FLEXMYHEAT REVIEW MEETING
DECEMBER 20 2024

INTRODUCTION

- Goal: understand the role that heat pumps and decentralized storage solutions can play in 2030 and 2050 as source of flexibility for the national electricity system
- Project main objectives
  - Assess the impact and value in 2030 and 2050 (heat pumps + PV + storage solutions)
  - Take the full picture: assess impact of local grid & energy community constraints
  - Adapt the market: valorize flex on energy markets via smart control algorithms
- Evaluate these objectives under 3 scenarios
  - Business-as-usual (no smart control) → Deliverable 1.1
  - Unconstrained flexibility exploitation → Deliverable 2.1
  - Flexibility operation with local restrictions → Deliverable 3.1

DATA COLLECTION AND ANALYSIS – LOAD DATA

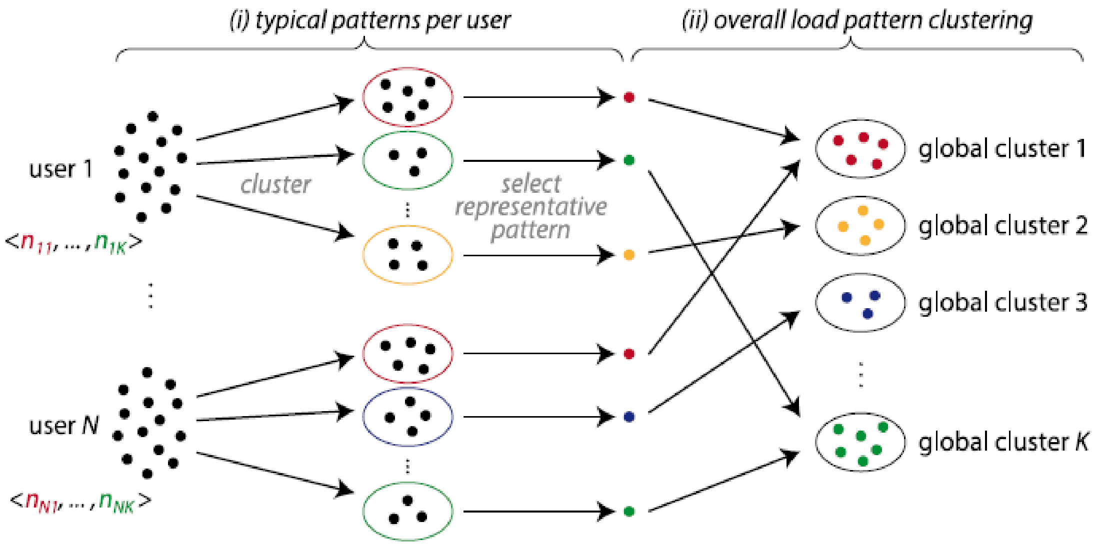
- Consumption profiles of low-voltage network users with 15 min resolution (via ORES)
- Data for 923 users for 2023 and 2024
  - Residential users: 751
  - Business users: 172
- Meta-data and survey results to better understand user behavior

Date_Heure_D	MeterSerialNumber_HASH	Offtake_Energy	Injection_Energy
01-11-22 0:00	f6ffac8ef019e6a8b6a47906d	0.017	0
01-11-22 0:15	f6ffac8ef019e6a8b6a47906d	0.048	0
01-11-22 0:30	f6ffac8ef019e6a8b6a47906d	0.019	0
01-11-22 0:45	f6ffac8ef019e6a8b6a47906d	0.009	0
01-11-22 1:00	f6ffac8ef019e6a8b6a47906d	0.025	0
01-11-22 1:15	f6ffac8ef019e6a8b6a47906d	0.032	0
01-11-22 1:30	f6ffac8ef019e6a8b6a47906d	0.01	0
01-11-22 1:45	f6ffac8ef019e6a8b6a47906d	0.011	0
01-11-22 2:00	f6ffac8ef019e6a8b6a47906d	0.033	0

EAN_HASH	MeterSerialNumber_HASH	Code postal	Raccordement	Puiss. contract. (kVA)	Type de client	Raccordement Gaz
a368e339a05	56c022e6570cc121754d04c2	6900	Tri	10	Professionnel	NON
d29de4ff614c	319dad62158e410a715b13c7	6001	Tri	25.1	Professionnel	NON
5eb18231ab2	eaf302d4477f12e4938b2109	6043	Tetra	55.4	Professionnel	OUI
c0e6f9845b25	78e9965a3ecd2cf0b5211a40	6020	Tri	15.9	Professionnel	NON
b1120786e27	377057e37edc659af2de70bb	6060	Mono	7.4	Professionnel	OUI
edcf5bfa4f71	d19b28d1e6c32e788e9800b	6030	Tri	31.9	Professionnel	OUI
70121a97488	dd1cad752909cd5f1ad95935	6031	Mono	4.6	Professionnel	NON
bc7f512489e1	0d9495c6397e2dc5839afa7e	6061	Mono	4.6	Professionnel	OUI
522bab845a4	da9a9a3d9f8ec9b3183641df	6061	Mono	9.2	Professionnel	NON

DATA COLLECTION AND ANALYSIS – CLUSTERING METHOD

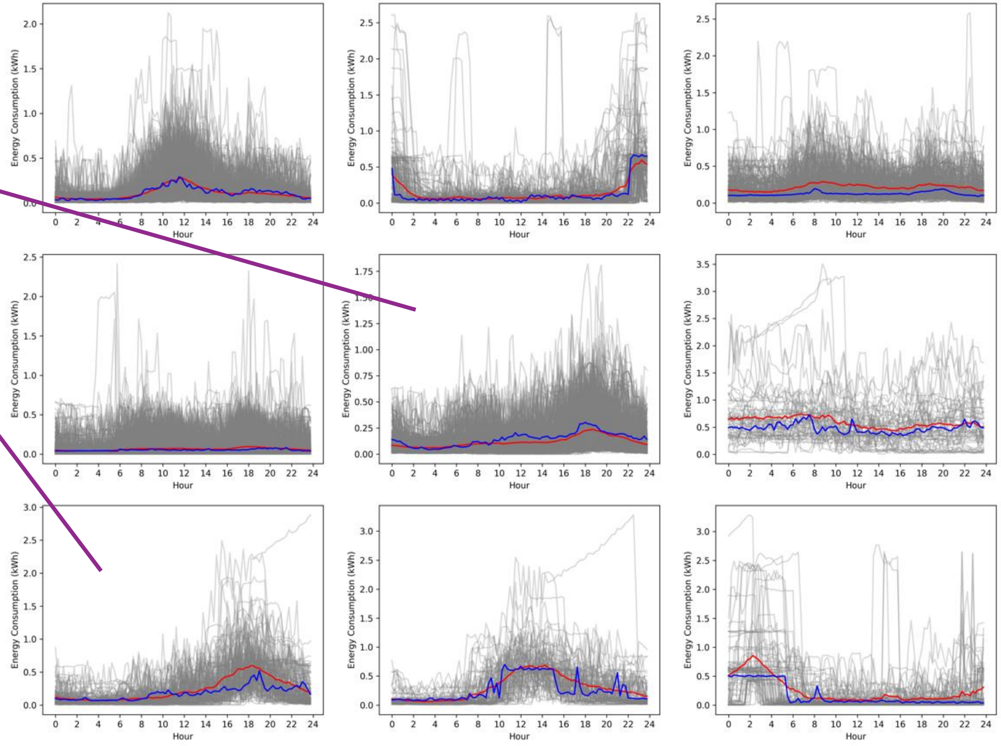
- Three-stage clustering approach
  - Cluster daily load patterns of a single user
  - Cluster representative days for all users
  - Cluster users based on their membership



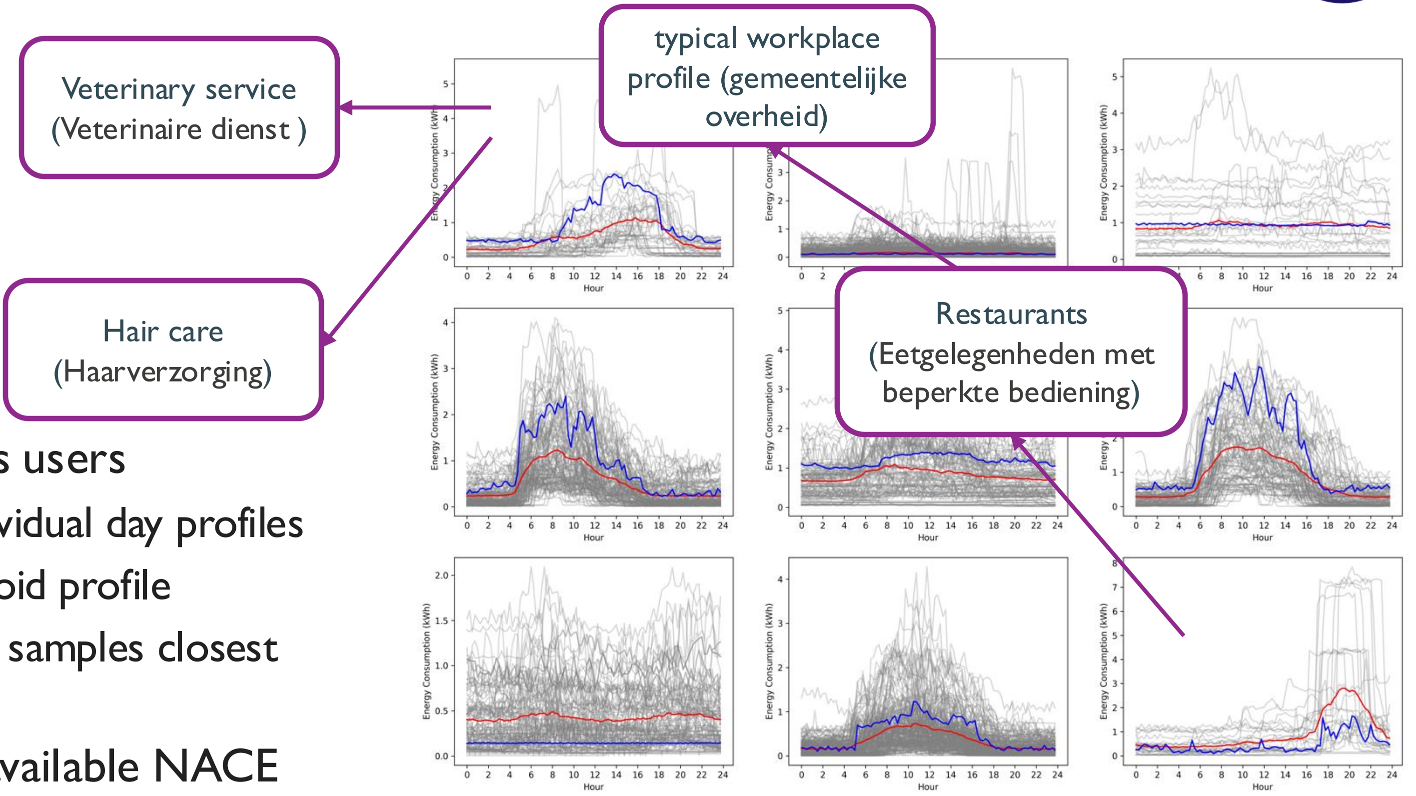
DATA COLLECTION AND ANALYSIS – CLUSTERING RESULTS

Typical household profile with an evening peak

- Results for residential users
  - grey lines → individual day profiles
  - red line → centroid profile
  - blue lines → real samples closest to the centroid



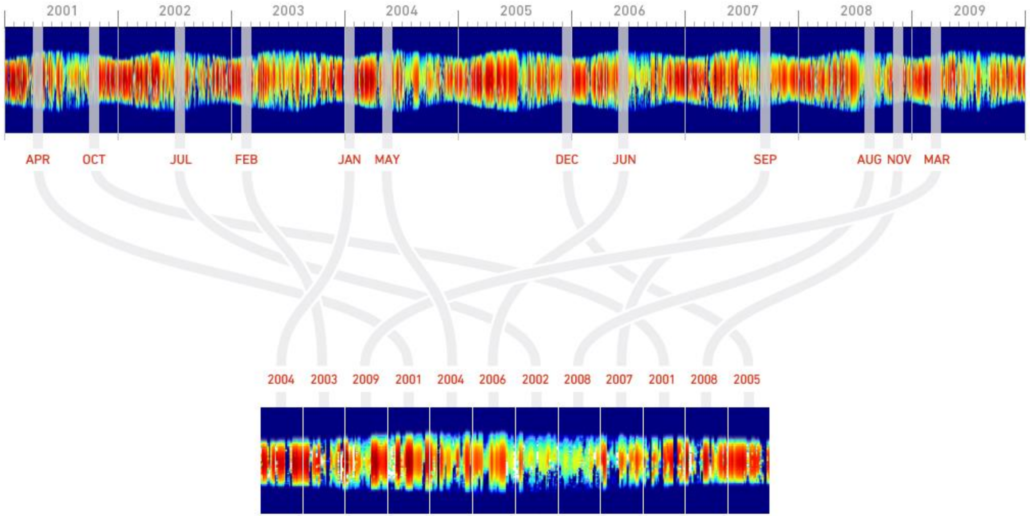
DATA COLLECTION AND ANALYSIS – CLUSTERING RESULTS



- Results for business users
  - grey lines → individual day profiles
  - red line → centroid profile
  - blue lines → real samples closest to the centroid
- Cross-check with available NACE codes

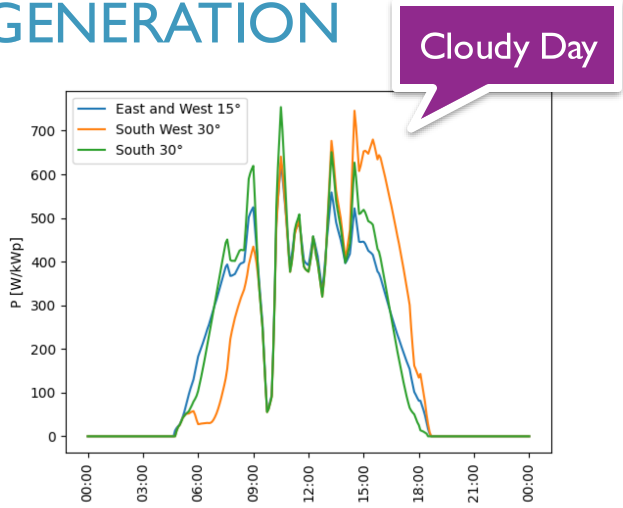
DATA COLLECTION AND ANALYSIS – PV GENERATION

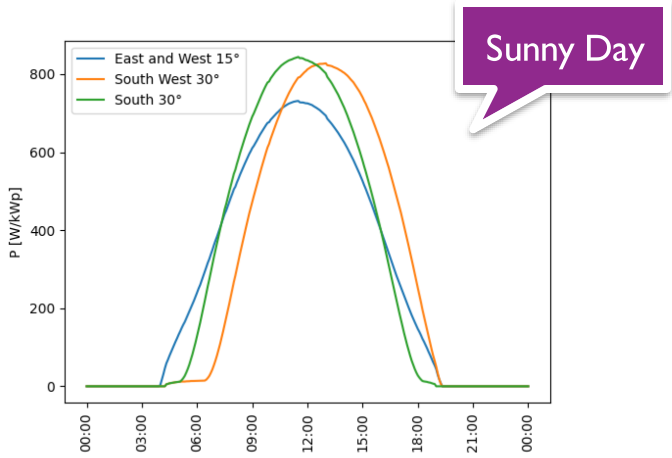
- Generate PV profiles using PVGIS based on historical weather data (by Energie Commune)
- Use typical meteorological year data for calculating PV generation in 2030
  - Instead of averaging yearly data, select the most typical month based on historical data, to keep a realistic variability in the data



DATA COLLECTION AND ANALYSIS – PV GENERATION

- Obtain 5-minute production profiles for
  - 5 different locations in Belgium
    - Antwerp
    - Butgenbach
    - Lessines
    - Marche-en-Famenne
    - Nivelles
  - 3 different combination of orientation and tilt
    - South orientation and tilt of 30°
    - South-West orientation and tilt of 30°
    - Both East and West orientations and tilt of 15°





MODELING ASSETS – BATTERY

- Capacity: ranging between 5kWh to 20kWh
- Rated power: ranging between 3kW and 10kW
- Round trip-efficiency: 96% (same for both charge and discharge)
- Idle loss: 0.00168% per minute
- Minimum SoC: 10%

MODELING ASSETS – HEAT PUMP

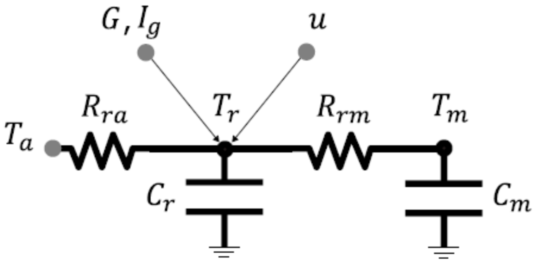
- Rated power: 3.5 or 5 kW (thermal power)
- Coefficient of performance (COP):
  - Model with a constant yearly seasonal coefficient of performance
  - Ranging between 3.89 and 4.26
- Min off time: 10min
- Min on time: 15min
- Data source: *heatpumpmonitor.org*

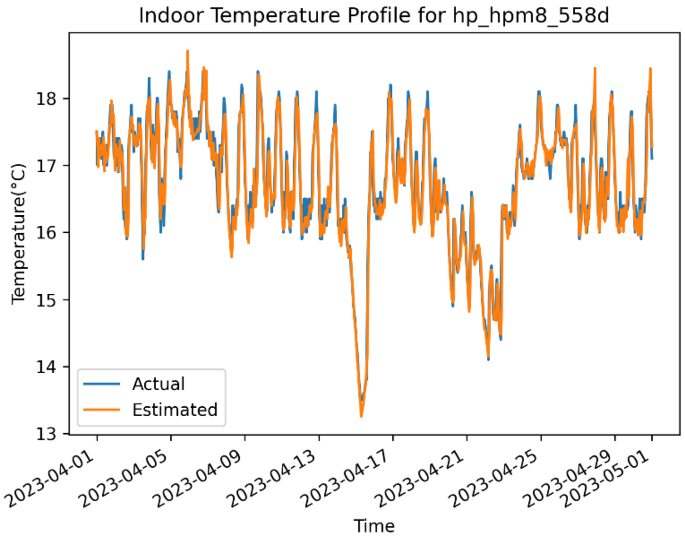
MODELING ASSETS – THERMAL STORAGE

- Capacity: ranging between 3.5 and 9.5 kWh (thermal)
- Rated power: 5 kW (thermal)
- COP: 4
- Idle loss: 0.0055% per minute
- Number of cells: 2
- Each cycle must be fully completed to minimize PCM degradation
  - SoC: 0, 50, or 100%

MODELING ASSETS – BUILDING THERMAL MODEL

- Model building using a 2-state resistance-capacitance (2R2C) network
- Use the stochastic gradient descent (SGD) approach to solve the regression problem
- Estimated the thermal parameters for 3 different buildings
  - Floor area: 75, 100, 134 m^2
  - Building type: detached, semi-detached, and terraced





BUSINESS-AS-USUAL CASE STUDY DESCRIPTION

- Case study
  - Choose 24 residential load profiles based on clusters
  - PV profiles for 5 locations + 3 different orientations + noise
  - 3 heatpumps + 3 thermal storage + 5 batteries + 3 building model configurations, assigned randomly
  - Expected electricity consumption growth in 2030: 55%
  - Expected electricity cost in 2030: 16% lower

→ 120 Users

- Electricity cost
  - Commodity (supplier)
    - Single-hourly tariff
    - Bi-hourly tariff
    - 3-level tariff
    - Day-ahead price
  - DSO (grid fee)
    - Single-hourly tariff
    - Bi-hourly tariff
    - 3-level tariff
    - Capacity tariff

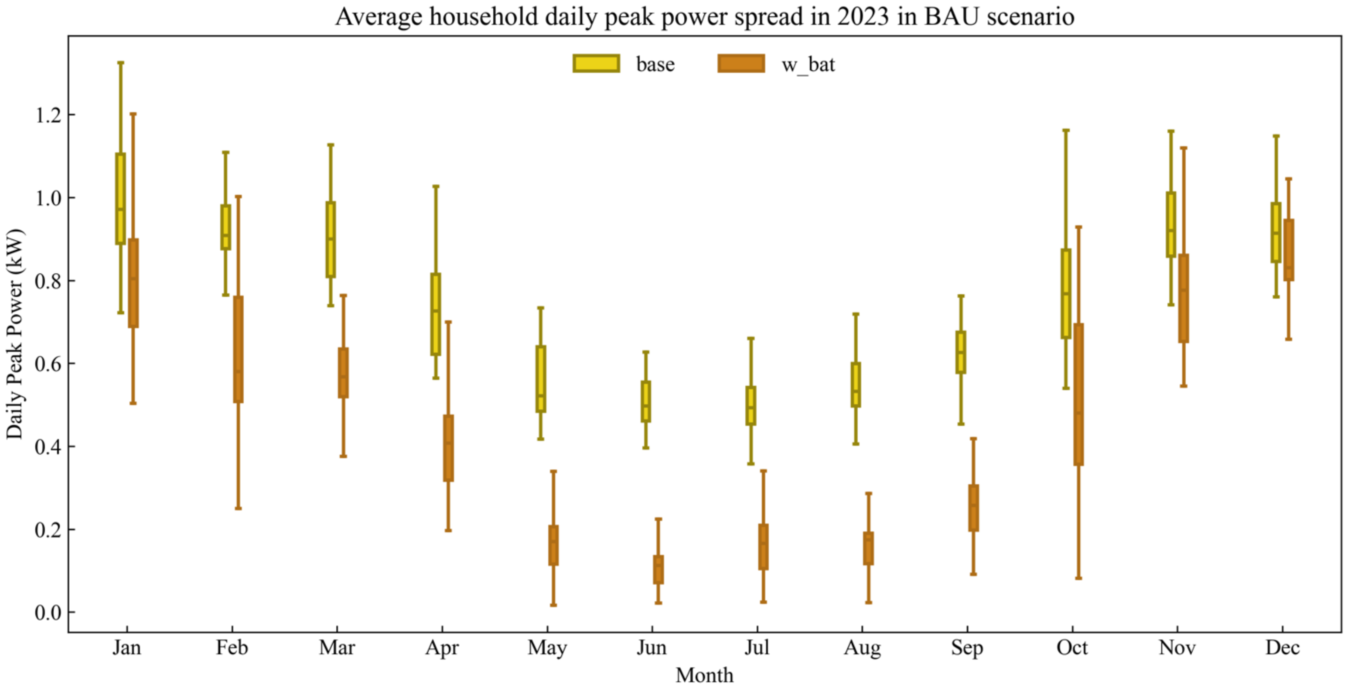
BAU SCENARIOS DEFINITION

Used rule based control strategies:

- Heat pumps: maintain indoor temperature within defined comfort range ([18 °C, 22 °C])
- Electrical/thermal storage: maximize PV self consumption (charge if PV production > local consumption, discharge if PV production < local consumption)

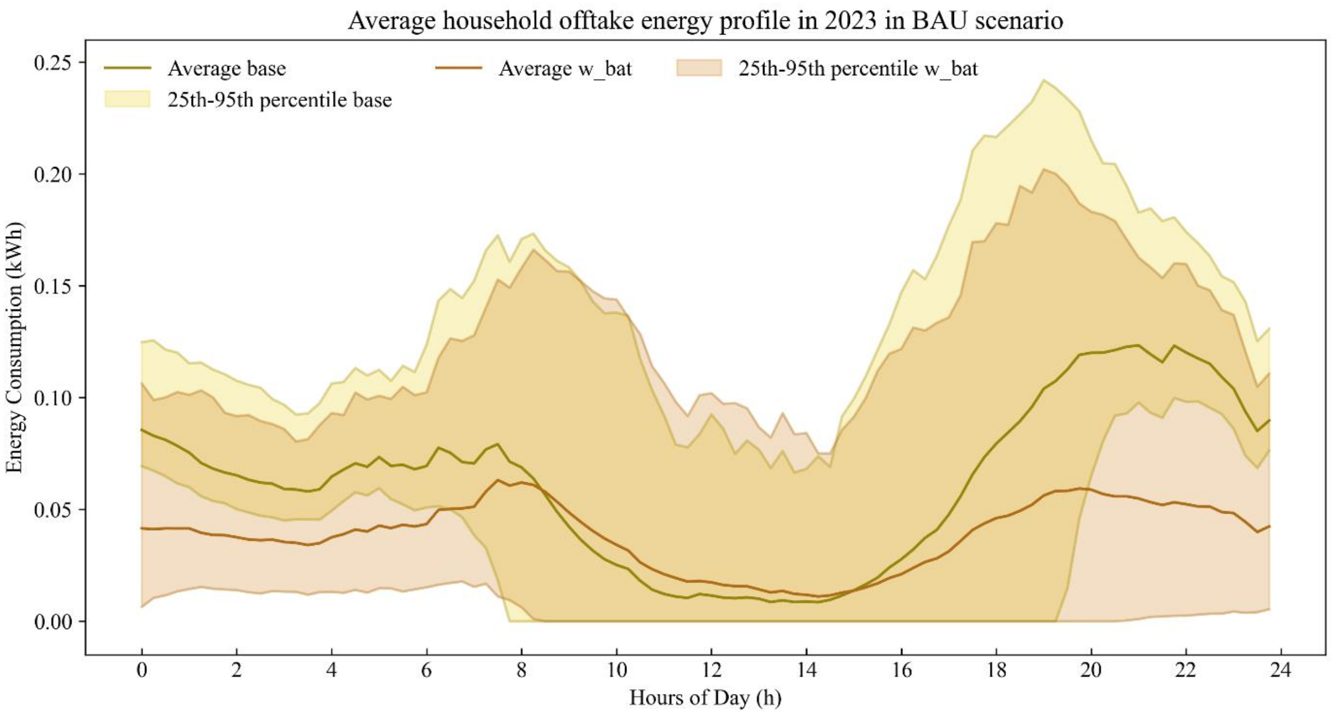
- Base scenario: base load with PV without any flexible asset
- Scenario 1: base scenario + battery
- Scenario 2: base scenario + heat pump
- Scenario 3: base scenario + heat pump + thermal storage
- Scenario 4: base scenario + heat pump + battery
- Scenario 5: base scenario + heat pump + battery + thermal storage

RESULTS FOR 2023



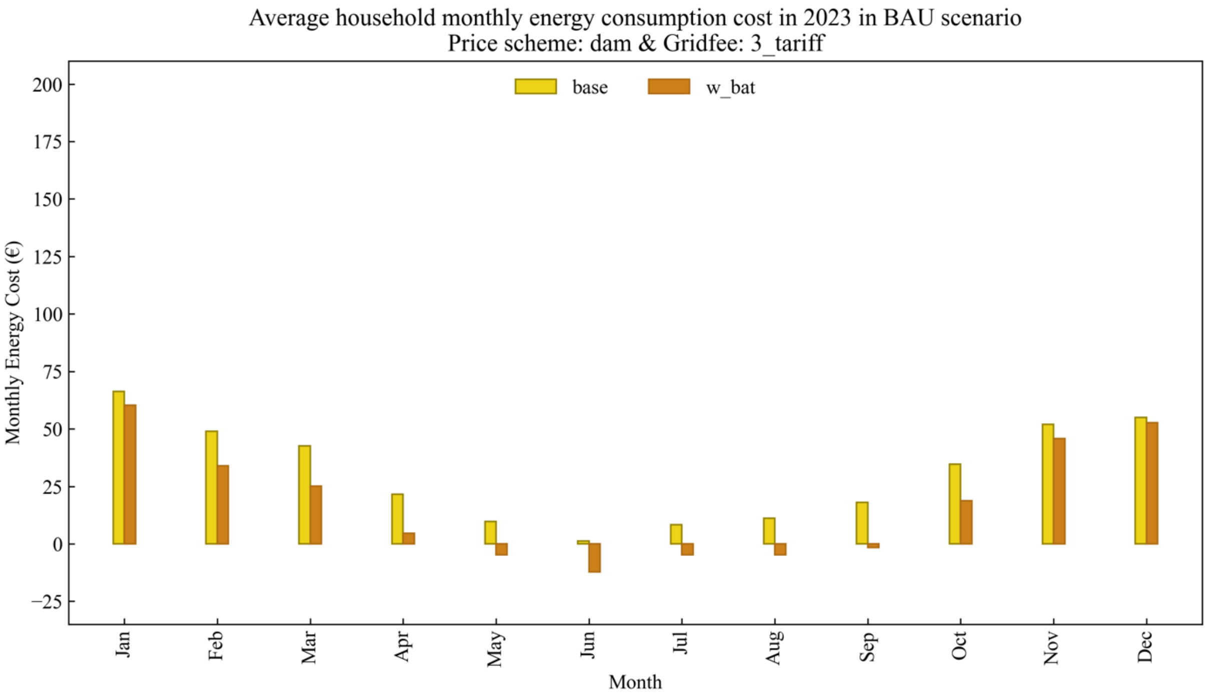
- Considering only base scenario and scenario 1 (low penetration of heat pumps)
- Reduce household daily peak power on average by 0.3 kW using batteries
- Larger reduction during summer due to increased PV generation

RESULTS FOR 2023



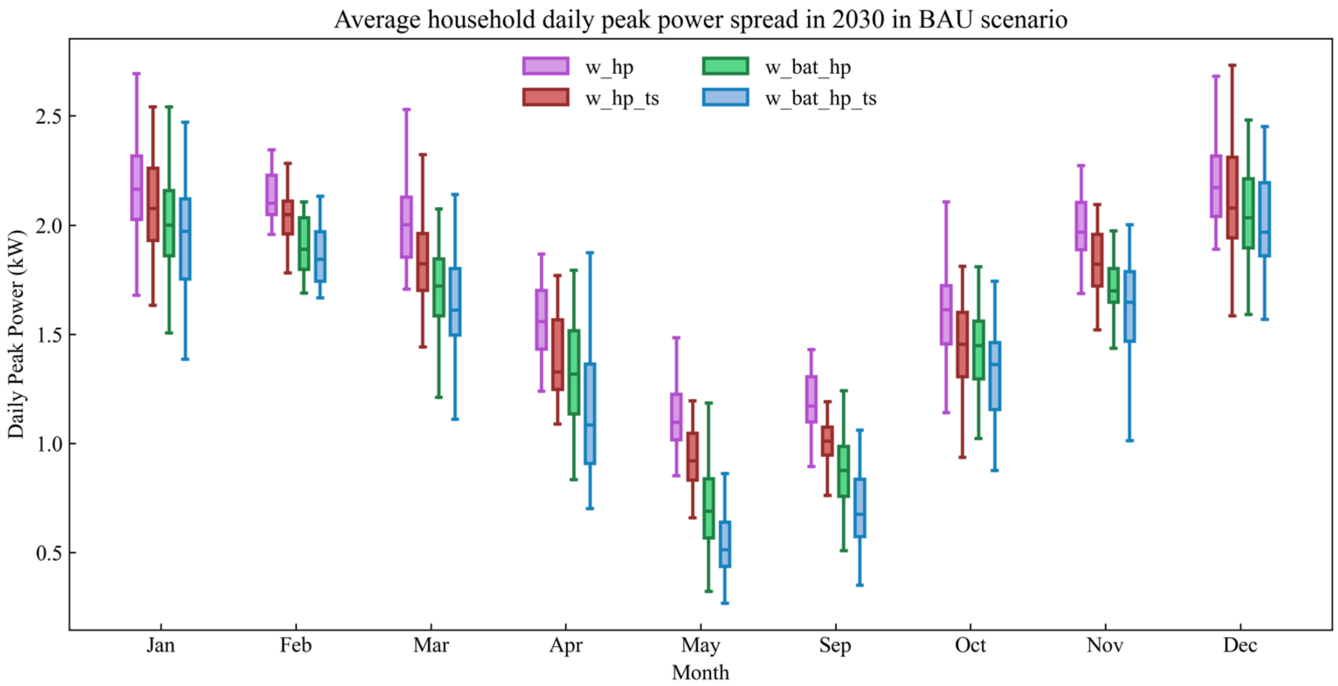
- Batteries mainly reduce evening peak with the used (simple) control strategy
- Often no grid offtake during the day

RESULTS FOR 2023



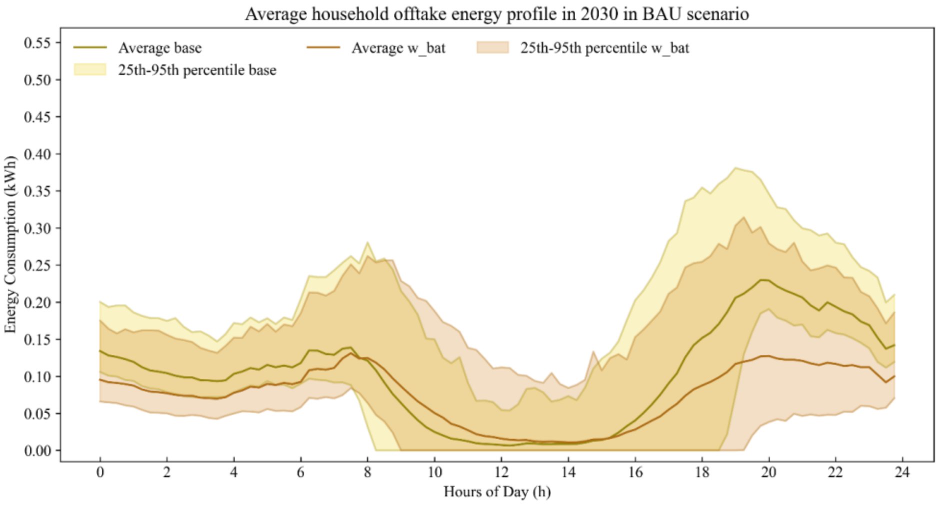
- Significant contribution of batteries to decrease electricity bill during summer
  - On average suppliers pay users in summer
- No significant contribution during winter

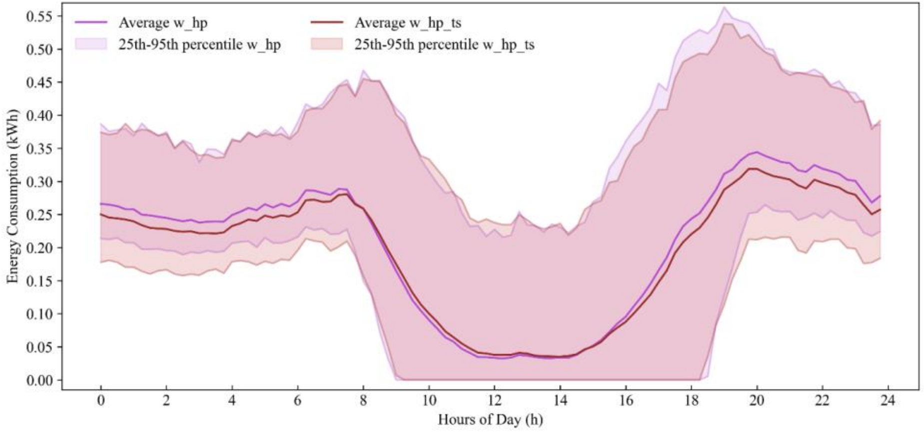
RESULTS FOR 2030

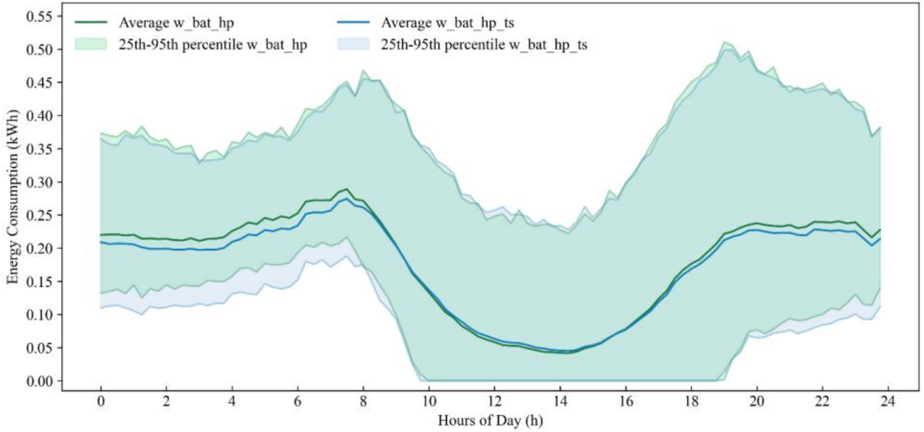


- Ignore June, July, and August as heat pumps are not used for space heating then
- Average increase of 0.53 kW (+42%) in daily peak power because of adopting heat pumps
- Decrease daily peak power on average by 22.65% compared to scenario 2 after adding batteries and thermal storage
  - Limited effect in winter due to limited availability of PV power to charge storage

RESULTS FOR 2030







Heat pumps increase consumption during evening, night and early morning → interesting to combine with storage solutions

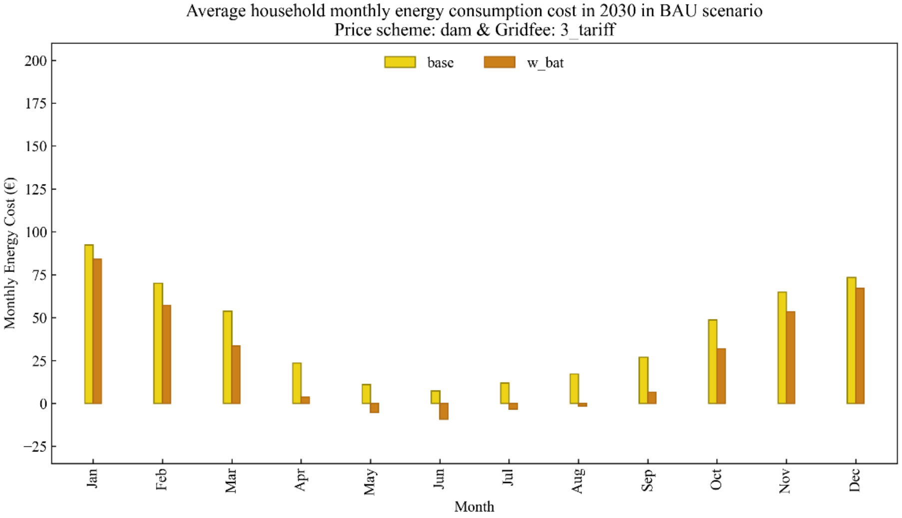
RESULTS FOR 2030

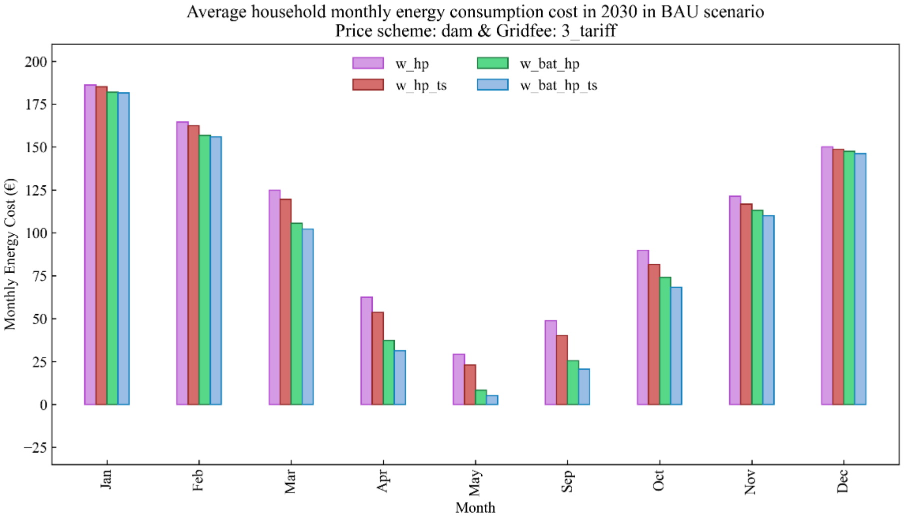
- Average annual electricity bill across all households in 2030
- Highest costs when exposed to dynamic prices (because control strategies are only PV based and don't take prices into account)
- Reduction in the electricity bill mainly due to batteries (higher rated power than thermal storage)

DSO	Supplier	Base (€) Only PV	S1 (€) Batt	S2 (€) HP	S3 (€) HP+ TS	S4 (€) HP+ Batt	S5 (€) HP+TS + Batt
Single-hourly tariff – ORES	Single-hourly tariff	495.61	323.03	1105.74	1050.64	936.75	905.13
	Day-ahead price	551.76	361.91	1168.90	1107.77	979.70	944.79
Bi-hourly tariff - ORES	Bi-hourly tariff	454.52	297.64	1003.19	958.50	850.98	825.67
	Day-ahead price	496.89	325.17	1052.37	1001.27	882.30	853.83
3-level tariff – ORES	3-level tariff tariff	495.93	310.55	1041.54	991.13	855.62	829.77
	Day-ahead price	522.77	331.23	1074.36	1019.91	880.53	852.29
Capacity tariff - Fluvius	Single-hourly tariff	331.54	213.46	751.34	717.86	643.97	623.99
	Day-ahead price	388.55	253.17	815.34	775.72	687.70	664.31

RESULTS FOR 2030

- Significant contribution of storage solutions to decrease electricity bill during summer
- No significant contribution during winter with control logics only based on available PV power





CONCLUSIONS AND NEXT STEPS

- Significant increase in daily peak power by widespread adoption of heat pumps in 2030
- Results showed that integrating heat pumps with storage moderates their effects
- Importance of smart control logic for flexible assets
- Next steps:
  - Continue development of smart controllers for heat pumps and storage to fully unlock their flexibility potential
  - Take local constraints into account

PUBLIC PROJECT RESULTS

- Public website (https://flexmyheat.ilabt.imec.be/)with overview of project objectives, scenarios, methodology and main results
- Published results
  - Deliverable D1.1 – Business-as-usual scenarios
  - 5 scientific papers with acknowledgement of FlexMyHeat
    - **Multi-source Transfer Learning in Reinforcement Learning-based Home Battery Controller** → Reuse of smart control strategies over households using transfer learning. Use of ORES load data for validation.
    - **Control policy correction framework for reinforcement learning-based energy arbitrage strategies** → Ensure safety of RL based control algorithms
    - **Distill2Explain: Differentiable decision trees for explainable reinforcement learning in energy application controllers** → Improve explainability of RL based control policies for flexible residential loads
    - **Explainable reinforcement learning-based home energy management systems using differentiable decision trees** → Improve explainability of RL based control policies for flexible residential loads
    - **Distributional reinforcement learning-based energy arbitrage strategies in imbalance settlement mechanism** → RL based control policies that take into account uncertainty to minimize risks

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