The value of flexibility under different retail contract designs

A case study of the Swiss household sector

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Background

Decarbonization of the energy sector

- Fundamentally reshaping the structure and operation of electricity systems
- Driven by two main forces:
  - Increasing deployment of renewable energy sources (RES)
  - Electrification of the heating and mobility sectors

Challenges for the power system

- Maintaining grid stability
- Ensuring cost-effectiveness
- Optimizing the system’s operation

Background

Household sector

- Largest consumer of electricity (34.5%) in Switzerland (BFE, 2025)
- Electricity consumption is expected to rise in the coming years
- By operating their demand flexibly, households could:
  - reduce their electricity costs
  - Contribute to the efficient operation of the power system

What is flexibility?

Flexibility as “serving a system need”

- Flexible operation means adjusting operation dynamically based on the system’s conditions
  - Reflected in price signals
- Improves overall economic efficiency of the power system
- Can be provided by all kinds of assets: demand, storage, supply

Importance of flexibility

- Critical for ensuring the system’s reliability, efficiency and sustainability
- Estimating the value of flexibility can help to establish and prioritize appropriate regulatory measures to promote it

Methodology

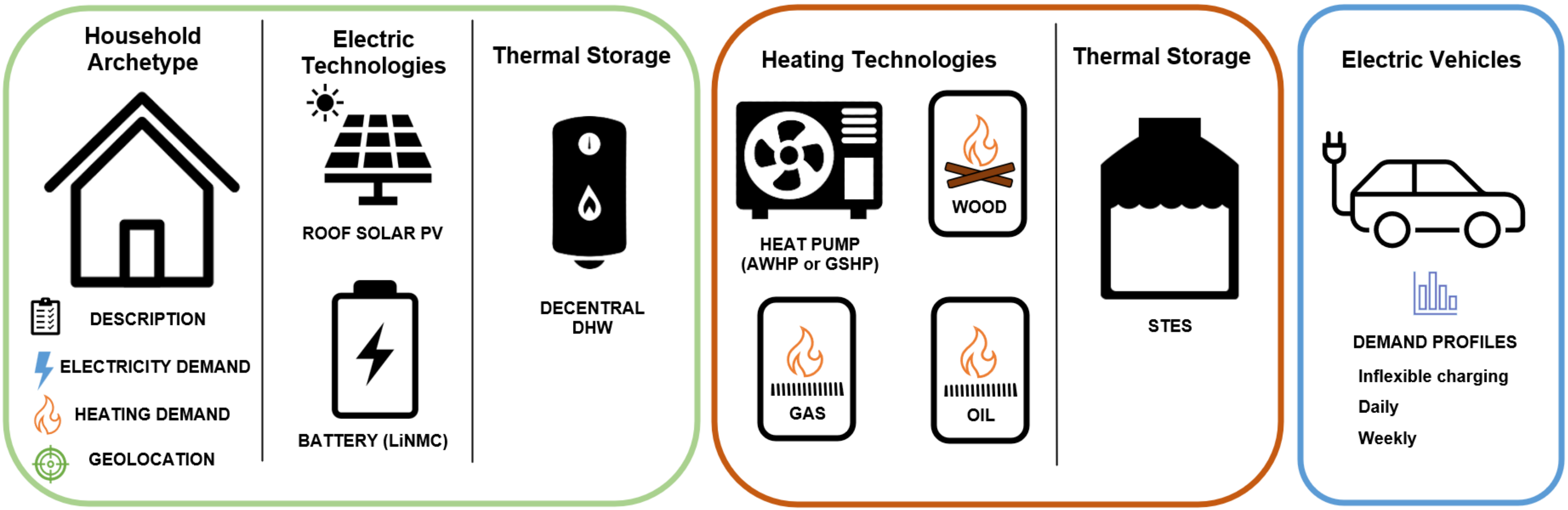
SwissStore Model

- Techno-economic energy model of the Swiss household sector

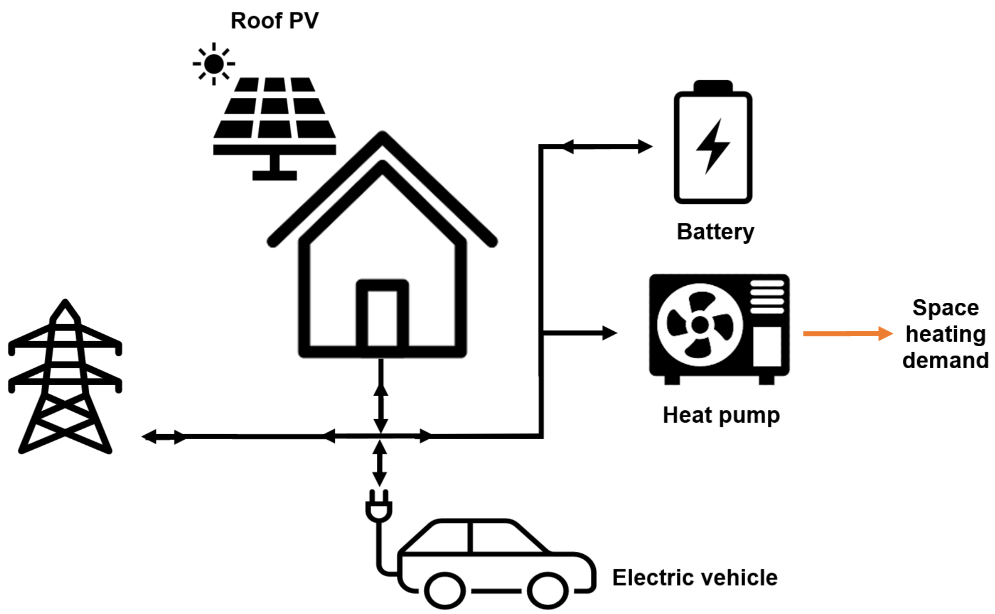
Implementation

- Selection of a randomized sample of **2000 single family households** from SwissStore's dataset
- Assignment of an **EV demand profile** to each household
- Exposure of households to the **tariff and EV charging scenarios**
- Estimation of the **value of flexibility for end-consumers**

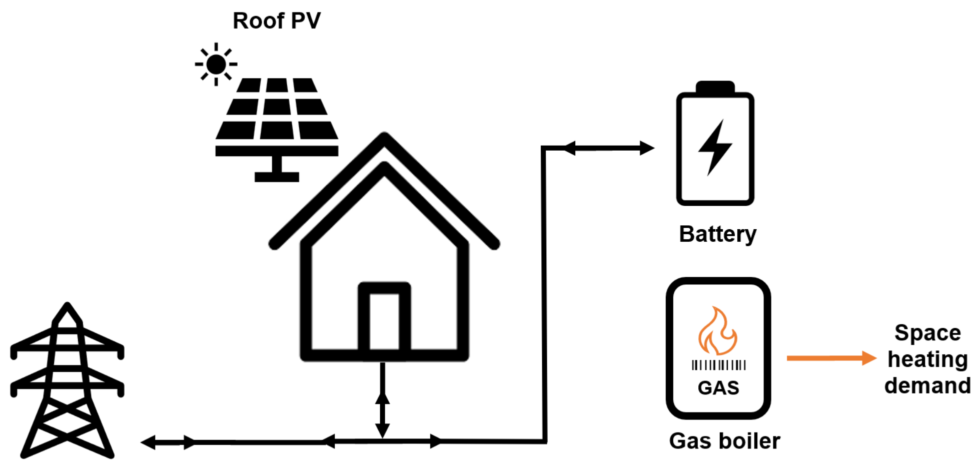
SwissStore: Modularity



SwissStore: Technology scenarios



a) Technology bundle A:
PV, battery, heat pump and EV



b) Technology bundle B:
PV, battery, gas boiler

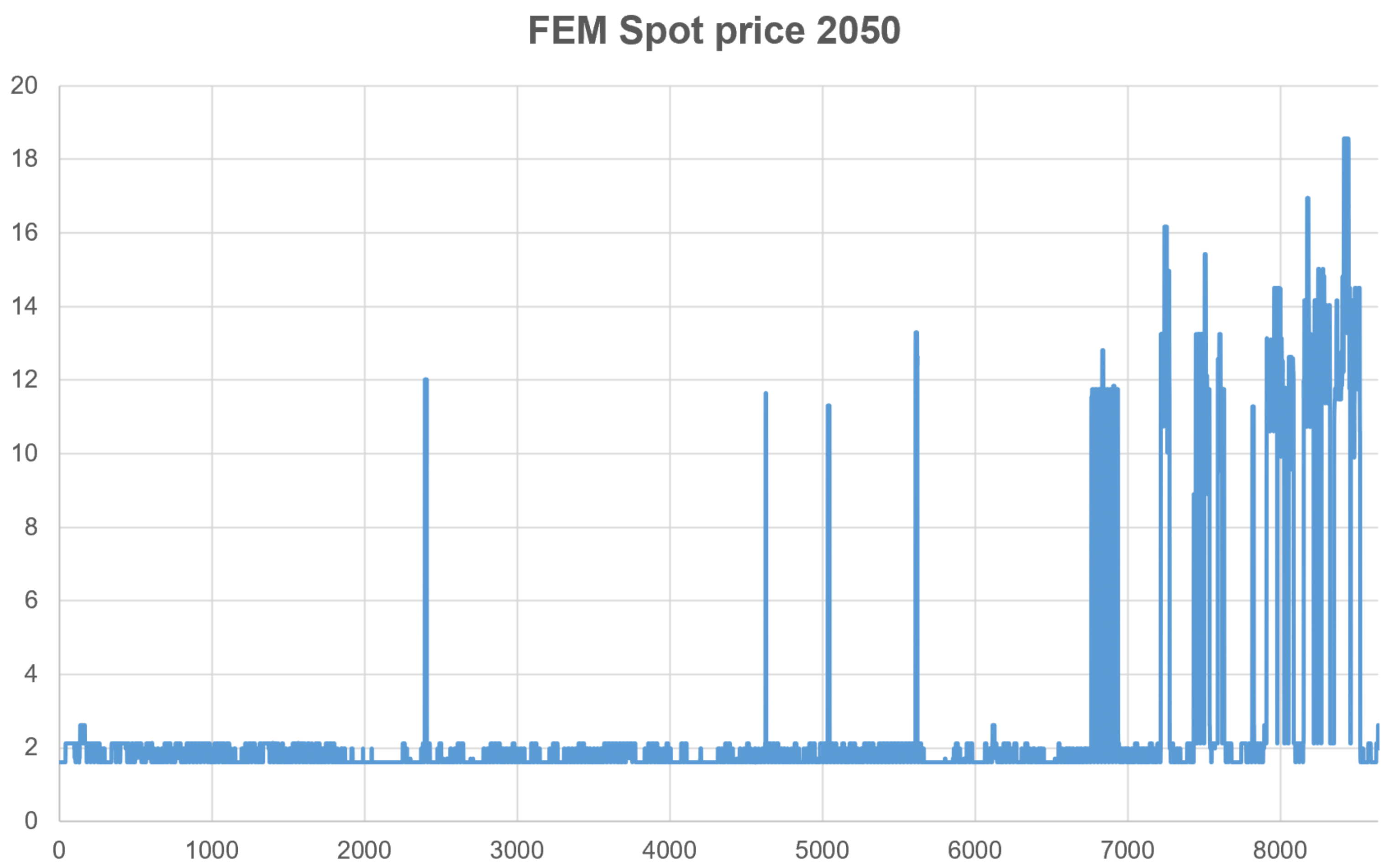
Tariff scenarios

Tariff scenario	Type	Description
Flat	Flat - No FiT	Zero flexibility incentives
Dynamic	Hourly - Hourly FiT	Full flexibility incentives

Electricity tariffs: “Future Energy Market” (FEM) (Darudi et al, 2024)

- We use the electricity price output from the FEM market model
- We construct the retail tariff with all price components (i.e., grid usage, taxes)

Tariff scenarios



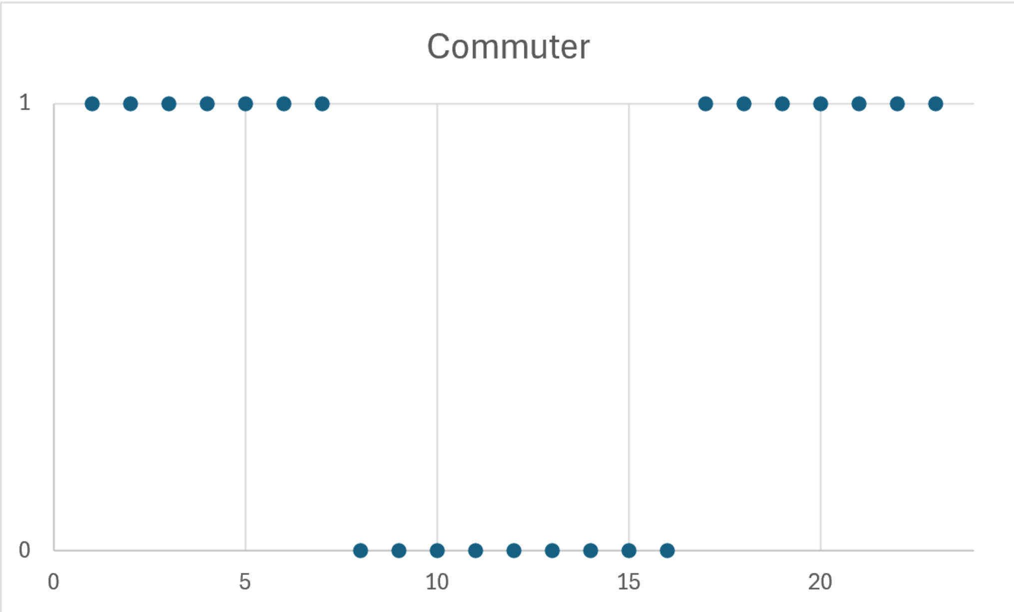
EV charging scenarios

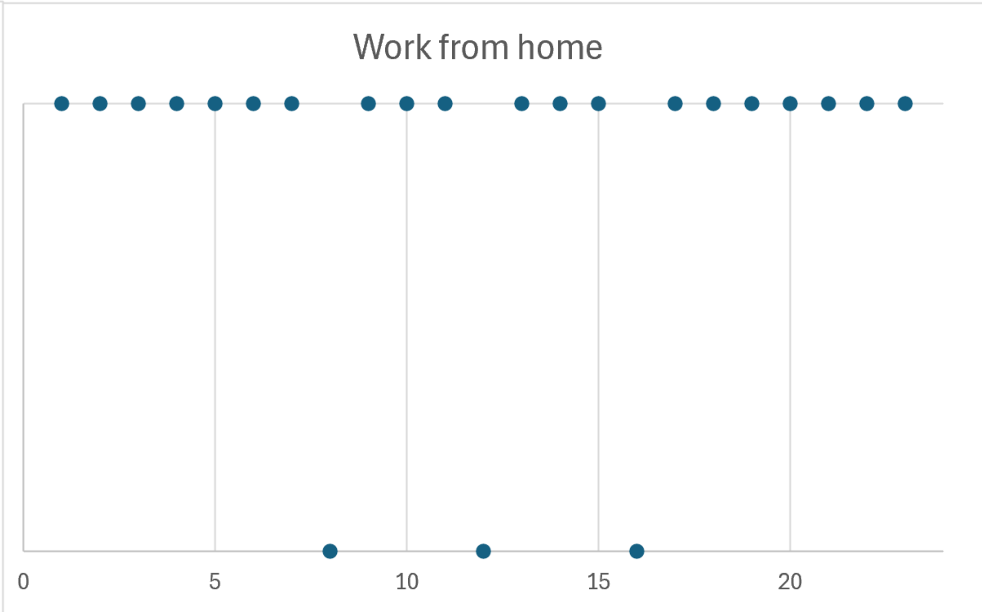
EV scenario	Description
no_ev	Building without EV
ev_inflex	Inflexible EV demand
ev_daily	Daily EV charging flexibility

EV demand: NETFLEX project (Winzer et al, 2022)

- **We aggregate NETFLEX's demand per day** and let the model choose freely when to charge
- EV charging is **bidirectional**
- Charging is constrained by the scenario's different time windows
- For the **inflexible** scenario, we assume **full-capacity charging from18.00 hrs** until the daily demand is met

EV charging availability profile





End-consumer energy costs

EV and heat pump retail cost per tariff scenario

$$ev\_cost_t = \sum_t (Q\_EV\_EL_t \cdot q\_price\_el_t) - (D\_EV\_EL_t \cdot d\_price\_el_t) \qquad \forall\ t$$

$$hp\_cost_t = \sum_t (D\_HP\_EL_t \cdot d\_price\_el_t) \qquad \forall\ t$$

Value of flexibility for end-consumers

Since the EV and HP ***Inflexible*** scenario has a **default flexibility value of zero**:

- The **value** of flexibility can be determined **relative to *the cost of inflexible demand***

EVs

$$ev\_flex\_value_{tariff\_scen} = ev\_cost_{tariff\_scen} - ev\_cost_{ev\_inflex}$$

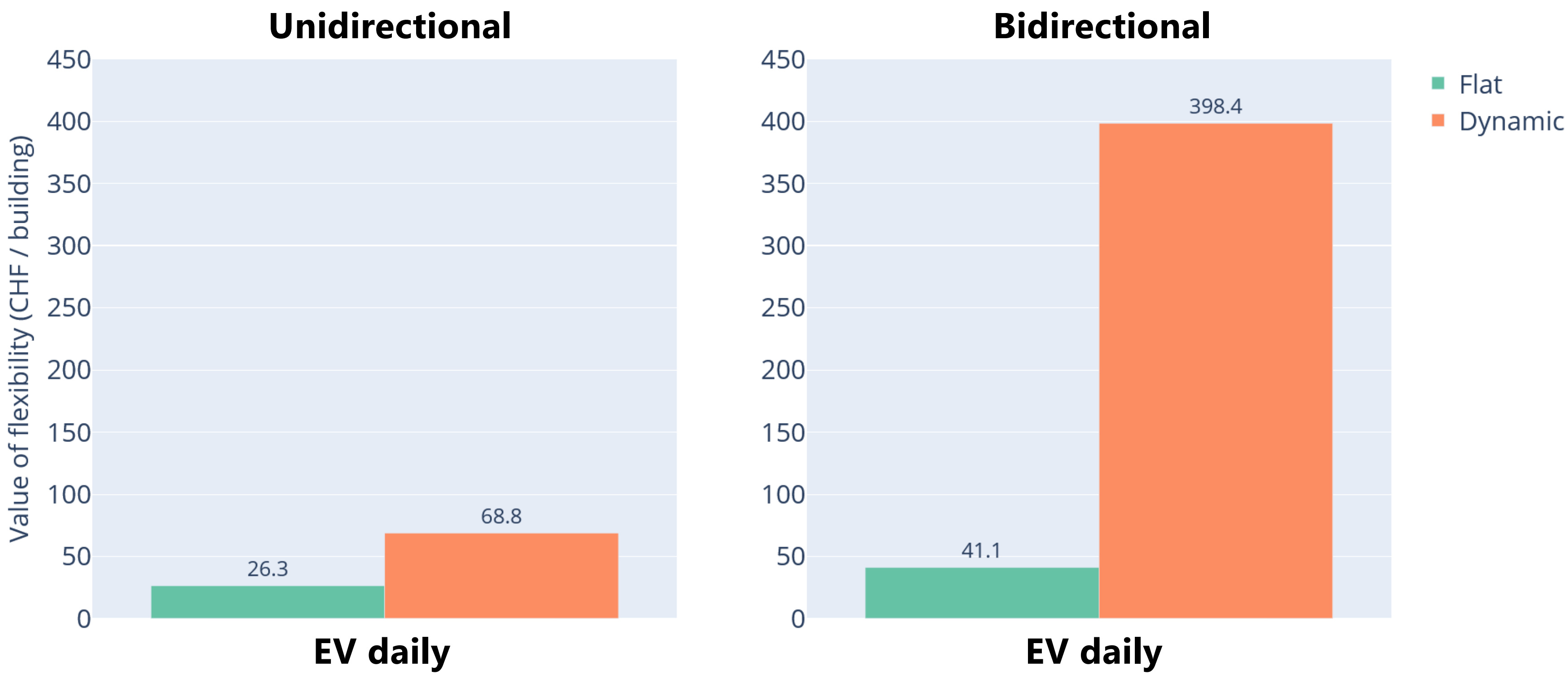
HPs

$$hp\_flex\_value_{tariff\_scen} = hp\_cost_{tariff\_scen} - hp\_cost_{hp\_inflex}$$

Value of Flexibility from EVs per year for end-consumers (2050) – Daily flex

Findings

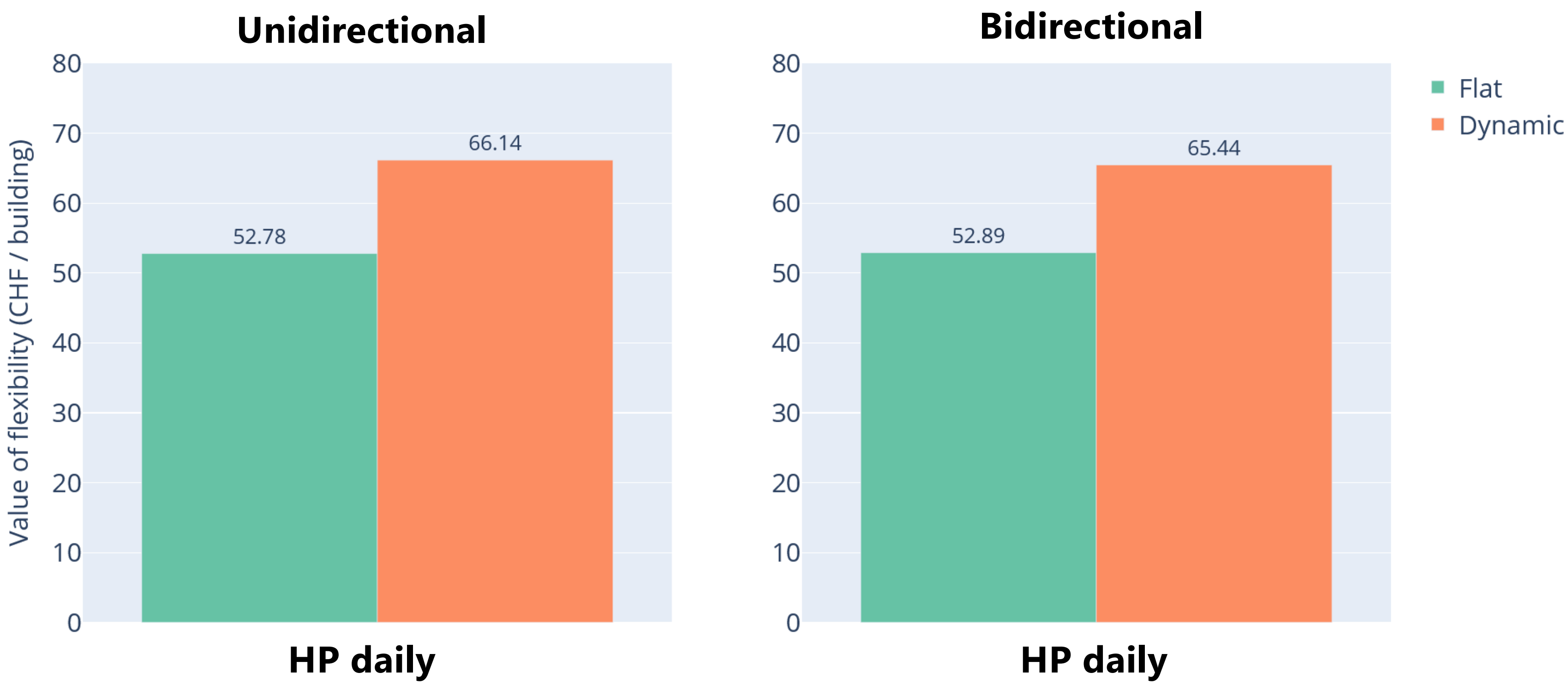
- Mean flex retail value from EVs per household ranges from **26 to 400 CHF per year**
- **The more flexible** EV charging is, **the more value** end-consumers can get
- **Bidirectional** charging has significantly **more value** when exposed to **dynamic tariffs**



Value of Flexibility from HPs per year for end-consumers (2050) – Daily flex

Findings

- Mean flex value from HPs per household ranges from **53 to 66 CHF per year**
- **HP flex value** does **not vary** significantly with **EV charging** scenarios
- **Flex value** from HPs **is higher** with **dynamic tariffs**

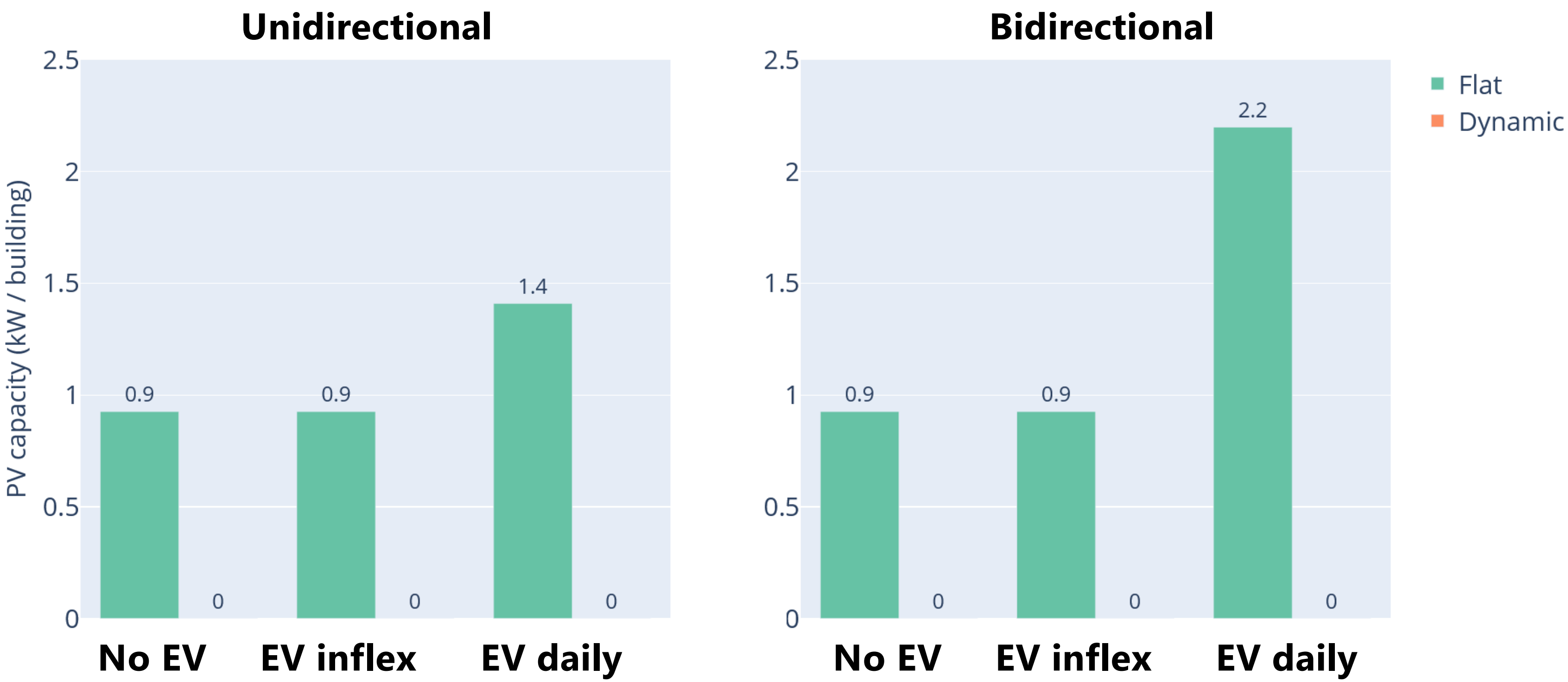


Average PV deployment per building (2050) – Daily flex

Findings

- Having **flexible demand** and **bidirectional** charging **incentivizes PV** deployment -> maximizes self-consumption

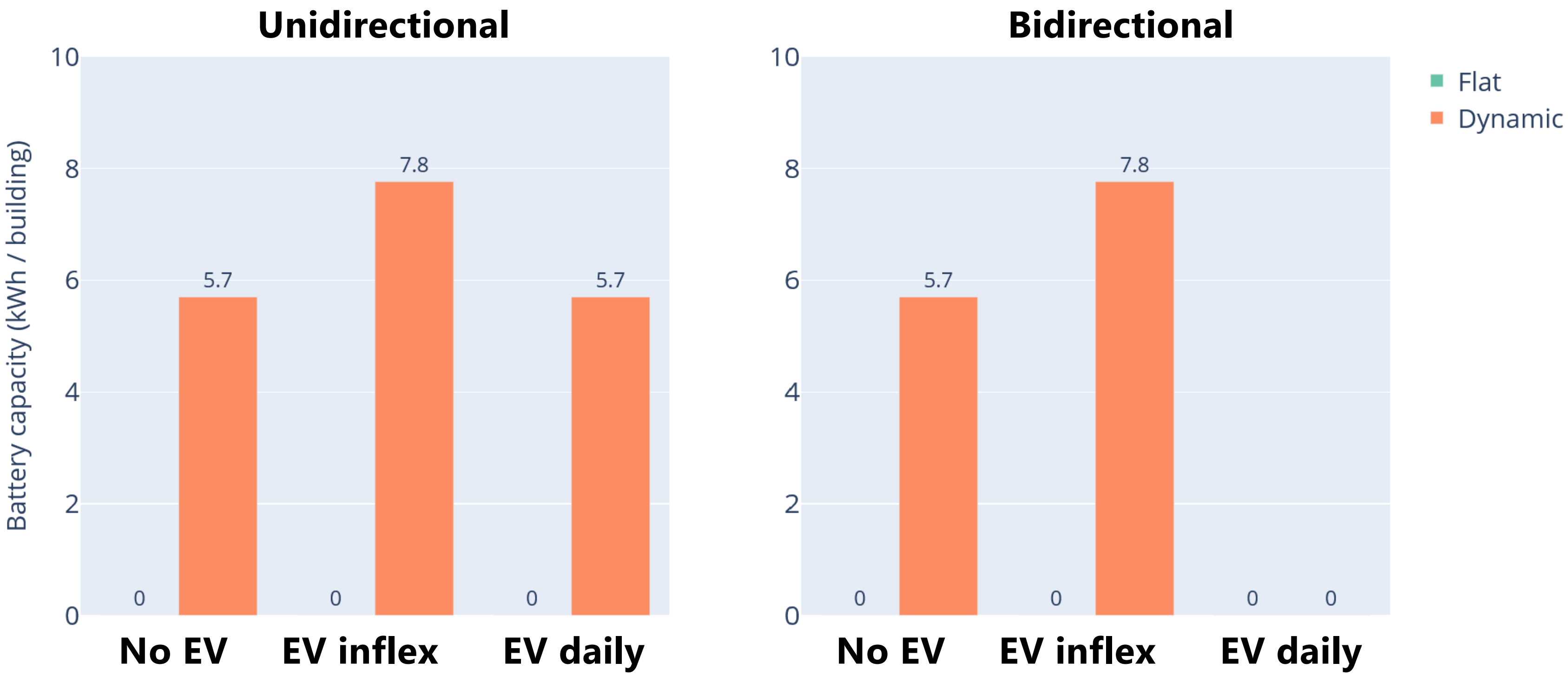
- There is **no PV deployment** with dynamic tariffs but…
- Highly **sensitive** to technology **cost and price** profile **assumptions**



Average battery capacity per building (2050)

Findings

- Having a **Flat tariff discourages battery deployment**
  -> no arbitraging
- EV **daily flexibility substitutes battery** capacity
  -> optimal capacity for self-consumption
- **Inflex EV** has **higher** overall **deployment**
  -> high incentives for **load-shifting**

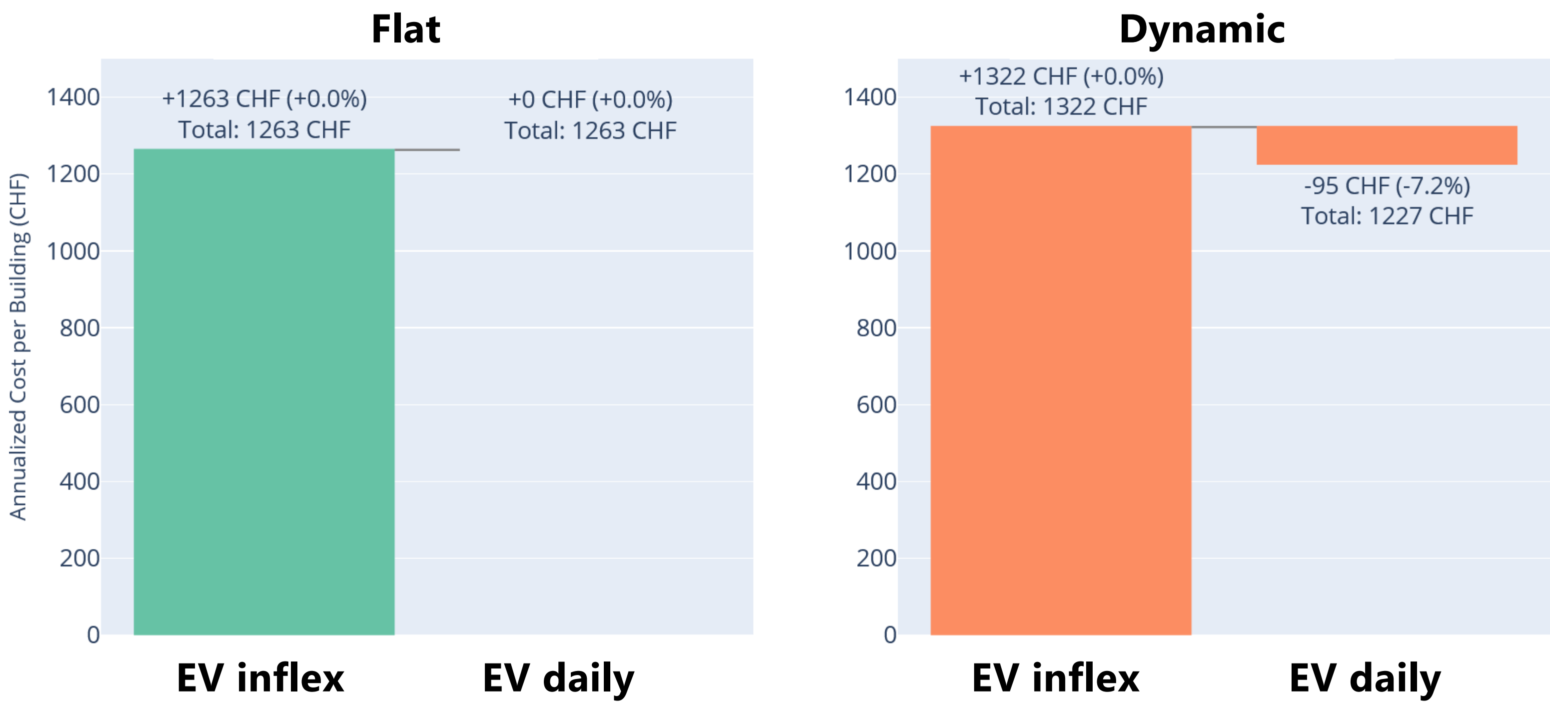


Annualized system costs per building (2050) – Unidirectional - Daily flex

Findings

- **Dynamic tariffs** with **inflexible demand increases** costs
  -> not possible to shift EV's load, higher price risk

- The **Flat** tariff shows **no saving** potential
  -> same deployment of PV and batteries
  ->same level of self-consumption
  -> price profile and the absence of FiT do not incentivize investments

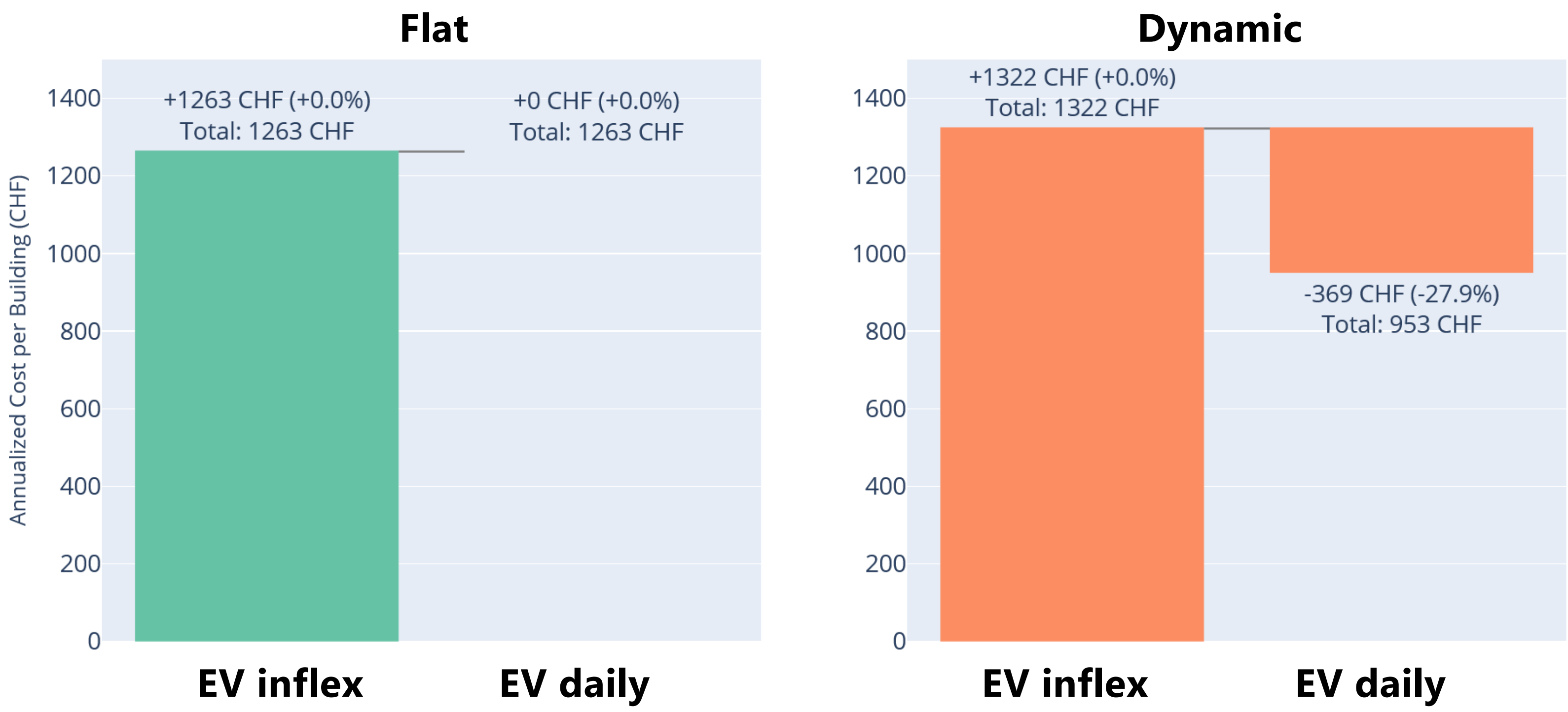


Annualized system costs per building (2050) – Bidirectional - Daily flex

Findings

- **Bidirectional** charging **with dynamic prices** leads to **higher savings**
  -> aprox. **953 CHF / year**

- **Important to consider the EV's charging profile**



Conclusions & Next Steps

Conclusions

- Exposing household to dynamic tariffs can reduce their overall energy costs
  - But if they do not operate flexibly, there is a risk due to price volatility
- Flexible demand can dynamic tariffs can incentivize investments in PV and batteries
  - But these investments are highly sensitive to the model's assumptions (price profiles, mobility patterns)
- Bidirectional charging has the potential cost significantly and can even substitute battery investments

Next steps

- Consider more technology combinations to identify individual values and synergies
- Include more sophisticated tariff designs (e.g., profile contracts)
- Sensitivities for EV mobility patterns and electricity price profiles

Thank you for your attention!

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