Impacts of EV and HP Flexibility – EU & Swiss Perspectives

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sweet swiss energy research for the energy transition

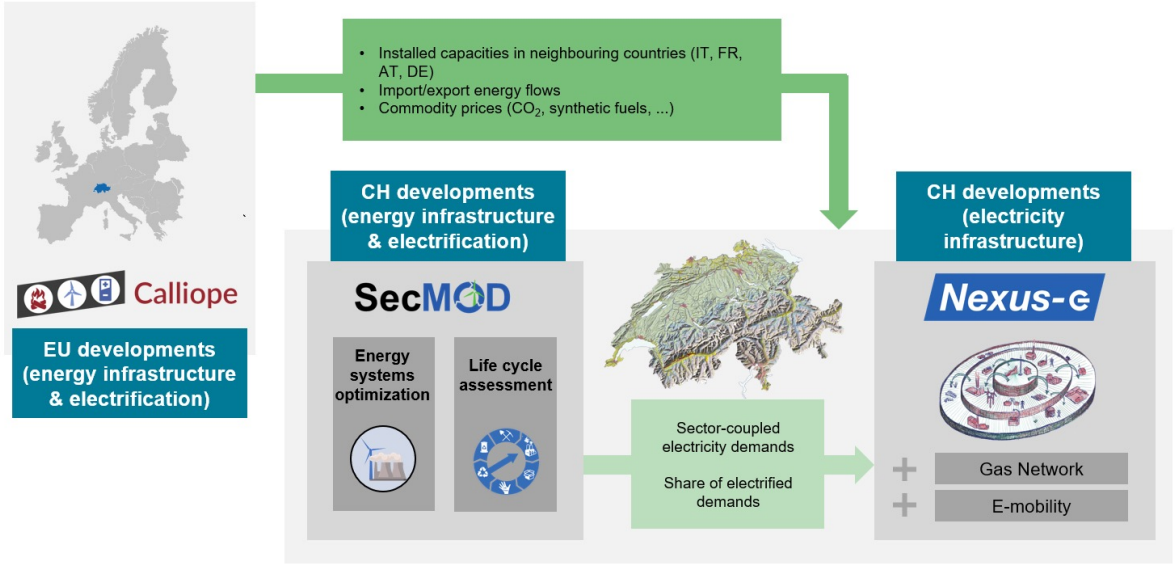
PATHFNDR

Lunch talk series V:
Flexibility provision from buildings and electromobility

1. **Impacts of electric vehicles and heat pumps flexibility: European and Swiss perspectives**
2. End-user flexibilities for electrical distribution grid planning
3. Modelling flexibility from electric vehicles: where, when, why, and how
4. Modelling flexibility from heat pumps: a bottom-up approach for Swiss buildings
5. Electrification, flexibility or both?
6. Emerging trends in recent Swiss and European policy
7. Operation and market mechanisms: from dynamic electricity tariffs to day-ahead and intraday auctions

Agenda

- What is PATHFNDR
- A sequence of energy system models
- A focus on EVs & HPs
- Scenarios & Requirements
- Results
  - EU Perspective
  - CH Energy System Perspective
  - CH Electricity Sector: a deeper dive
- Take Away Messages



SWEET PATHFNDR: Focus on flexibility and sector coupling for the Swiss energy transition

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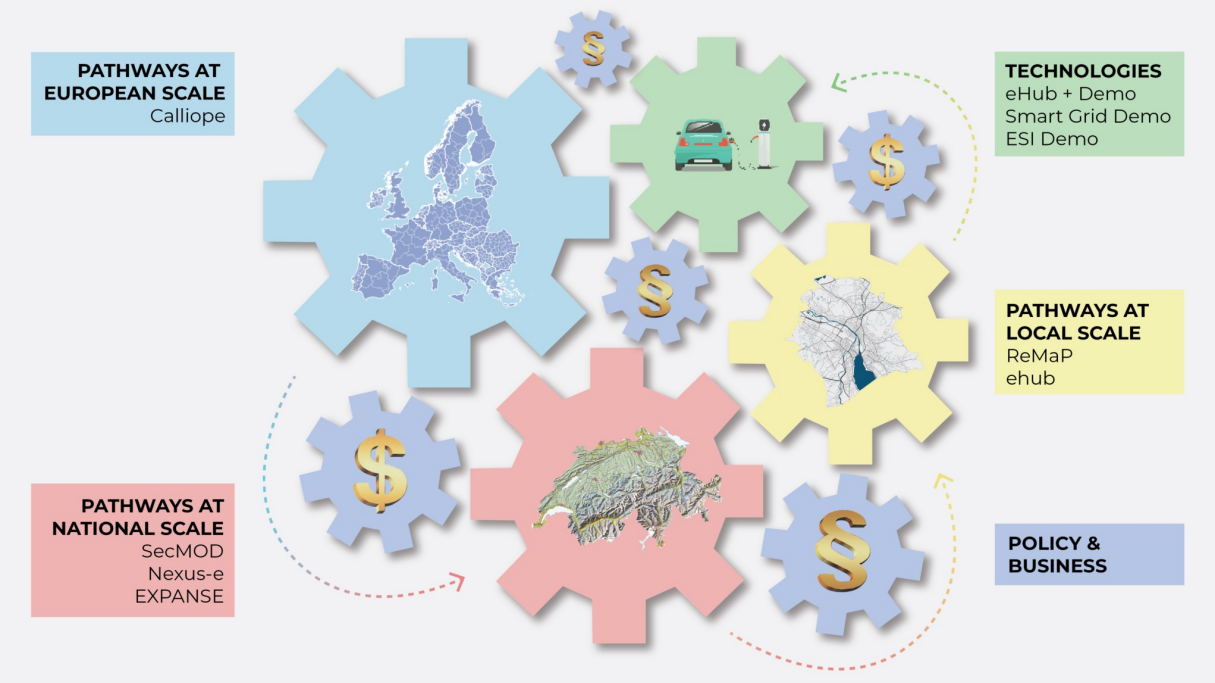
PATHFNDR

Aim

Develop and assess pathways to an efficient future energy system through flexibility and sector coupling

PATHFNDR website

We imagine as a Machine



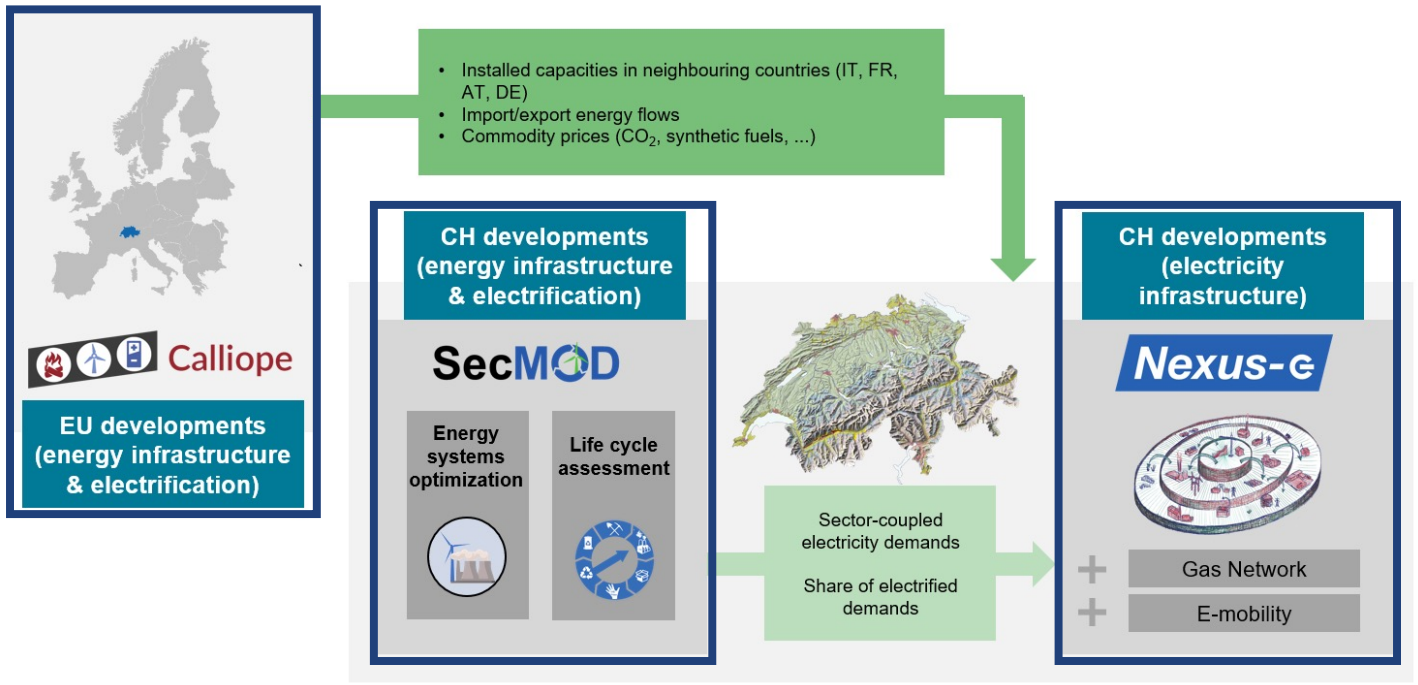
WP1 Scope: International and National Perspective
A series of energy system models

Linking models to combine strengths across 3 dimensions
1. Spatial scope
2. Energy system scope
3. Time horizon

Calliope: All EU & all energy sectors, aggregated
→ Optimize the EU developments

SecMOD: CH only & all energy sectors, few days
→ Optimize the CH electrification

Nexus-e: CH and neighbors & only electricity sector, nodal
→ Optimize CH electricity investments & operation



But what does sector coupling and flexibility have to do with EVs and HPs?

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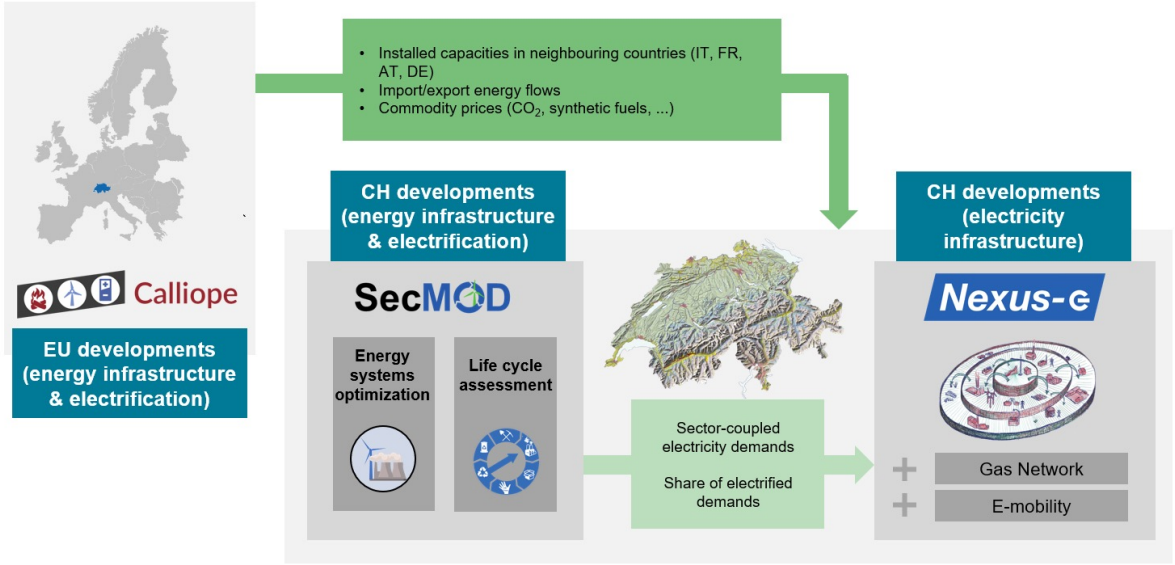
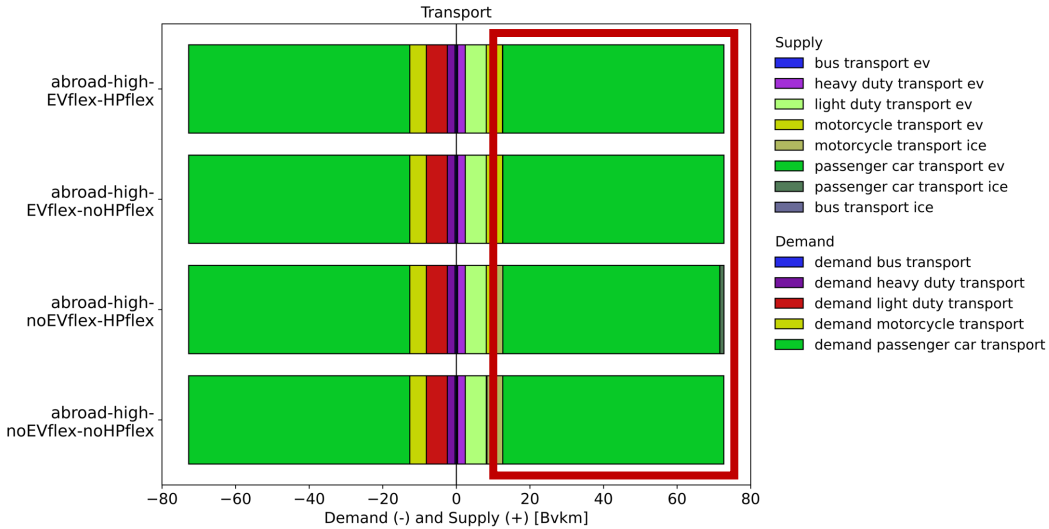
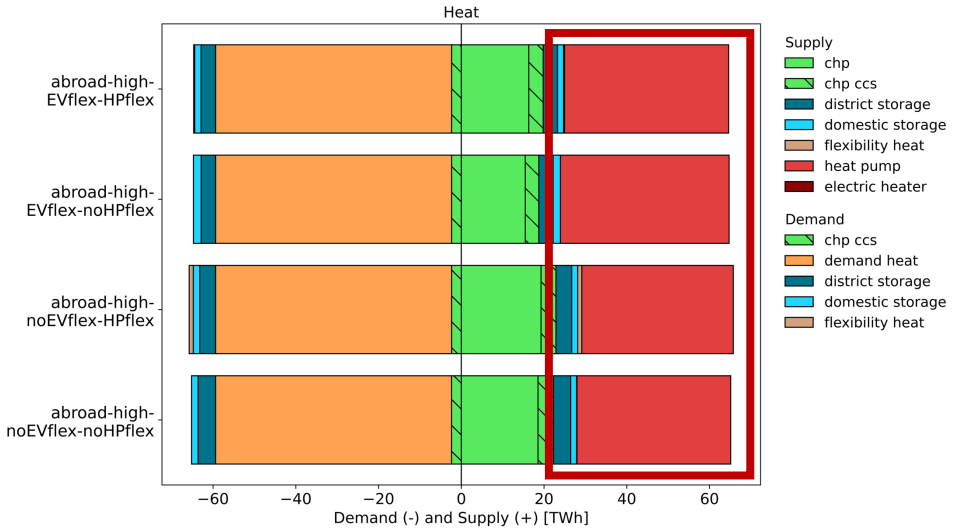


Why focus on the impacts of EV and HP demand flexibility?

Motivation: The aim to decarbonize leads to electrification of both the transport and heating sectors





- Research aim: quantify the potential benefits of flexibility from these demands
  - Investments, operations, curtailments, imports/exports, costs, prices
- Key challenge: how to represent these physical nature of these flexibilities and in an aggregated way
- Innovation: implement in the model realistic representations of EV and HP flexibility across Switzerland

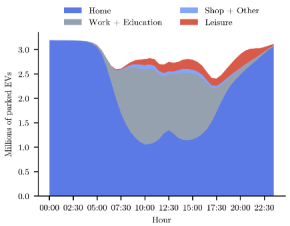
Modeling: EV demand and flexibility potential

Bottom-up & aggregating while reflecting physical capabilities

*by Maria Parajeles Herrera

Nationwide Transport Simulation [1]

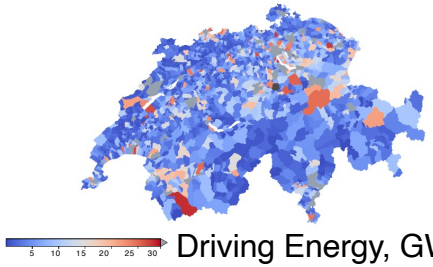
Parking geographic location



Daily distribution of parking location by type

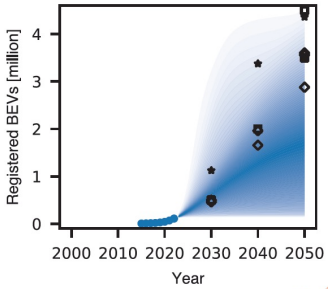
Georeferenced Energy Needs

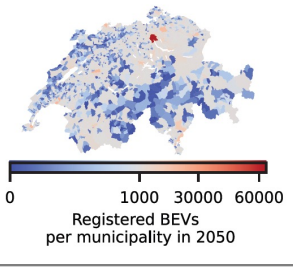
Vehicle-specific Driving Energy Estimation [2]



Driving Energy, GWh

Charging Profiles Formulation





EV flexibility limits: shift only during existing plug in sessions & same SOC at end of every parking session

→ No impact on vehicle owner experience

[1] A. Horni, K. Nagel, and K. Axhausen, Eds., Multi-Agent Transport Simulation MATSim. London: Ubiquity Press, Aug 2016.
[2] M. Parajeles Herrera, M. Schwarz, and G. Hug, "Spatio-Temporal Modelling of Large-Scale BEV Fleets Charging Energy Needs and Flexibility" SEST 2024.

Modeling: HP demand and flexibility potential

Bottom-up & aggregating while reflecting physical capabilities

*by Yi Guo & Jan Linder

Building Data & Energy Demand Parameters

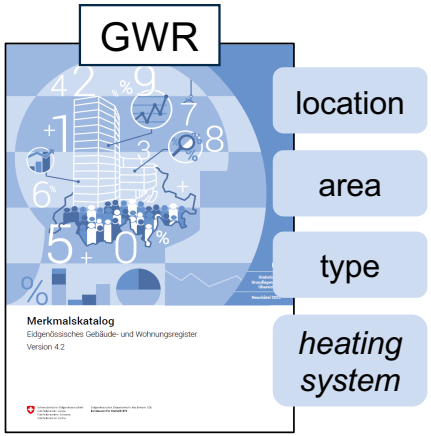
GWR

location

area

type

heating system



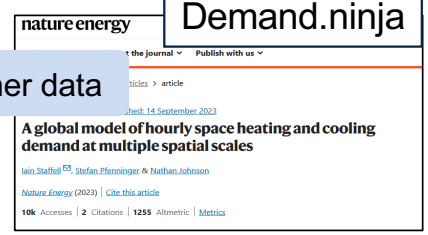
Energy Demand Parameters & Weather Data

SIA2024

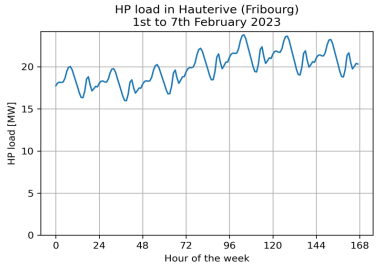
energy demand parameters

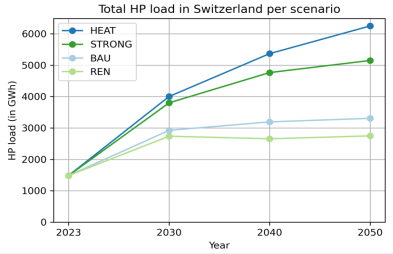
Demand.ninja

weather data



HP Load Profiles Formulation [3]





HP flexibility limits: cumulative daily energy consumption bounds → ensures building temperature range

→

No impact on building occupant comfort

[3] J. Linder, "Buildings' flexibility in the future Swiss electricity system: an analysis of direct load control policies for heat pumps," Masters Thesis, ETH Zurich, Feb 2024.

Scenarios & Requirements

Scenarios

EV & HP flexibility

- The relative values of EV and HP flexibility to the system

Energy market integration

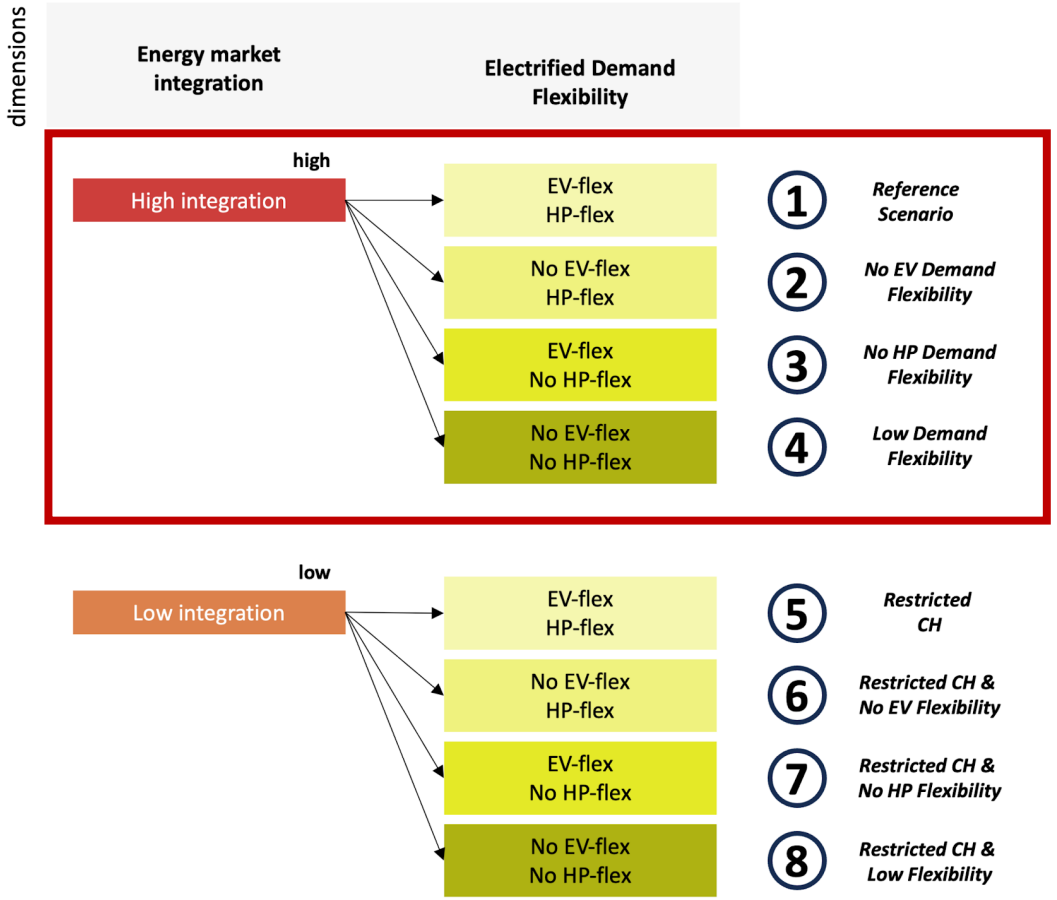
- How does lack of ability to import power & fuels impact sector coupling & flexibility?

Requirements to achieve

- Net Zero EU & CH – energy sectors must offset hard-to-abate sectors
- Net Zero CH – energy system
- CH RES – 45 TWh of non-hydro renewables

Data and assumptions vary between the models

- Harmonize as much as possible



Results Euro-Calliope: European energy system
Design for a net-zero 2050

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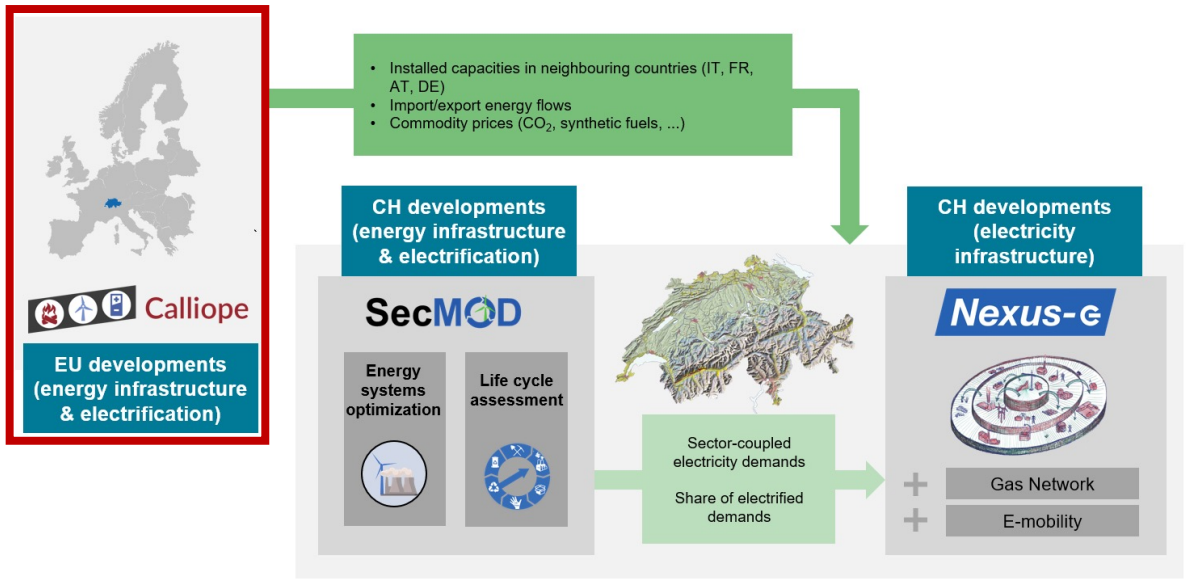


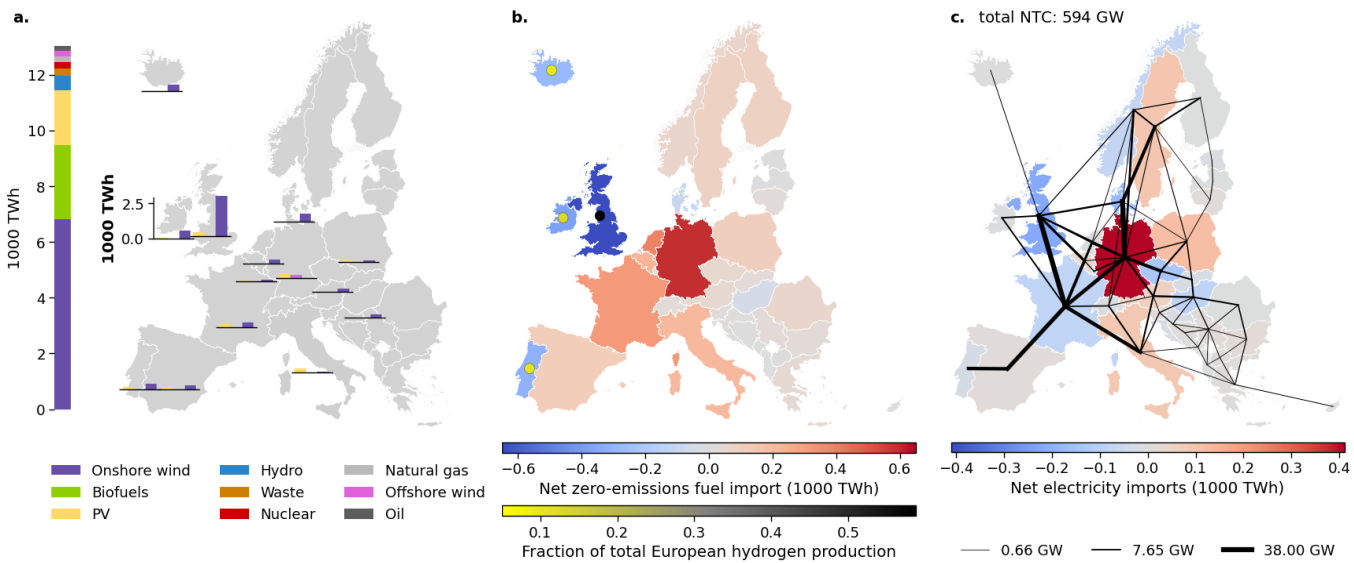
Results: Calliope EU Perspective

Why do we model the European energy system?

- Endogenously determine the import and export electricity flows
- Endogenously determine the fuel import and export
- Apply a European-wide carbon target that allows for compensation among countries.

Main assumptions:

- Europe is self-sufficient + greenfield deployment
- Free fuel trade among modelled countries
- EU CO_2 target: -200 MtonCO_2
- Switzerland CO_2 target ≤ -5.7 MtonCO_2 (positive emissions have to be offset domestically)



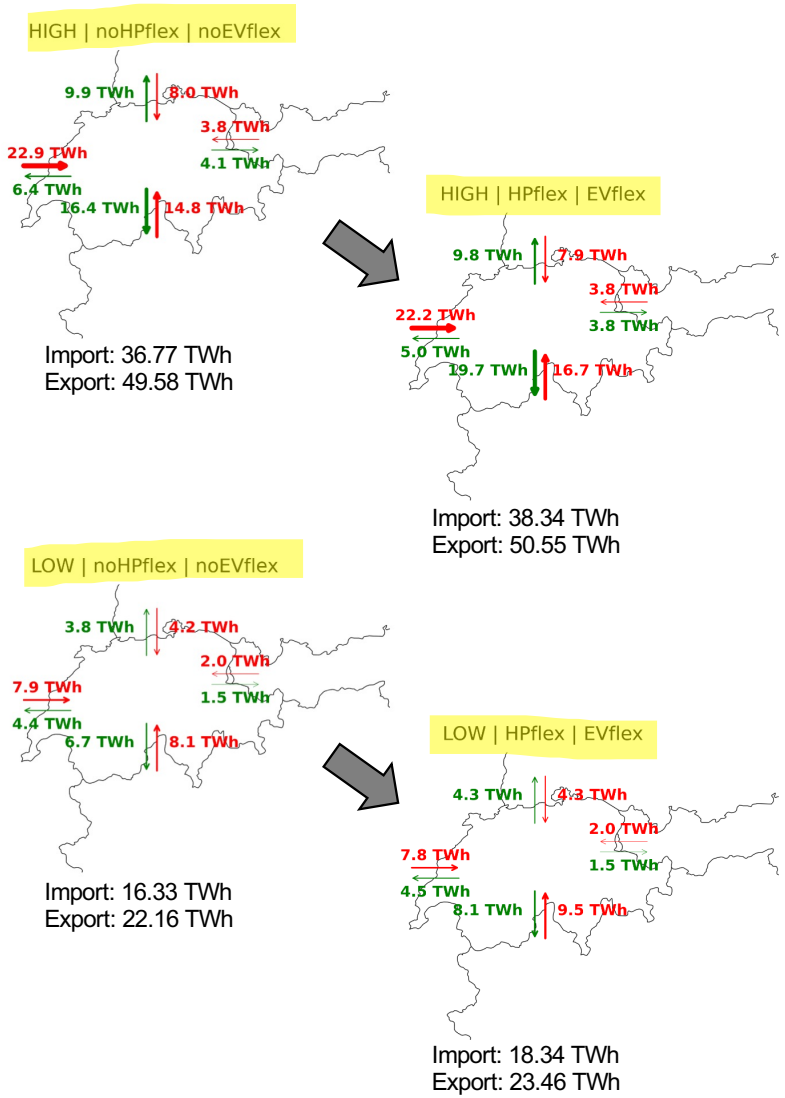
European macrotrends:

- High electrification: 100% electrification of transport and 77% heat pump penetration.
- EU captures 328 MtonCO_2 capture
- 128 MtonCO_2 positive emissions, of which 40 MtonCO_2 comes from non-biogenic emissions from wastes

Results: Calliope EU Perspective

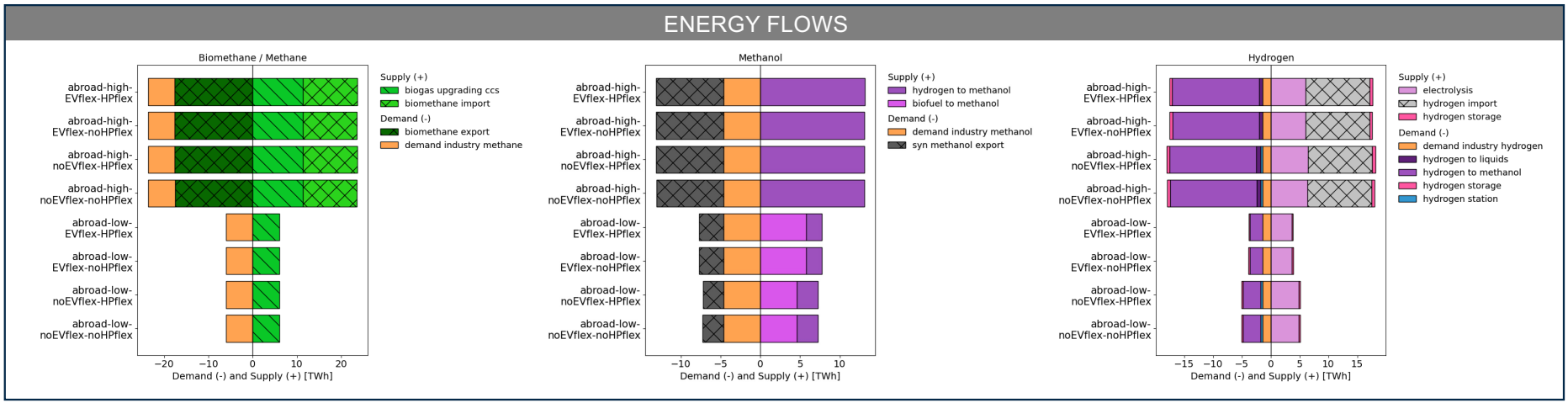
- The employment of a **European energy system model** allows for **determining the boundary conditions** of the Swiss energy system. The import and export electricity values are then used as upper limits when Switzerland is modelled at higher spatial detail.

- Being able to **represent and endogenously model the boundary conditions** (e.g. import and export electricity flows) gives us **an extra degree of freedom when designing scenarios** instead of relying on exogenous data.



Results: Calliope EU Perspective

- The European model computes the fuel trades from and to Switzerland, mirroring the **interconnected nature of the integrated European energy system**.
- However, a **single-node Swiss energy system falls short in representing the domestic dynamics** that heavily influence the assessment of flexibility provision and usage. This is the reason why we need extra modelling steps to dig into the system value of EV and HP flexibility.
- Despite that, the single-node Swiss energy system provides **consistency checks** for a smooth integration of different models showing the same macrotrends of SecMOD and Nexus-e.



Results SecMOD: Swiss energy system
Swiss electrification and industry supplies for a net-zero 2050

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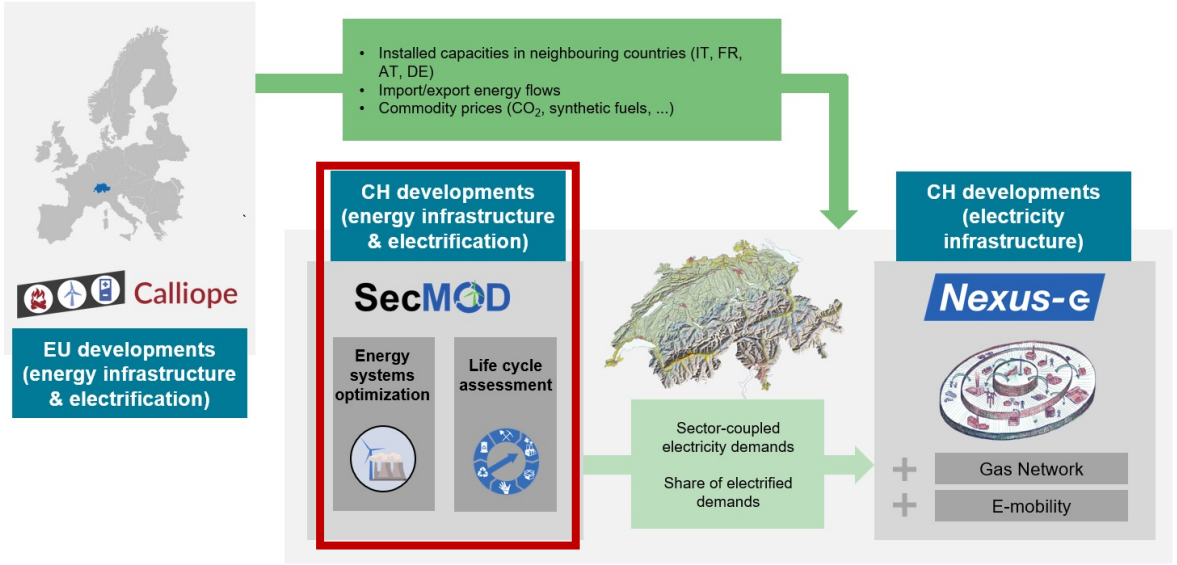
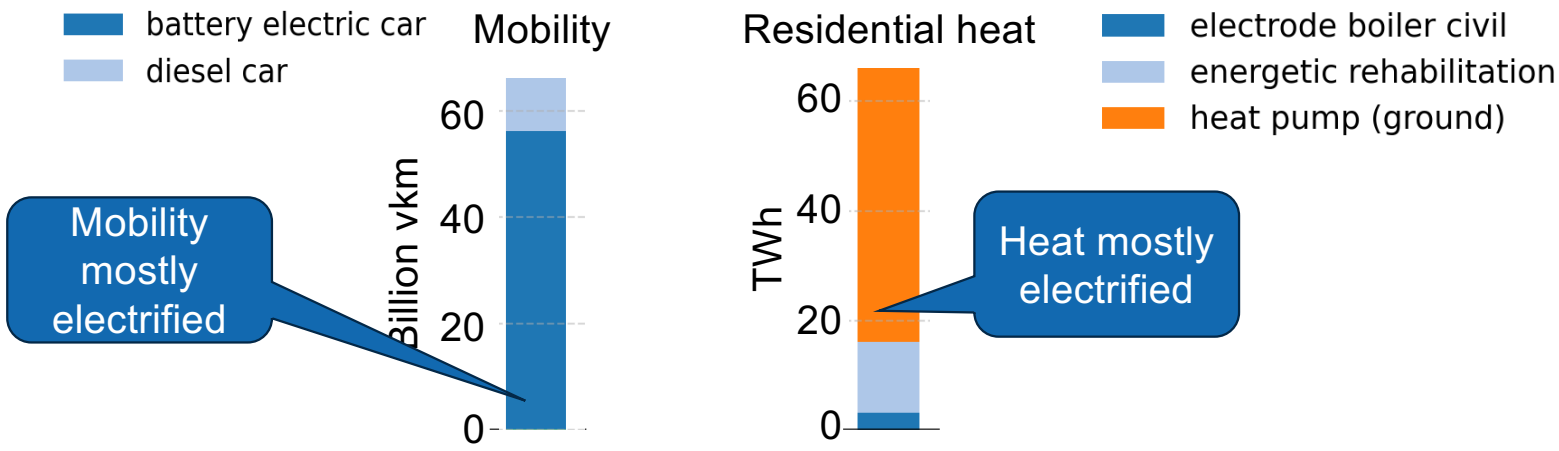


The Swiss sector-coupled net-zero energy system in 2050



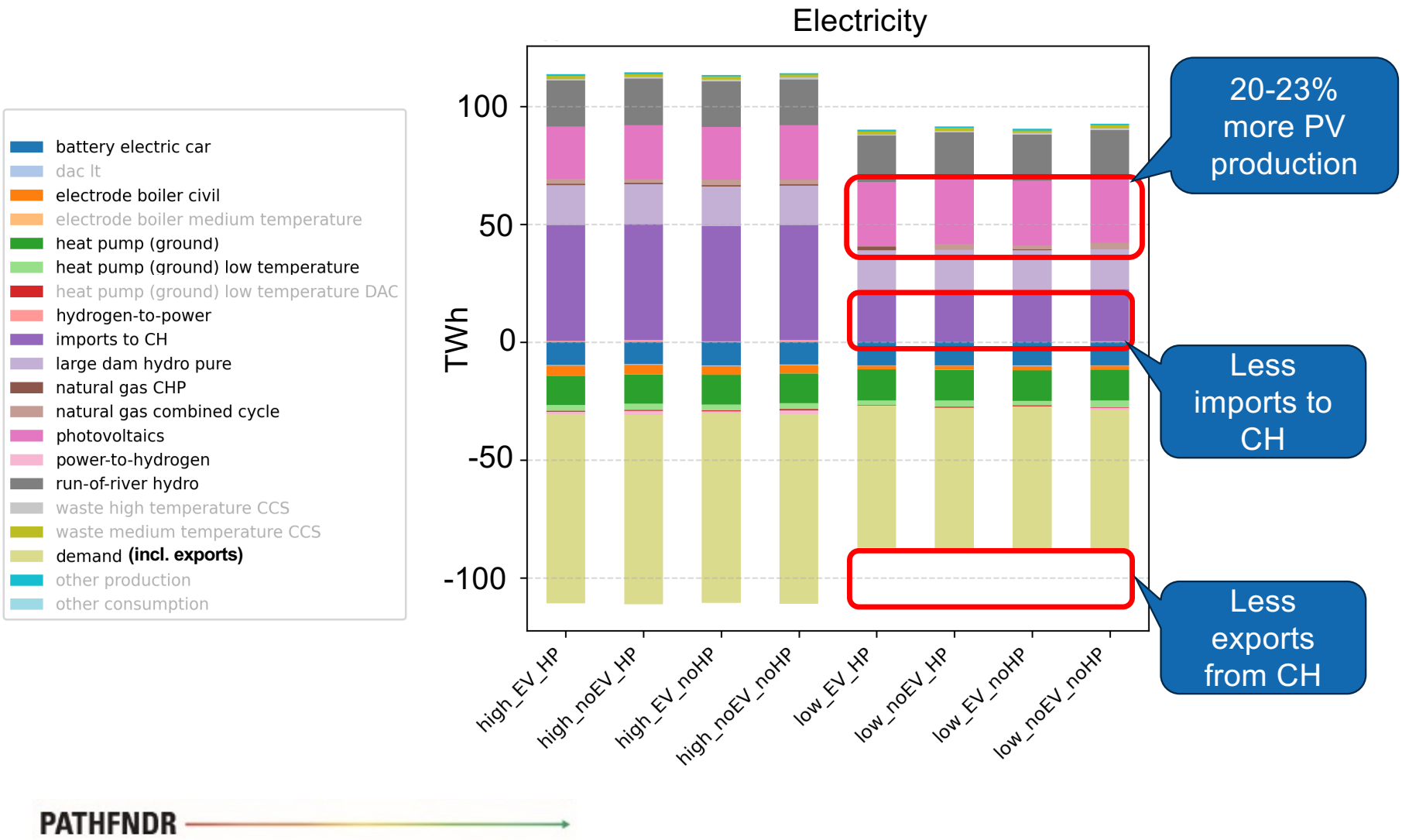
Base electricity demand in 2050: 45.2 TWh (vs. 56.1 TWh in 2023[1])

Electrified heat and mobility demands: 25 TWh

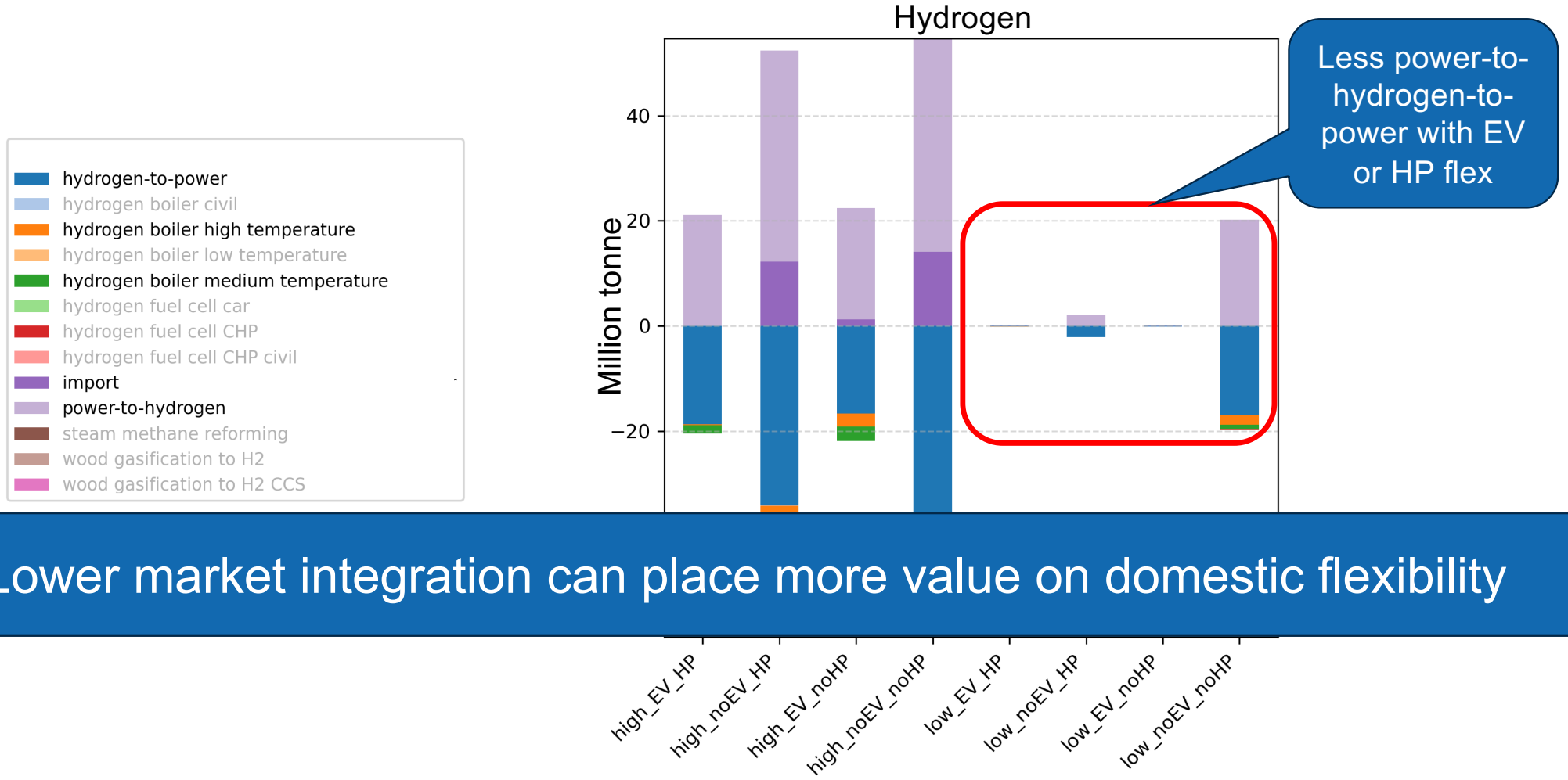
Total electricity demand of net-zero Switzerland: 70.2 TWh

[1] News Service Bund, https://www.news.admin.ch/en/nsb?id=100748

Effect of market integration on the sector-coupled system

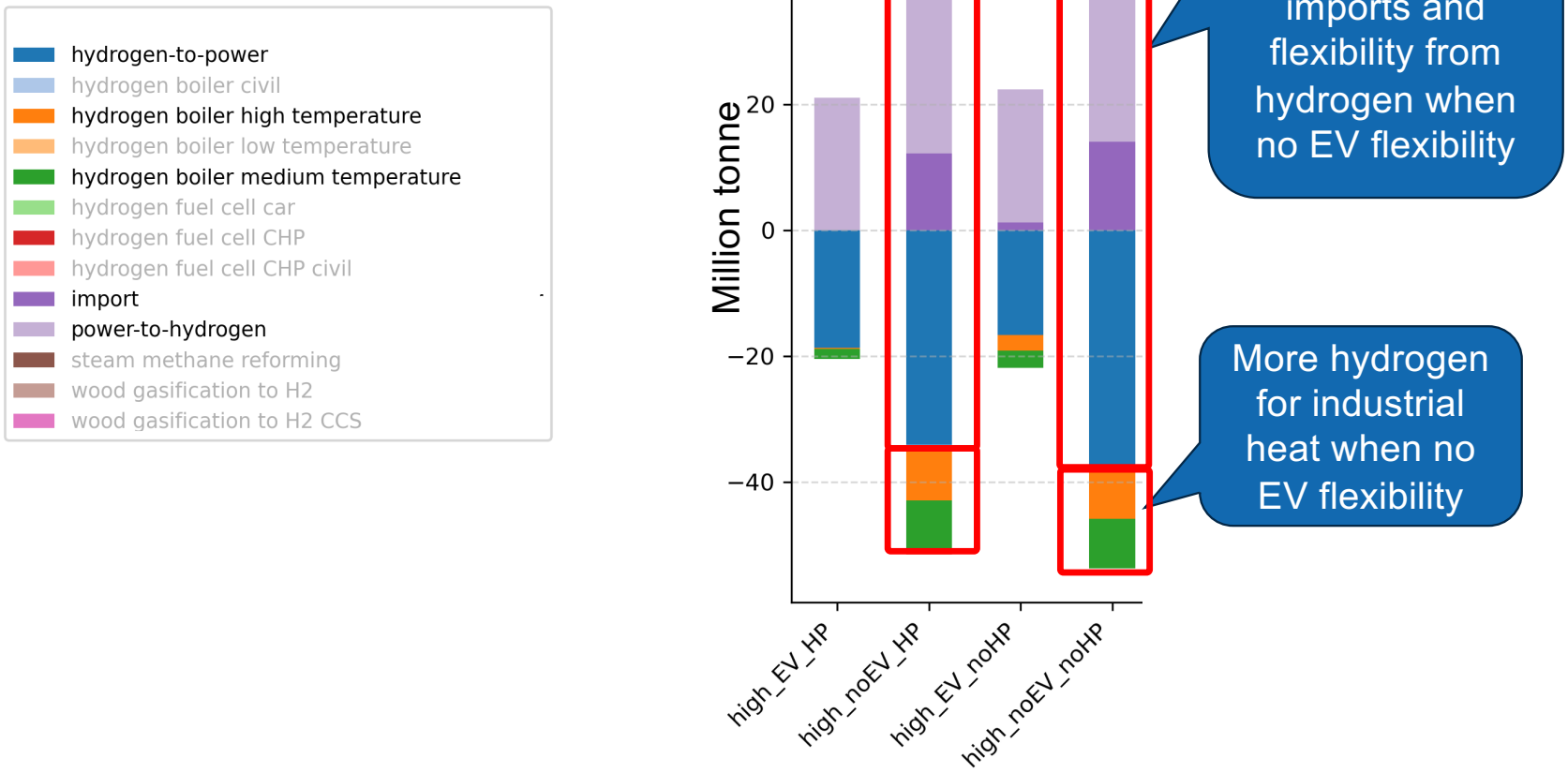


Effect of market integration on the sector-coupled system

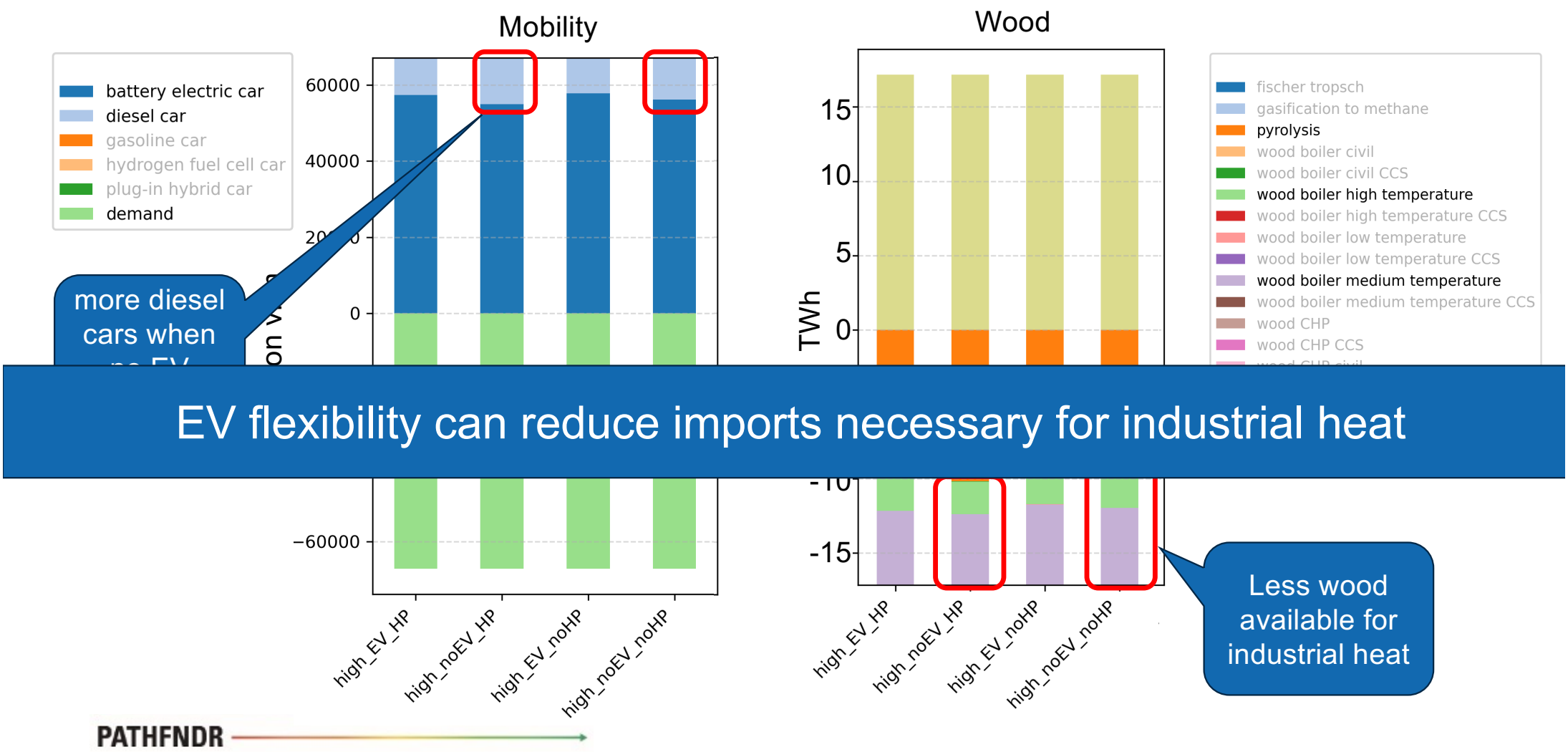


Lower market integration can place more value on domestic flexibility

Effect of EV flexibility on the sector-coupled system



Effect of EV flexibility on the sector-coupled system



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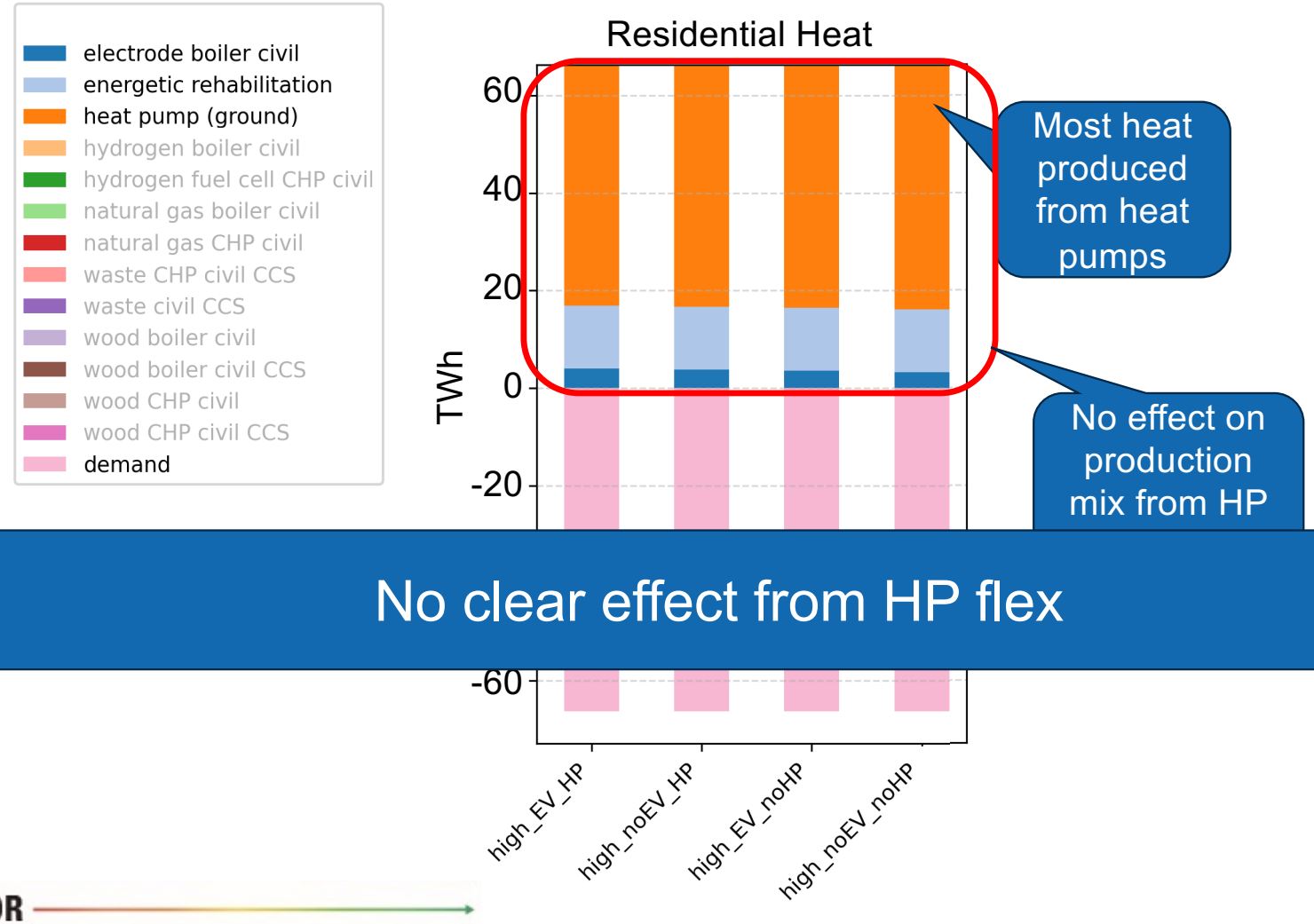
Effect of HP flexibility on the sector-coupled system



No clear effect from HP flex

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Results Nexus-e: Swiss electricity sector
Electricity sector investments and operation (focus on flexibility)

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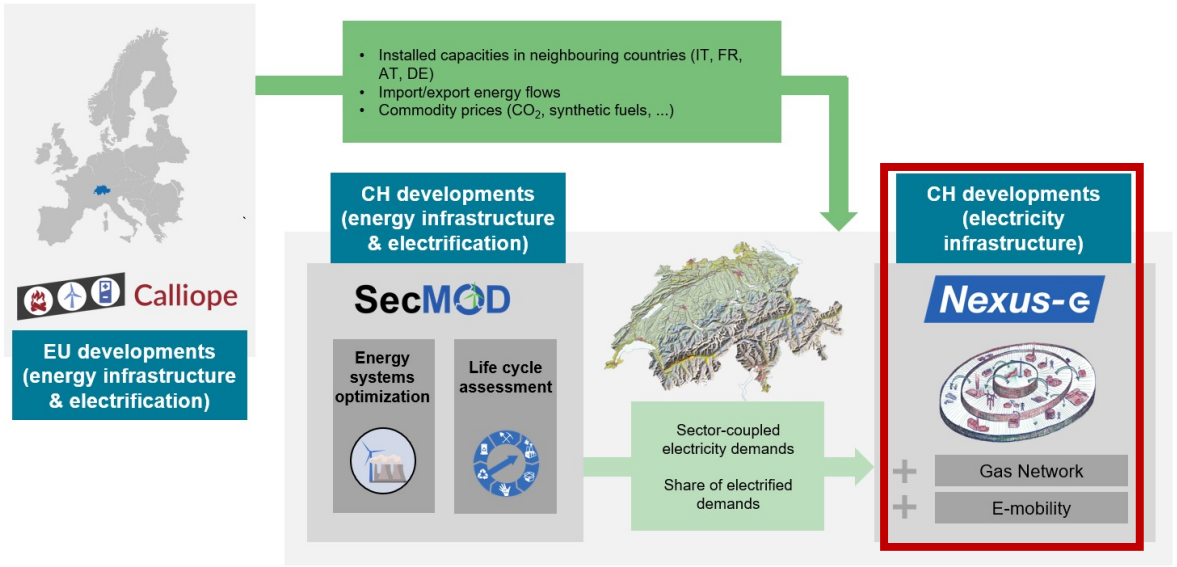
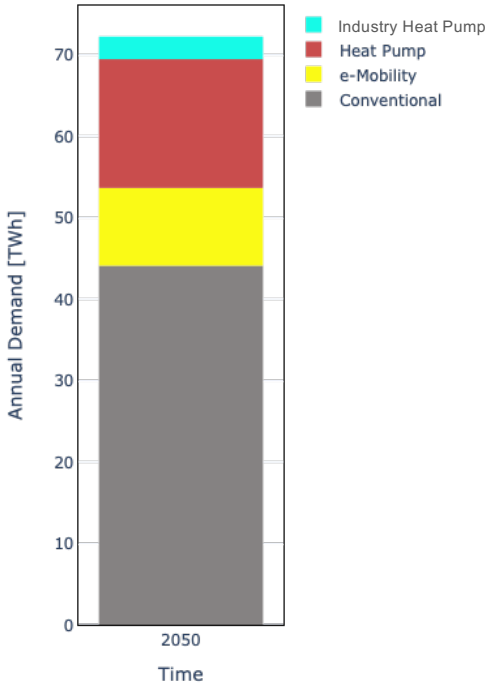
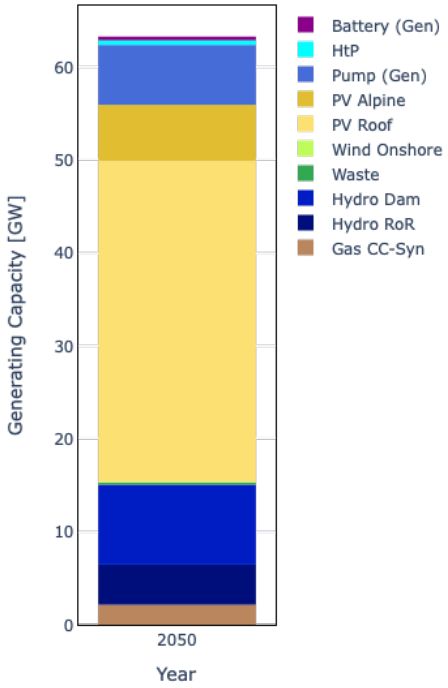


First a snapshot of the Swiss electricity system without EV & HP flexibility

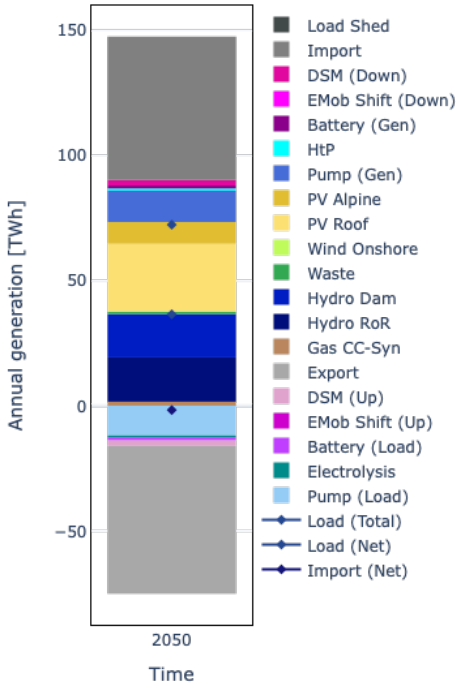
Demand



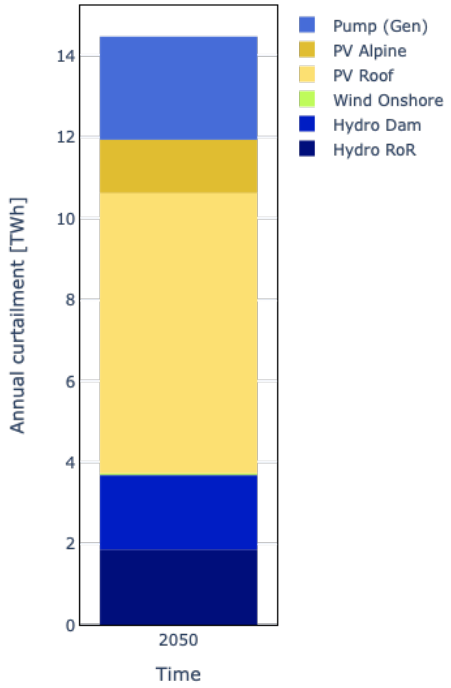
Installed Capacity



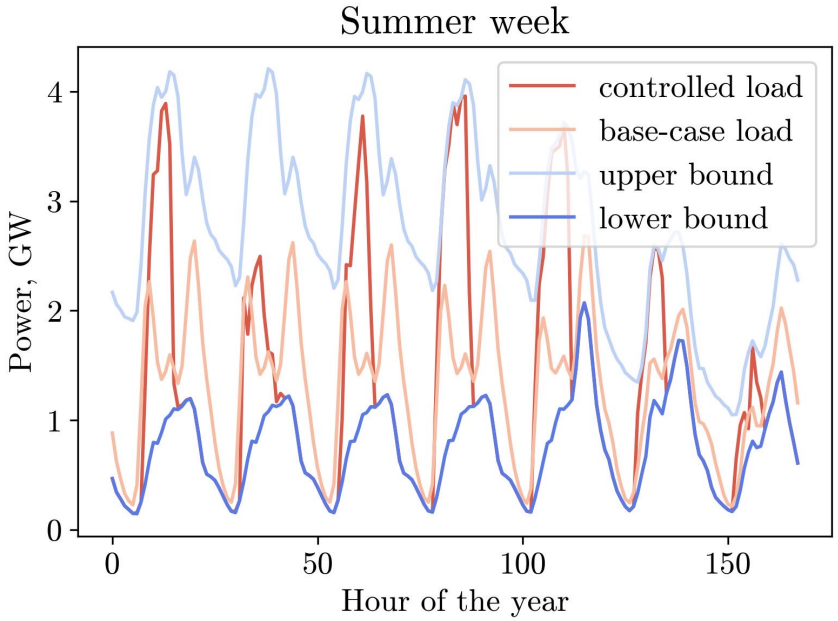
Generation



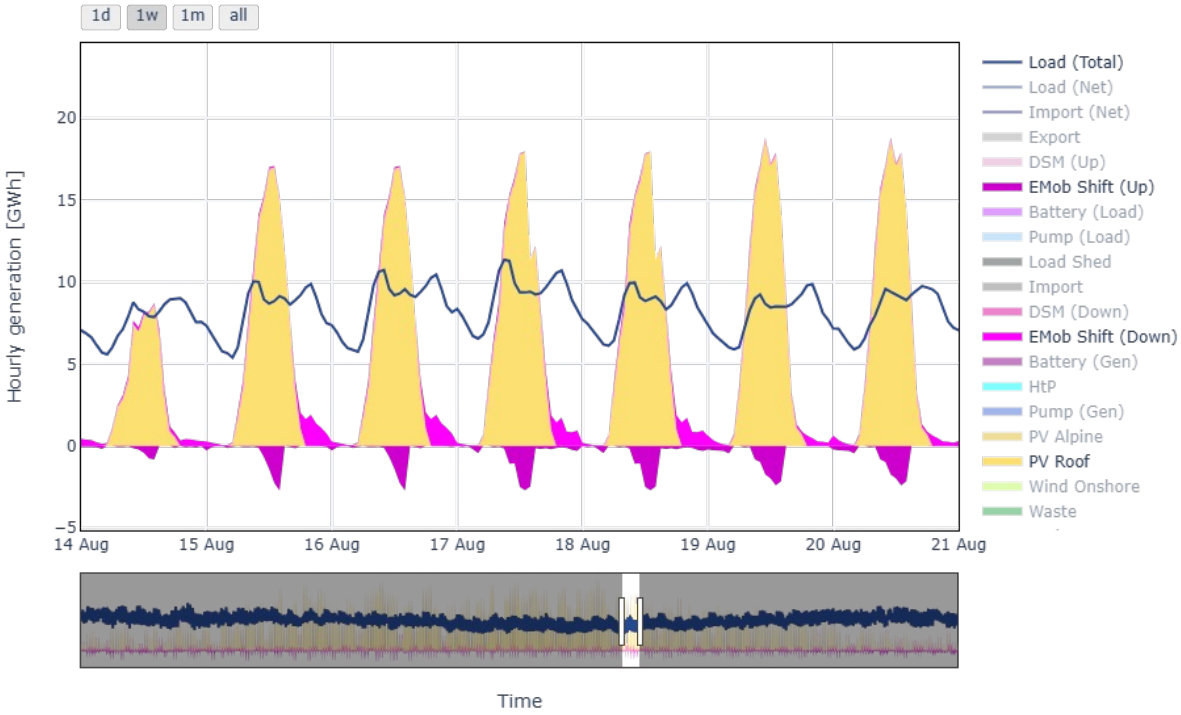
Curtailments



EV shifting – 20% of EV demand is shifted (2 TWh)

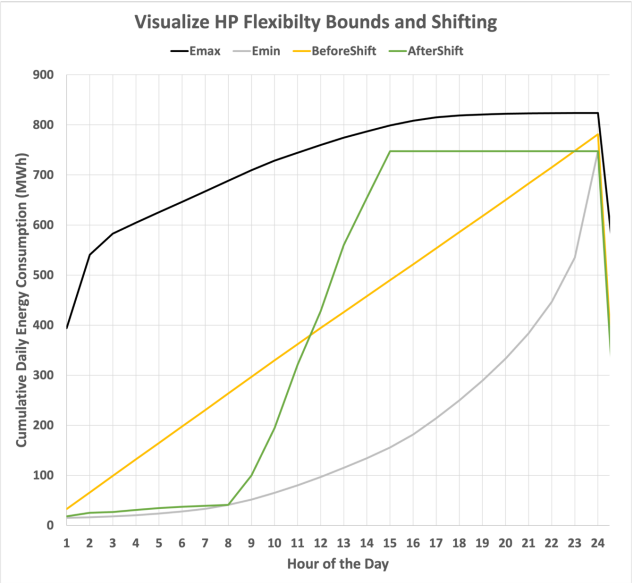


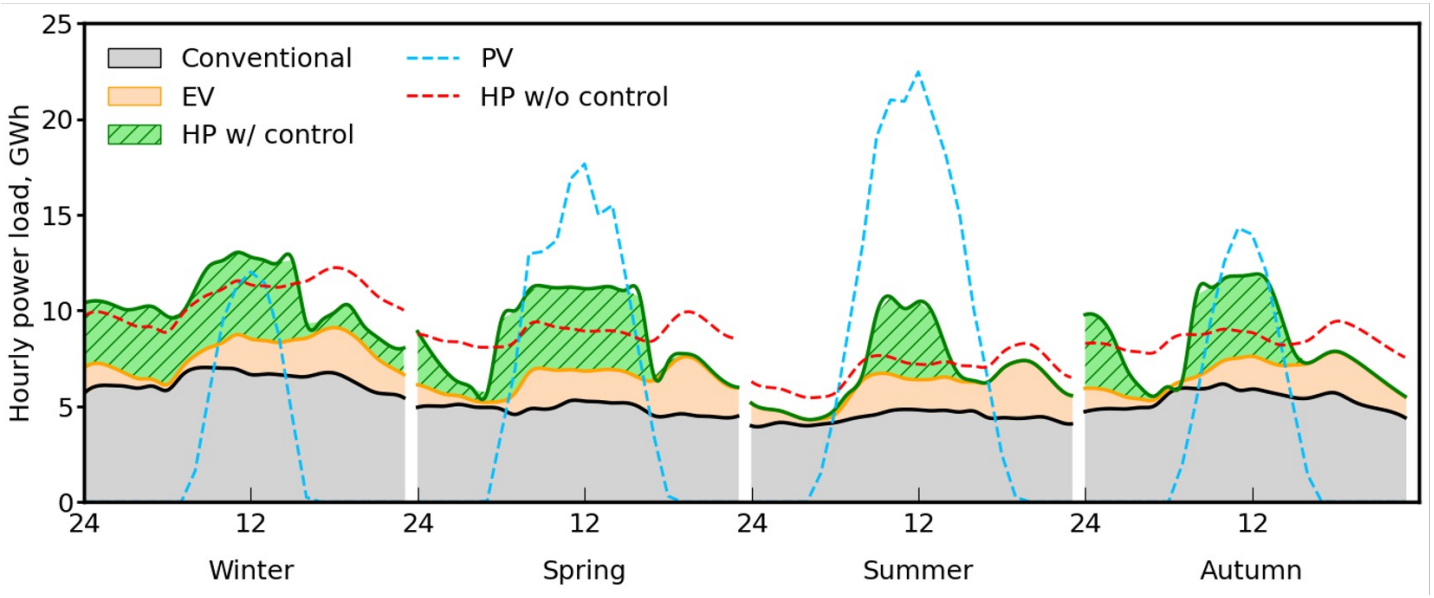
Shifting of EV demand stays within defined limits



Shifting of EV demand aligns with summer PV

HP shifting – 23% of HP demand is shifted (3.8 TWh)

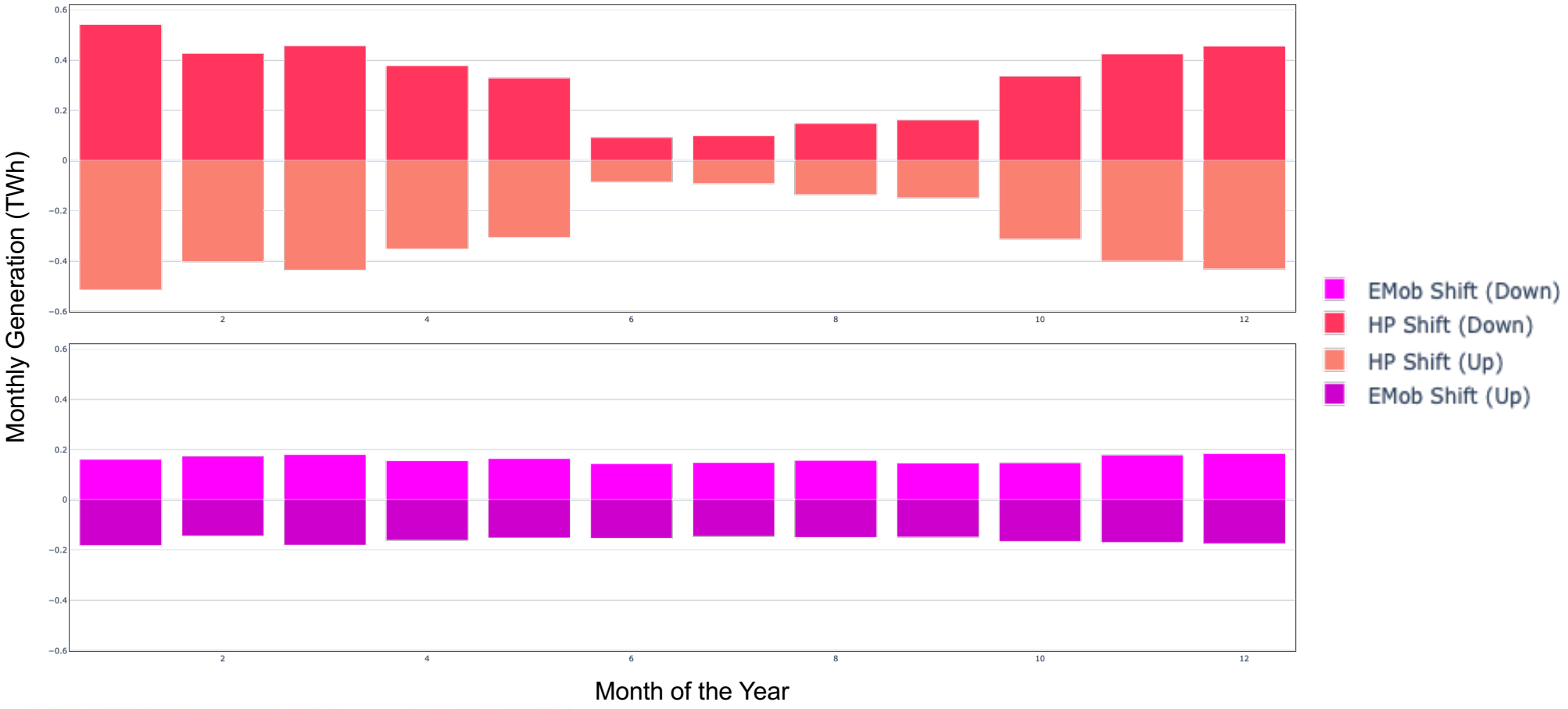




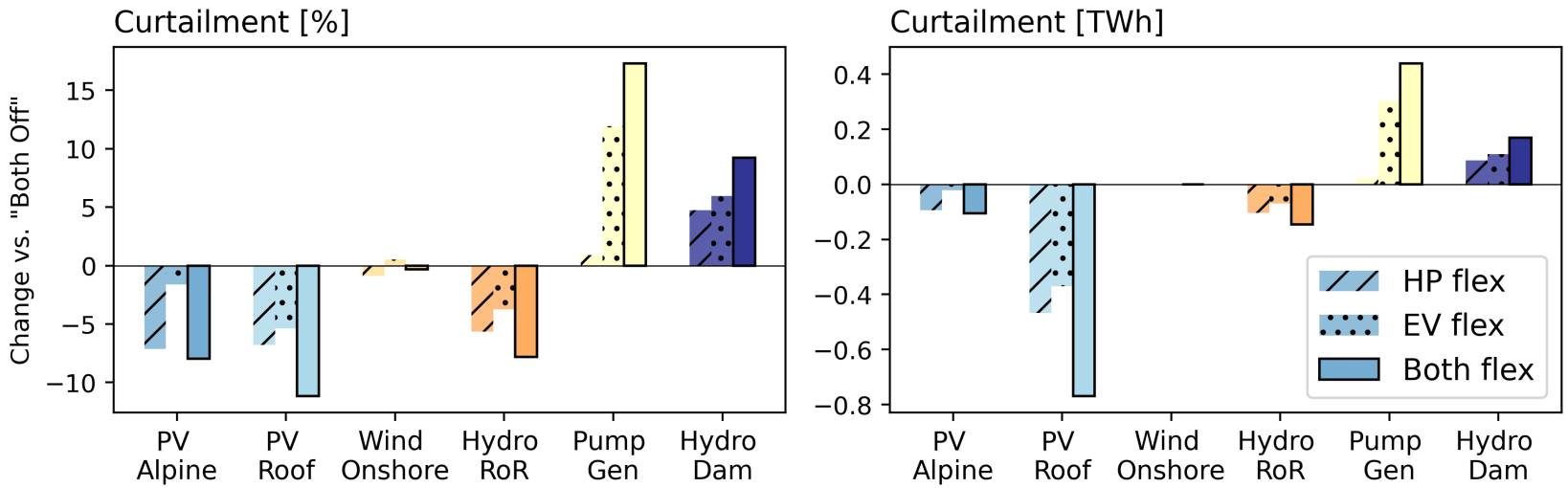
Shifting of HP demand stays within defined limits

Shifting of HP into midday and away from evening

HP flexibility is more seasonal than EV flexibility

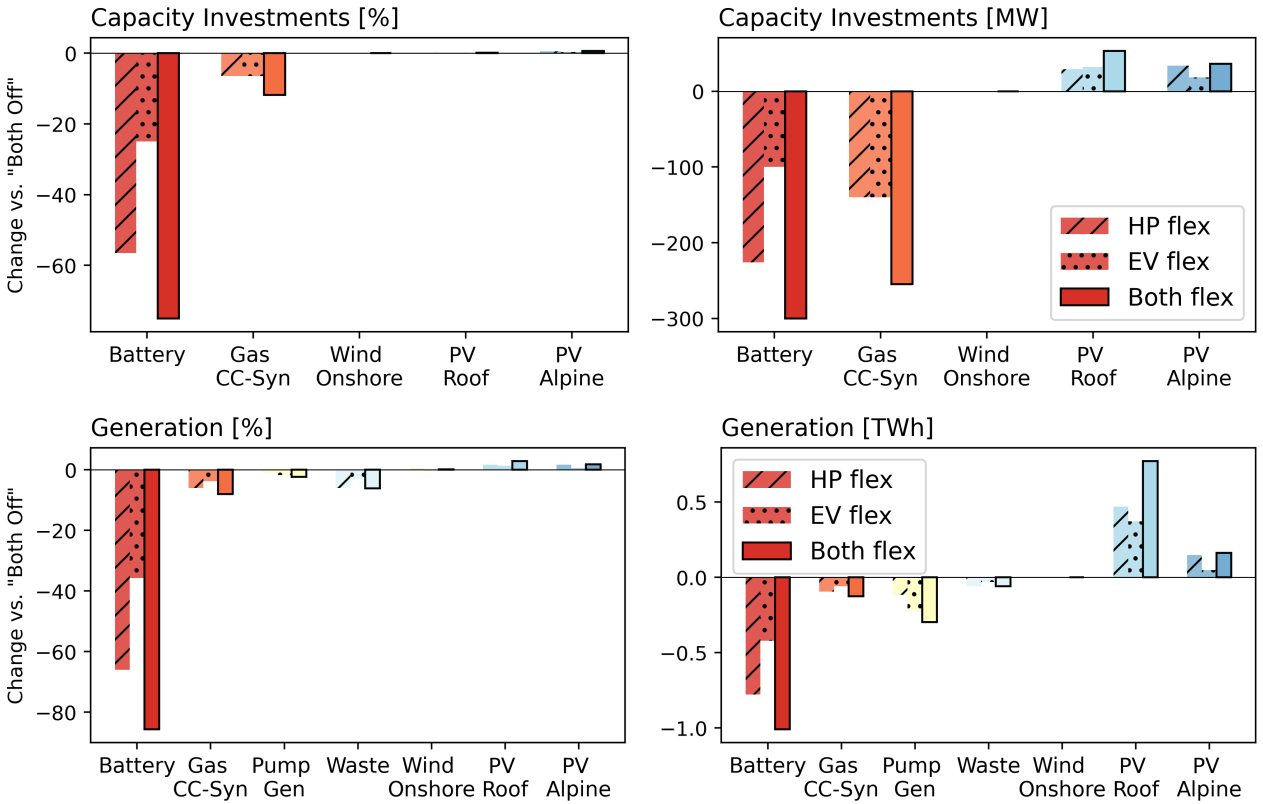


Allowing EV & HP flexibility reduces curtailments (supports RES)



EV & HP flexibility: similar magnitude of changes
Cumulative: ”Both flex” achieves nearly the sum of the benefits
Curtailments: benefit to RES (0.9 TWh) but more water spilled (0.5 TWh)

Presence of EV & HP flexibility reduces the need of other flexible assets

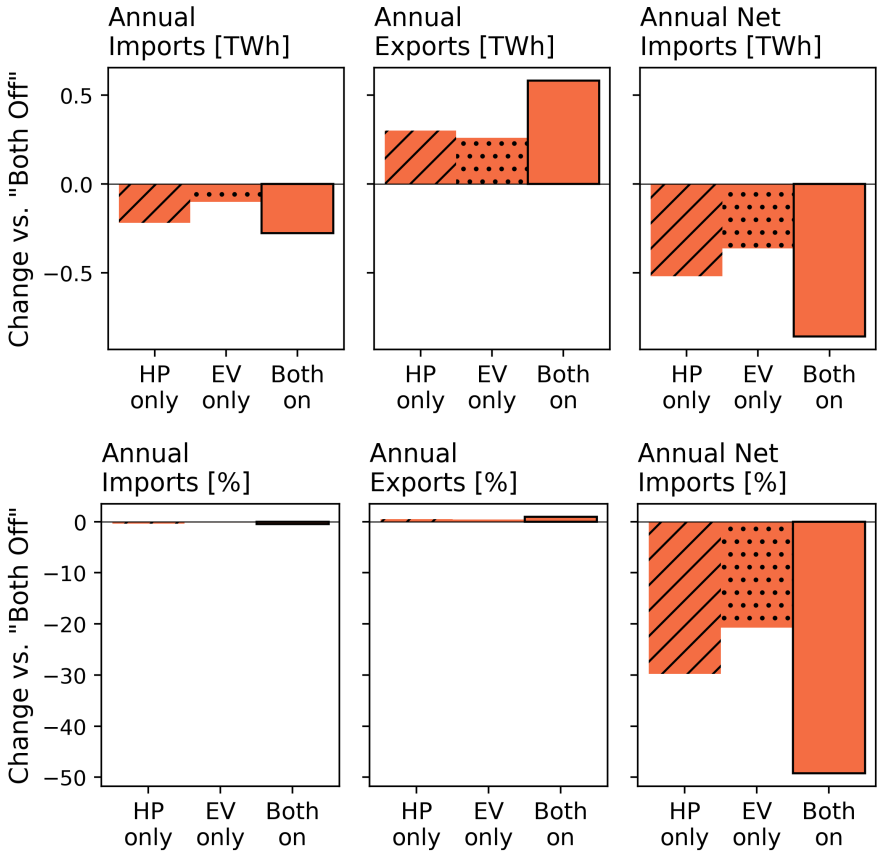


Less investments & less generation from other flexible assets:

- BESS
- Syn-GasCC

Also less generation from Hydro Pump

Presence of EV & HP flexibility also reduces the need for trade as a form of flexibility



Exports increase while Imports reduce

Move further into being a net exporter*

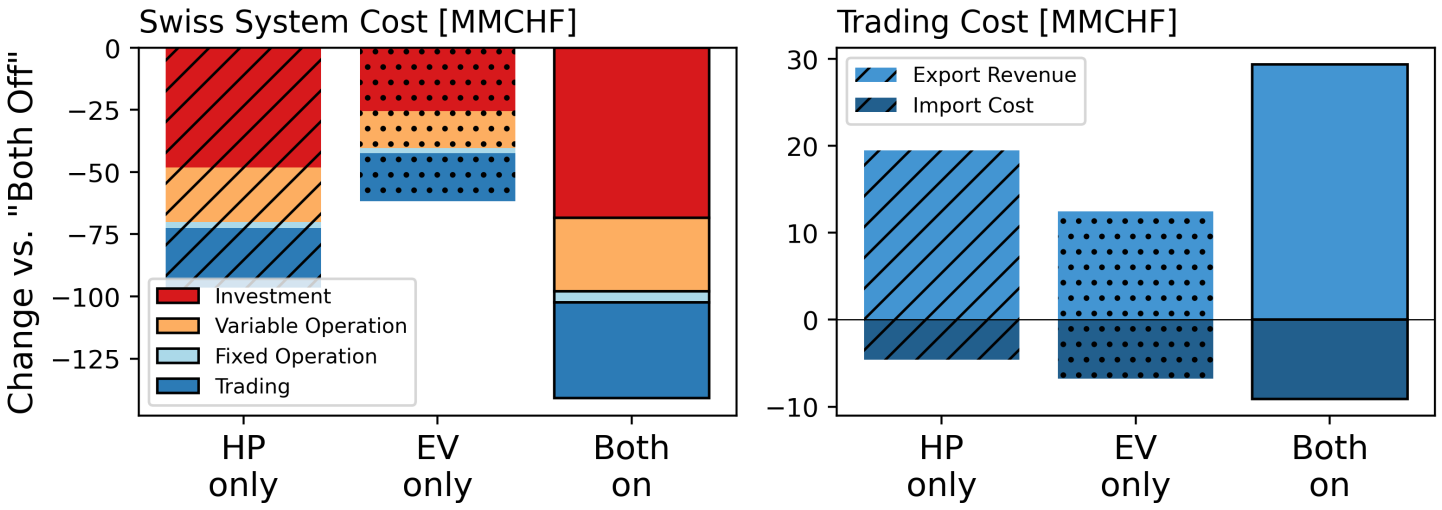
- 2.6 TWh/a (Both on)

Magnitude of Imports ~57 TWh/a

Magnitude of Exports ~59 TWh/a

*CH is already a net exporter (1.7 TWh/a) in the 'No Flex' case

These changes result in lower electricity system cost



Investment savings

- Building less BESS and Syn-GasCC

Variable cost savings

- Operating less Syn-GasCC

Trading

- Reduce Import costs
- Increase Export revenues

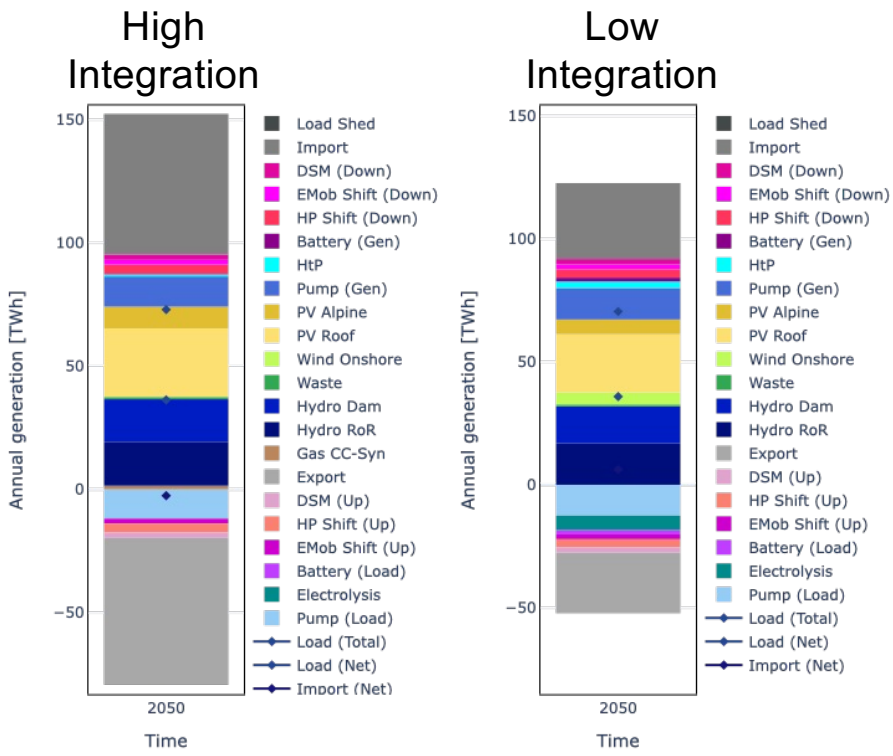
Build and operate other flexible assets less
Trading shifts away from import costs and toward export revenues

Low energy market integration leads to many negative outcomes

- Increases in BESS, Fuel Cell & Wind capacities
  - Focus for domestic supply (esp. Winter)
- Huge increase in RES curtailments & Hydro spilling
  - From ~14 TWh to over 24 TWh
  - Even with more investments, actual generation from RES is less
- Increase in investment costs and import costs
  - System cost increase from 4.5 to 5.5 Billion CHF/a
- Average annual Swiss electricity prices double
  - Prices in the neighboring countries also increase significantly

- Same utilization of EV & HP flexibility (already maximized)
- System cost savings from EV & HP flexibility is larger

➢ Value of these flexibilities is greater



Recommendations: Outcomes & Audience

Electrification: key trend to decarbonize

- consumers / sales / policy

EV & HP Flexibility: clear system benefits

- Value to replace other flexibility options (H2, Syn-Gas, BESS, Import)
- RES support
- Additionality / Saturation / Seasonal / Compliment
- Accessing allowed by consumers / mechanism-policies to enable access by: Bund, cantons, cities, municipalities, DSOs, TSOs, aggregators
- Value as leverage to implement incentives

Restricting trade opportunities: clear negative impacts, loss of flexibility

- policy makers / impacts by everyone

Lunch talk series V:
Flexibility provision from buildings and electromobility

1. Impacts of electric vehicles and heat pumps flexibility: European and Swiss perspectives
2. **End-user flexibilities for electrical distribution grid planning**
3. Modelling flexibility from electric vehicles: where, when, why, and how
4. Modelling flexibility from heat pumps: a bottom-up approach for Swiss buildings
5. Electrification, flexibility or both?
6. Emerging trends in recent Swiss and European policy
7. Operation and market mechanisms: from dynamic electricity tariffs to day-ahead and intraday auctions

sweet swiss energy research for the energy transition

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Take aways

Considering only EV or only HP flexibility

- **Seasonality of these demands impact flexibility use**: EV flexibility can help more consistently throughout the year while HP flexibility is more focused in winter
- **Impacts from each are the same order of magnitude**
- **Support the integration or RES**: (all cases achieve 45 TWh RES) EV & HP flexibility reduces curtailments toward this target
- **Reduce need of other flexibilities**: utilization of EV & HP flexibility leads to lower investments in BESS and Gas-fired generators, as well as reduce use of Pumped Hydro
- **Trade**: less need of flexible imports, while more capability to export
- **Substantial reduction of system costs**: mostly from lower trade costs and lower investment and operating costs from Gas-fired and BESS generators
- **Lower electricity prices**: mostly within Switzerland but also minor reductions in the neighboring countries

Considering both EV & HP flexibility

- **Cumulative benefits**: together they achieve the sum of their individual benefits (RES curtailments, electricity prices, net imports, Gas and BESS investments, system costs)
- **These flexibilities have not reached a saturation point**

Considering restricting energy market integration

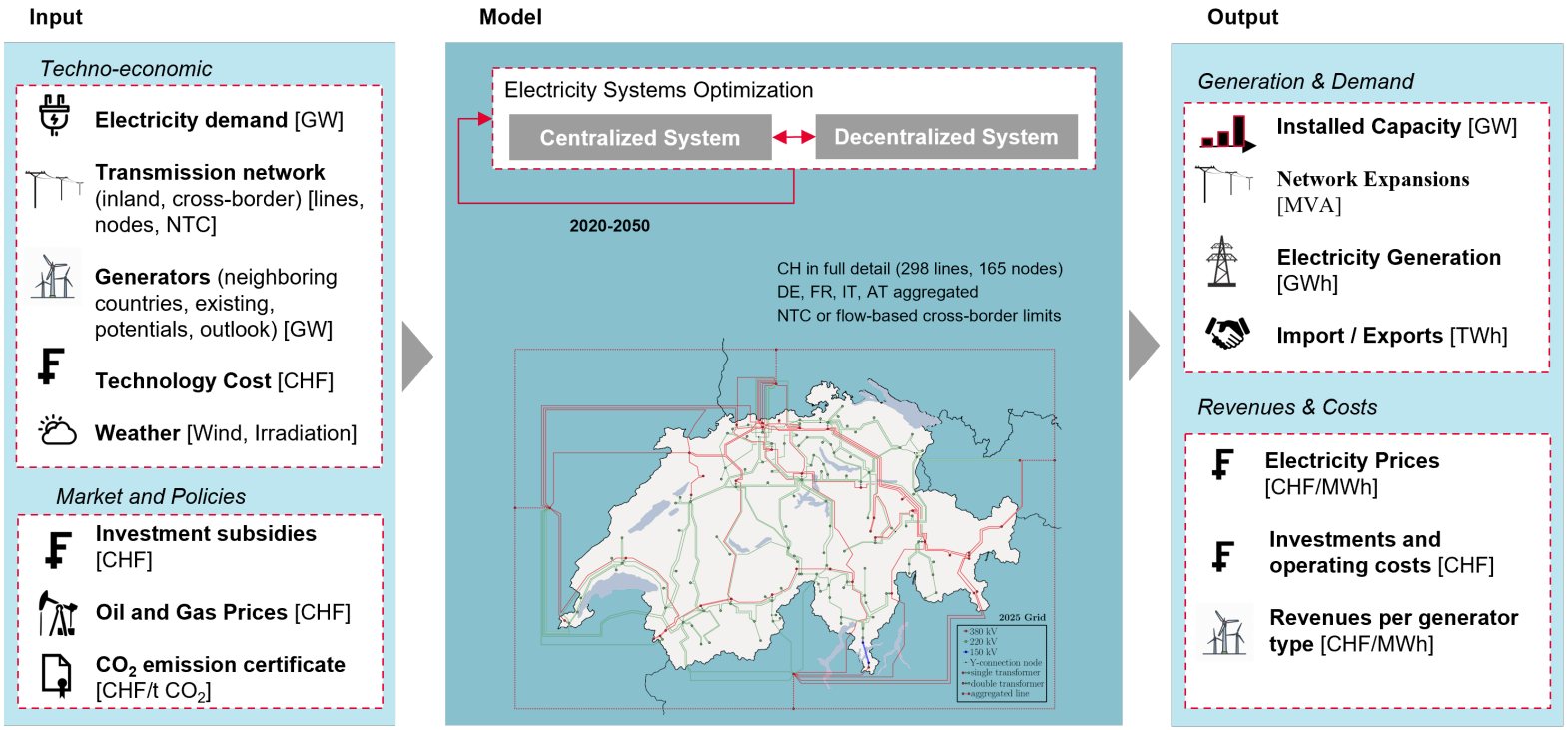
- **Many negative consequences**: higher investments, curtailments, system costs, electricity prices
- **Higher value of EV & HP flexibilities**: also same higher value for all forms of flexibility

Nexus-e: a platform of interconnected models
Combining expansion planning and hourly operation

Objective
Cost-based minimization of operation and investments in new assets from a system perspective

- generators / storages
- transmission lines / transformers

Capabilities
- Up to 8760 time steps
- All Swiss HV system nodes and branches
- Individual generators and storages
- Large set of technologies for candidate generators
- Spatially explicit investments
- Dispatch across all 5 countries
- endogenous treatment of cross-border flows



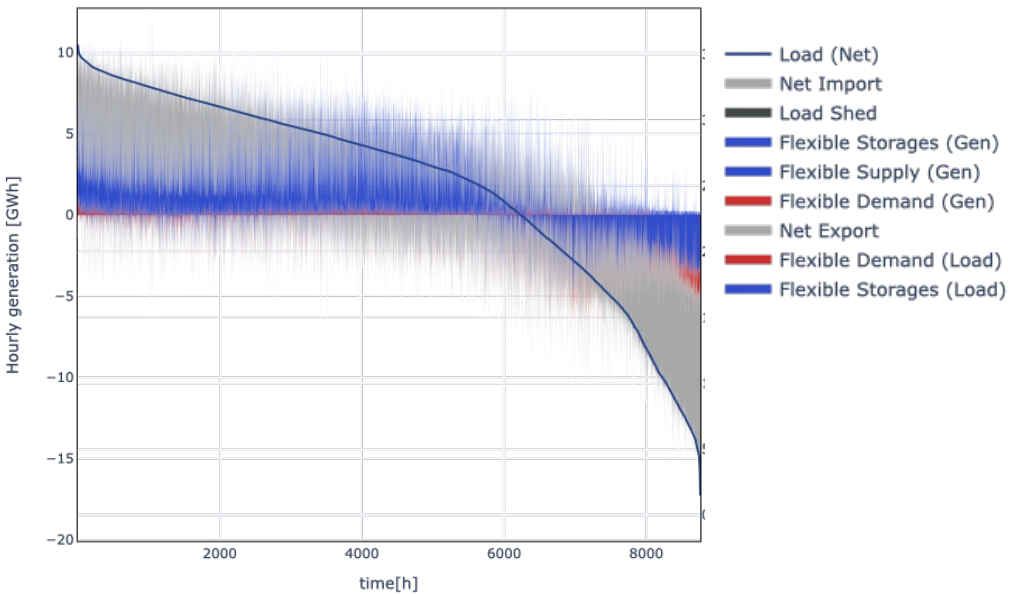
Impact of flexibility on the residual load duration curve

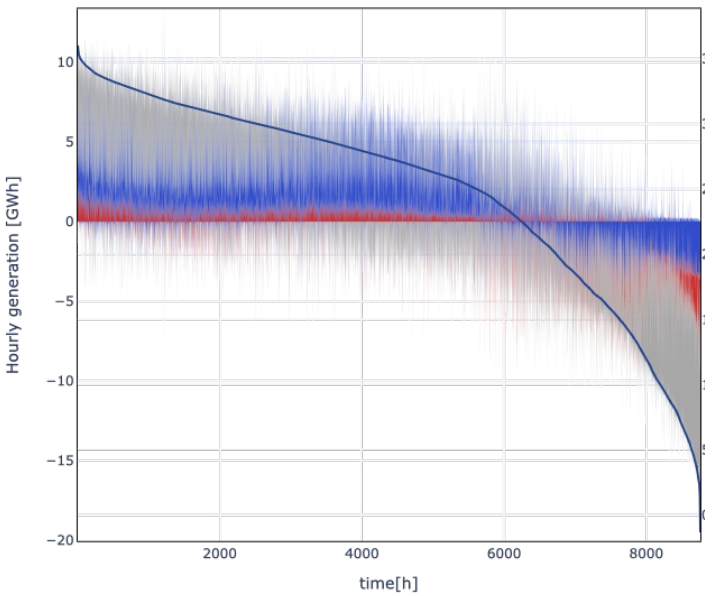
Without EV & HP flexibility

With EV & HP flexibility

Net need

Excess supply





EV & HP flexibility: shift demand away from hours with very low net-load and toward hours with higher net-load