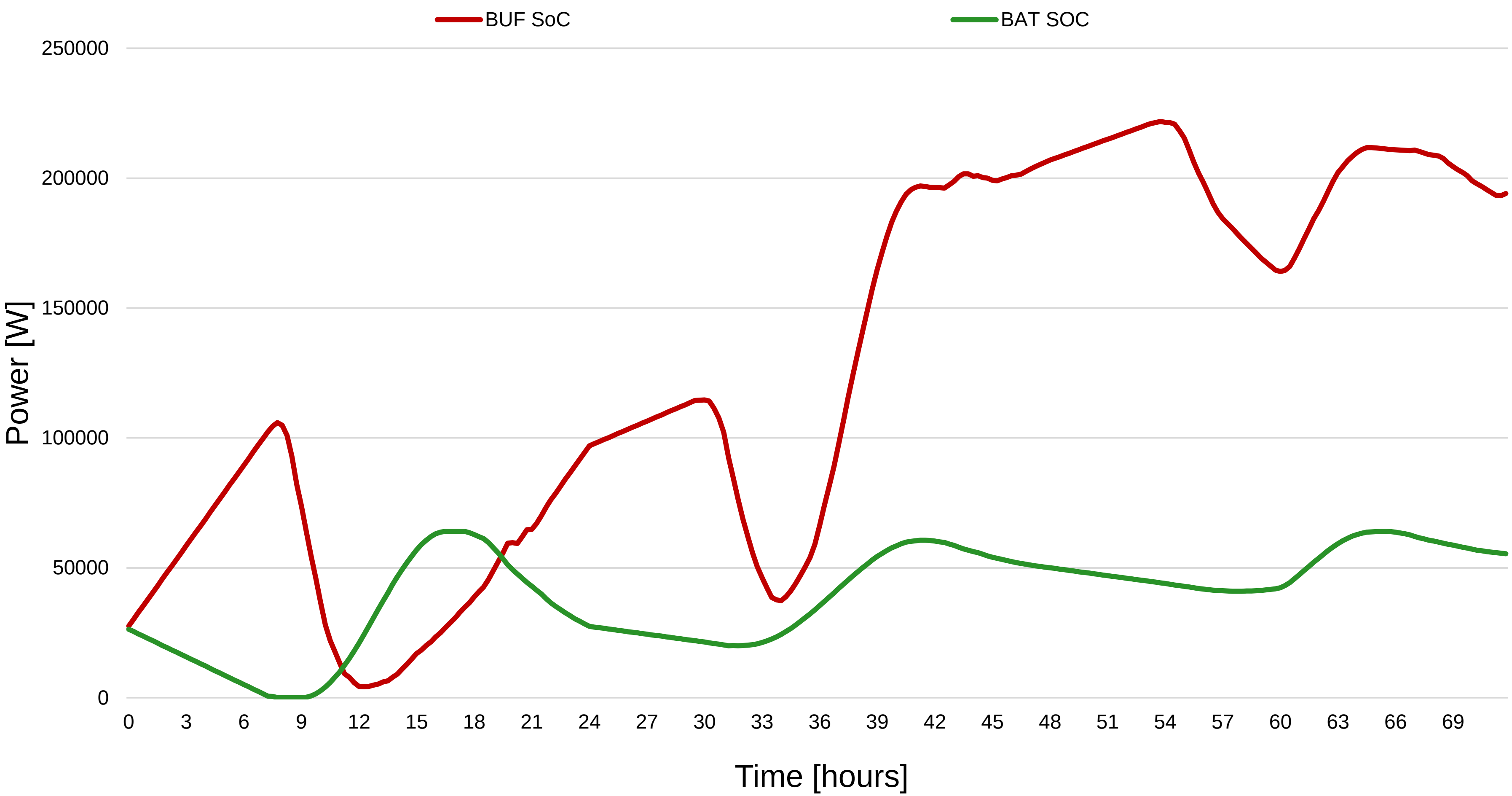
RESULTS

SPRING (ELECTRICITY)



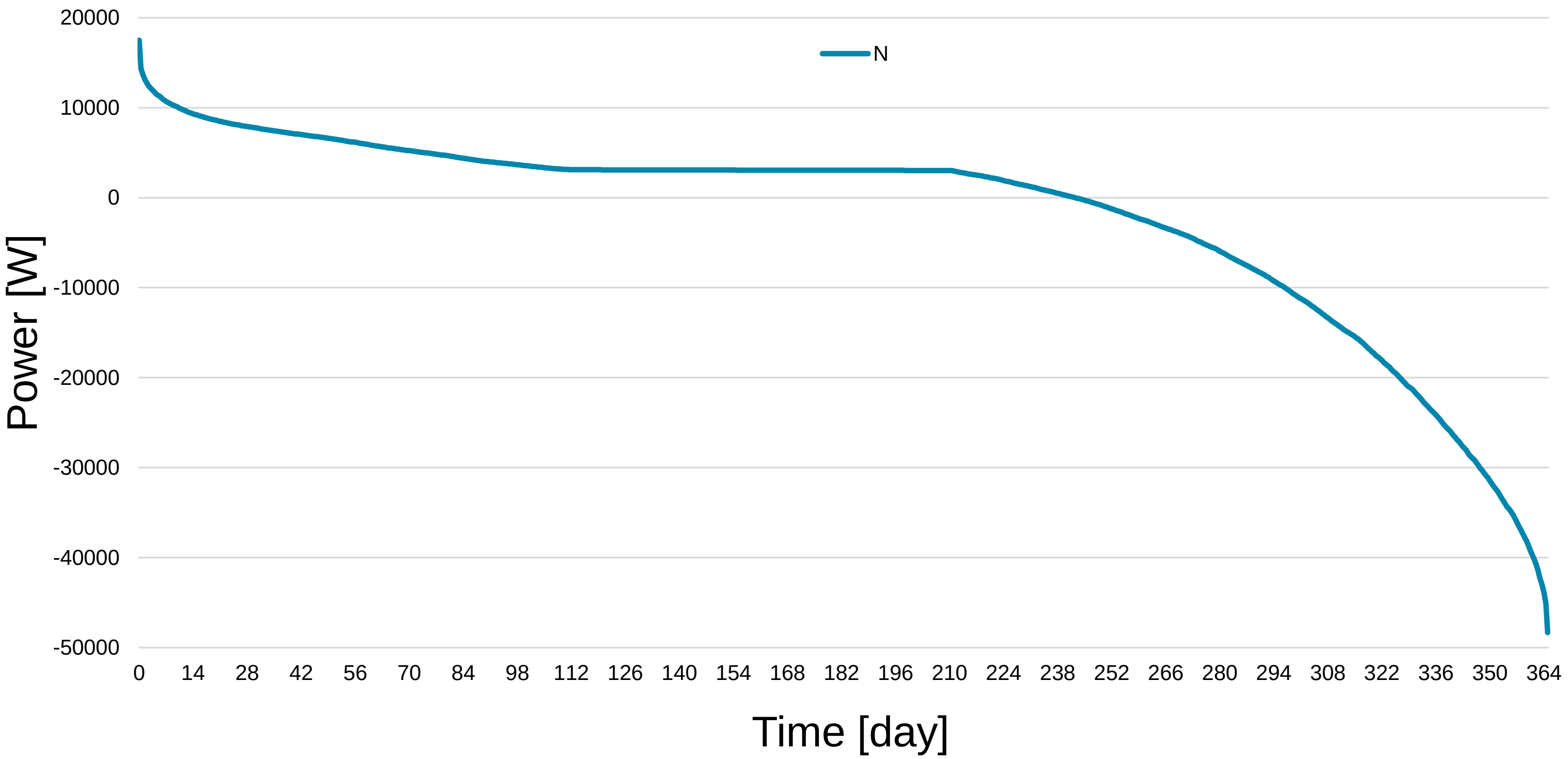
RESULTS

SPRING (SOC)



RESULTS

LOAD DURATION CURVE



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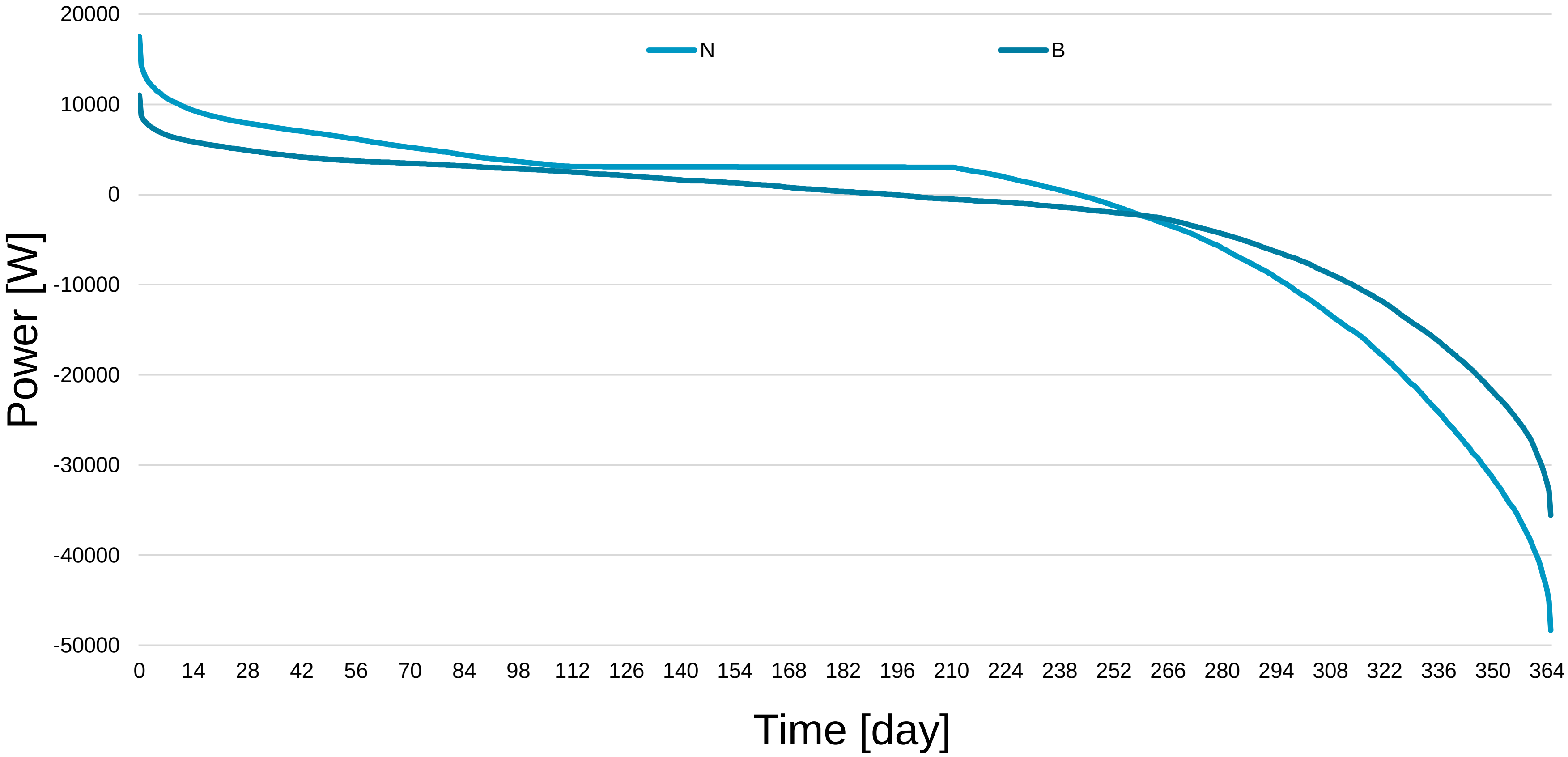

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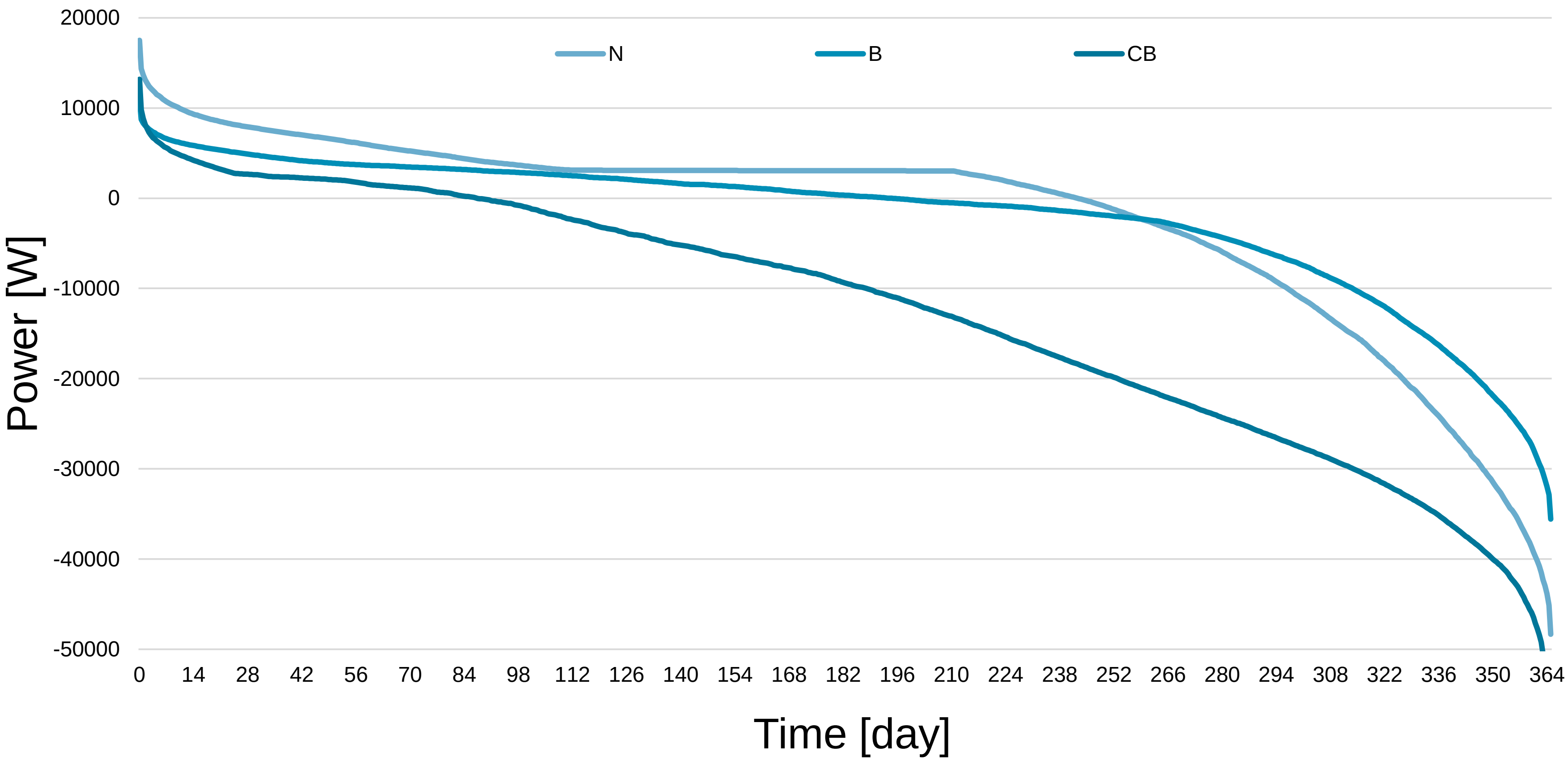

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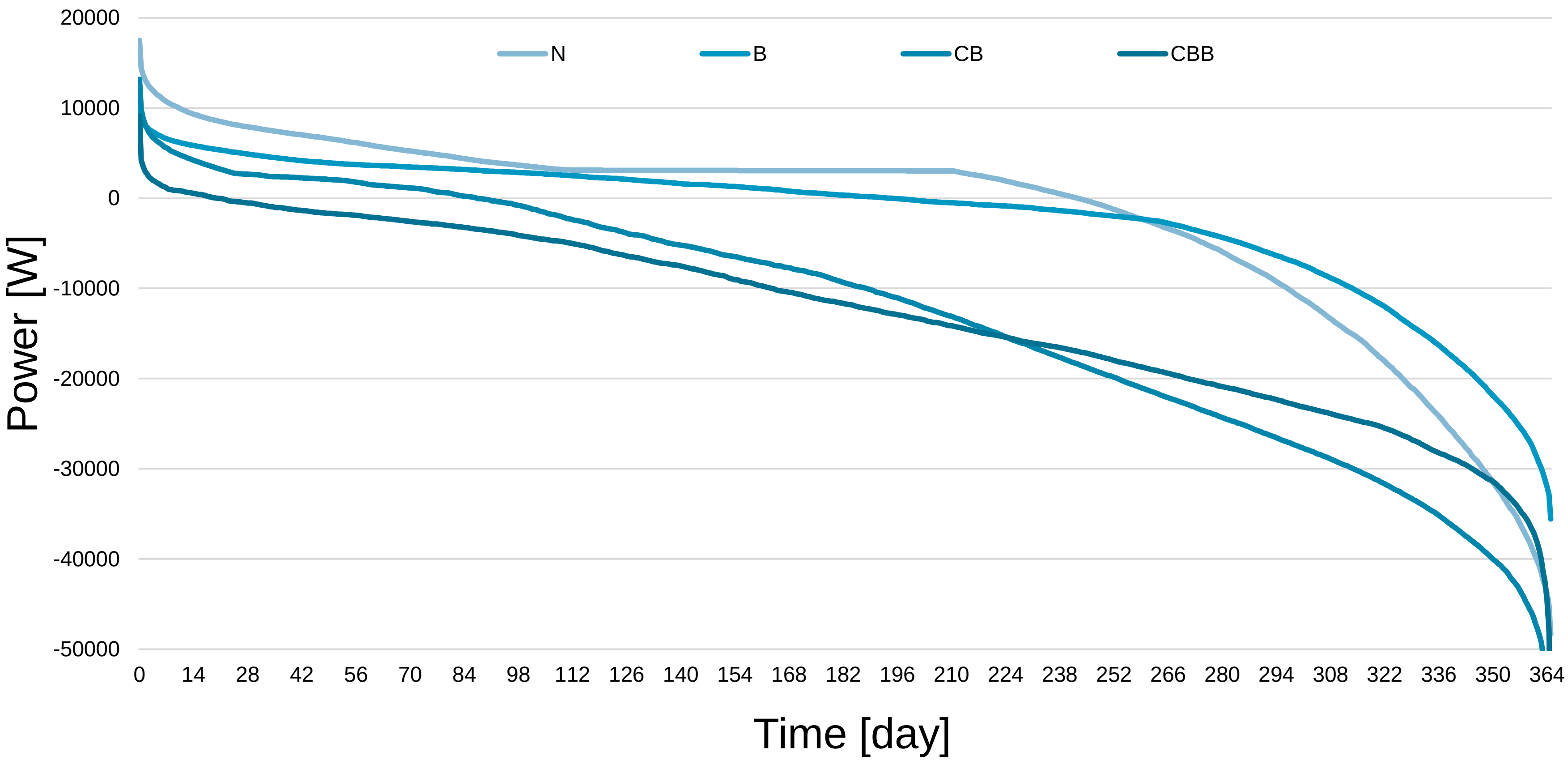
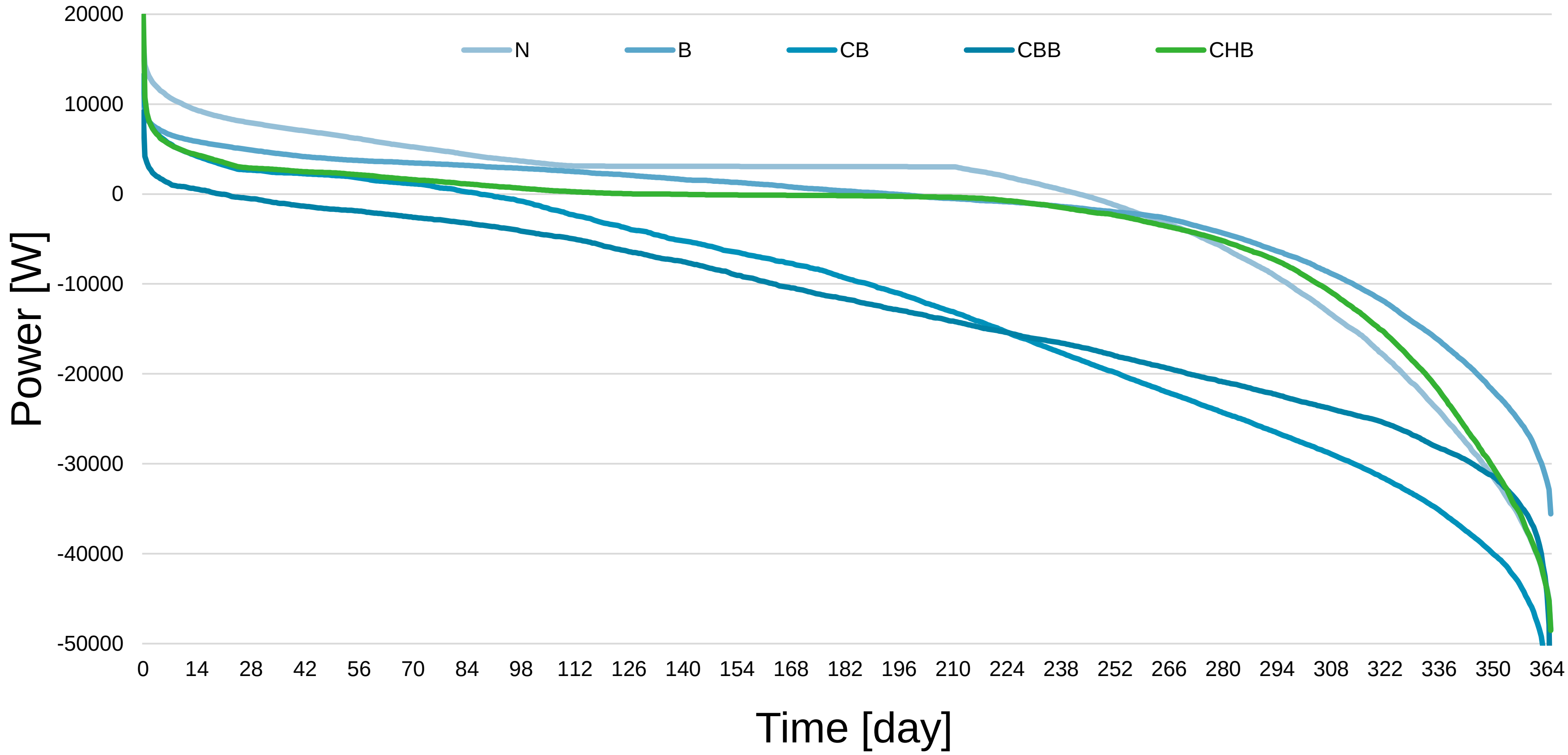
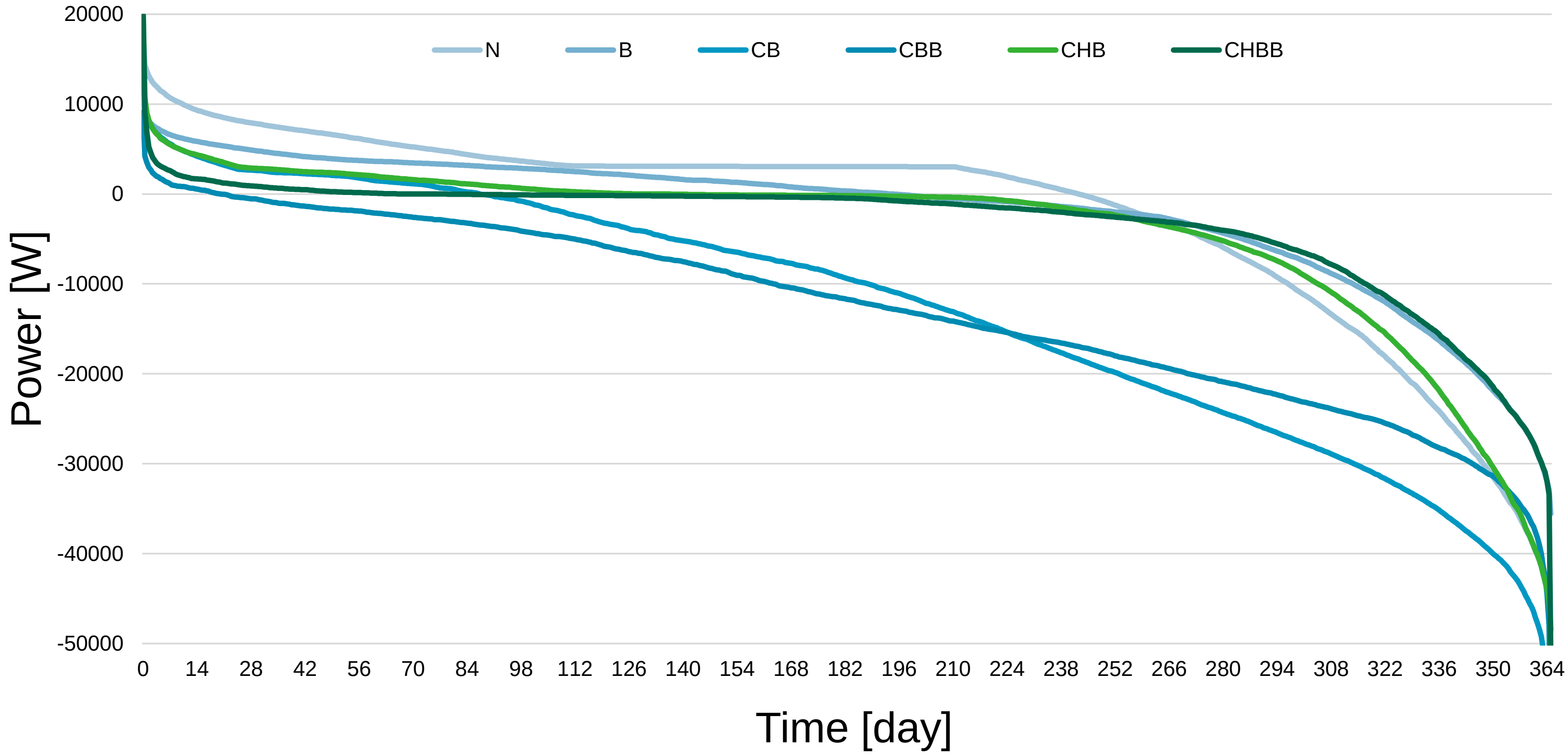


RESULTS
LOAD DURATION CURVE



RESULTS

LOAD DURATION CURVE



RESULTS

YEARLY ENERGY IMPORT/EXPORT PER HOUSE

	CHP	HP	BUF	BAT	Electricity In [kWh]	Electricity Out [kWh]	Natural gas [kWh]
N					1,612	2,733	-
B					852	1,975	-
CB					335	7,344	17,684
CBB					35	7,043	17,684
CHB					406	2,608	8,065
CHBB					115	2,008	7,453

RESULTS

WORK IN PROGRESS

Directions for improvements

- Reconsider energy carrier weights
  - Adapting commodity weights
  - Or use a different matrix norm
- Slowly restrict constraints (e.g. on heat) instead
- Schedule devices in order
  - From devices with least flex to those with most flex
- Parameter finetuning
- …

CONCLUSION

- Work-in-progress
- First results are promising and show potential

Future work

- Test possible improvements to the concept
- Include seasonal storage

QUESTIONS

Open source, free for research

Access on request, limited support

Website: https://www.utwente.nl/en/eemcs/energy

Contact: g.hoogsteen@utwente.nl

REFERENCES

16 houses case publications:

- https://www.sciencedirect.com/science/article/pii/S2352467719300566
- https://ieeexplore.ieee.org/document/7513972/

Profile Steering publications:

- https://ieeexplore.ieee.org/document/7232328/
- https://ieeexplore.ieee.org/document/8571823
- https://ieeexplore.ieee.org/document/7514033/
- https://ieeexplore.ieee.org/document/8260190/

Artificial Load Profile Generator

- https://ieeexplore.ieee.org/document/7513873/

PhD Thesis:

- https://research.utwente.nl/en/publications/a-cyber-physical-systems-perspective-on-decentralized-energy-mana