



Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

The Bottleneck Isn't the Grid — It's the Prosumer

Geneva, March 19th 2026, Prof. Dr. Christof Bucher

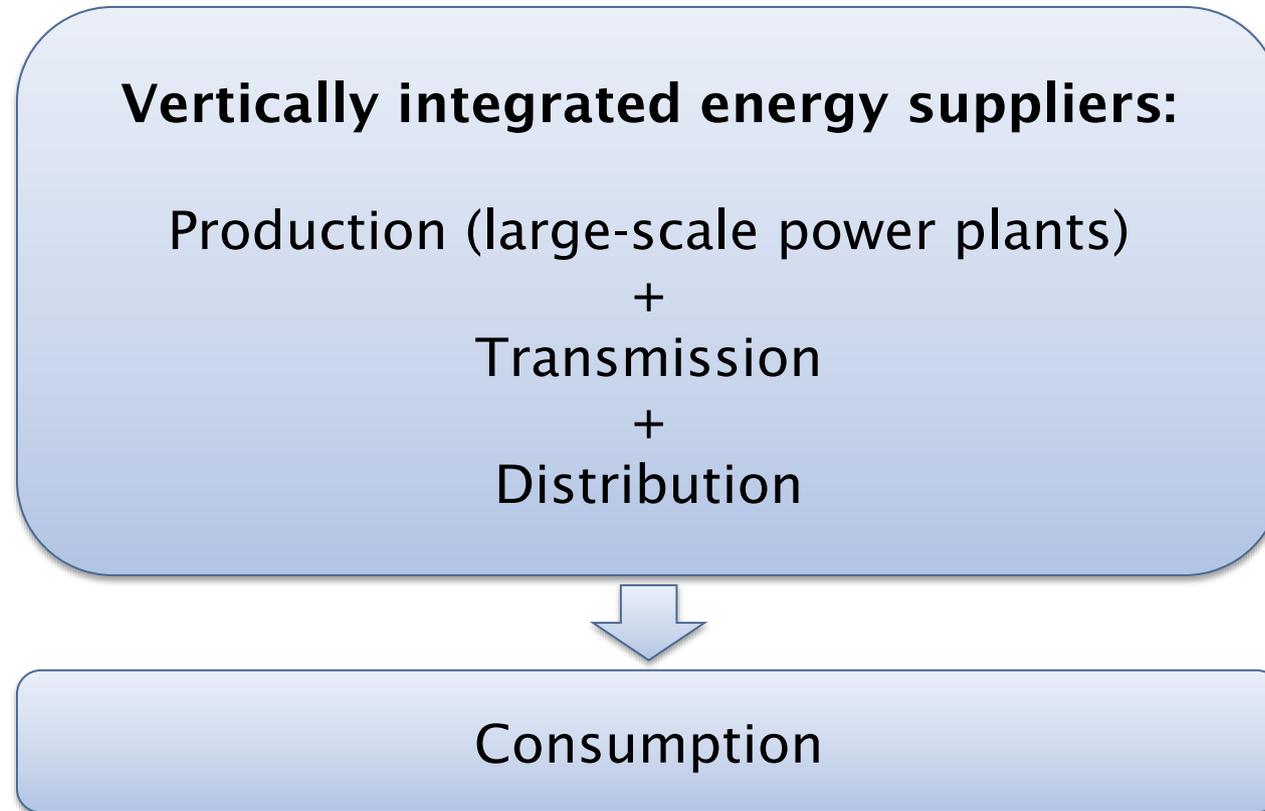
► BFH – TI – IEM – PV Lab

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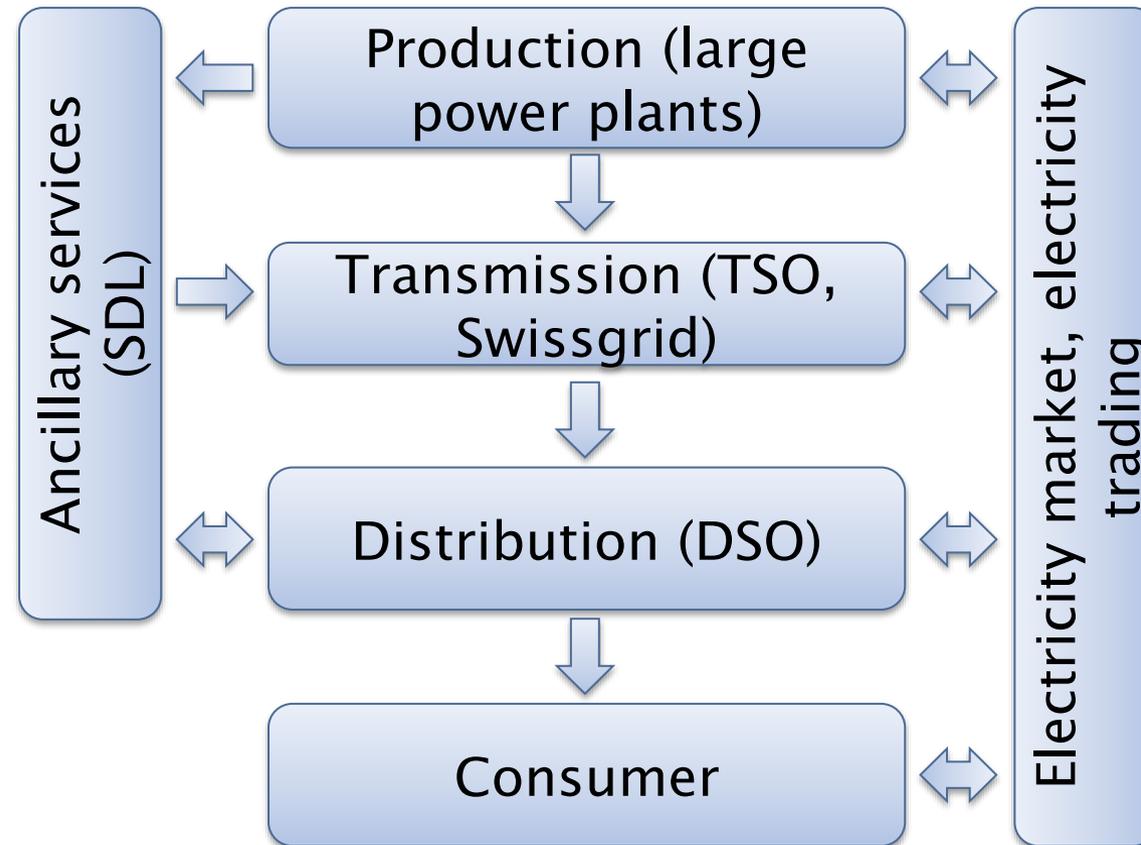
- ▶ Unbundling: Transformation Process
- ▶ PV Potential in Switzerland
- ▶ PV and Energy Strategy in Switzerland
- ▶ PV Integration Challenges
- ▶ Brief History of Grid Integration in Switzerland and Europe
- ▶ A PV System's Perspective
- ▶ Conclusion for PV Systems

Unbundling: Transformation Process

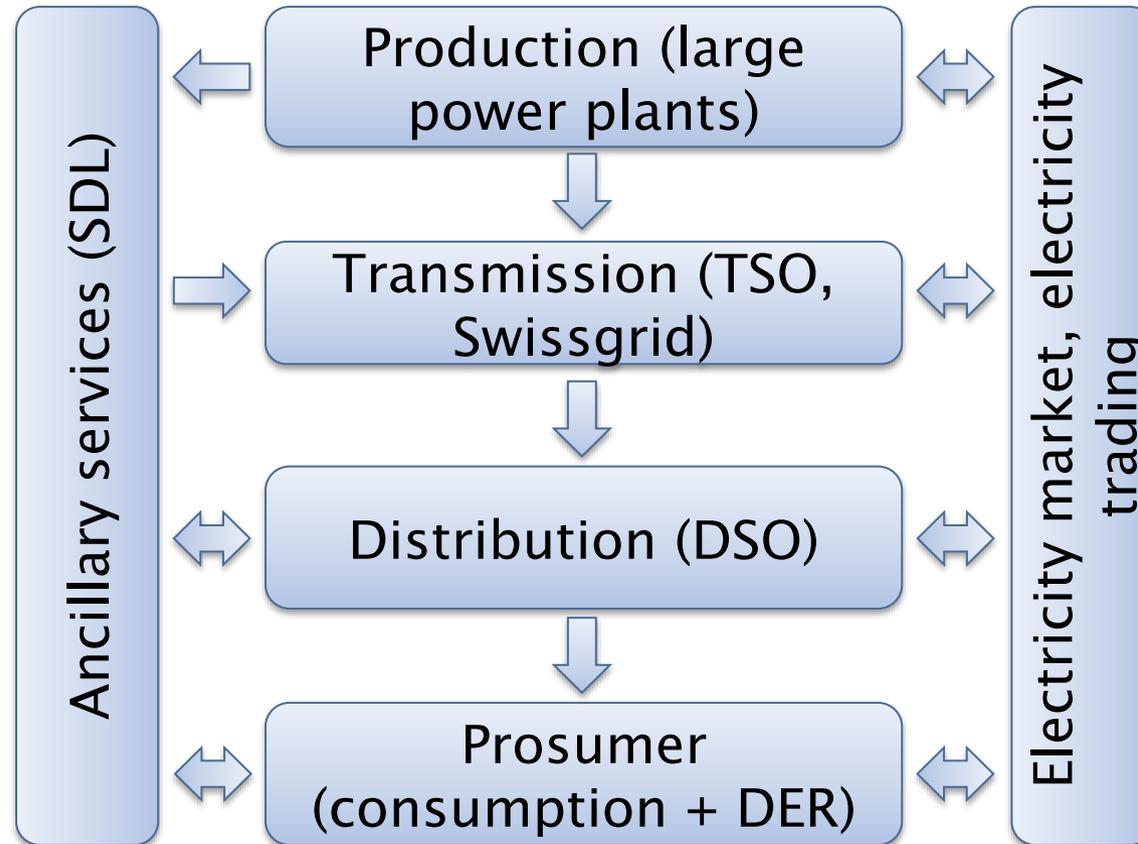
Energy System before Unbundling



Energy System after Unbundling

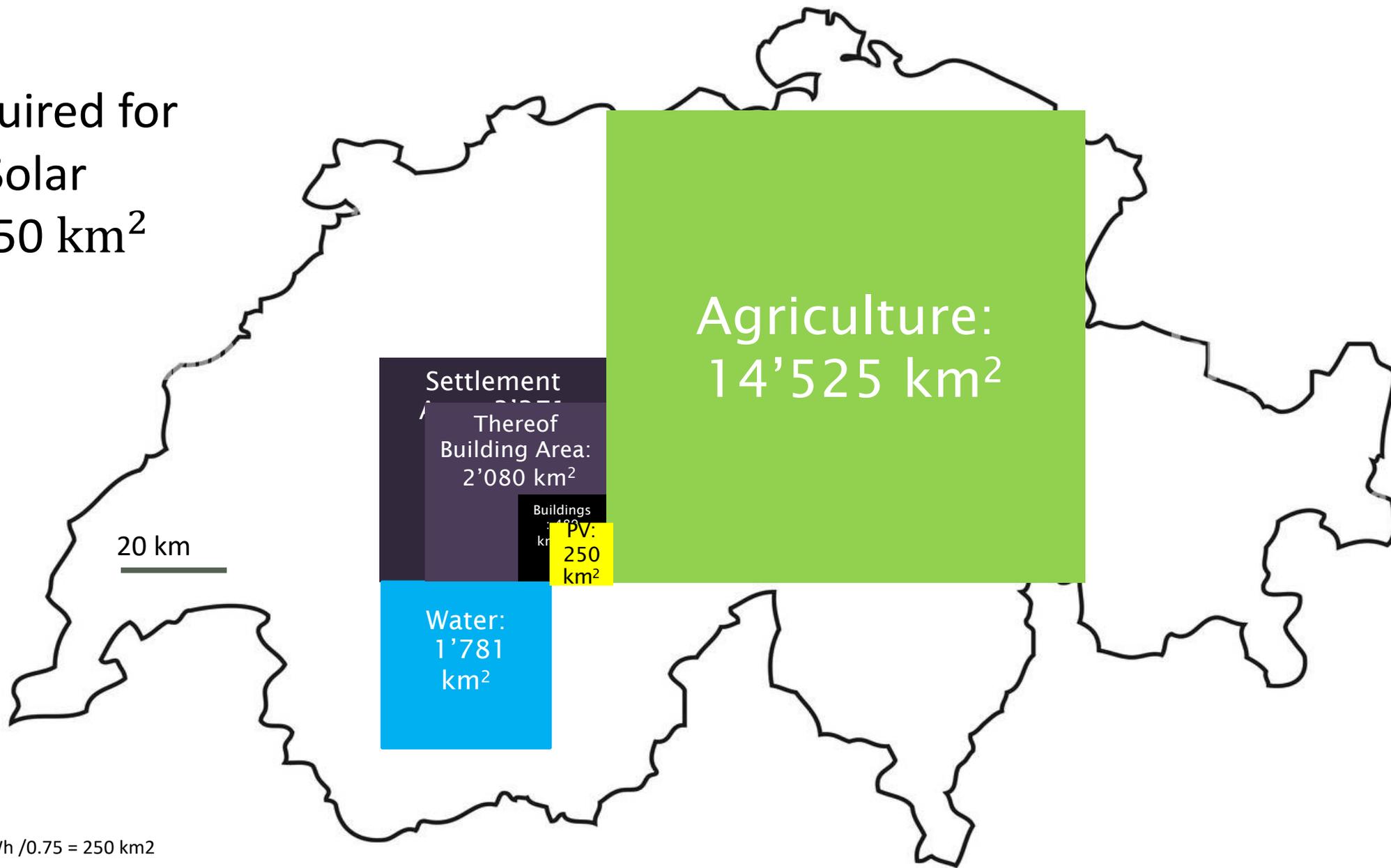


Energy supply, today and in the future



PV Potential in Switzerland

Area Required for 45 TWh Solar Power: 250 km²



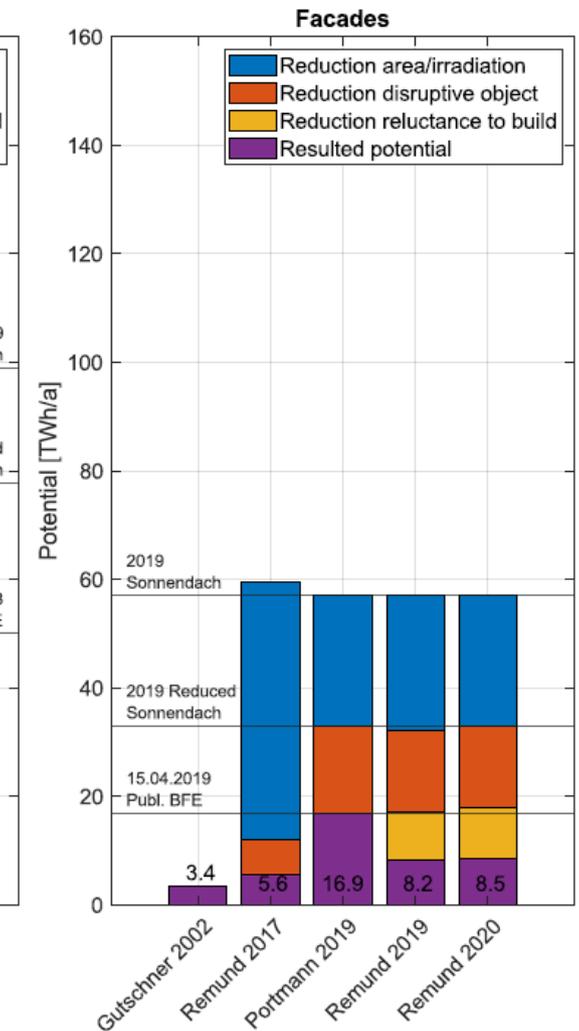
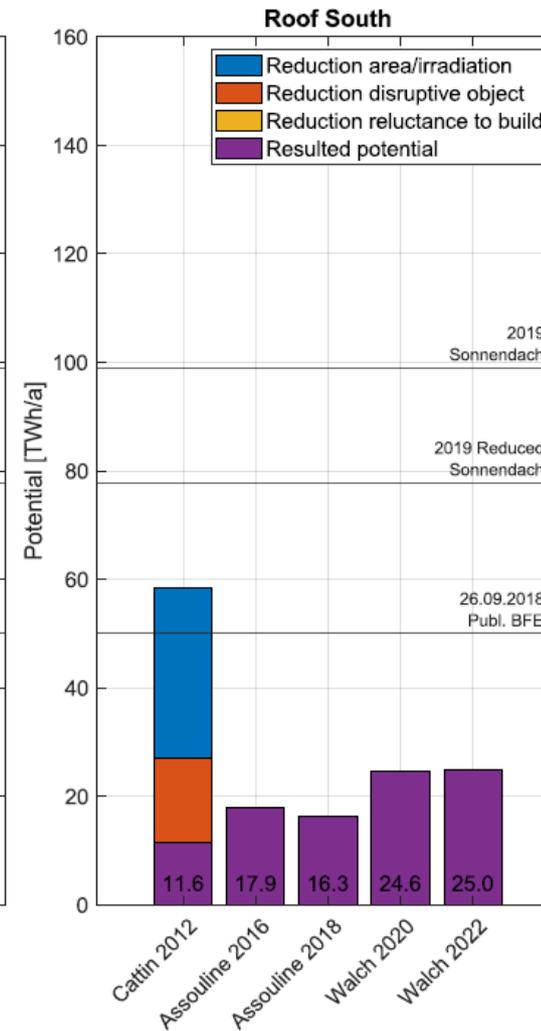
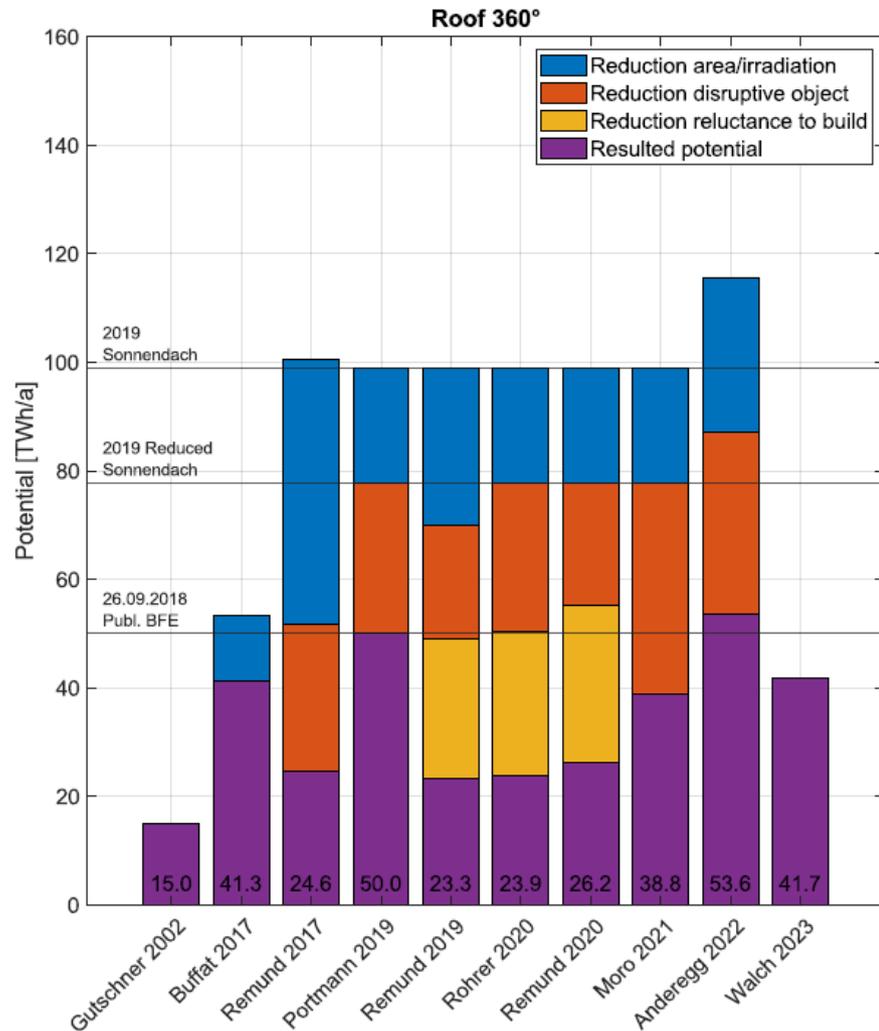
Annahmen für 45 TWh Solarstrom:

- Modulwirkungsgrad 24%
- 1 kWp benötigt 4.2 m² Fläche
- 1 kWp liefert 1 MWh/Jahr
- Belegungsgrad: 75%
- Berechnung: $45 \text{ TWh} \cdot 4.2 \text{ m}^2 / \text{MWh} / 0.75 = 250 \text{ km}^2$
- Quellen: Arealstatistik

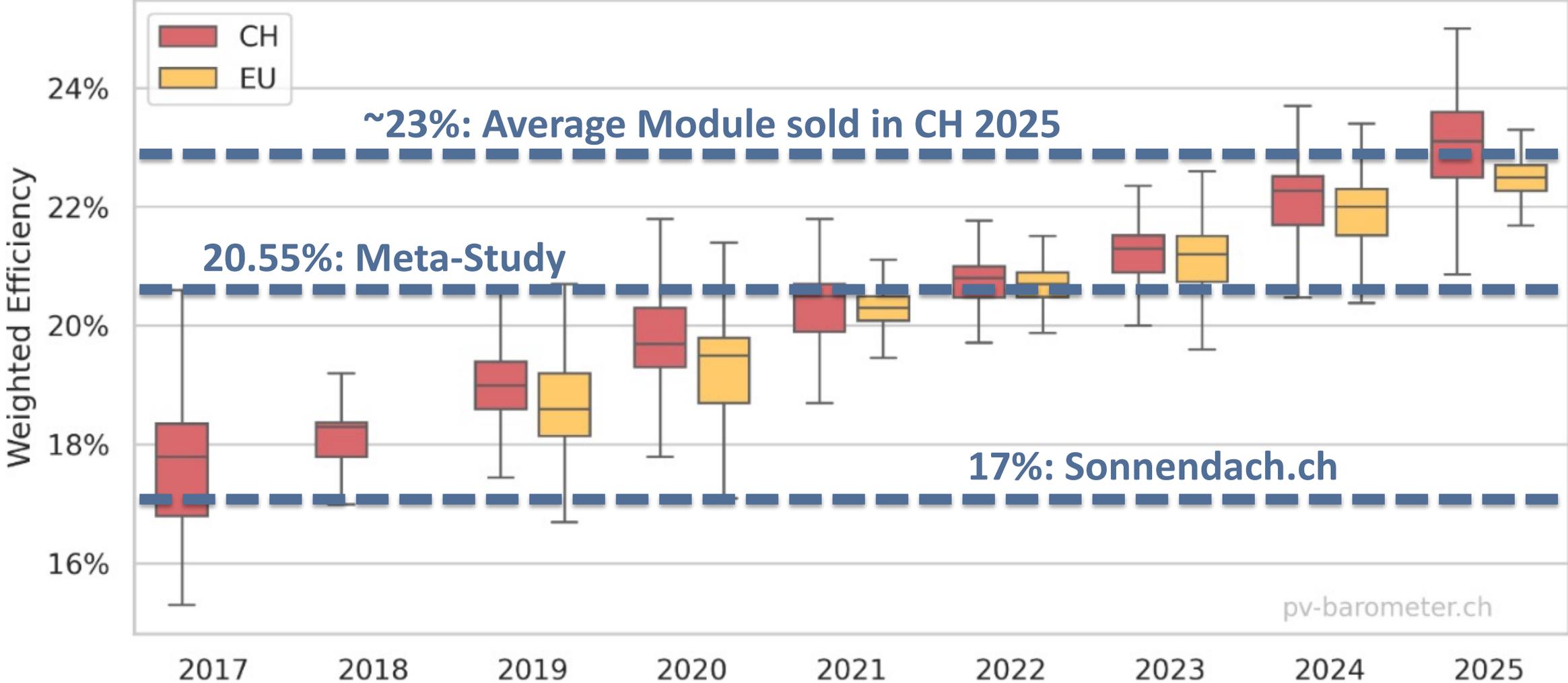
Meta Study – PV Potential on Buildings

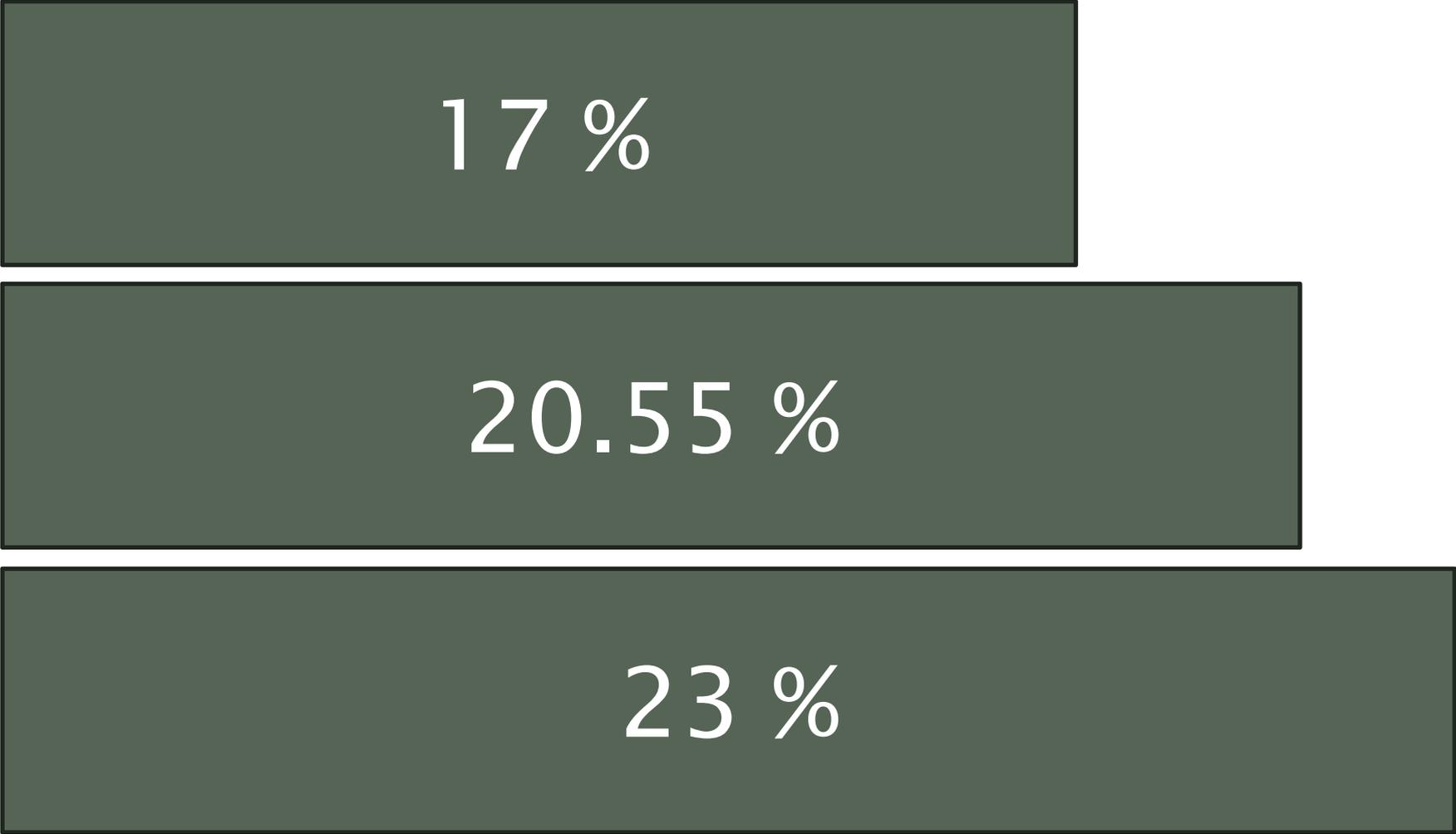
Hügi et al., Meta-study of potential for photovoltaic installations in Switzerland

<https://doi.org/10.1016/j.egy.2020.08.035>



Development of PV Module Efficiency





17 %

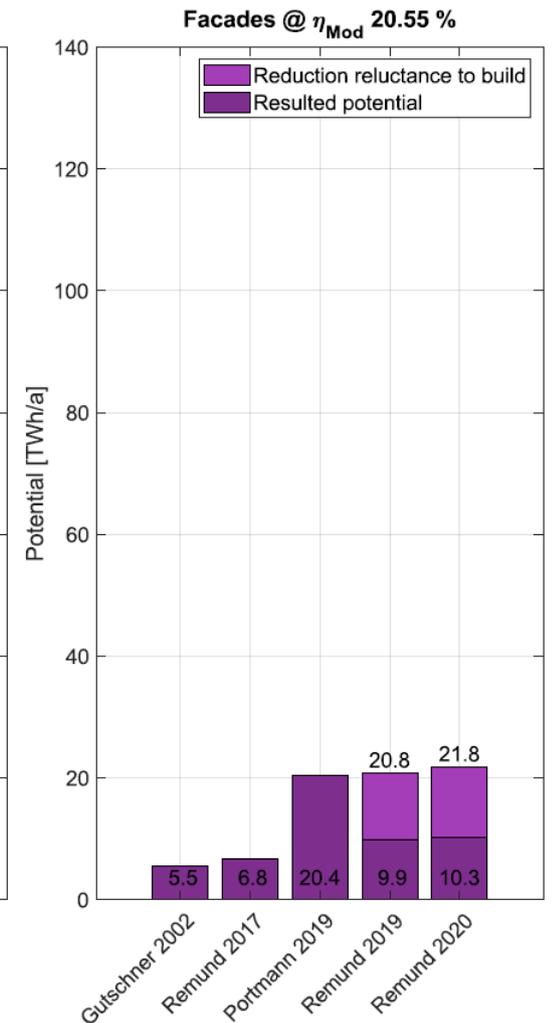
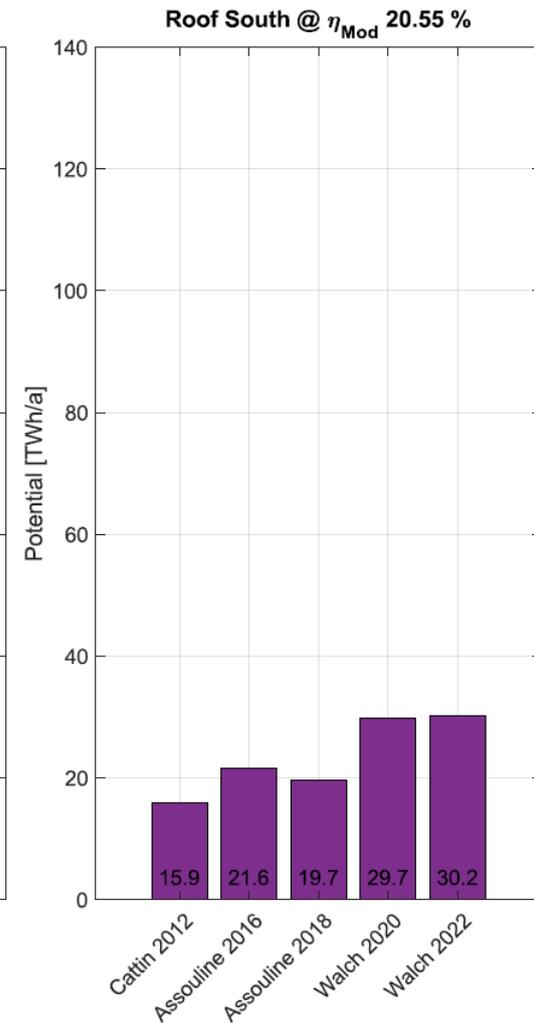
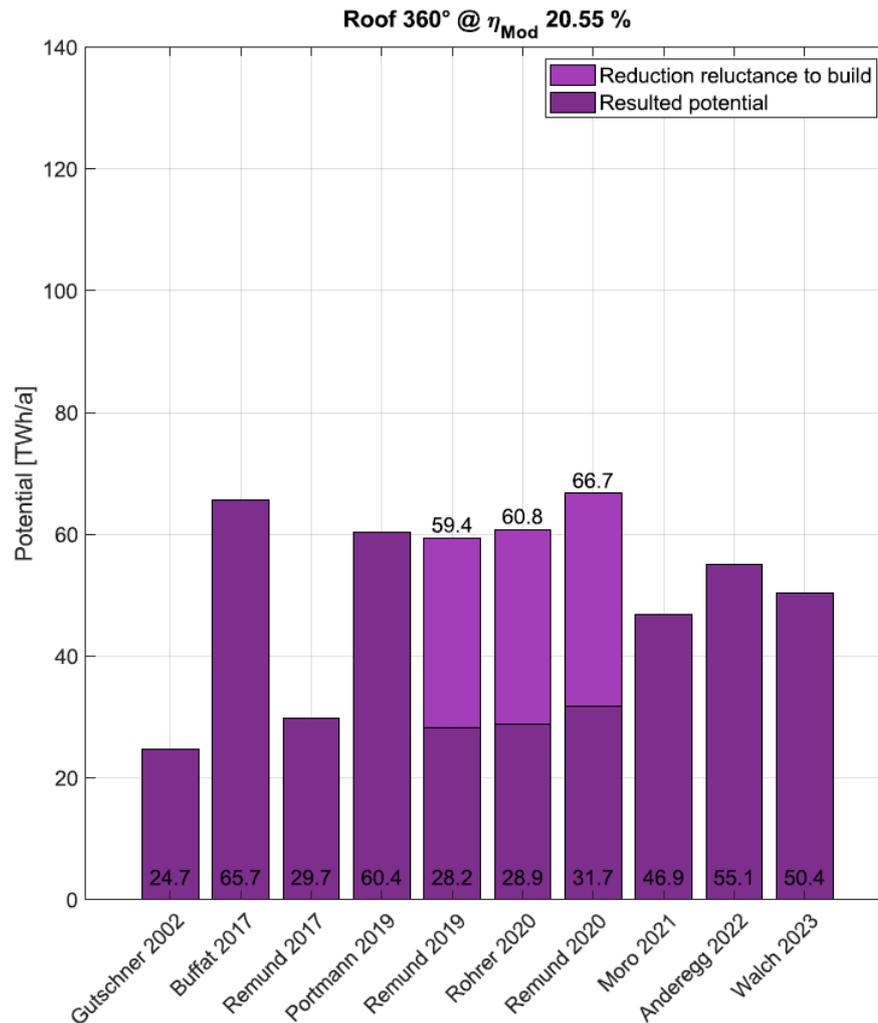
20.55 %

23 %

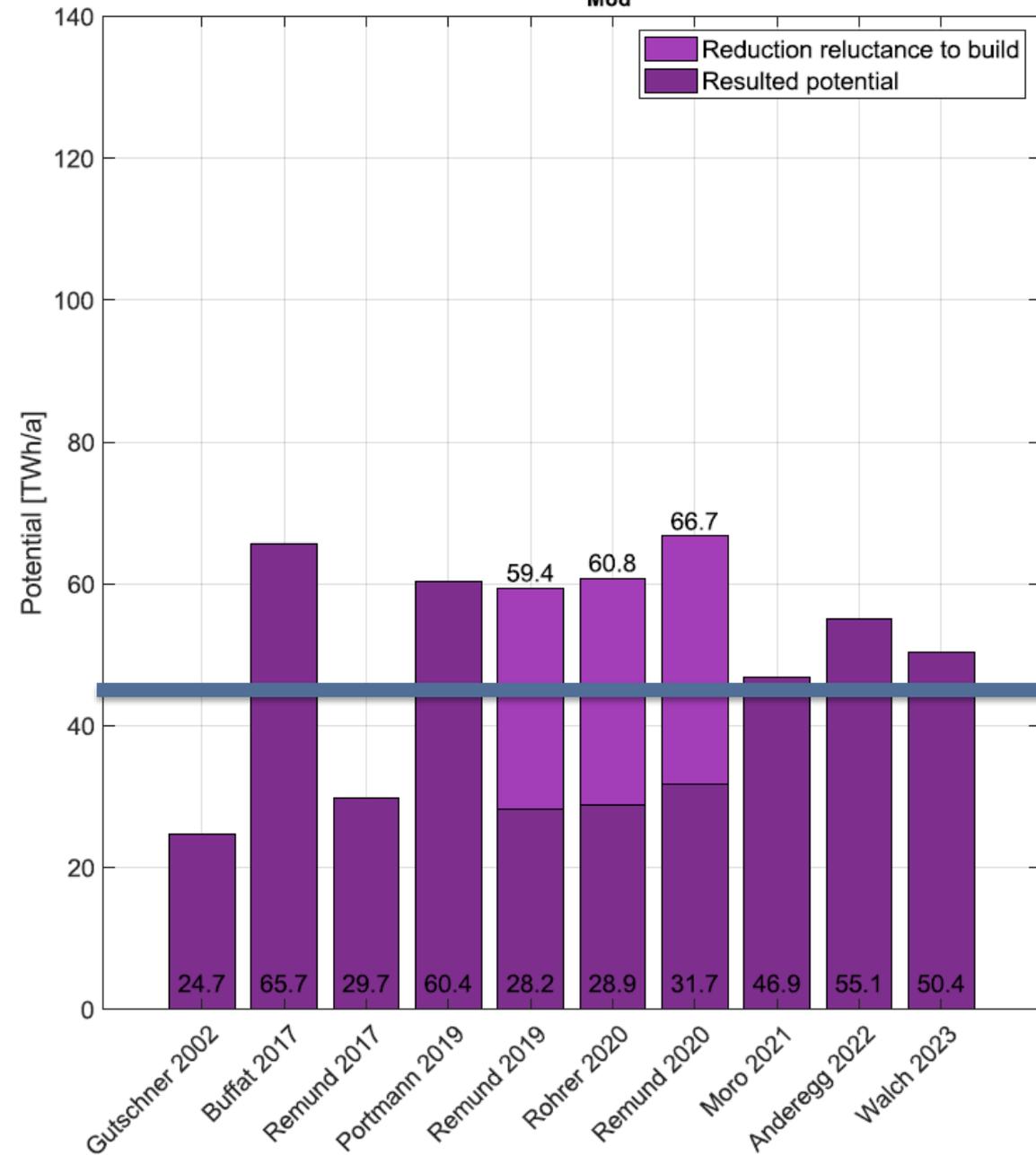
Meta Study – PV Potential on Buildings

Hügi et al., Meta-study of potential for photovoltaic installations in Switzerland

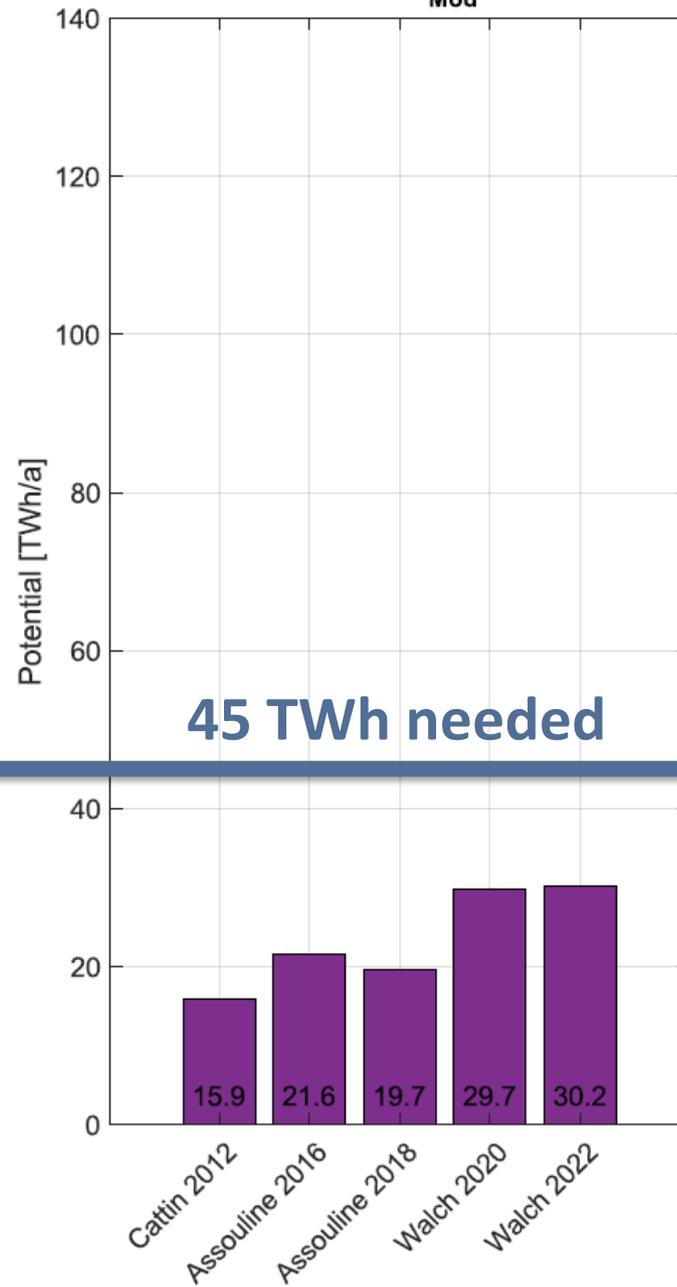
<https://doi.org/10.1016/j.egy.2025.08.035>



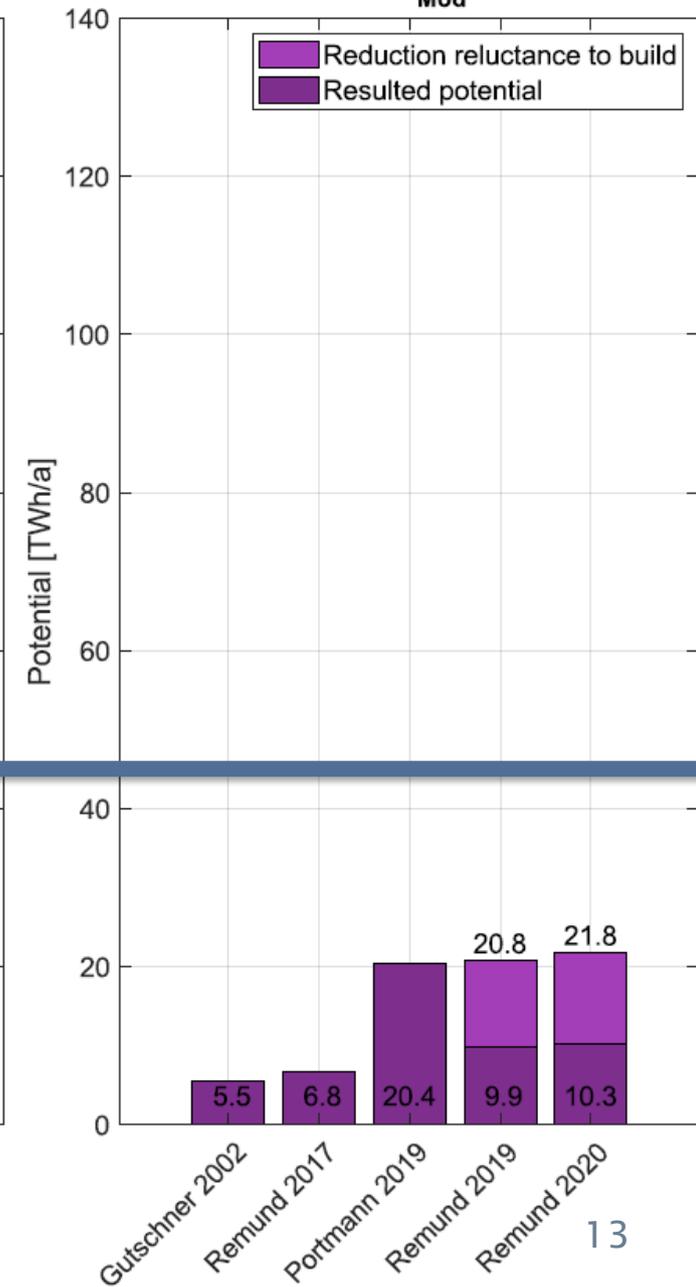
Roof 360° @ η_{Mod} 20.55 %



Roof South @ η_{Mod} 20.55 %



Facades @ η_{Mod} 20.55 %

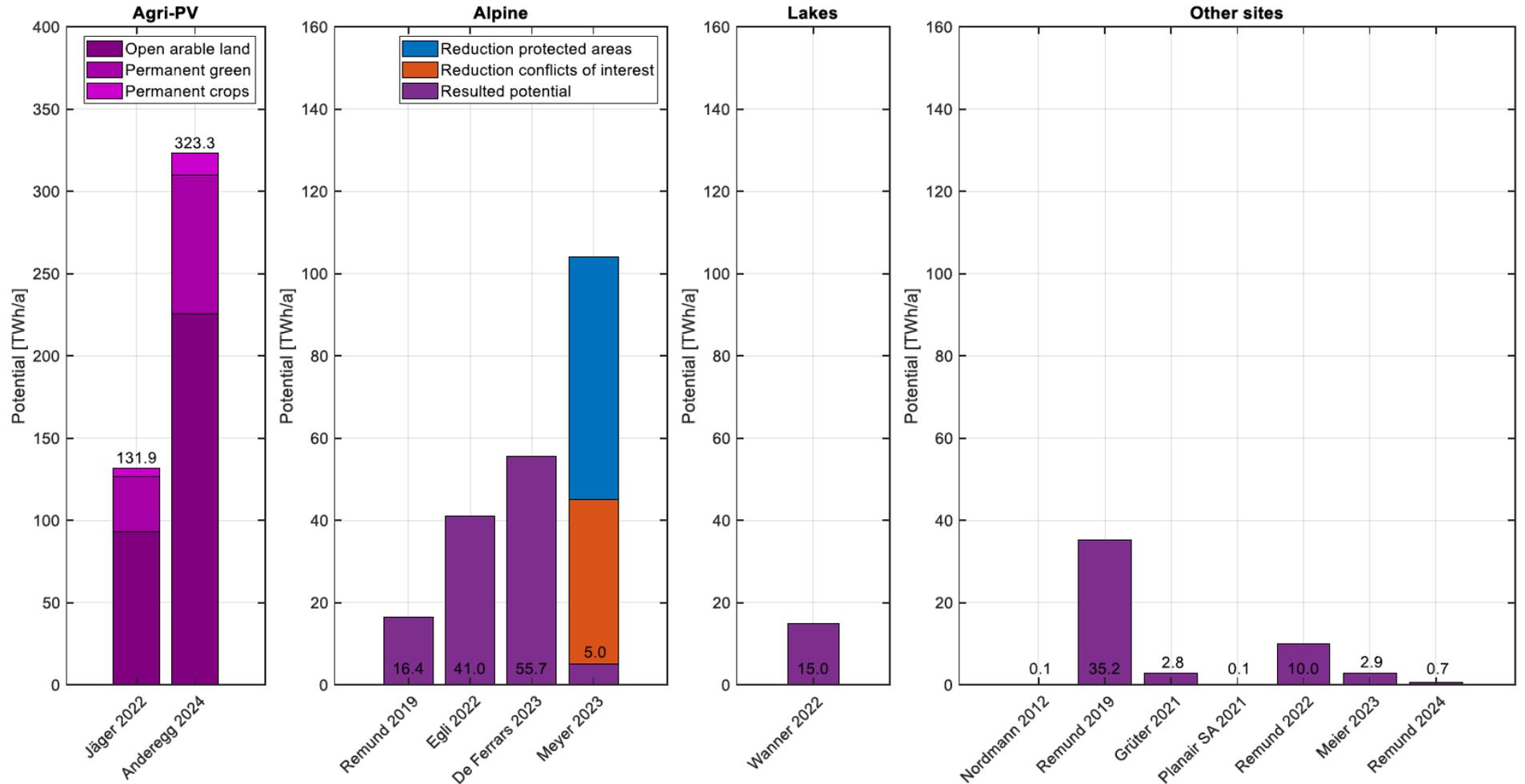


45 TWh needed

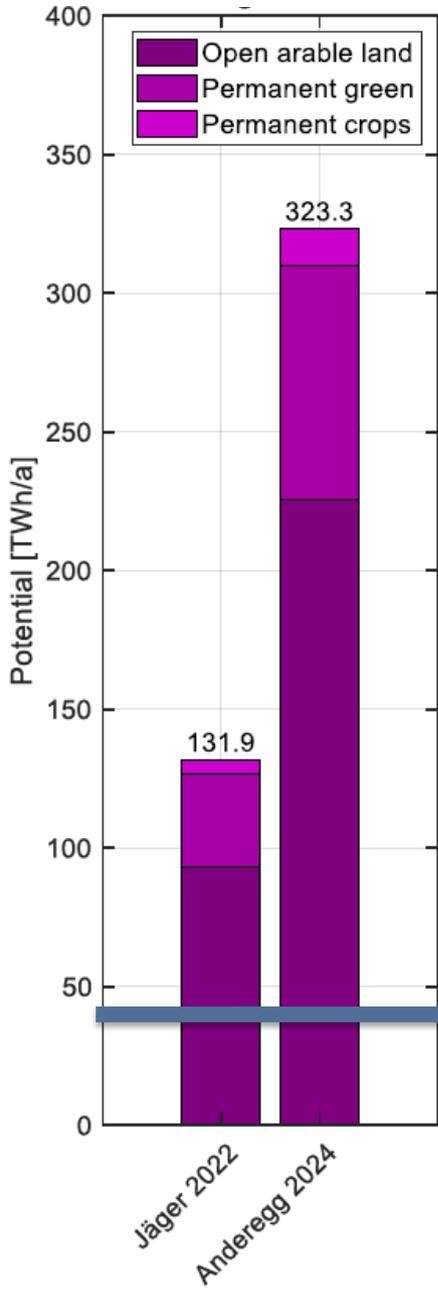
Meta Study – additional PV Potential

Hügi et al., Meta-study of potential for photovoltaic installations in Switzerland

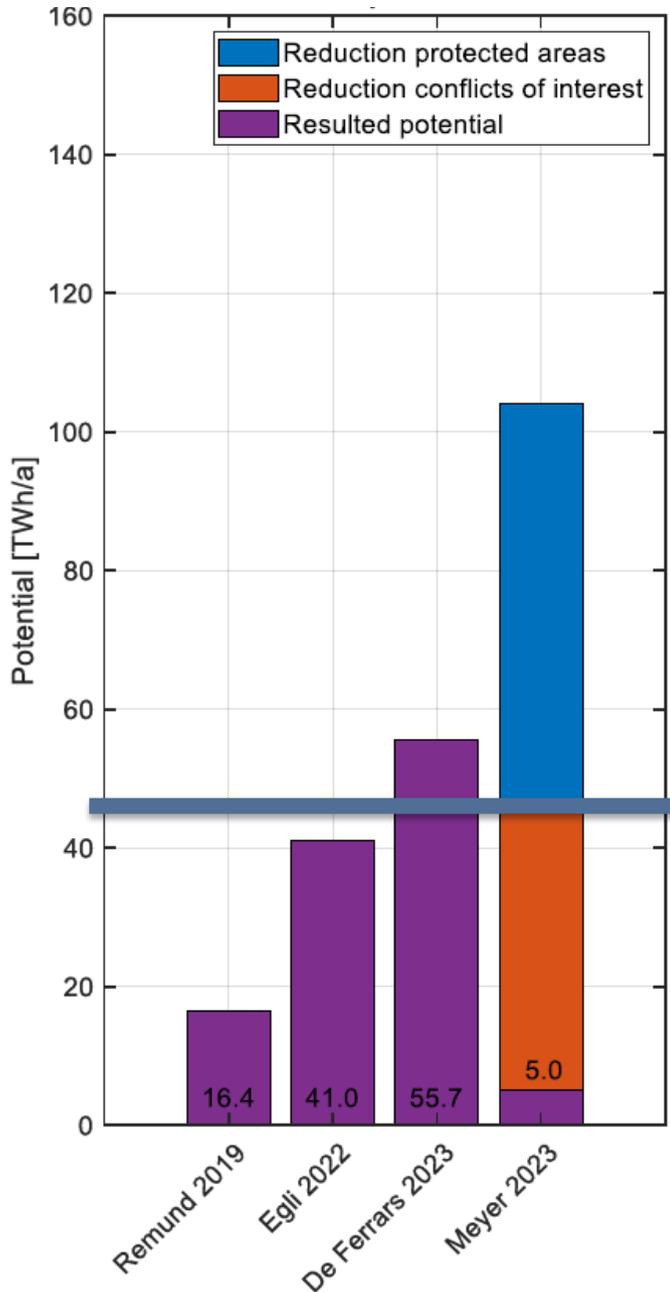
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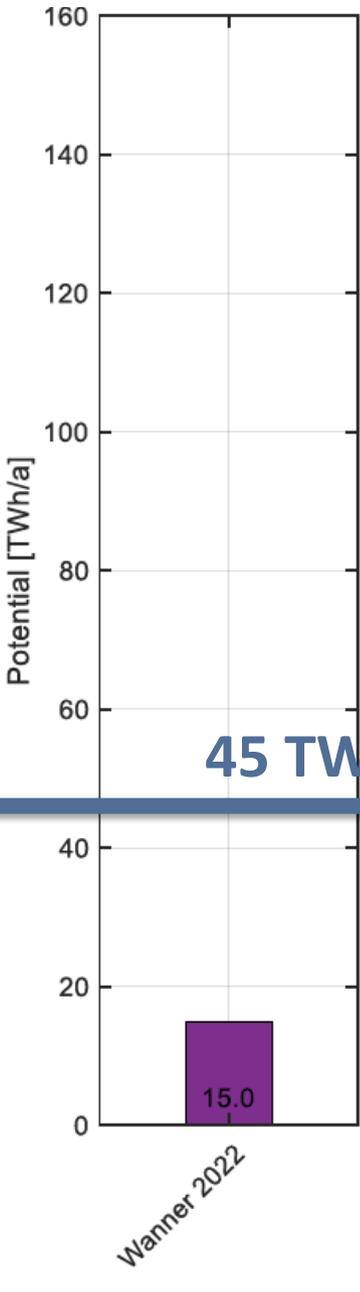
Agri-PV



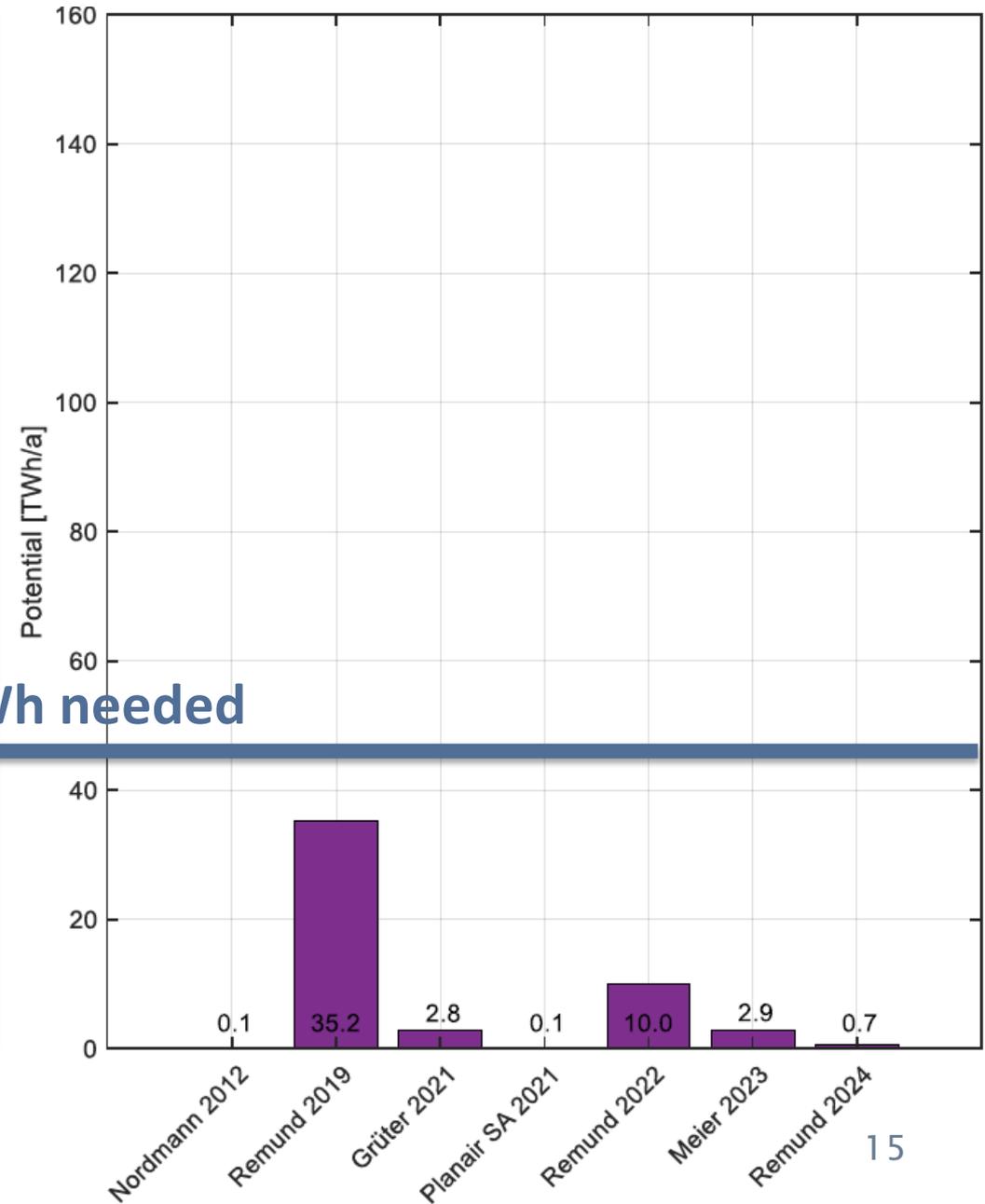
Alpine PV



Lakes



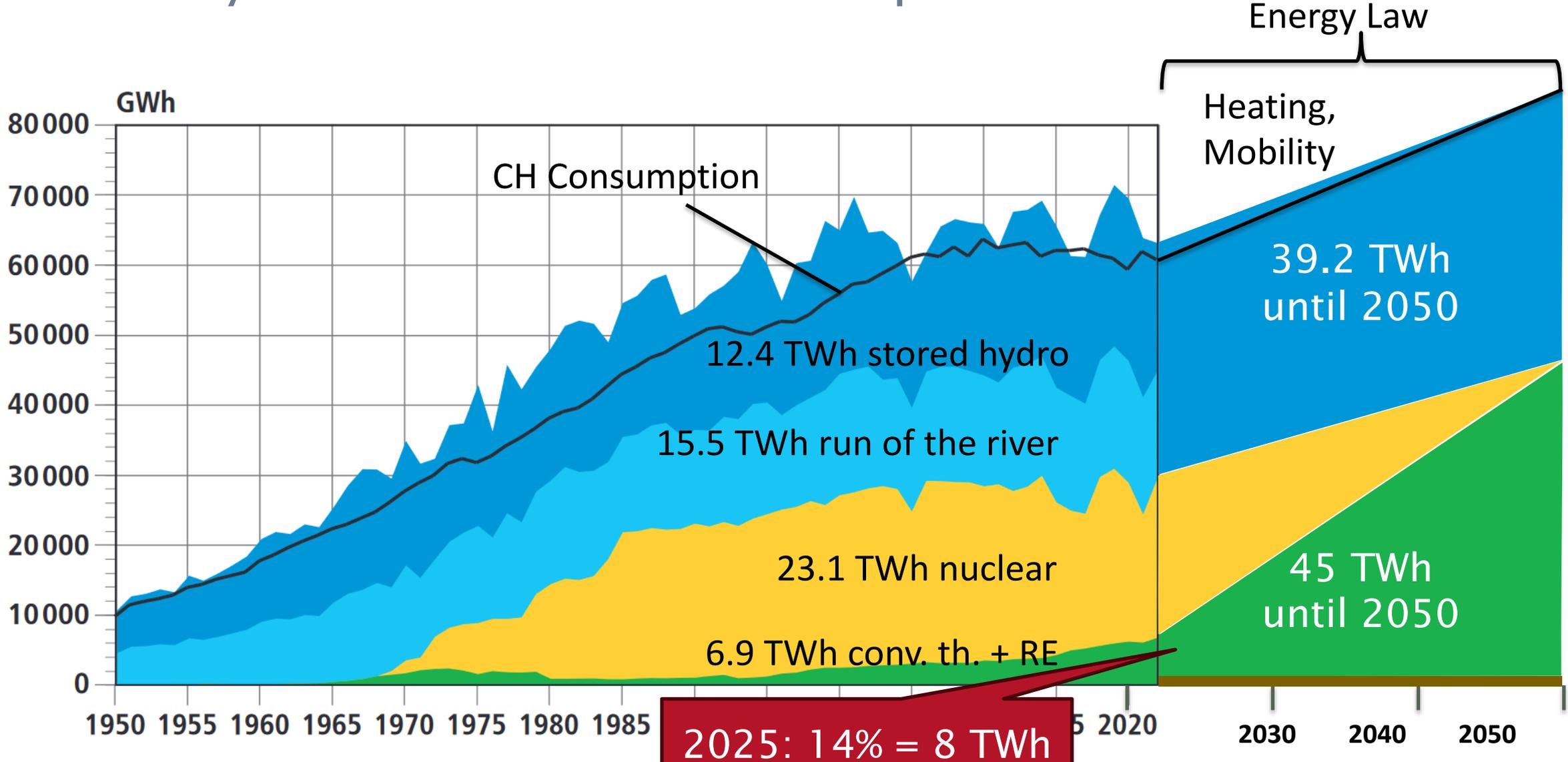
Other



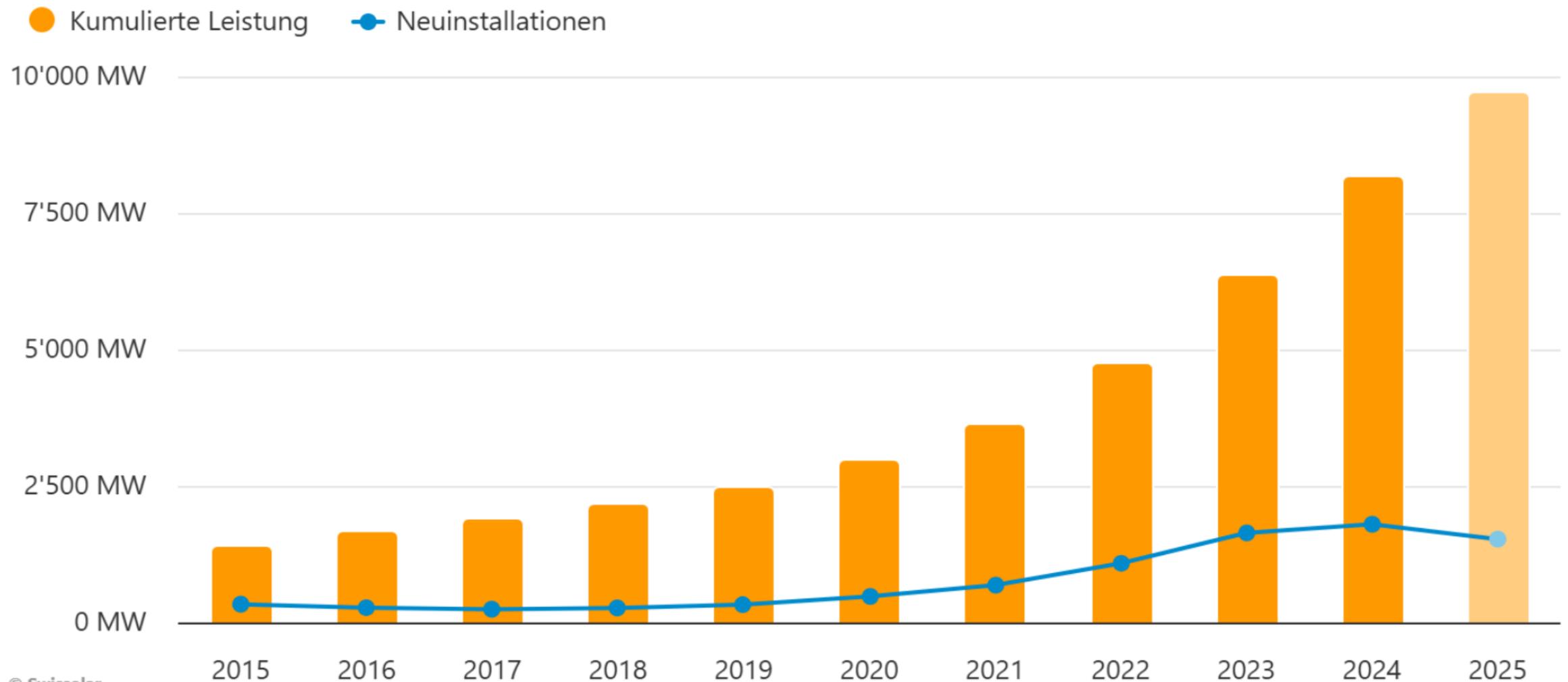
45 TWh needed

PV and Energy Strategy in Switzerland

Electricity Production and Consumption in Switzerland



Soon 10 GW, approx. 14% Solar Energy Share in Switzerland

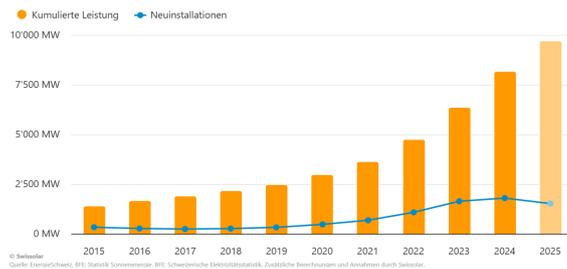


© Swissolar

Quelle: EnergieSchweiz, BFE: Statistik Sonnenenergie. BFE: Schweizerische Elektrizitätsstatistik. Zusätzliche Berechnungen und Annahmen durch Swissolar.

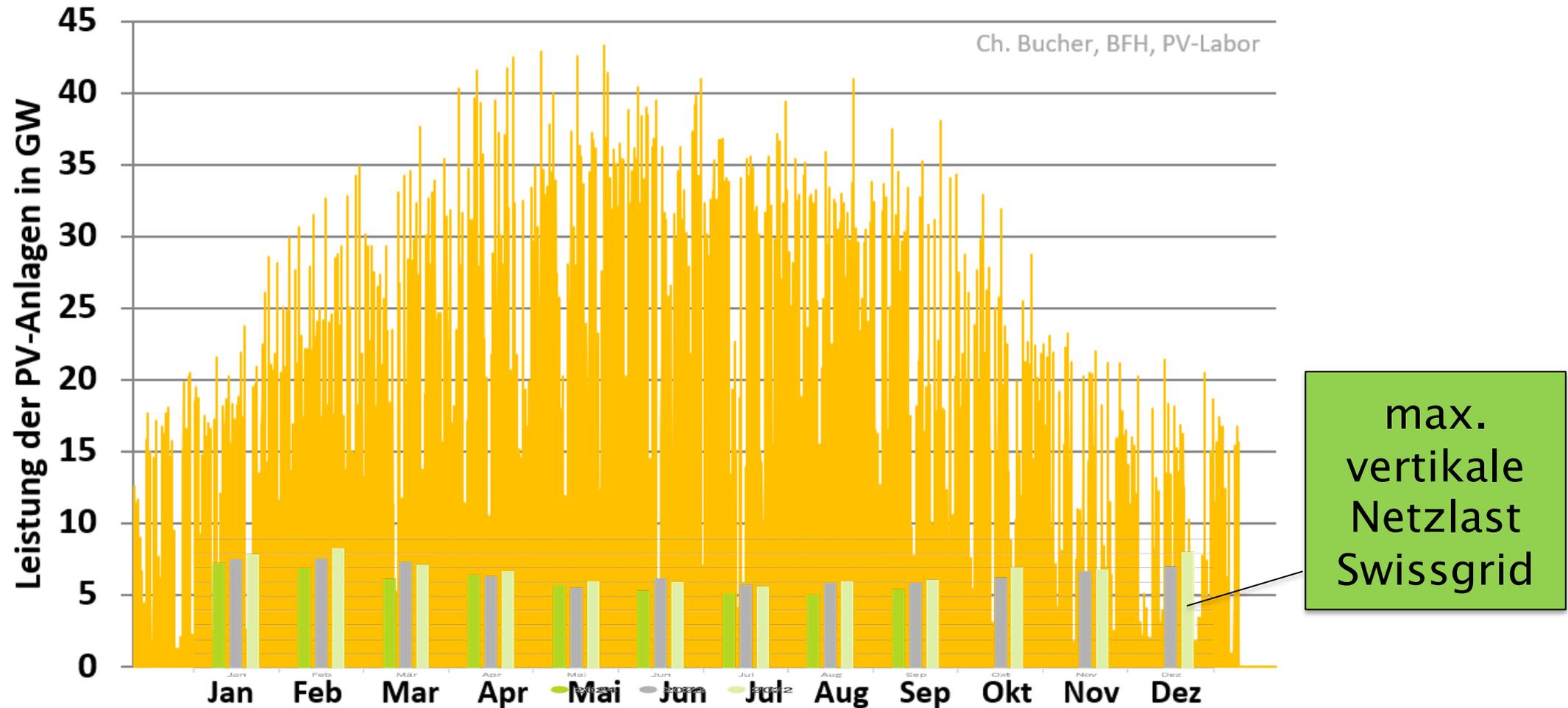
What Lies Ahead?

- ▶ 45 GW
- ▶ 45 TWh

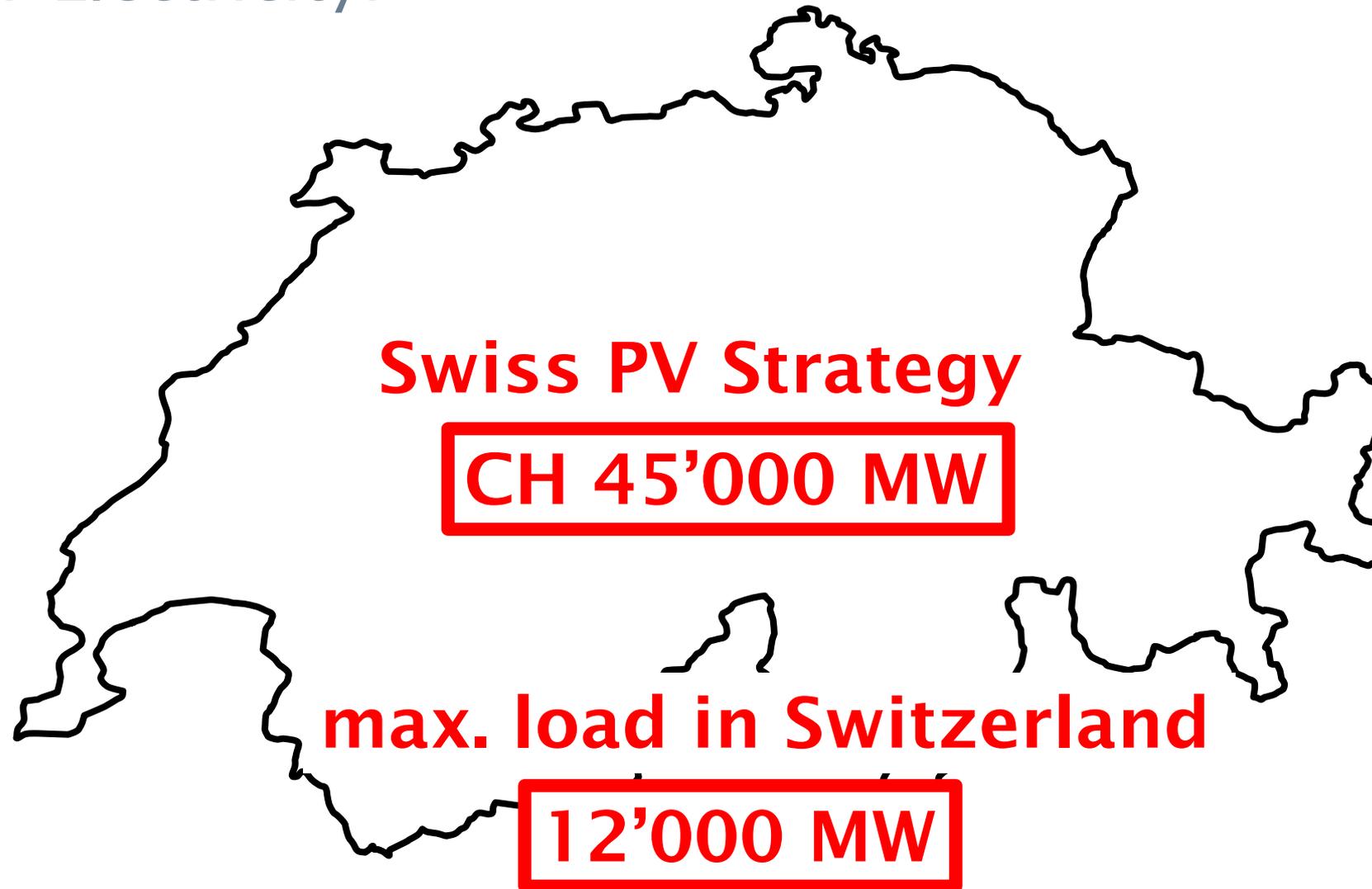


PV Integration Challenges

Solar Production after the Energy Transition has been Completed



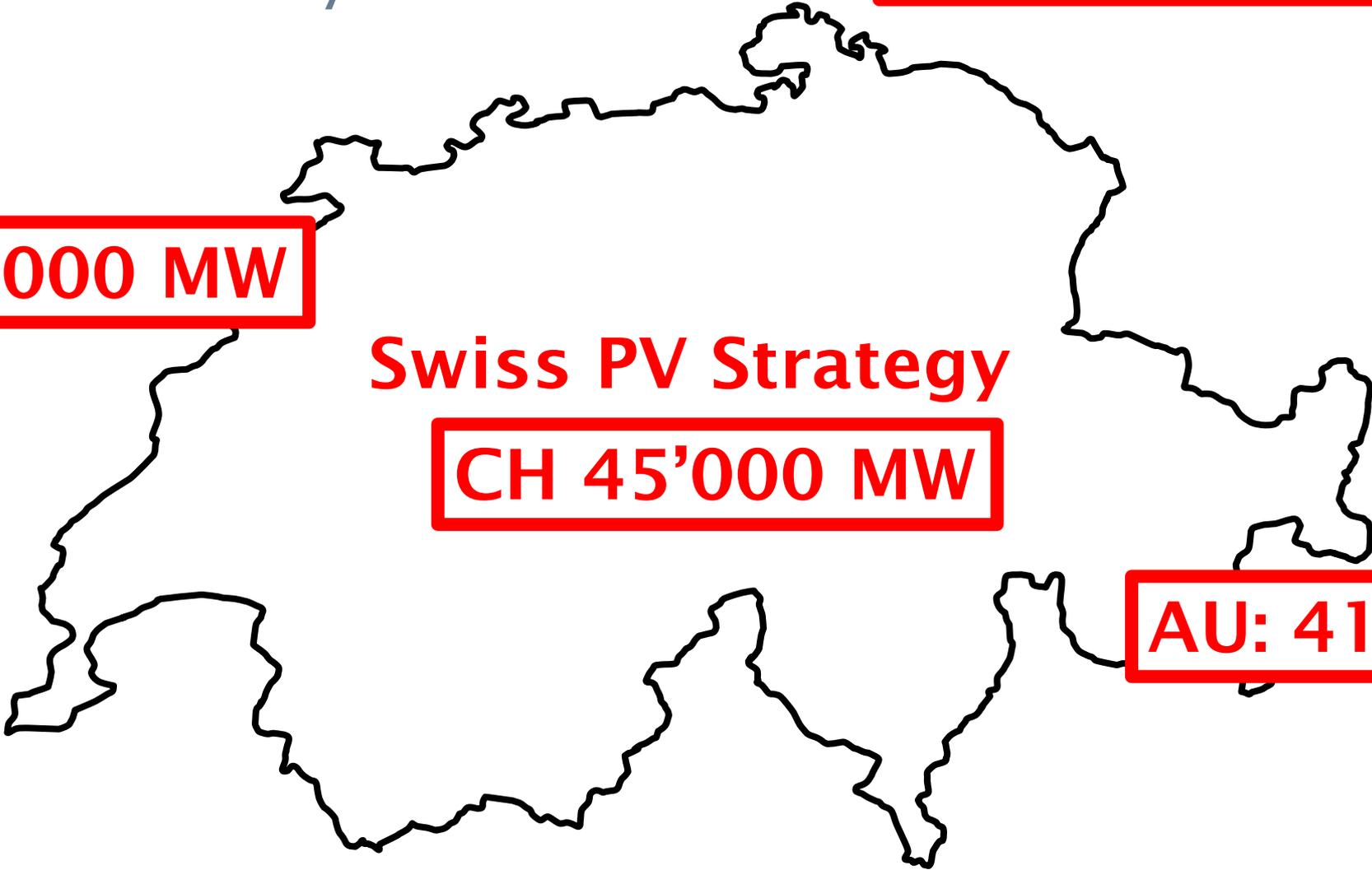
Export PV Electricity?



Export PV Electricity?

FR: 100'000 MW

DE: 400'000 MW



Swiss PV Strategy

CH 45'000 MW

AU: 41'000 MW

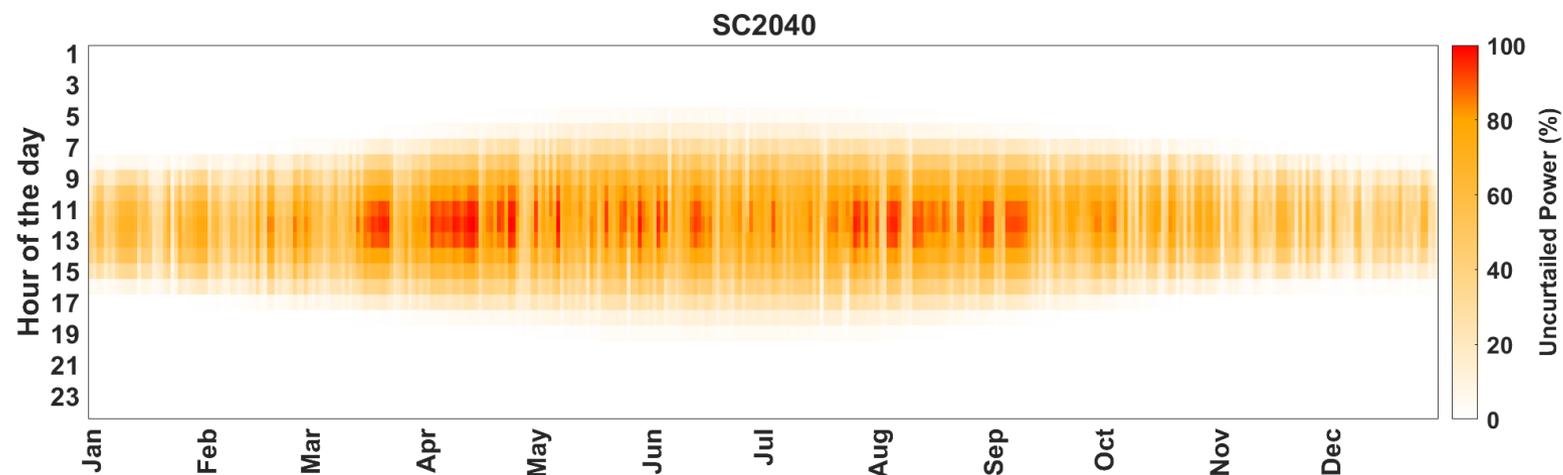
IT: 80'000 MW*

Electrical Loads in Switzerland

- ▶ Maximum vertical grid load (Swissgrid): 8.4 GW
- ▶ Maximum land consumption: about 12 GW
- ▶ Planned capacity of PV systems: 40-50 GW (45 TWh new renewables)
- ▶ Pumped storage power plants in Switzerland: approx. 3.5 GW
- ▶ Export of solar power: not possible on a large scale
- ▶ Purchasers at any time (despite self-consumption): cities, large consumers, ...

**What is the maximum power we can feed into the grid?
Is it 10 GW?**

Study BFH + Swissgrid: PV Production, no Curtailment

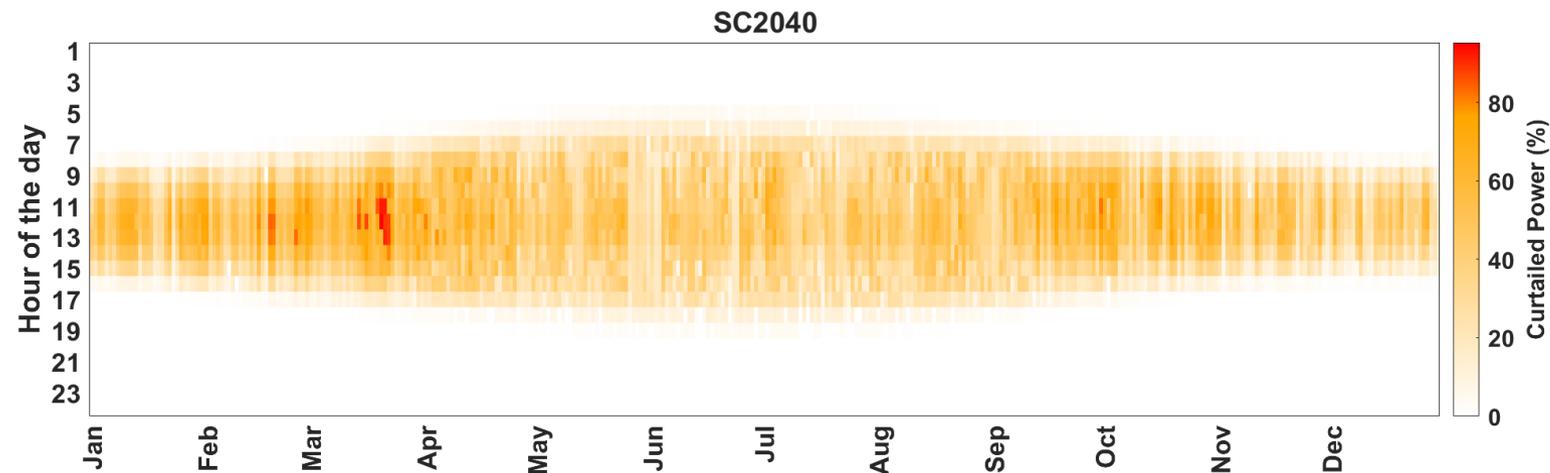


Scenario Sector Coupling

- ▶ 30 GW PV
- ▶ 30 TWh PV
- ▶ 0% Curtailment

Source: Studie BFH + Swissgrid, Market Implications on Grid Connection Sizing for Photovoltaic Systems: <https://www.tib-op.org/ojs/index.php/pv-symposium/article/view/2654>

Study BFH + Swissgrid: PV Production, market Curtailment

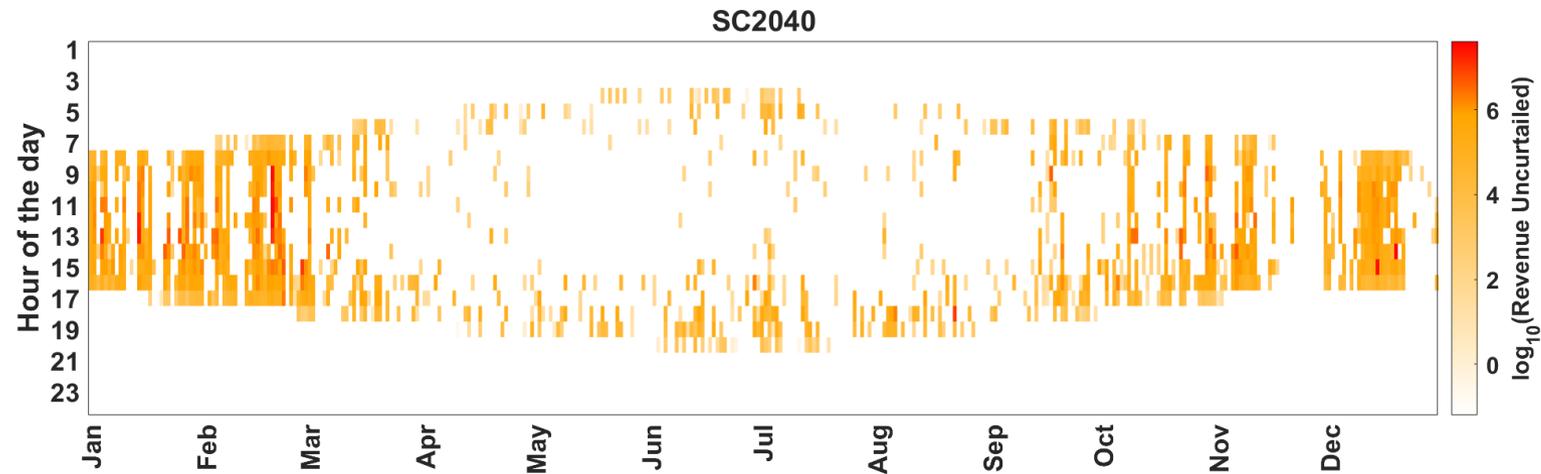


Scenario Sector Coupling

- ▶ 30 GW PV
- ▶ 23 TWh PV
- ▶ 28% Curtailment

Source: Studie BFH + Swissgrid, Market Implications on Grid Connection Sizing for Photovoltaic Systems

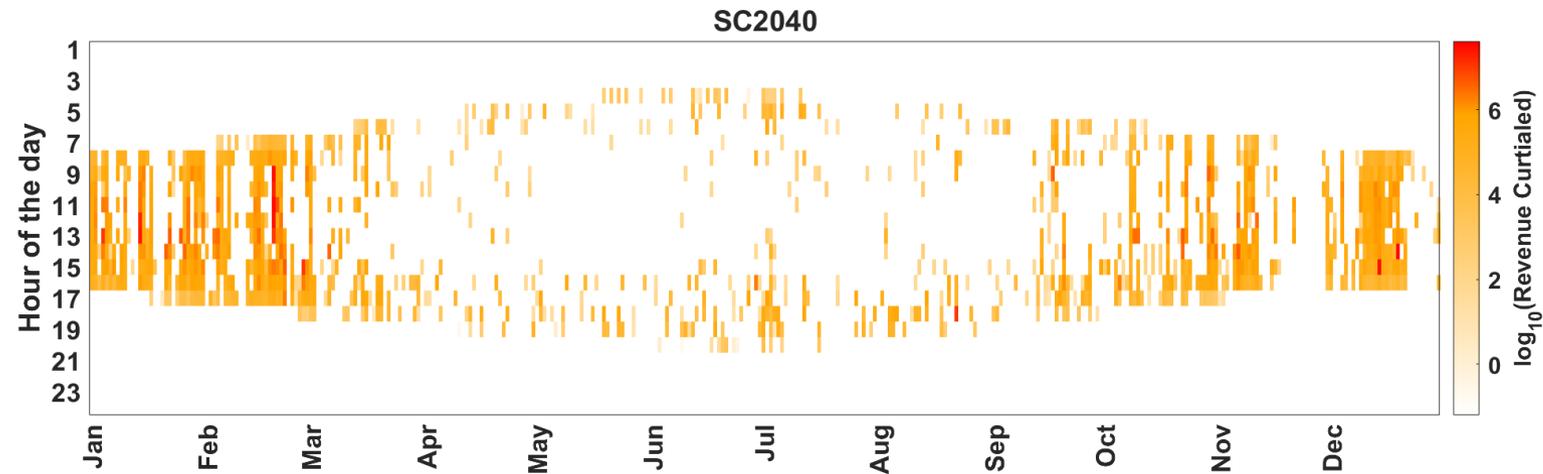
Value of solar power without curtailment



Scenario Sector Coupling

- ▶ 30 GW PV
- ▶ 30 TWh PV
- ▶ 0% Curtailment

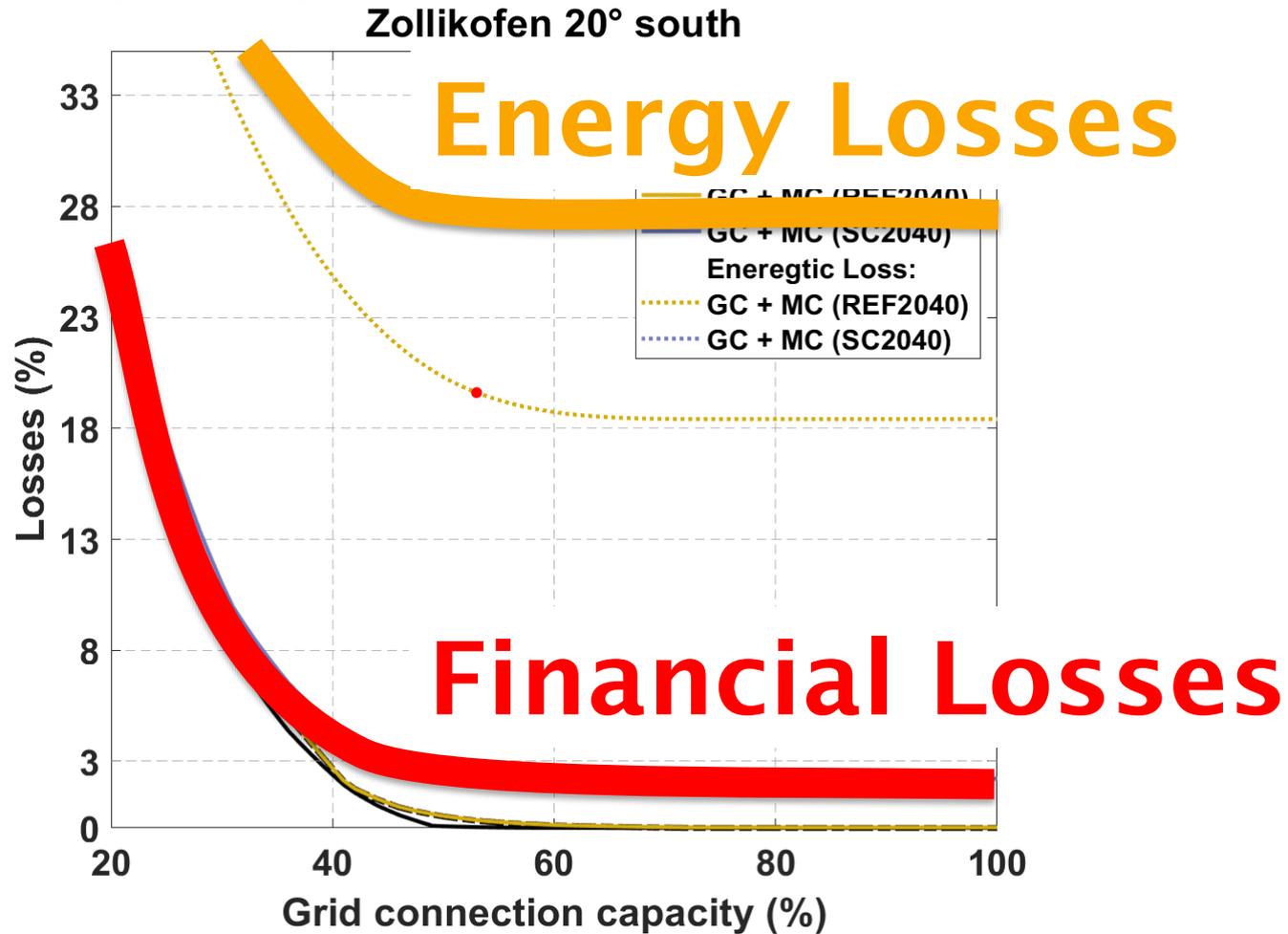
Value of solar power with curtailment



Scenario Sector Coupling

- ▶ 30 GW PV
- ▶ 23 TWh PV
- ▶ 28% Curtailment

Financial Losses as a Function of the Grid Connection Capacity



Conclusion: More grid capacity does not solve the integration challenge

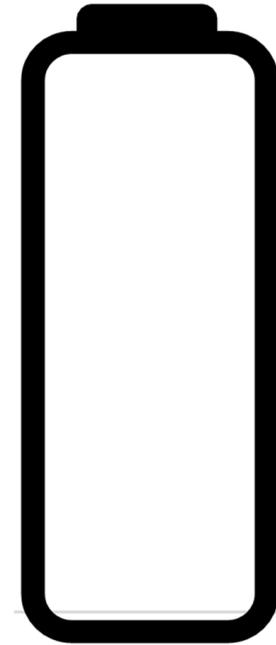
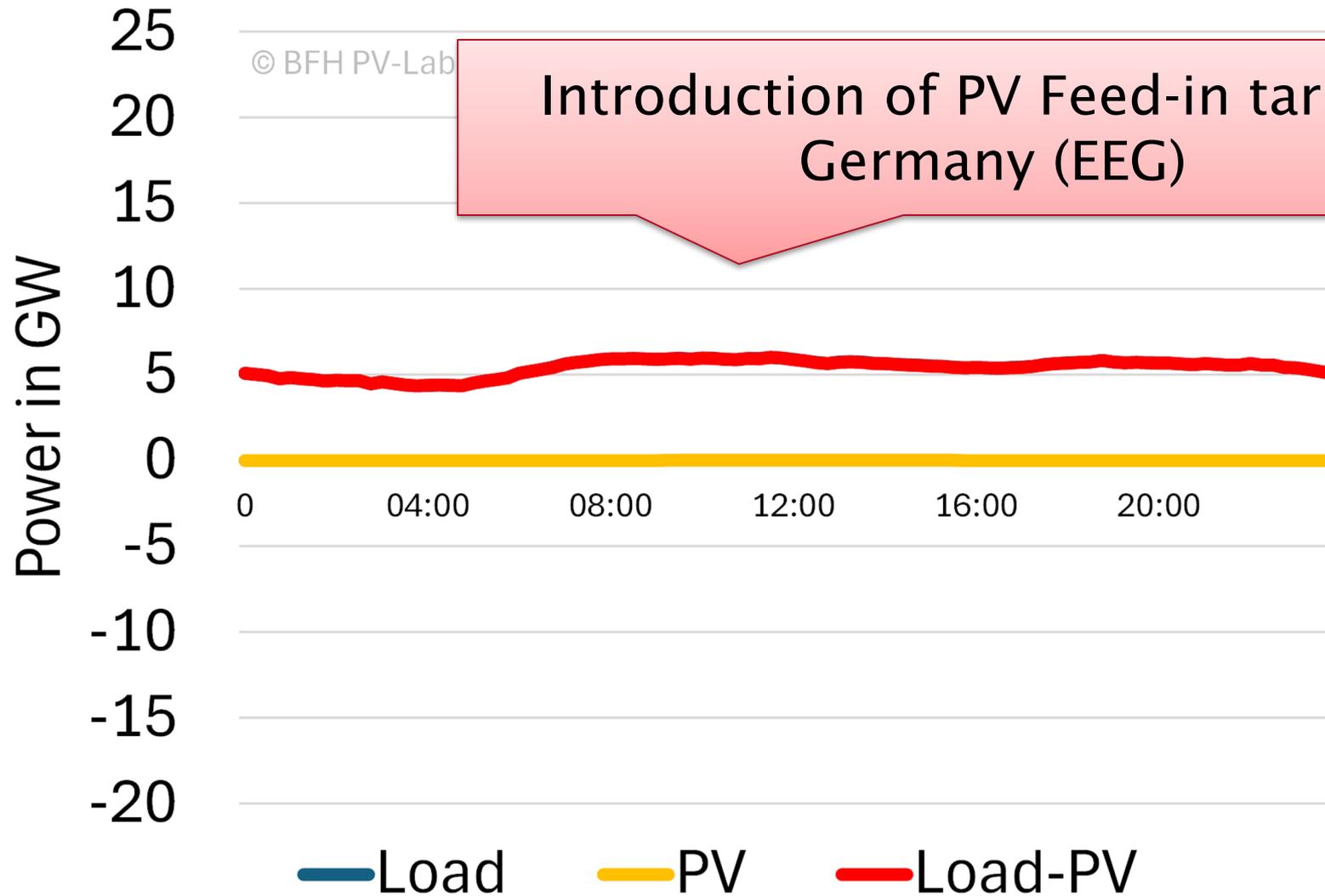
Brief History of Grid Integration in Switzerland and Europe

Brief History of Grid Integration in Switzerland and Europe

Following slides show:

- ▶ Amount of PV in the Swiss energy system
- ▶ Theoretical storage capacity needed to avoid curtailment, when PV supplies the load in summer
- ▶ The figures assume no change in the load profile
 - this is not a realistic assumption: The load profile might change a lot to host more PV

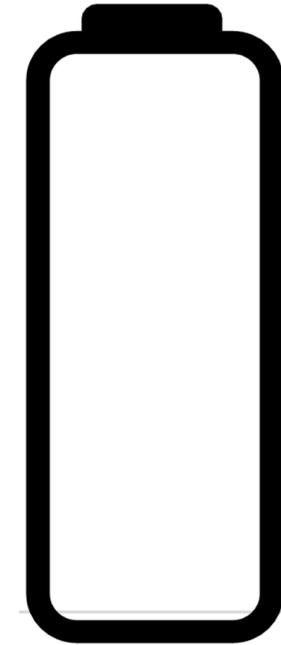
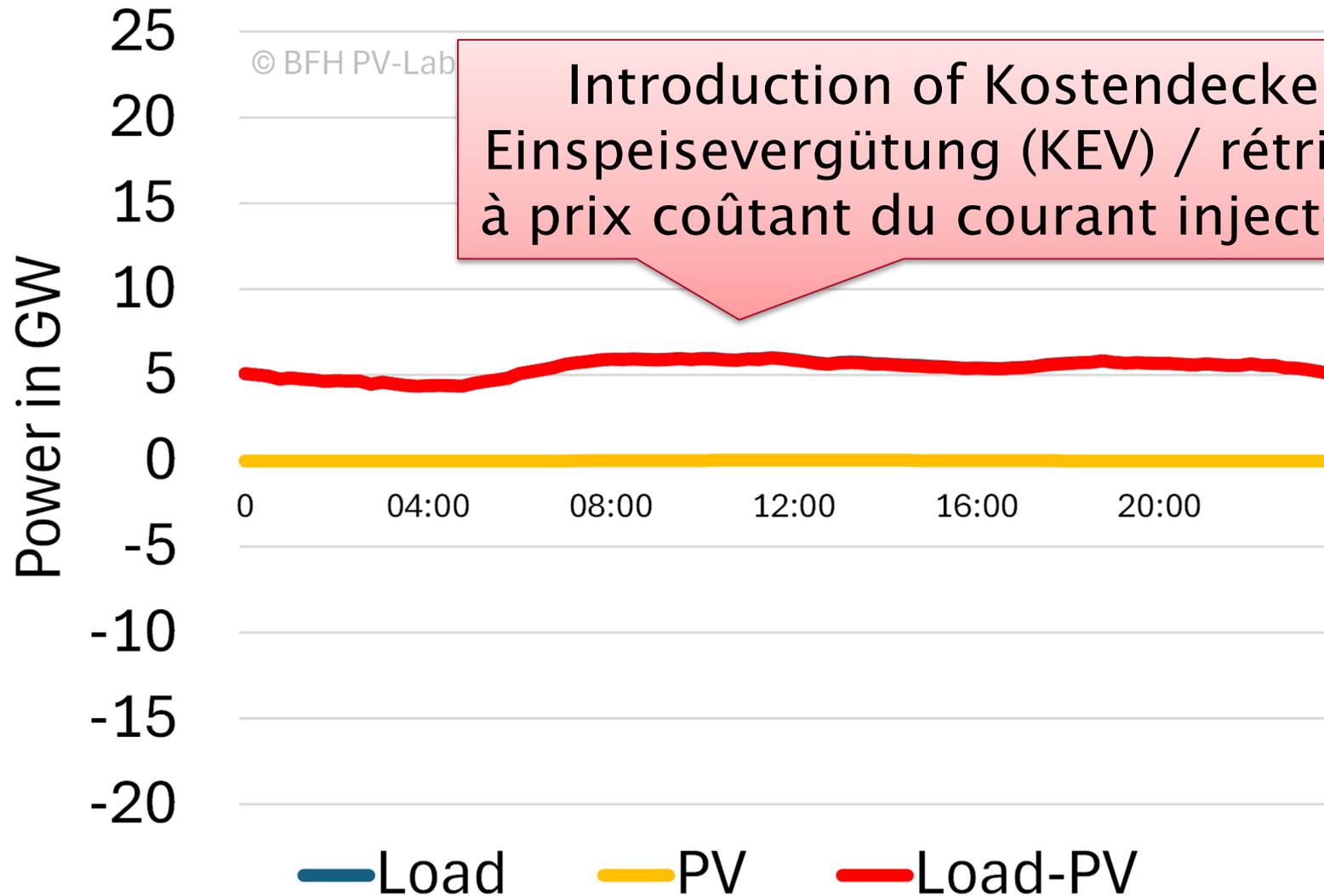
A Swiss Summer Day in: 2000



0 kWh/kWp

Storage capacity to
avoid curtailment

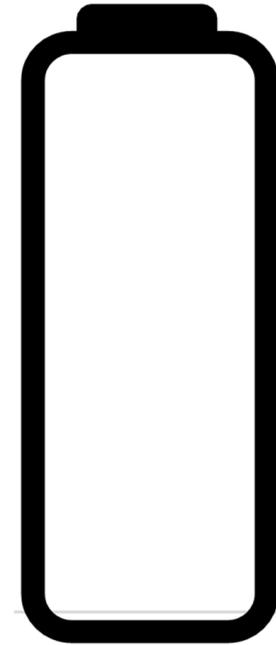
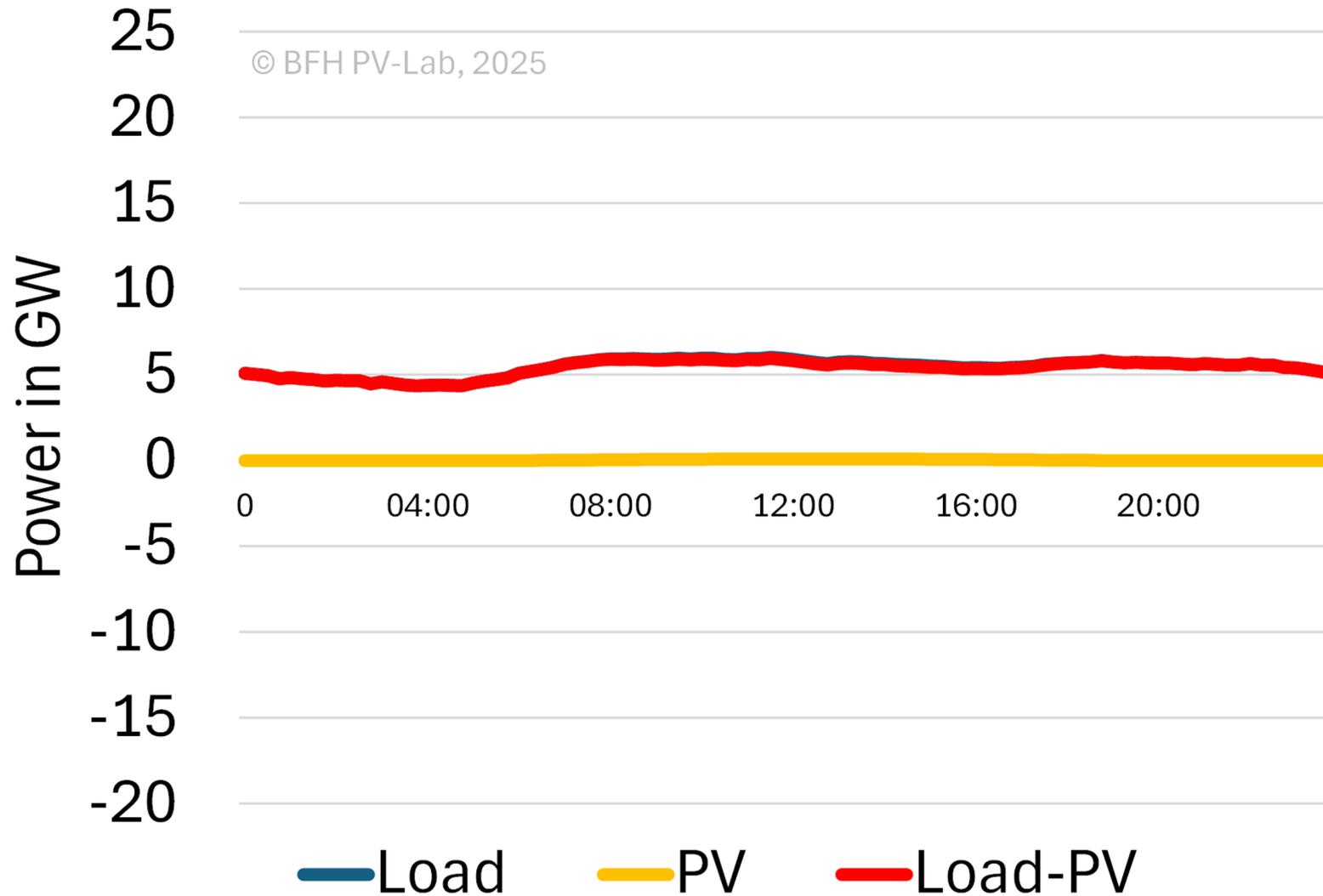
A Swiss Summer Day in: 2008



0 kWh/kWp

Storage capacity to avoid curtailment

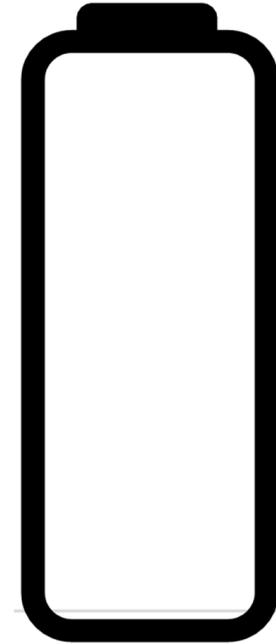
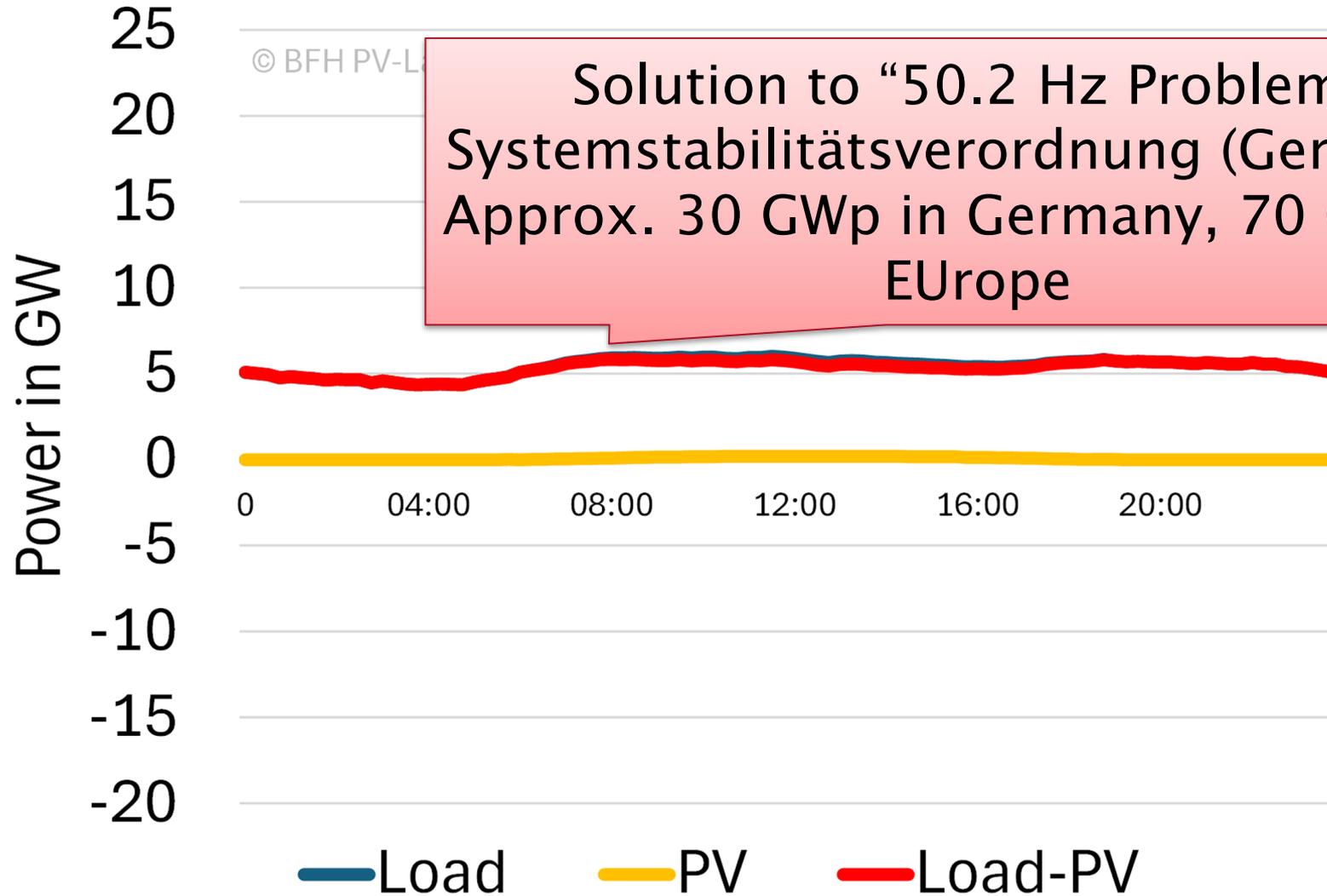
A Swiss Summer Day in: 2010



0 kWh/kWp

Storage capacity to
avoid curtailment

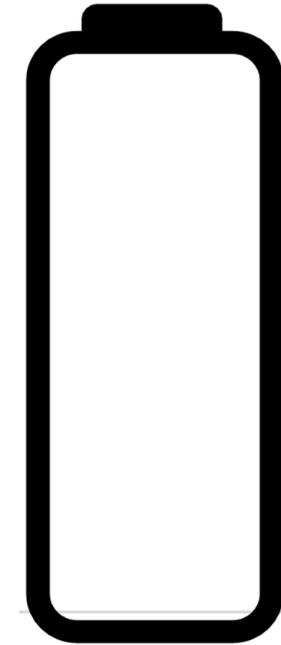
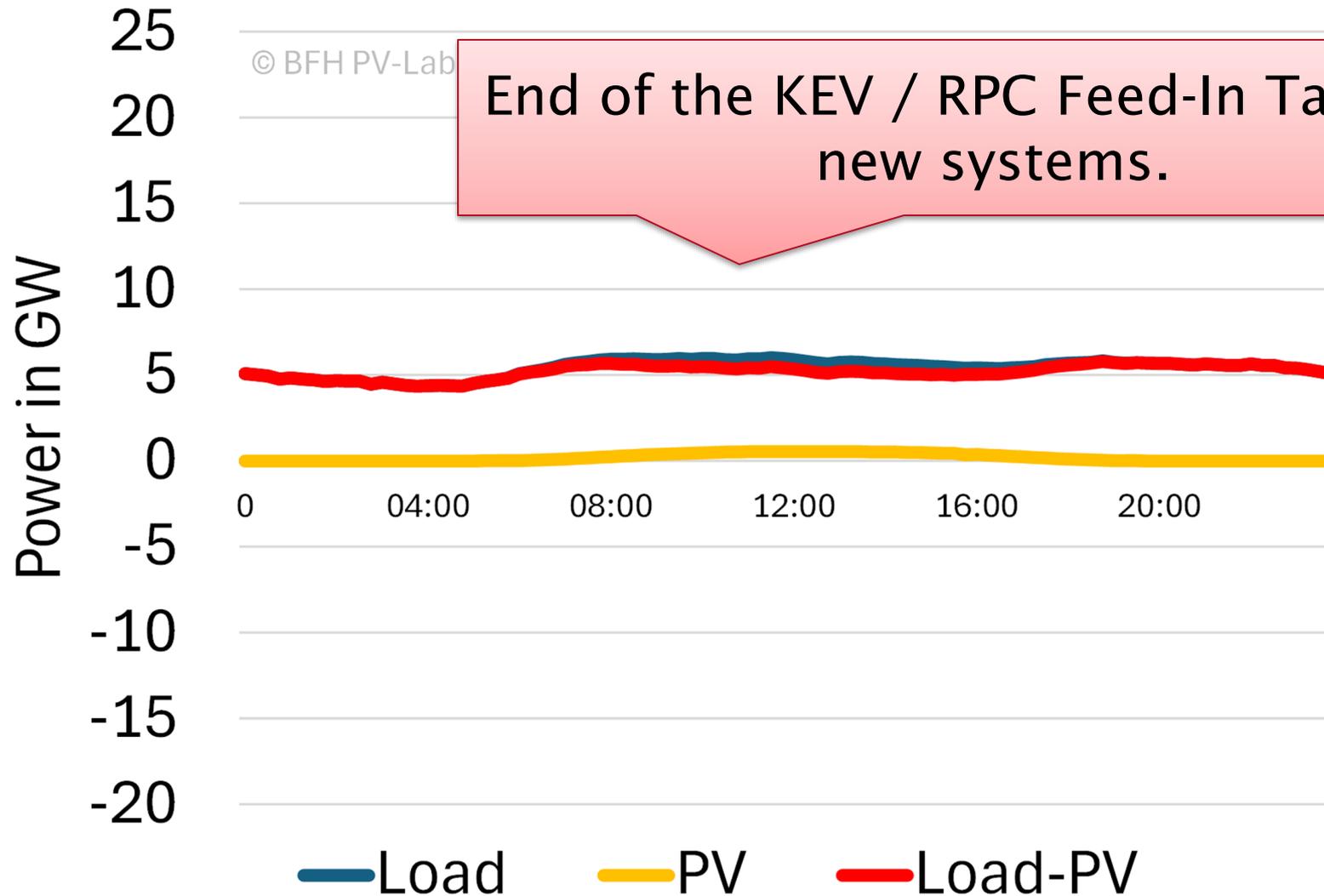
A Swiss Summer Day in: 2012



0 kWh/kWp

Storage capacity to
avoid curtailment

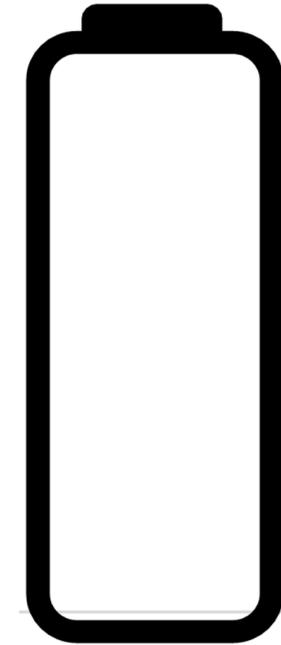
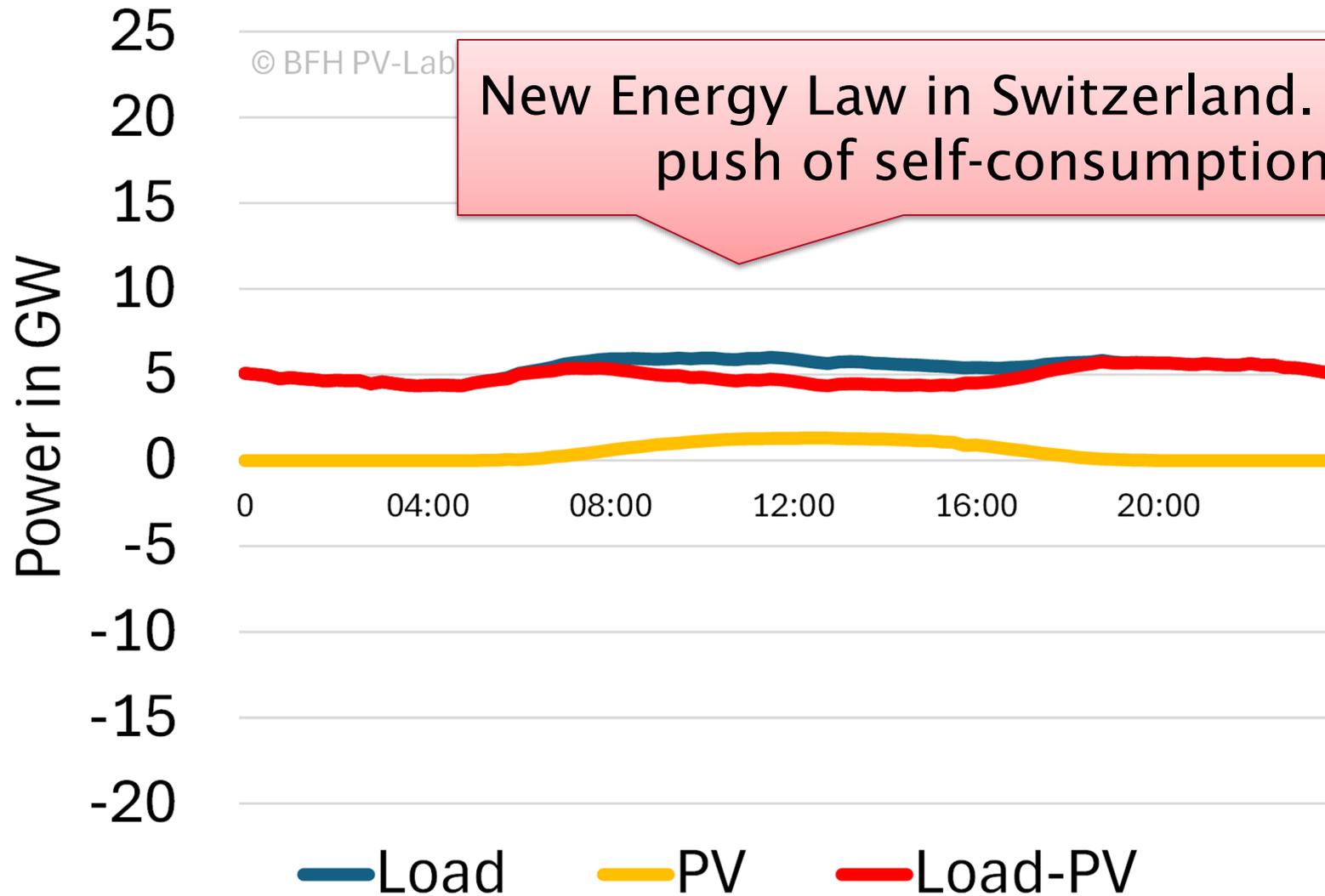
A Swiss Summer Day in: 2014



0 kWh/kWp

Storage capacity to avoid curtailment

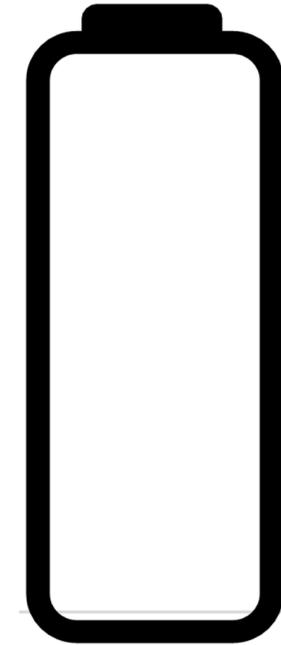
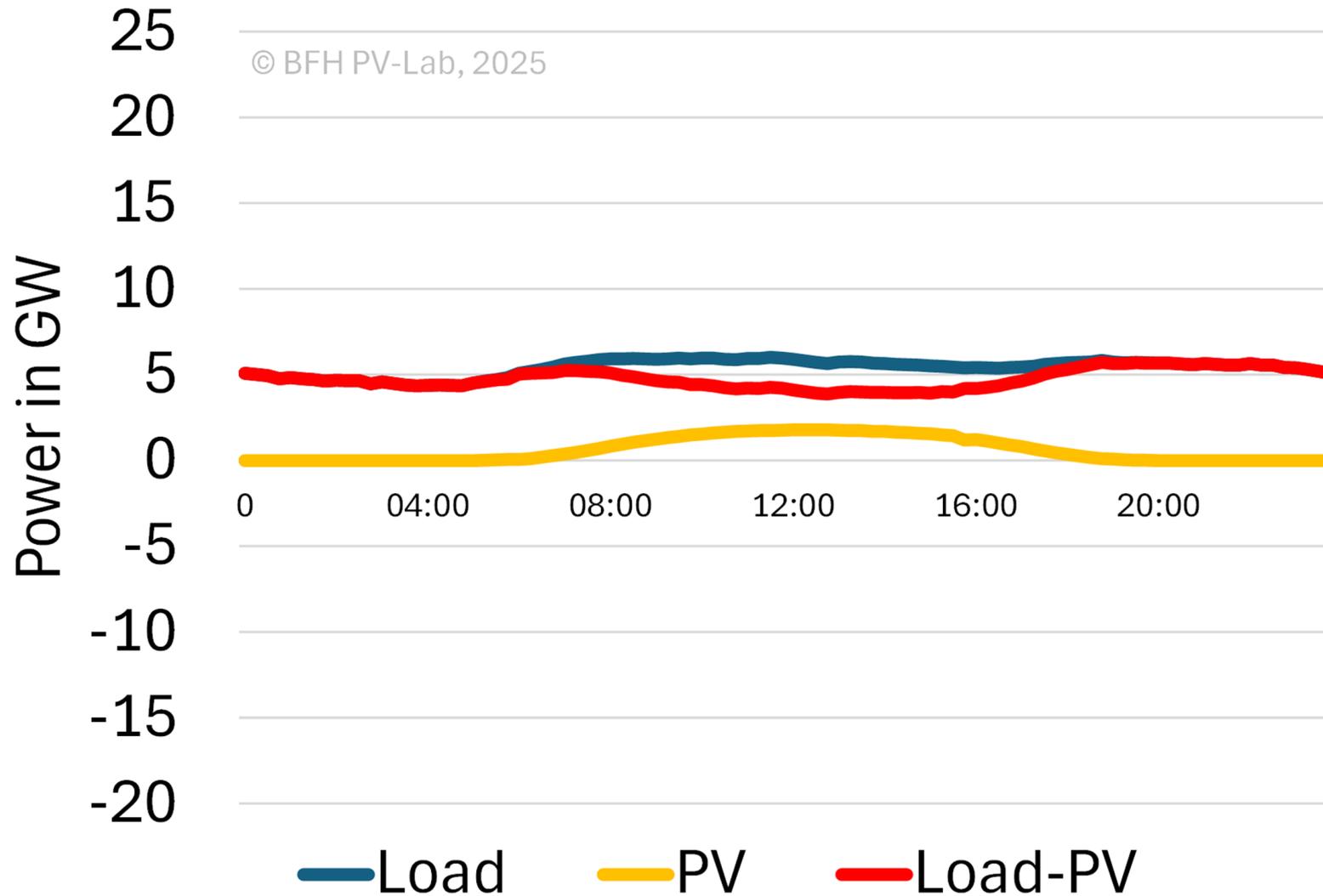
A Swiss Summer Day in: 2018



0 kWh/kWp

Storage capacity to avoid curtailment

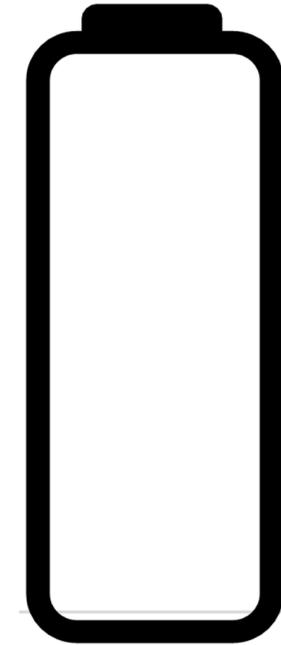
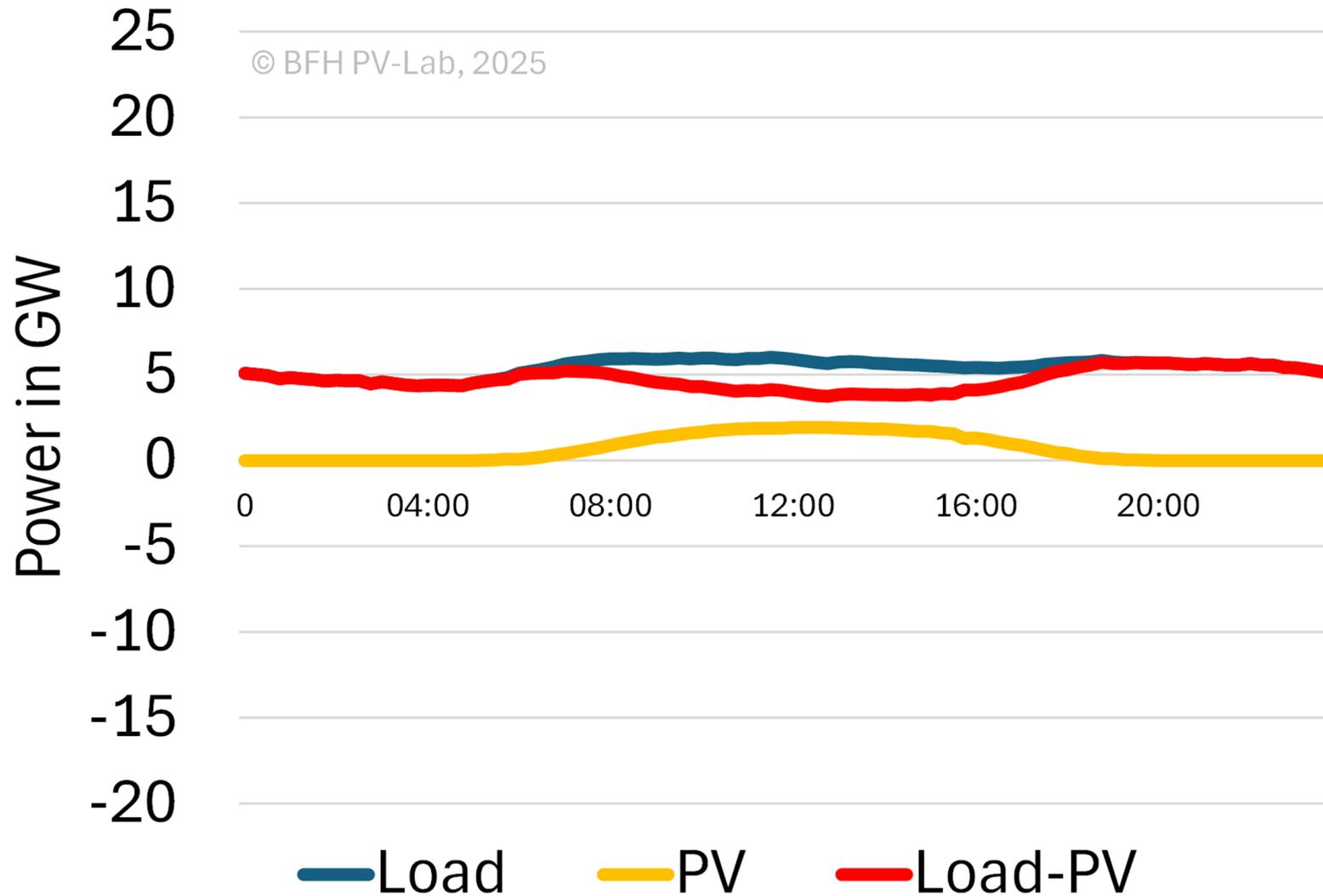
A Swiss Summer Day in: 2020



0 kWh/kWp

Storage capacity to
avoid curtailment

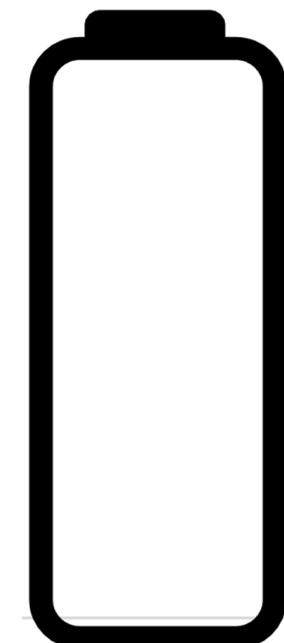
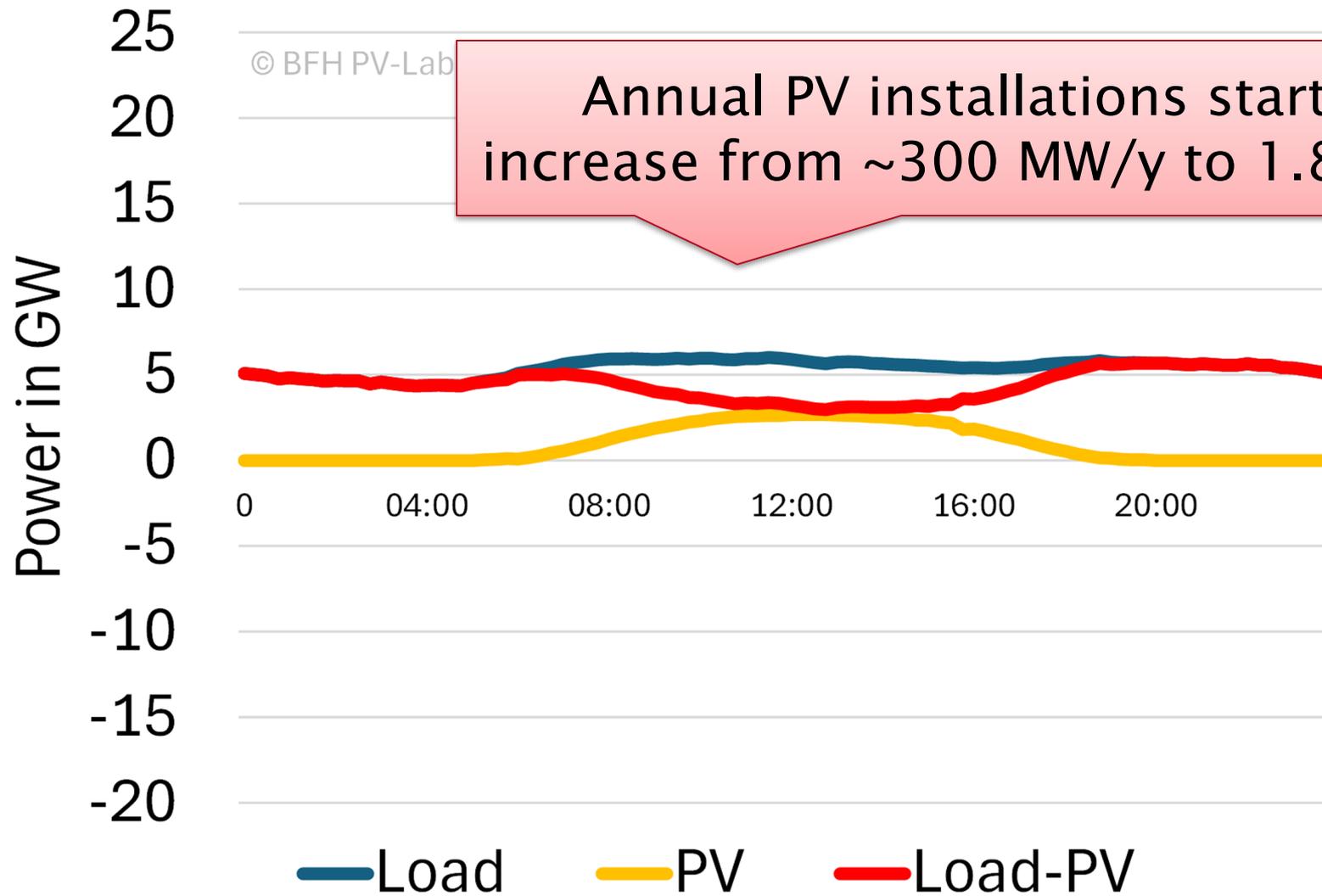
A Swiss Summer Day in: 2021



0 kWh/kWp

Storage capacity to
avoid curtailment

A Swiss Summer Day in: 2022

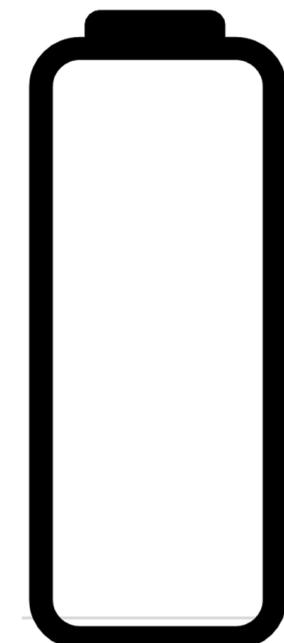
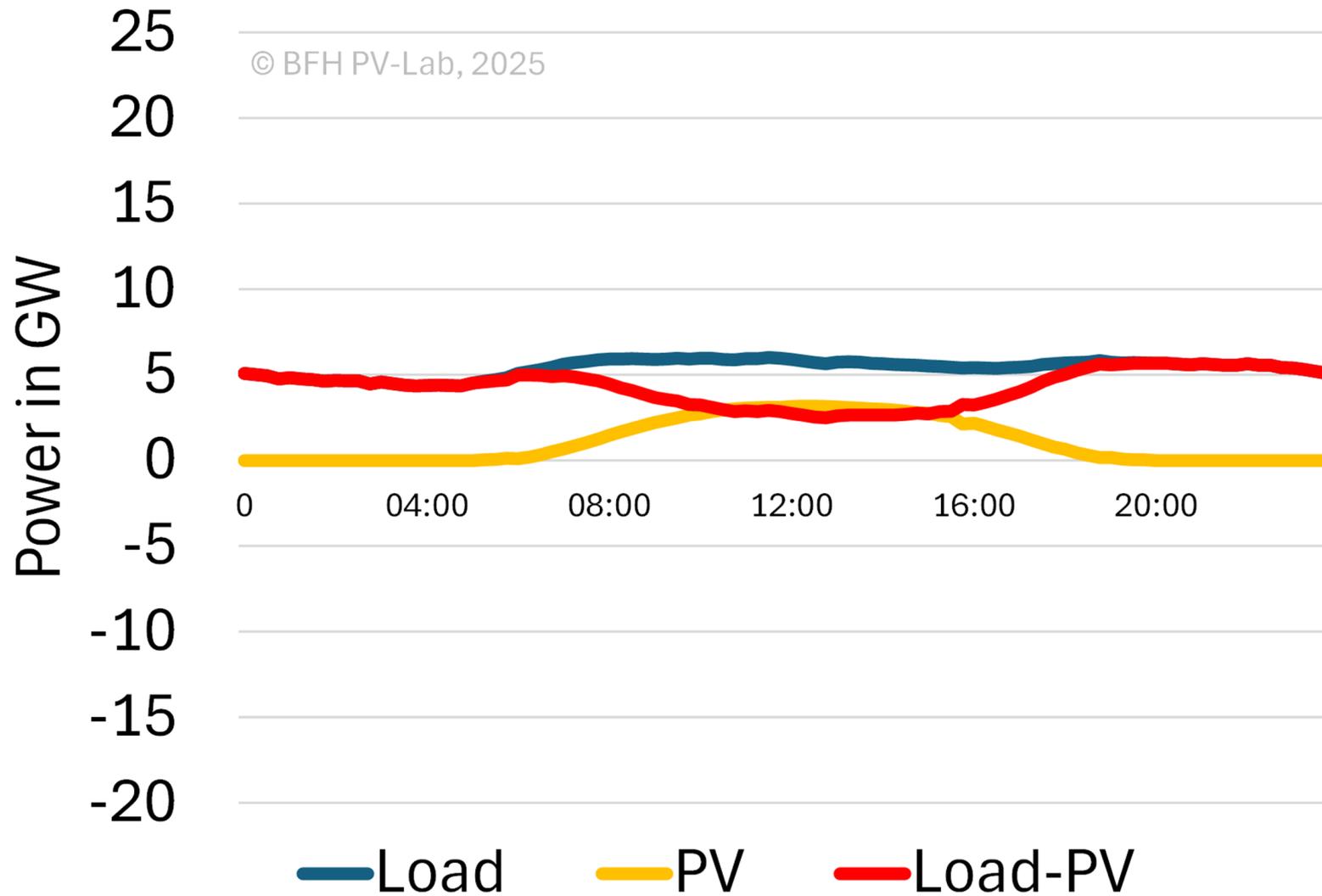


0 kWh/kWp

Storage capacity to avoid curtailment

Loads 2025: 54 TWh/y; PV capacity 2022: 3.9 GWp; PV simultaneity factor: 0.8; new flex load neglected.

A Swiss Summer Day in: 2023

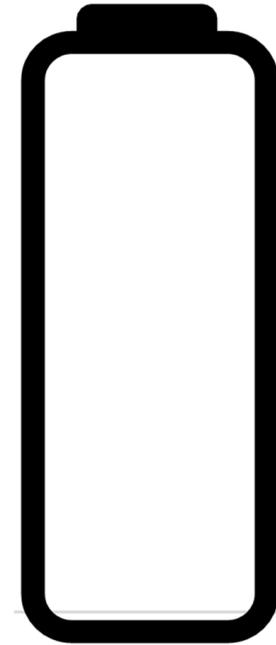
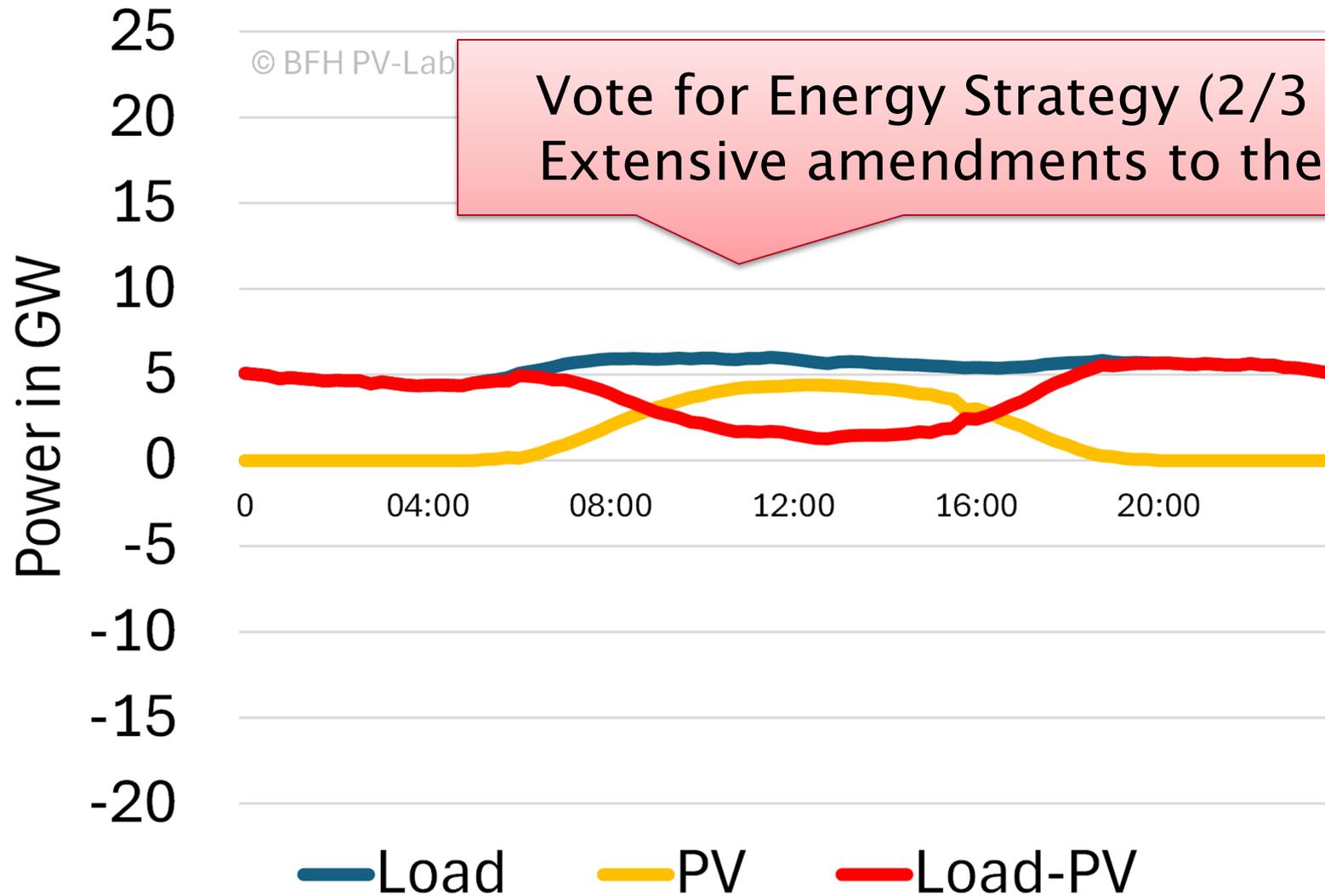


0 kWh/kWp

Storage capacity to avoid curtailment

Loads 2025: 54 TWh/y; PV capacity 2023: 4.6 GWp; PV simultaneity factor: 0.8; new flex load neglected.

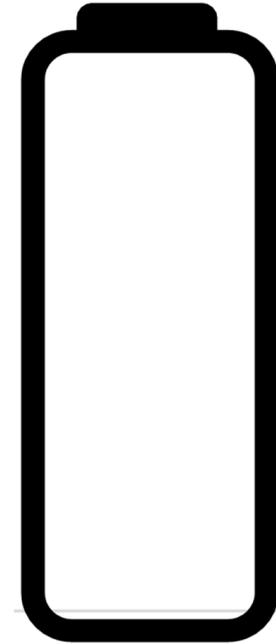
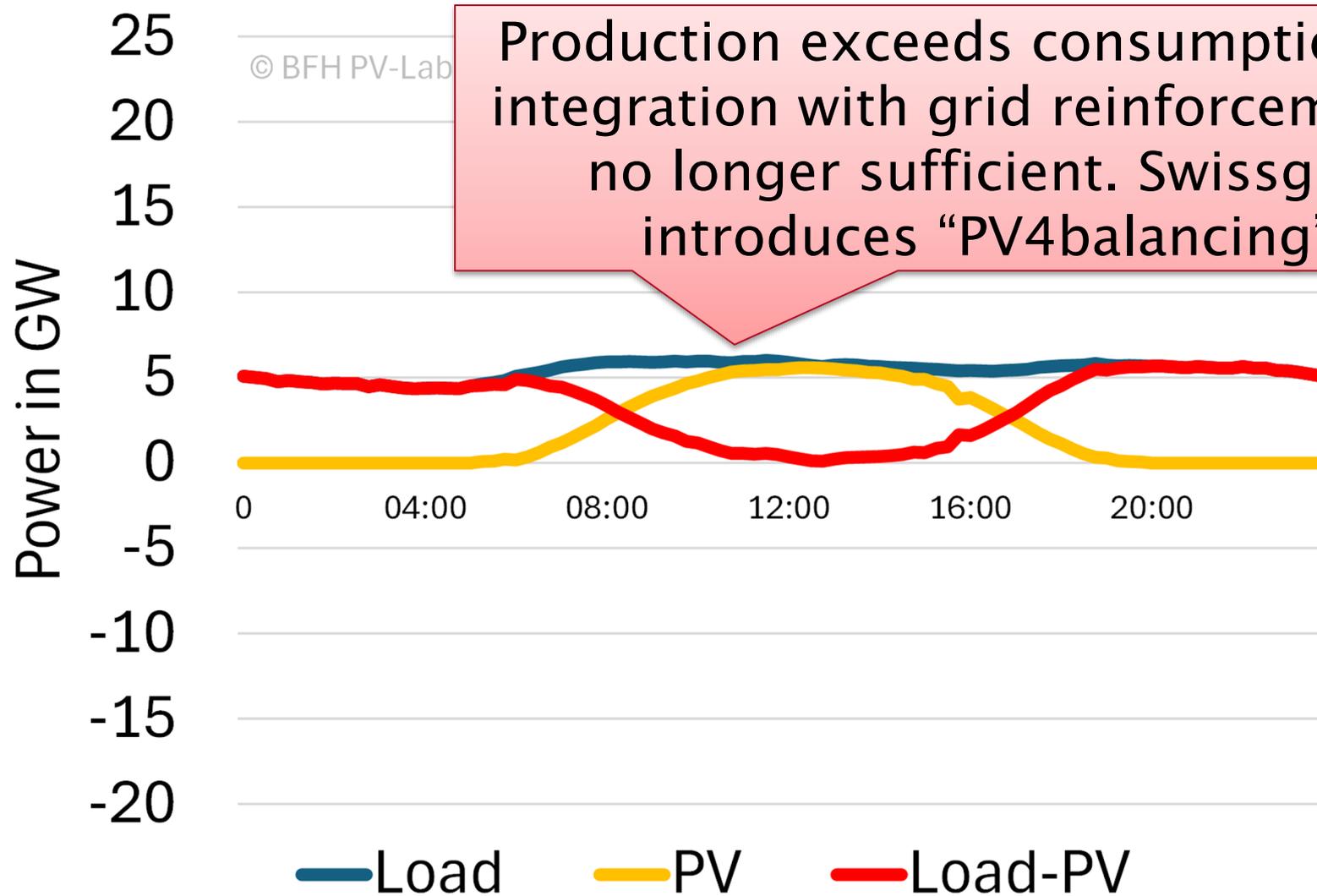
A Swiss Summer Day in: 2024



0 kWh/kWp

Storage capacity to
avoid curtailment

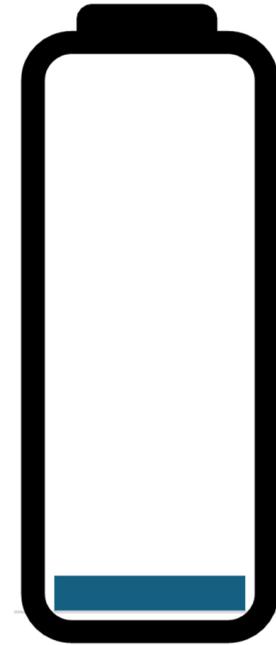
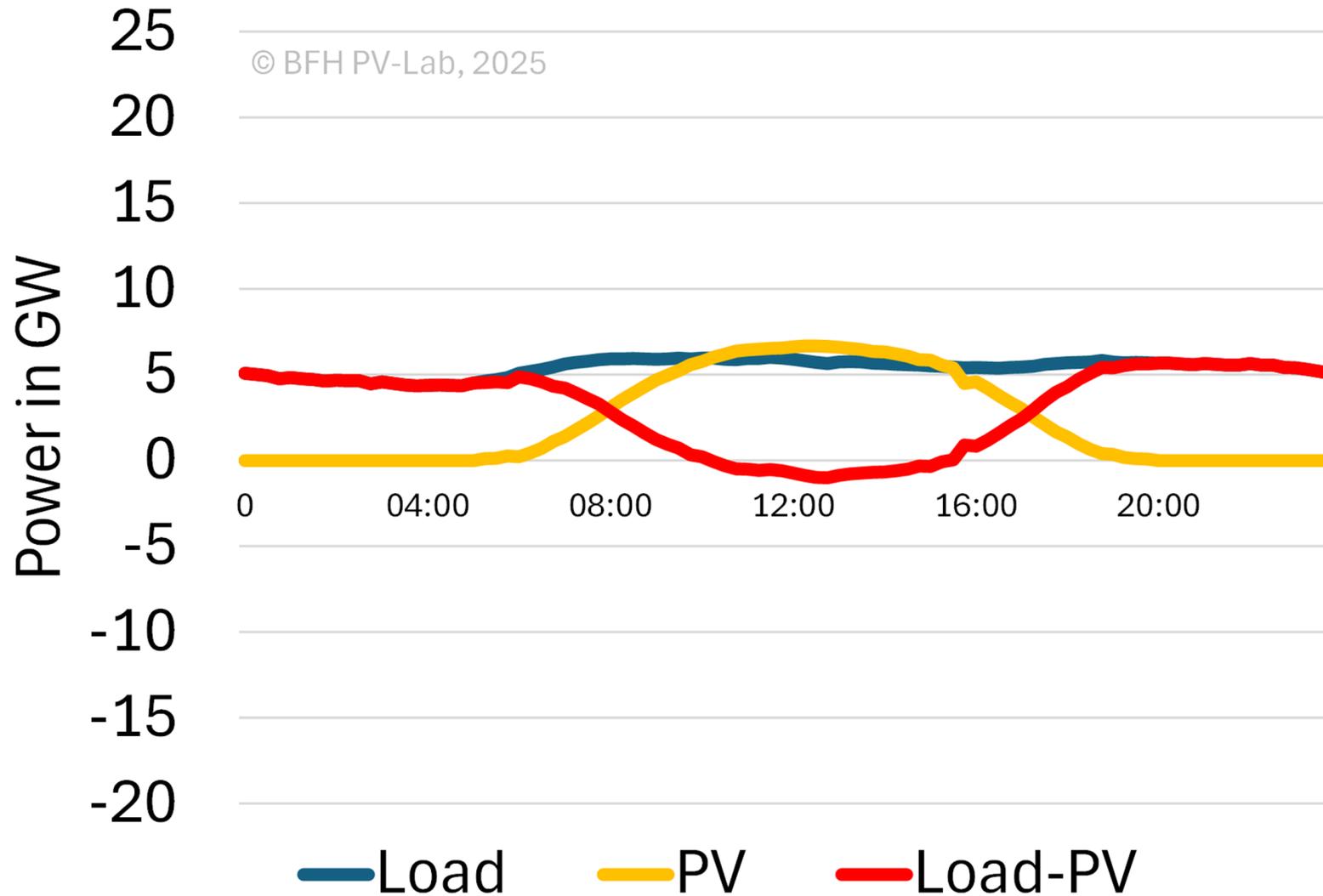
A Swiss Summer Day in: 2025



0 kWh/kWp

Storage capacity to avoid curtailment

A Swiss Summer Day in: 2026

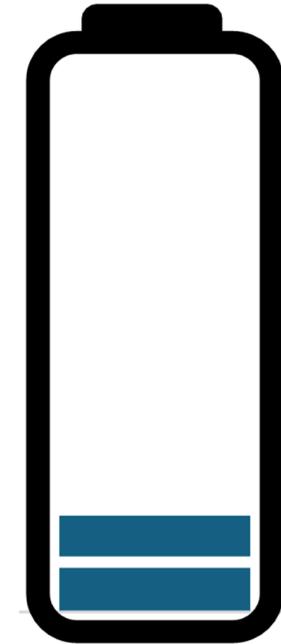
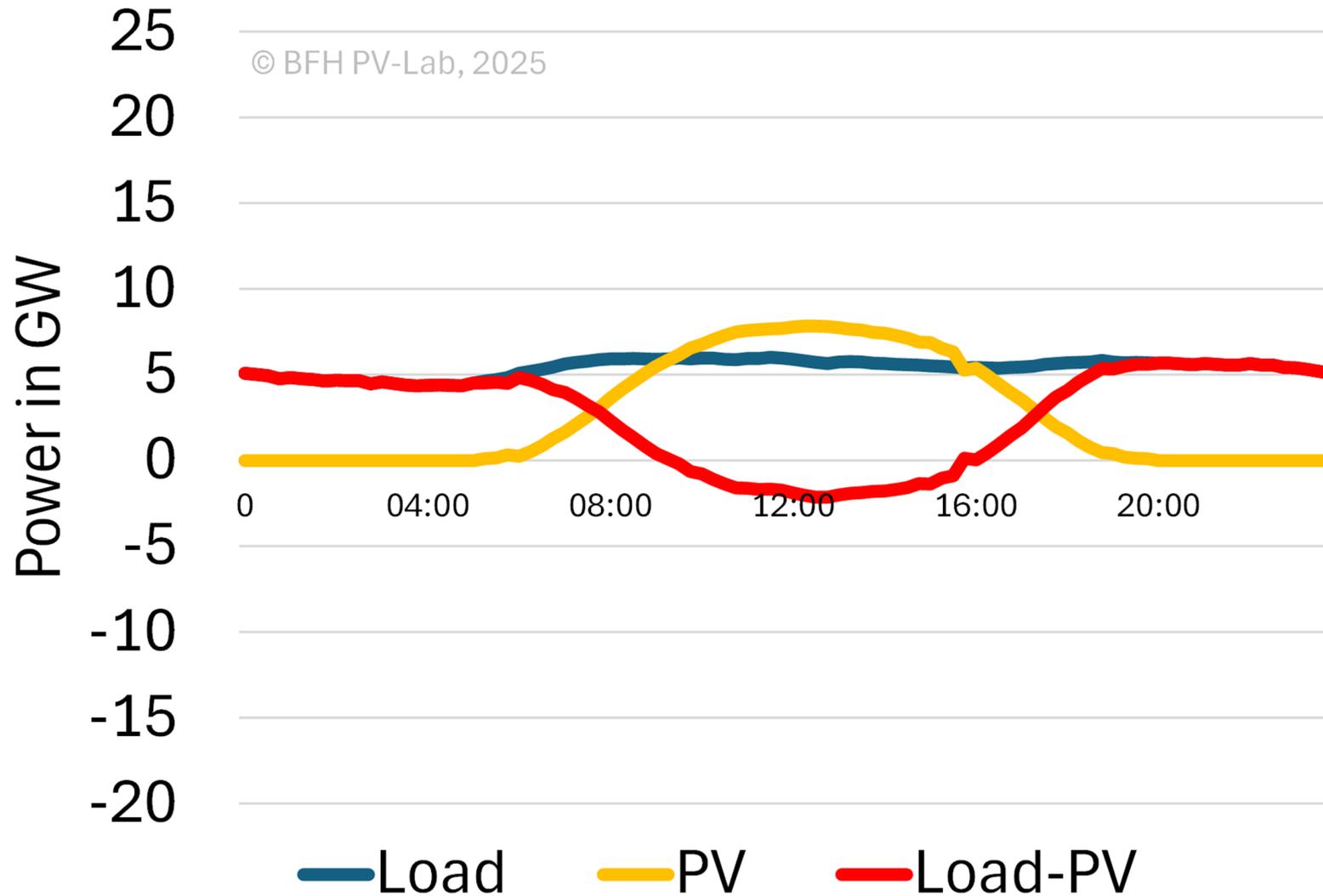


0.3 kWh/kWp

Storage capacity to
avoid curtailment

Loads 2025: 54 TWh/y; PV capacity 2026: 9.7 GWp; PV simultaneity factor: 0.8; new flex load neglected.

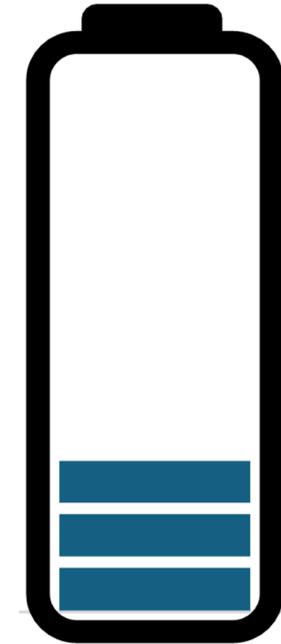
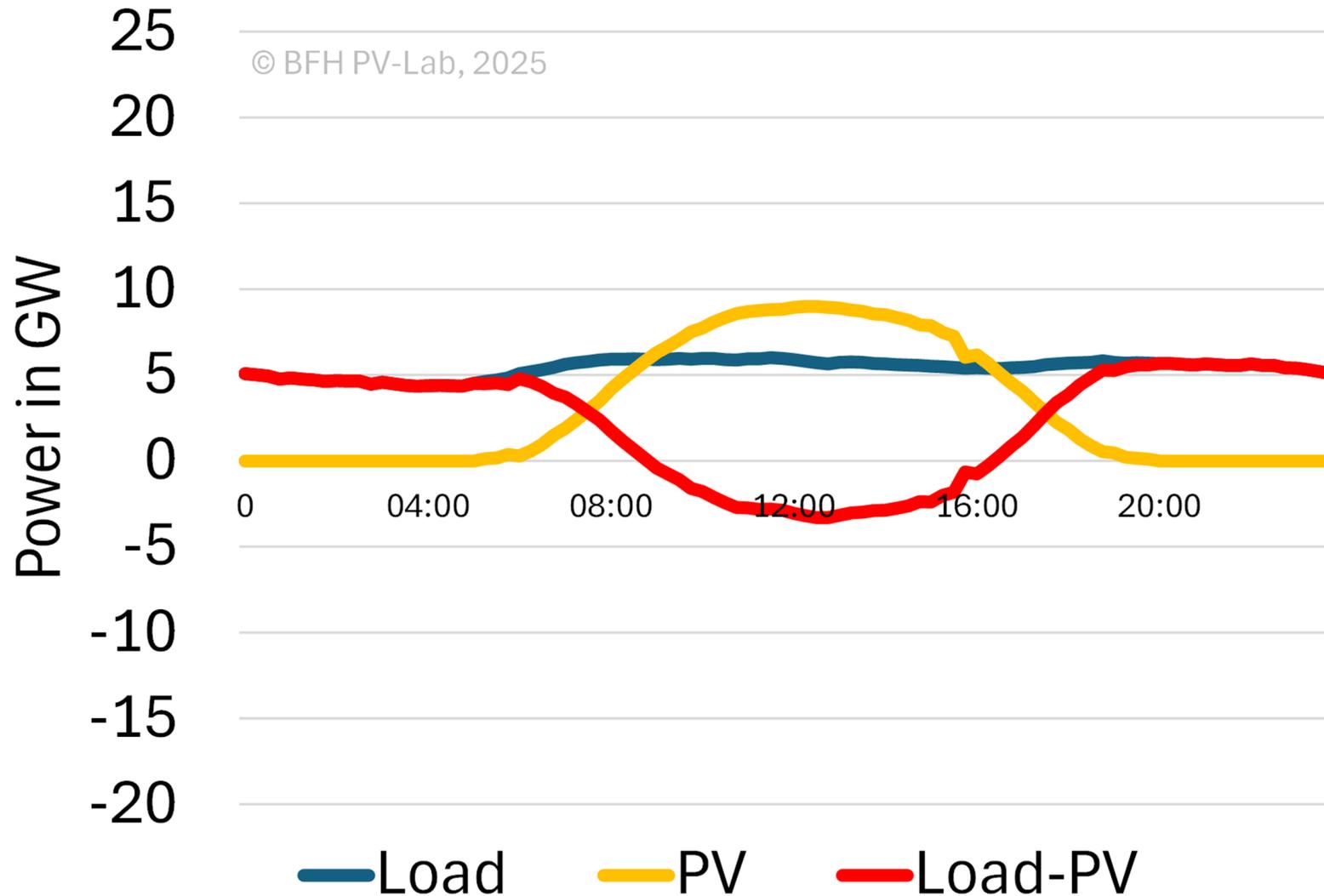
A Swiss Summer Day in: 2027



0.8 kWh/kWp

Storage capacity to
avoid curtailment

A Swiss Summer Day in: 2028

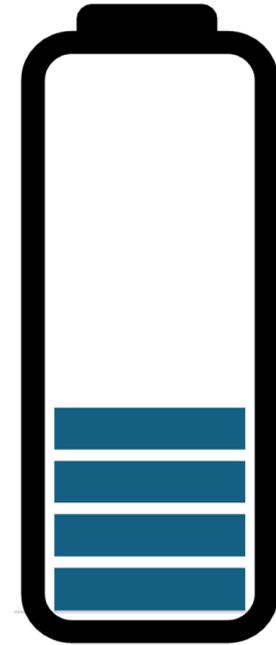
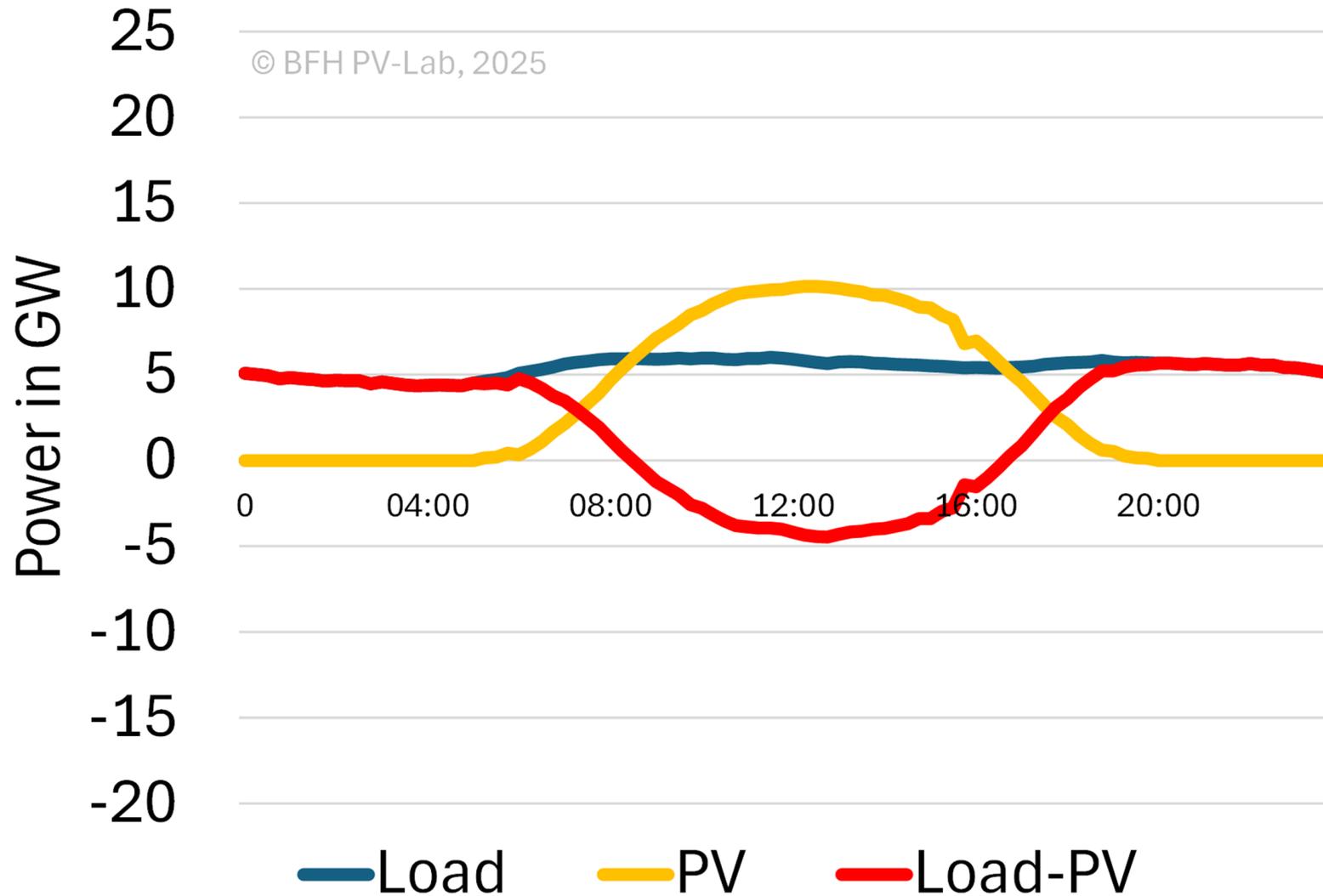


1.3 kWh/kWp

Storage capacity to
avoid curtailment

Loads 2025: 54 TWh/y; PV capacity 2028: 13.06 GWp; PV simultaneity factor: 0.8; new flex load neglected.

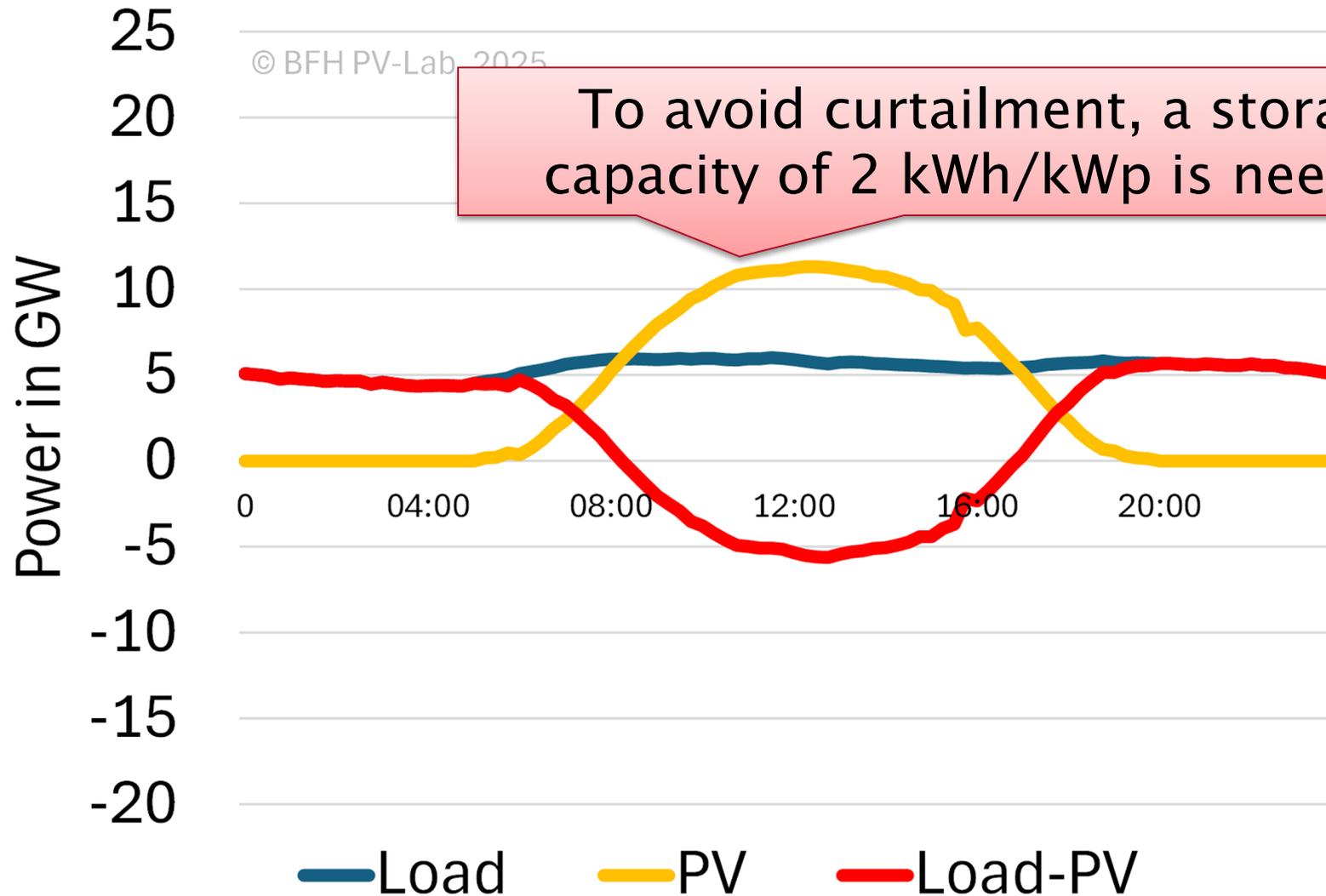
A Swiss Summer Day in: 2029



1.7 kWh/kWp

Storage capacity to
avoid curtailment

A Swiss Summer Day in: 2030



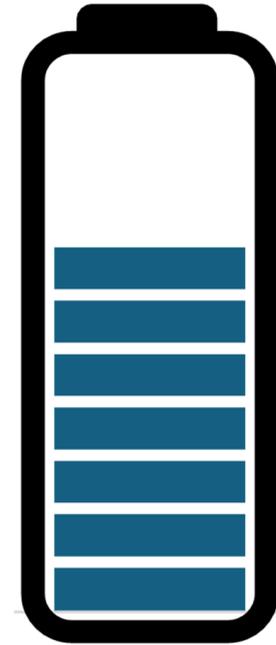
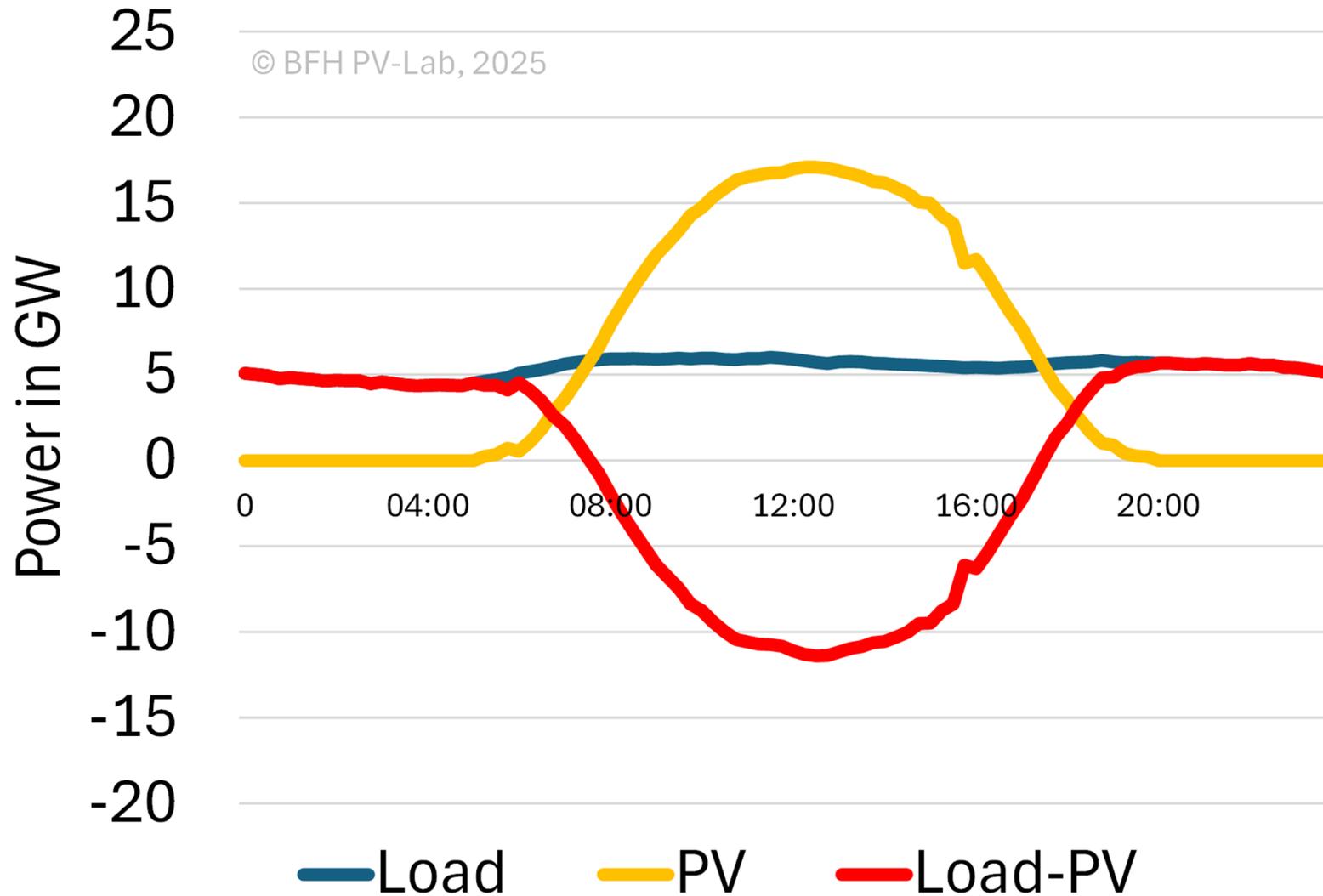
To avoid curtailment, a storage capacity of 2 kWh/kWp is needed.



2 kWh/kWp

Storage capacity to avoid curtailment

A Swiss Summer Day in: 2035

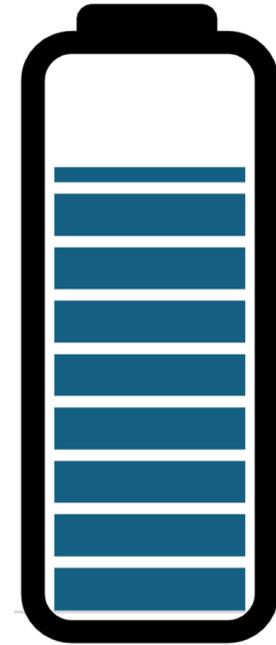
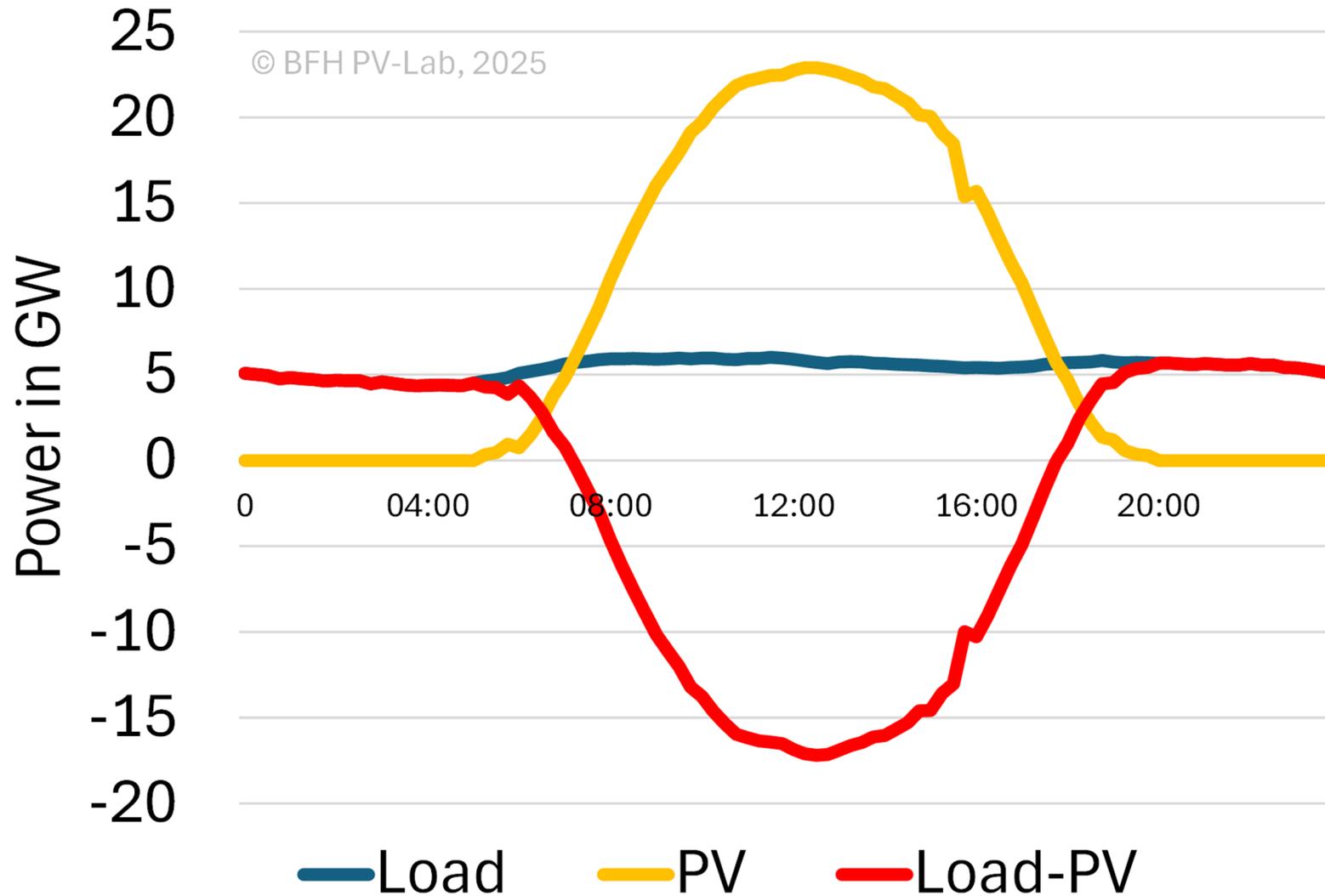


3.1 kWh/kWp

Storage capacity to
avoid curtailment

Loads 2025: 54 TWh/y; PV capacity 2035: 24.82 GWp; PV simultaneity factor: 0.8; new flex load neglected.

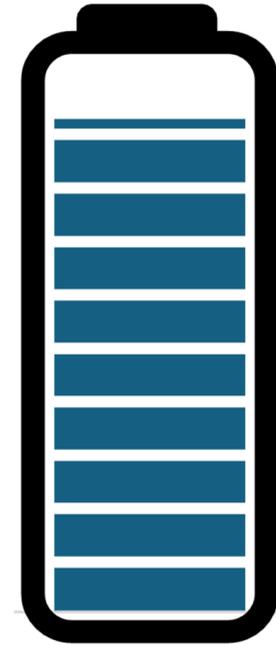
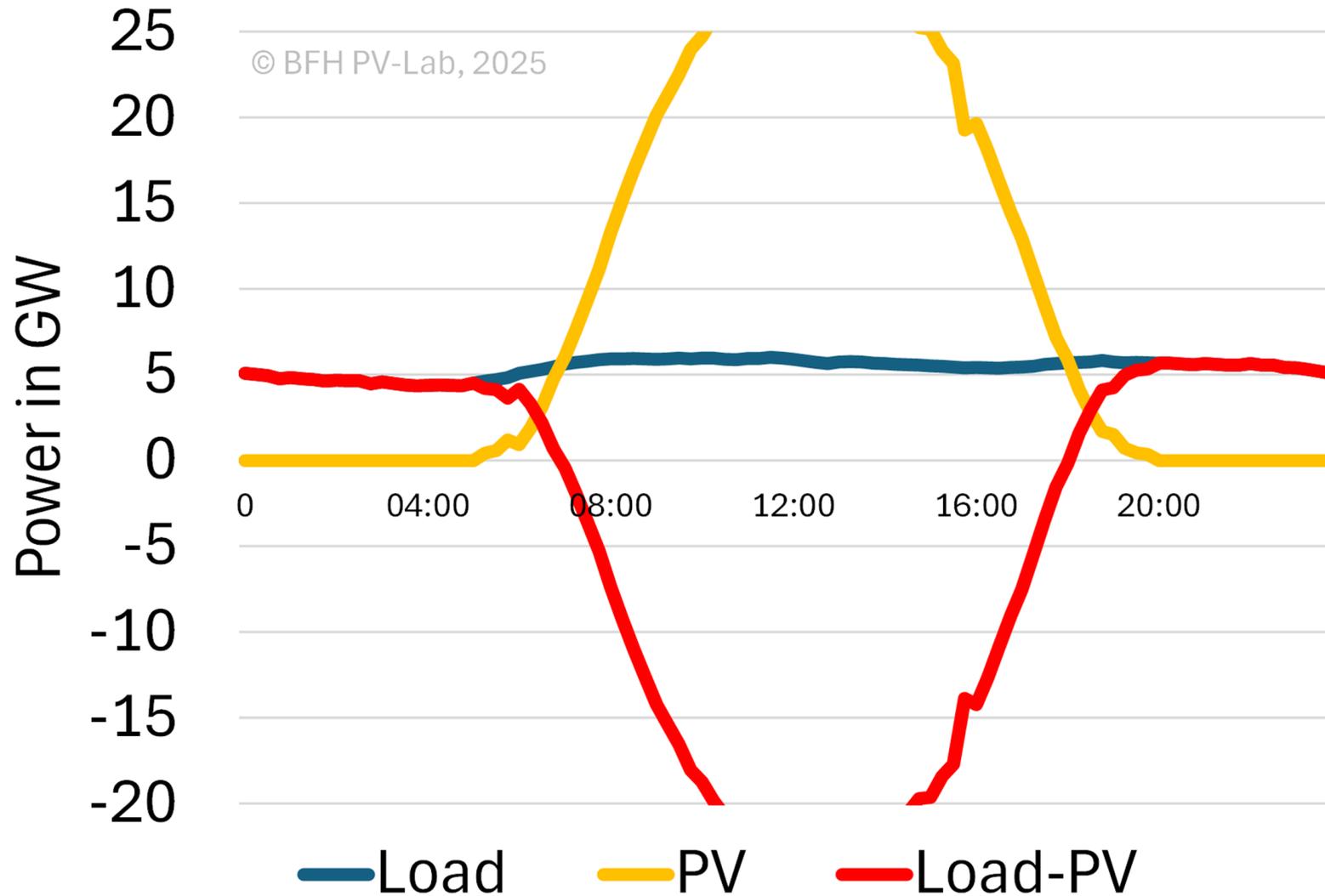
A Swiss Summer Day in: 2040



3.7 kWh/kWp

Storage capacity to
avoid curtailment

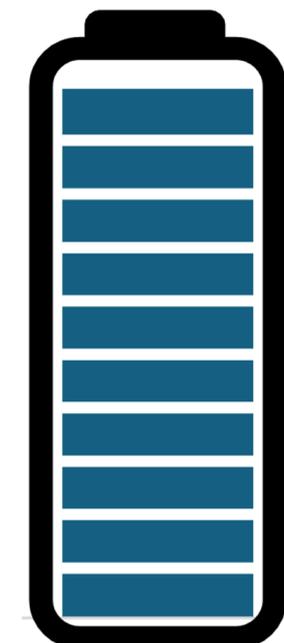
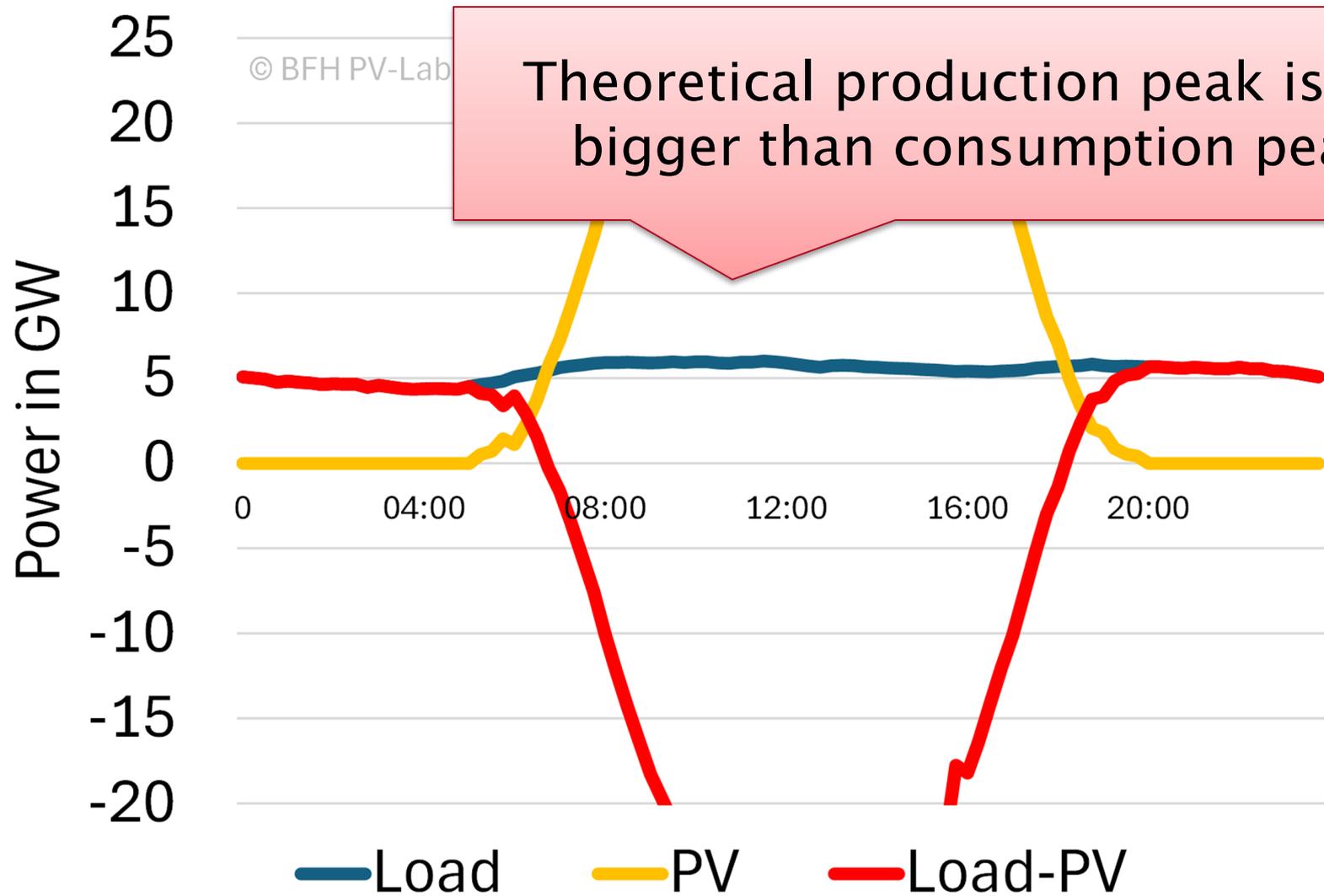
A Swiss Summer Day in: 2045



4.1 kWh/kWp

Storage capacity to avoid curtailment

A Swiss Summer Day in: 2050



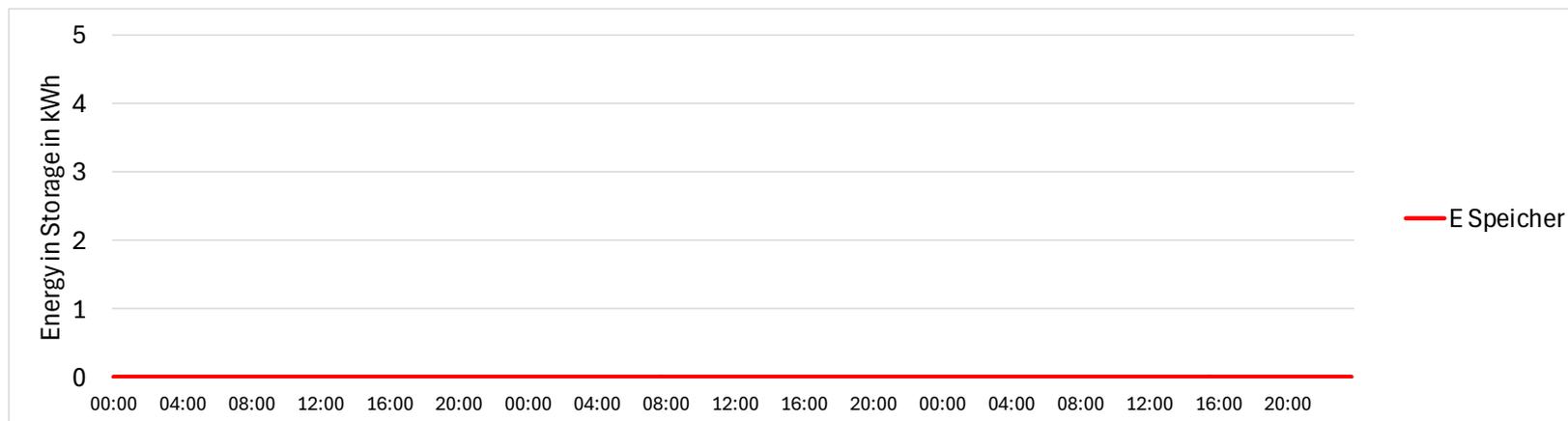
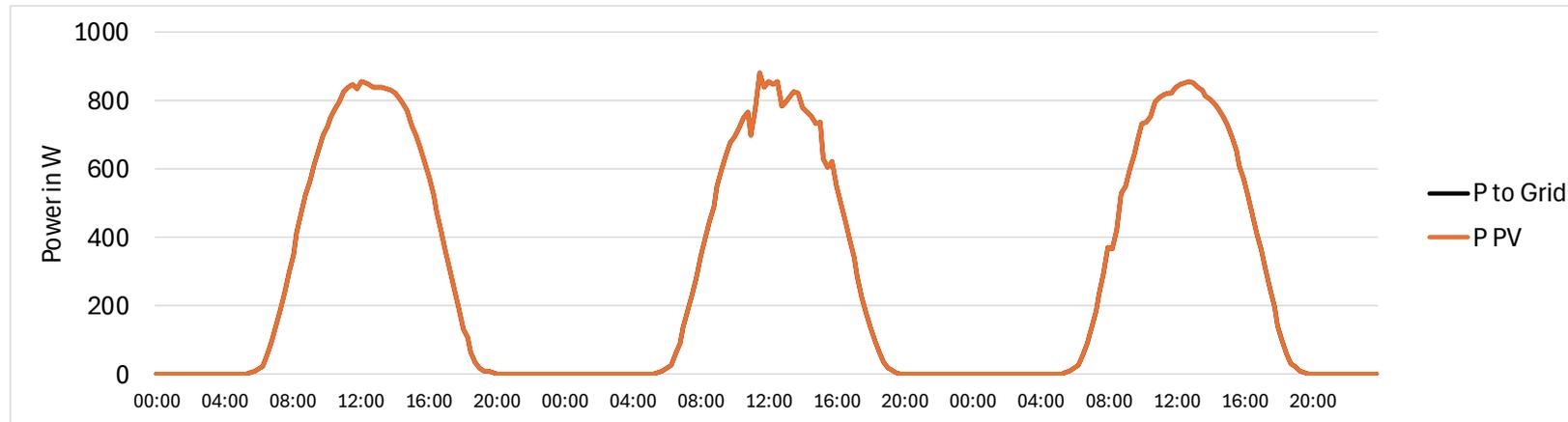
4.4 kWh/kWp

Storage capacity to avoid curtailment

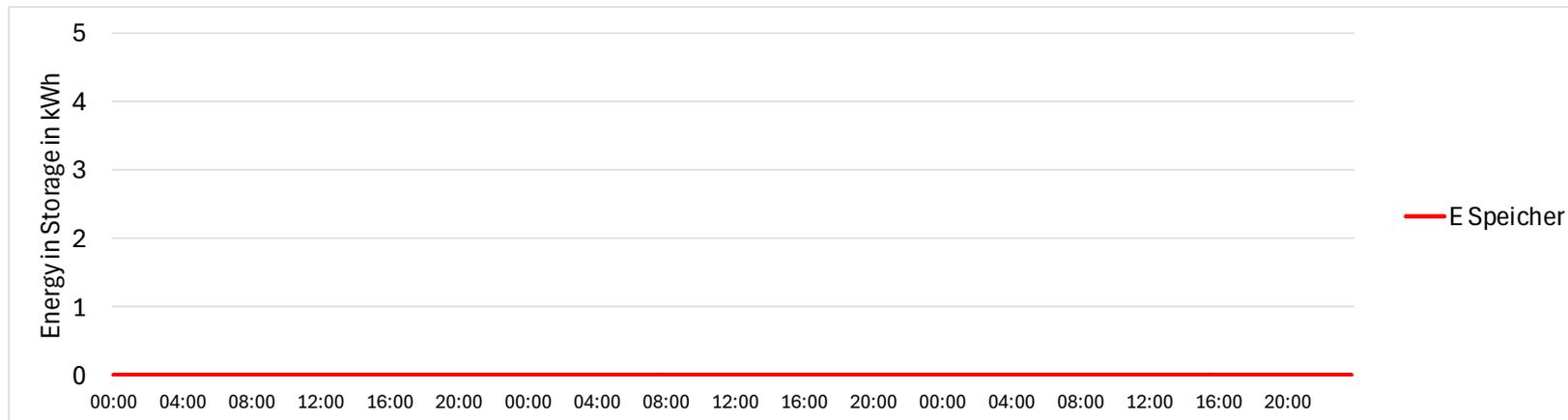
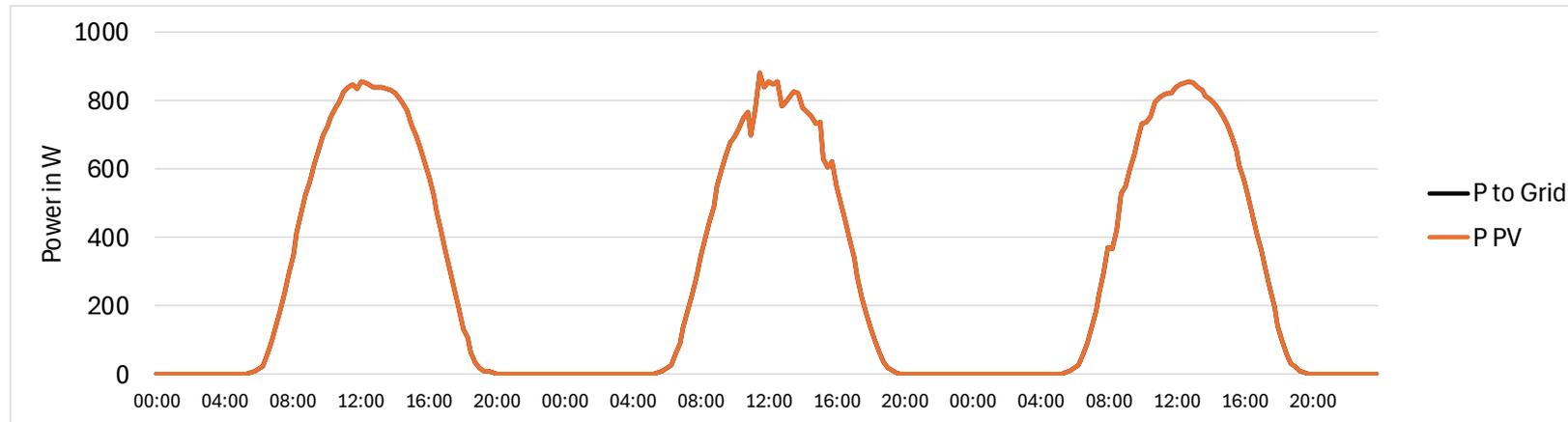
Loads 2025: 54 TWh/y; PV capacity 2050: 50.02 GWp; PV simultaneity factor: 0.8; new flex load neglected.

A PV Systems' Perspective

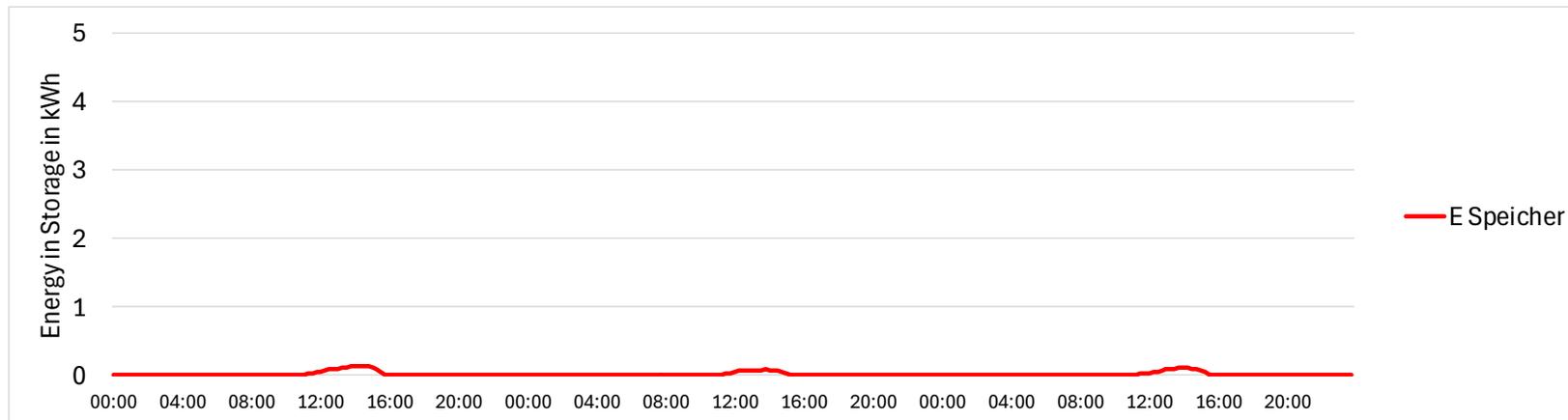
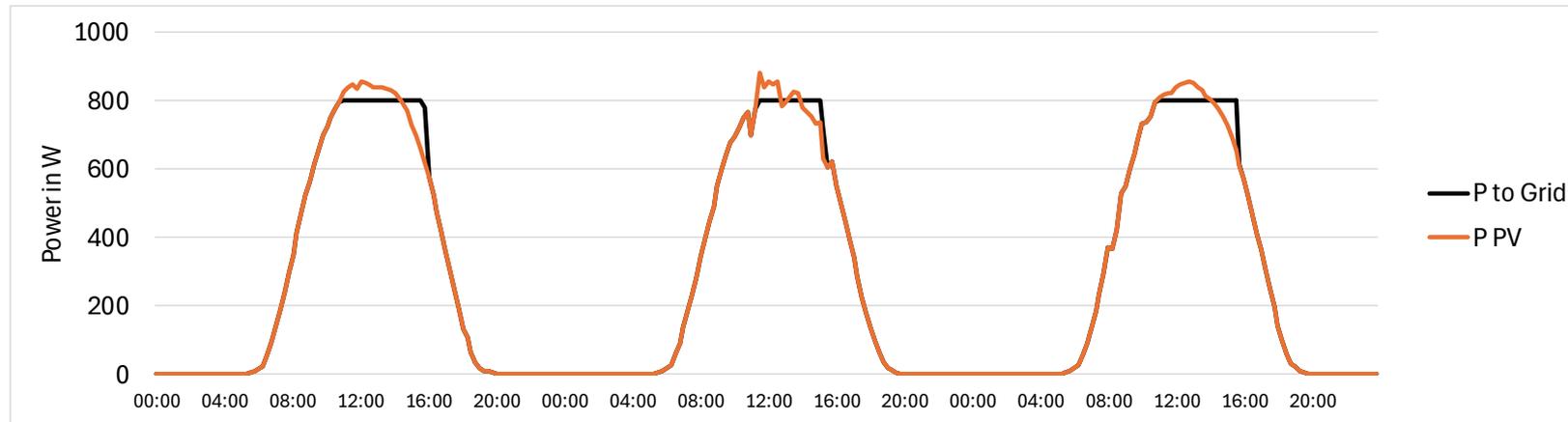
Grid Connection Capacity: 100% (no Curtailment)



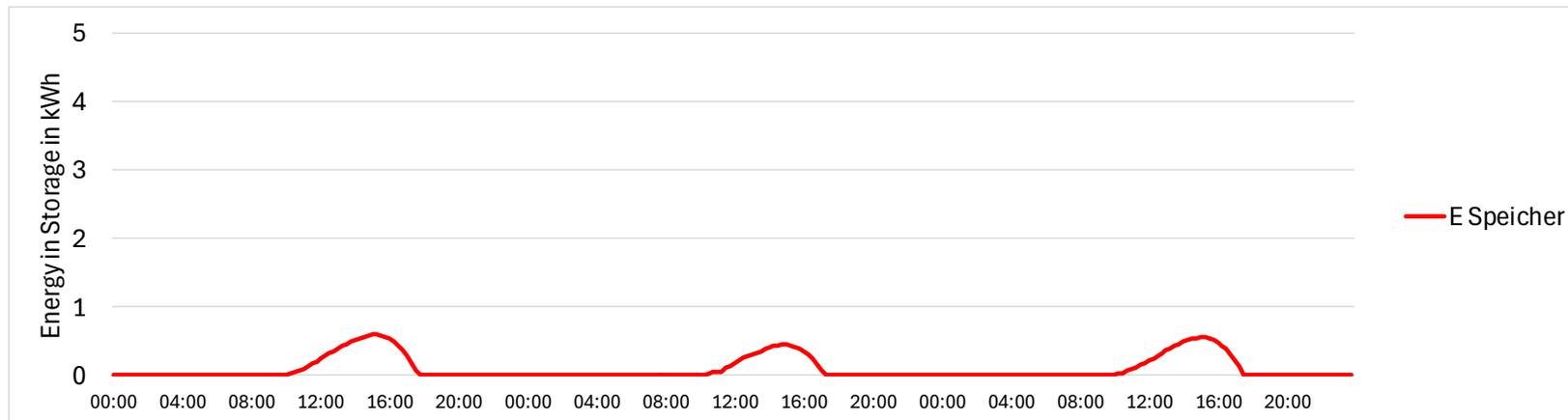
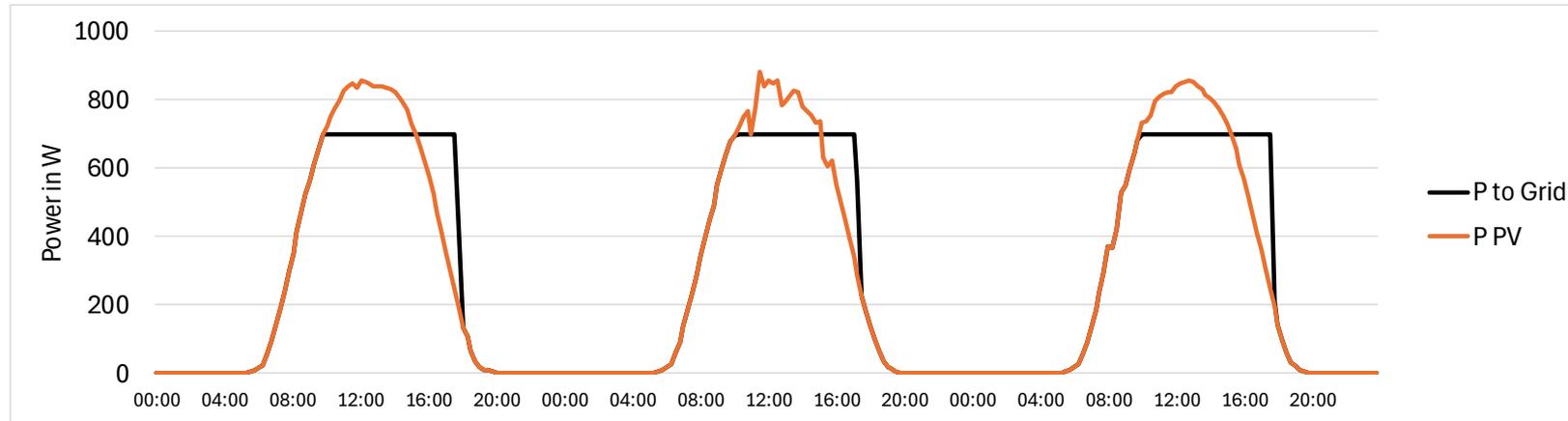
Grid Connection Capacity: 90%



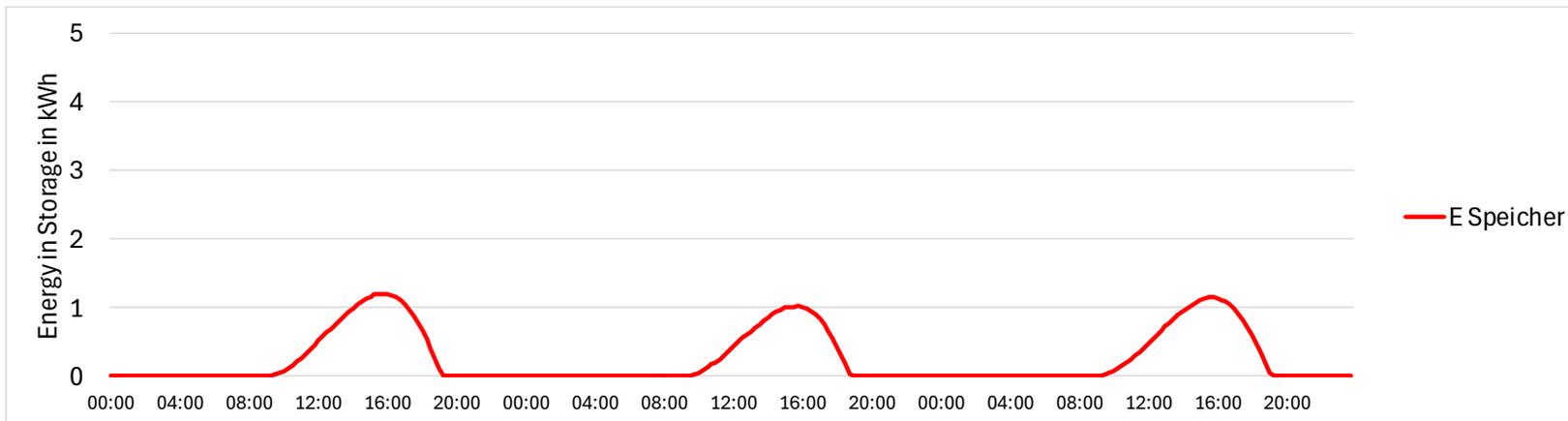
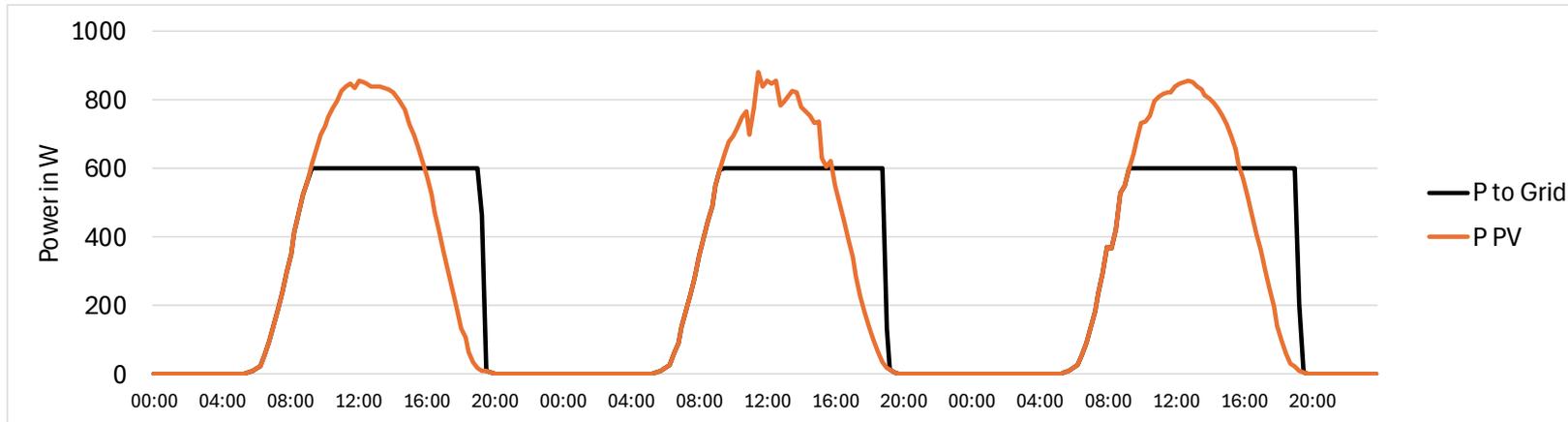
Grid Connection Capacity: 80%



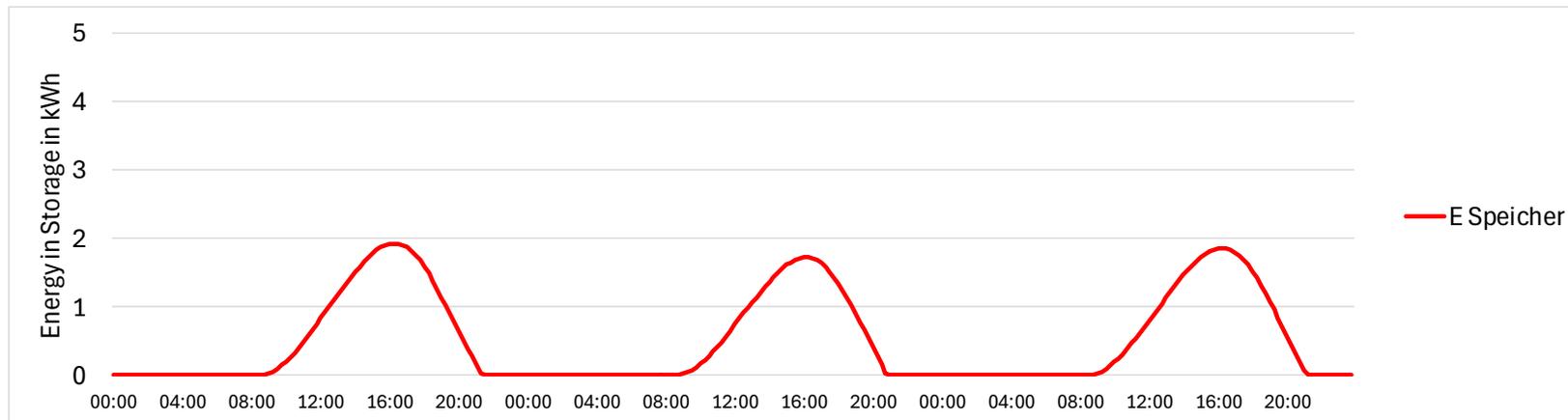
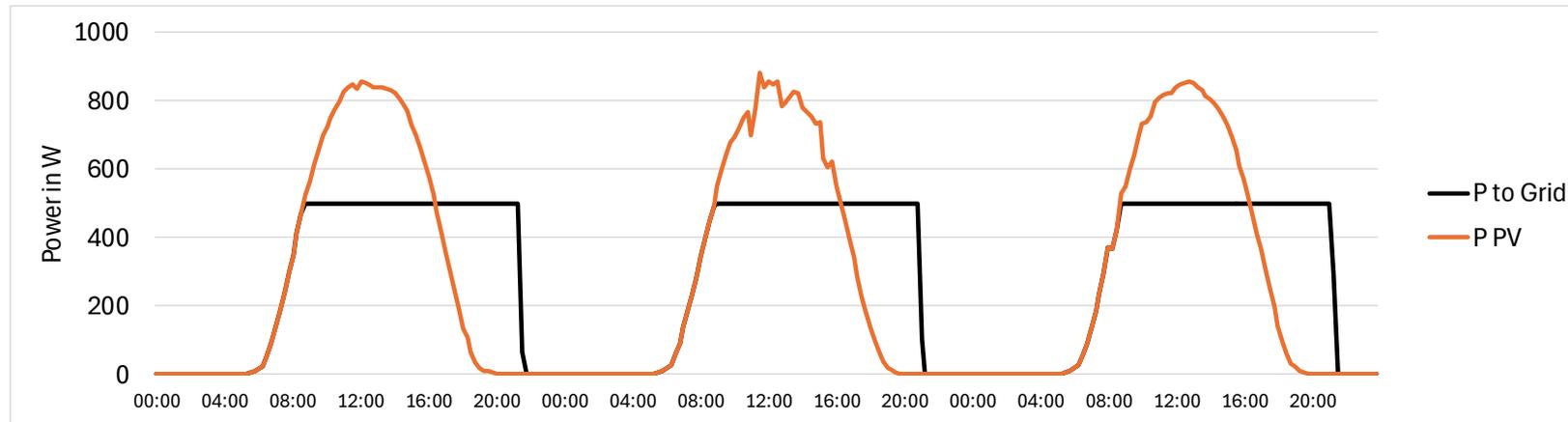
Grid Connection Capacity: 70%



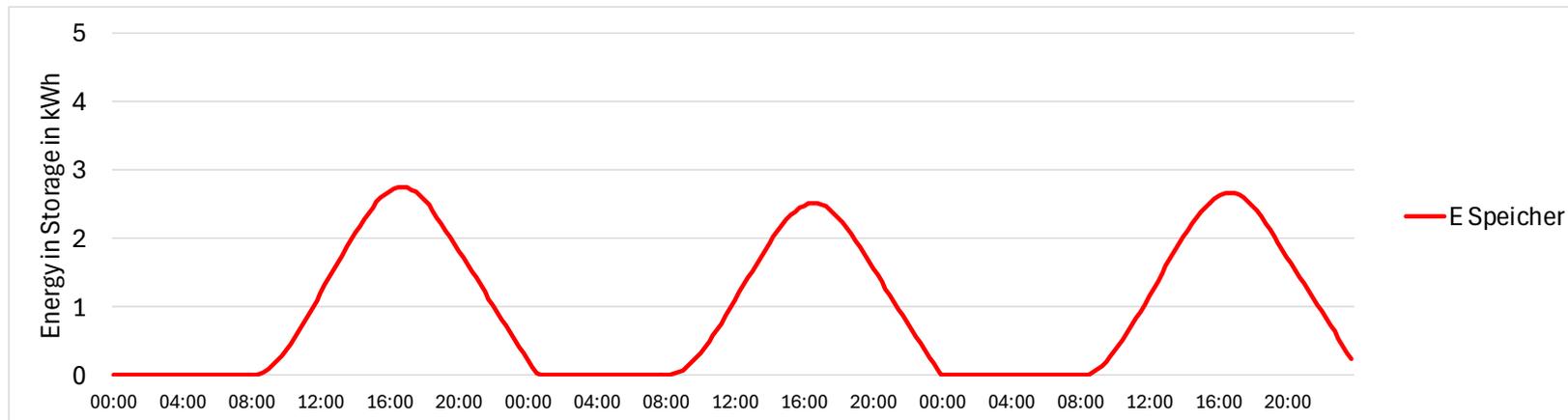
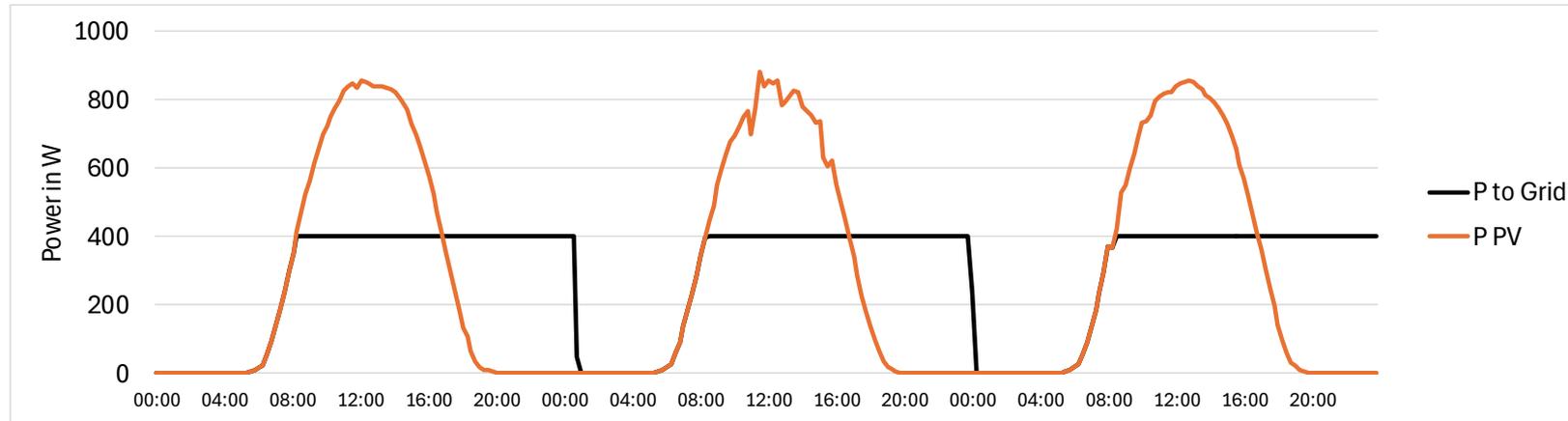
Grid Connection Capacity: 60%



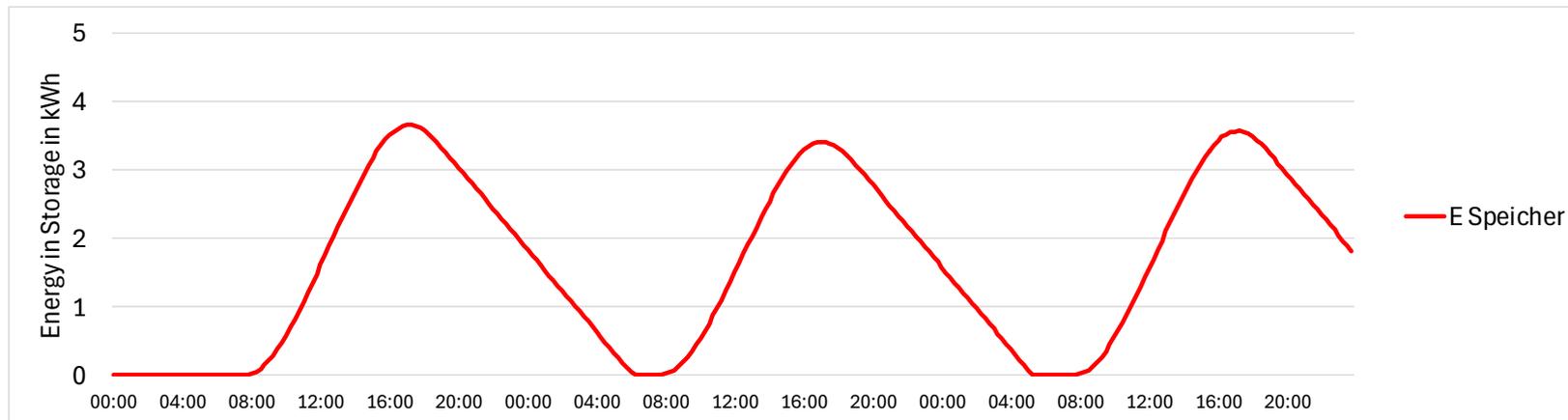
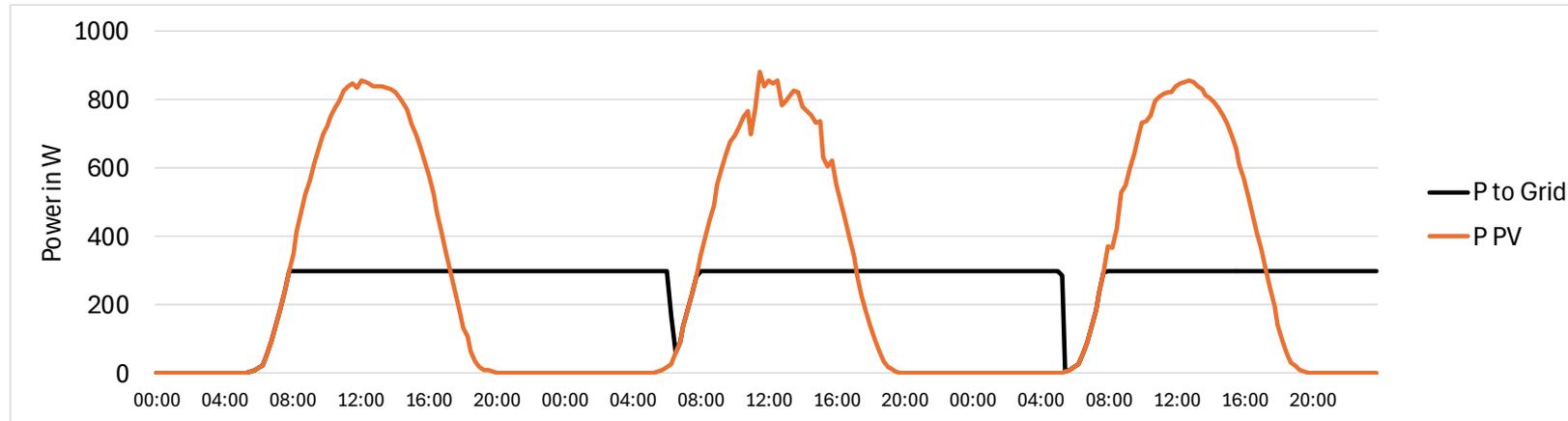
Grid Connection Capacity: 50%



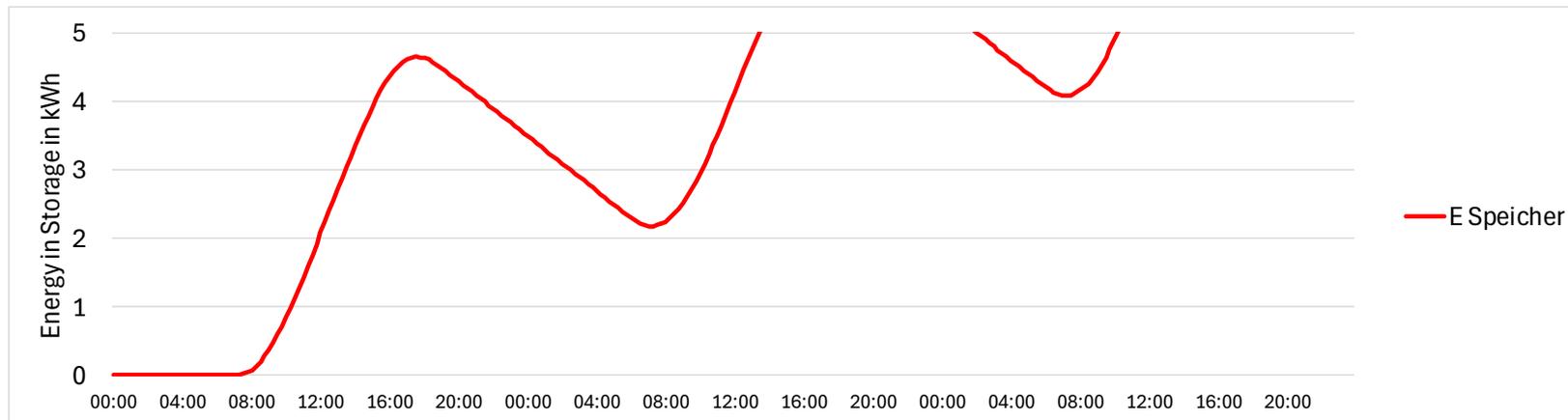
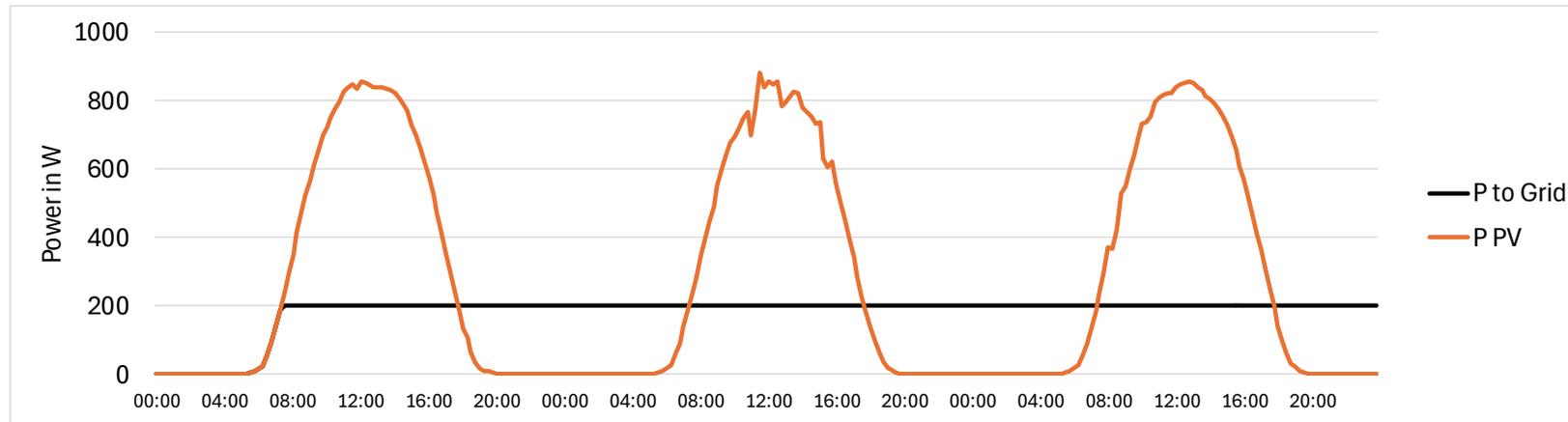
Grid Connection Capacity: 40%



Grid Connection Capacity: 30%



Grid Connection Capacity: 20%



Conclusion for PV Systems

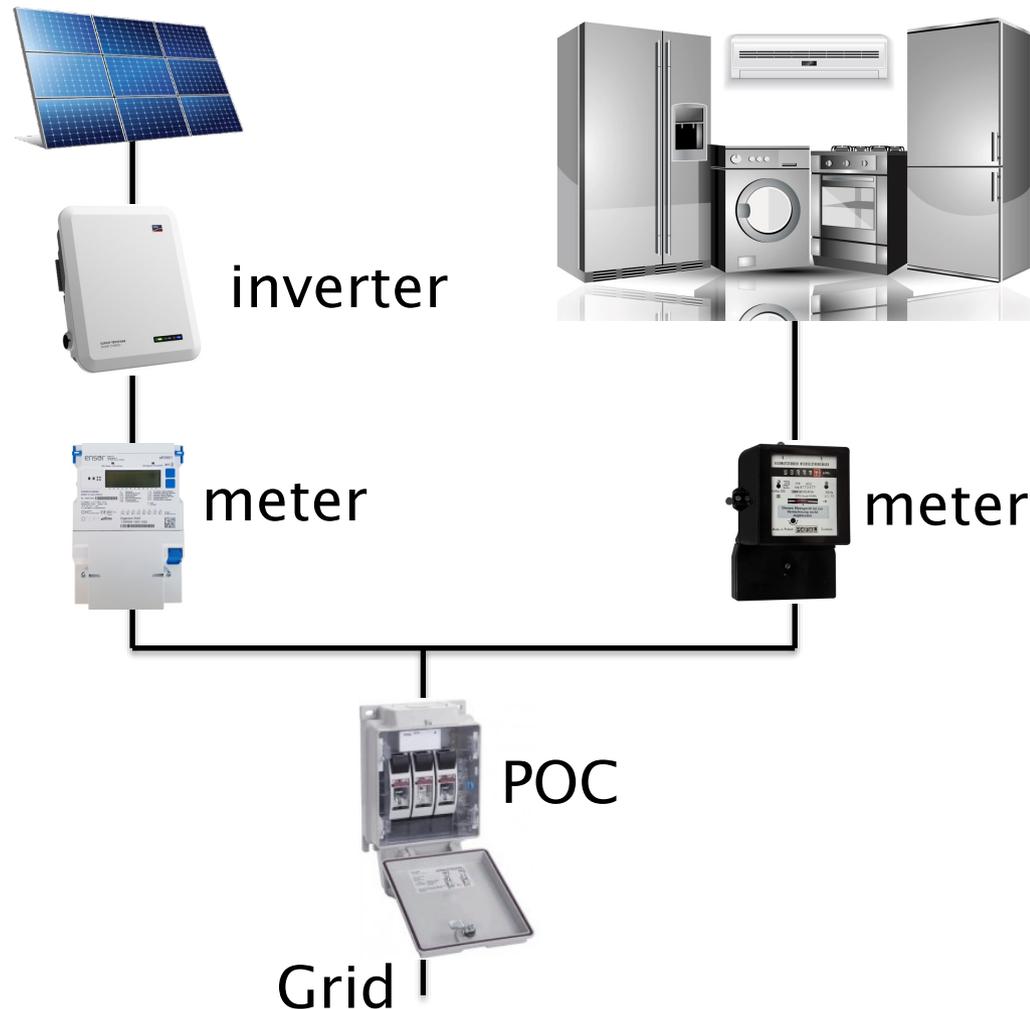
The Bottleneck Isn't the Grid — It's the Prosumer

- ▶ Lack of load during solar peak production times.
- ▶ Grid reinforcement does not change this situation.

However:

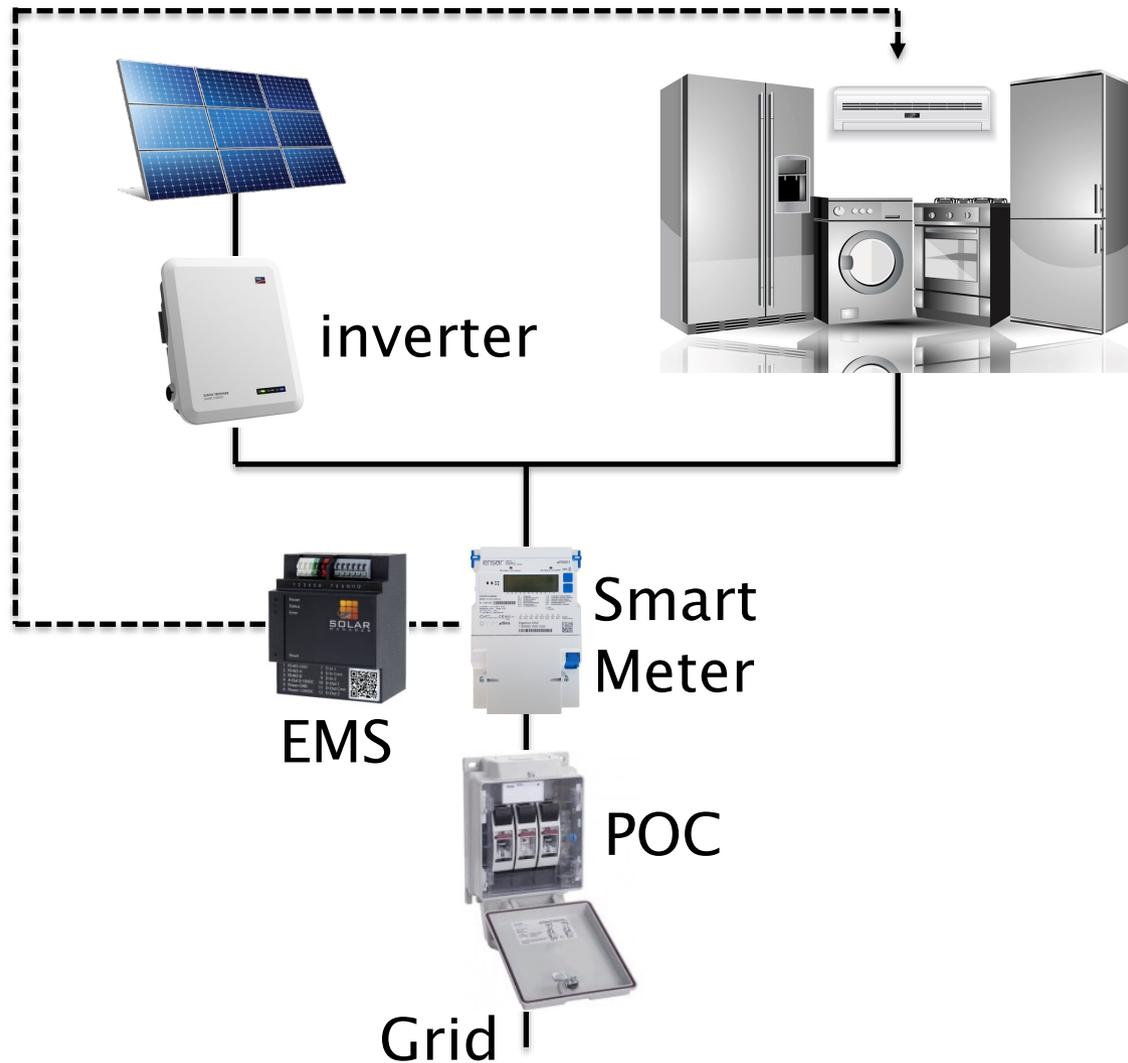
- ▶ Some strategic grid expansion projects are important.
- ▶ Large solar power plants located far from consumption centres require grid reinforcement.
- ▶ However, the grid's PV hosting capacity could be tripled if PV systems if storage and curtailment was used wisely.

PV Systems Yesterday



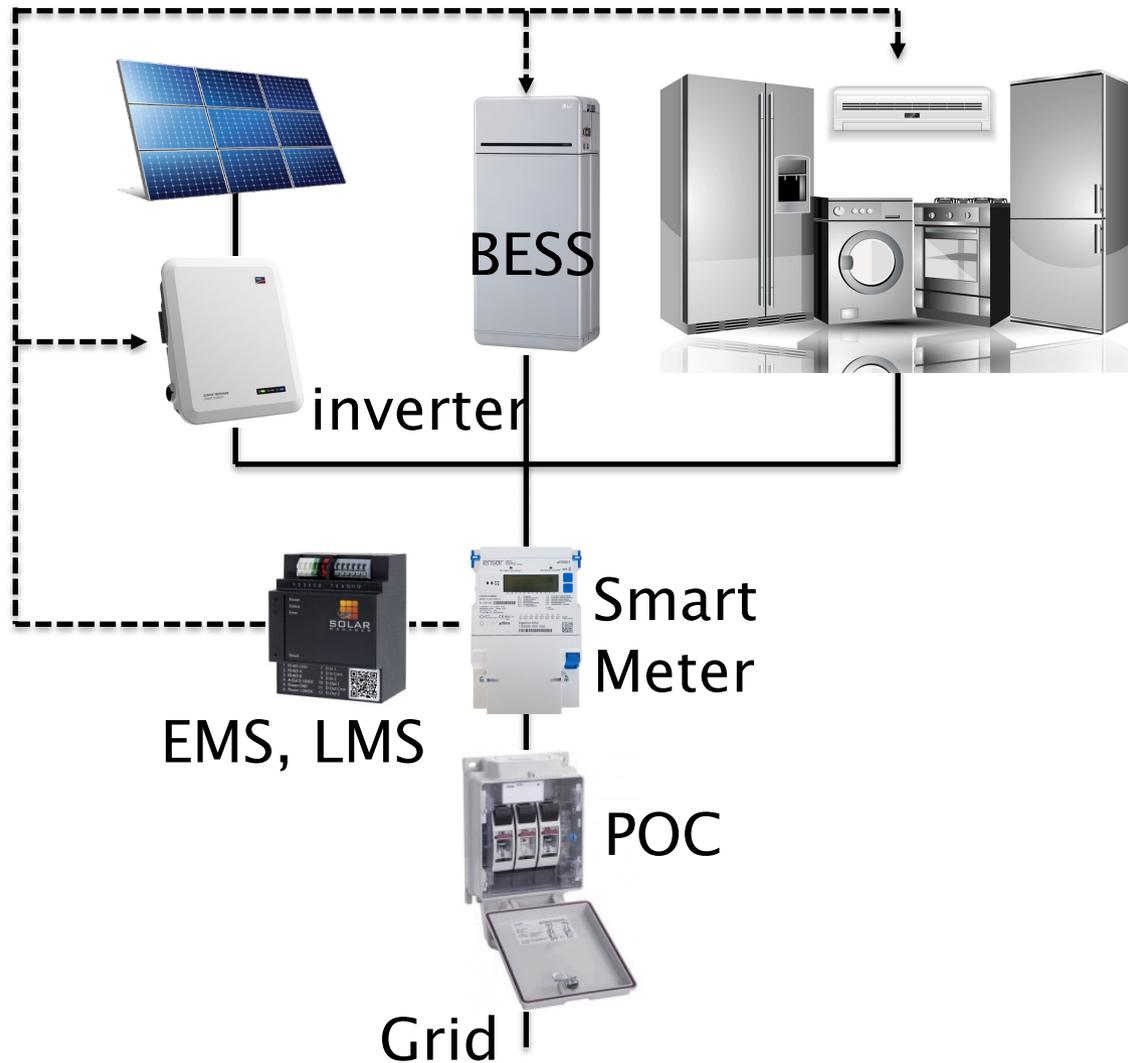
- ✓ 100% Feed-In
- ✓ Every kWh counts
- ✗ Self-consumption
- ✗ Feed-in control
- ✗ Dynamic tariffs

PV Systems Today



- ✗ ✓ 100% Feed-In
- ✗ ✓ Every kWh counts
- ✓ Self-consumption
- ✗ Feed-in control
- ✗ Dynamic tariffs

PV Systems Tomorrow

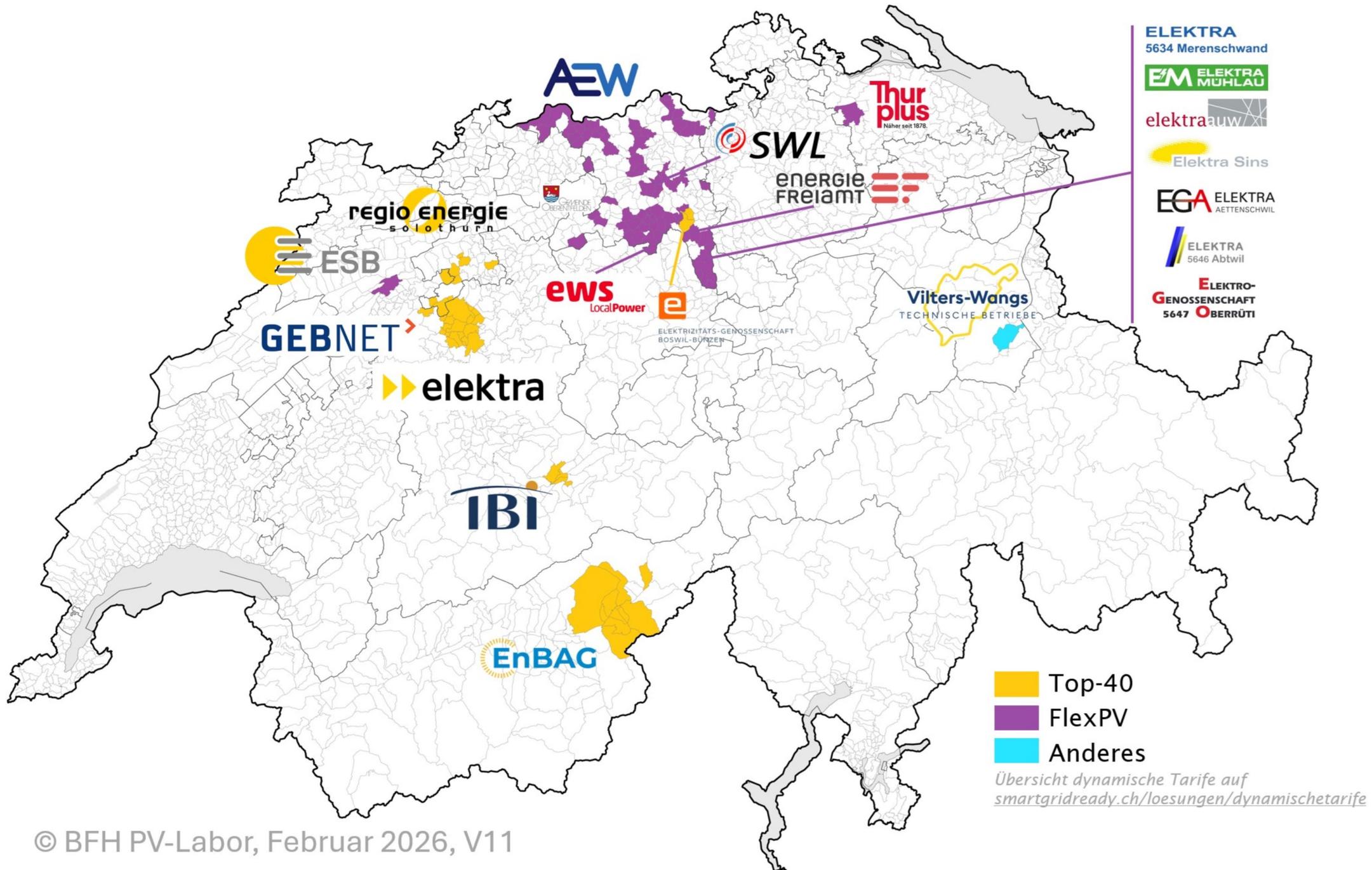


- ✗ 100% Feed-In
- ✗ Every kWh counts
- ✓ Self-consumption
- ✓ Feed-in control
- ✓ Dynamic tariffs

The PV system Compatible with the Energy Transition

- Fills the roof to the maximum: As much DC power as possible.
- Has an energy AND power management system. Regulates at the grid connection
- Can process signals (incentive and control signals):
 - ▶ From the Internet
 - ▶ From the grid operator
 - ▶ From an aggregator
 - ▶ From the building (smart meters, from devices)
- Communication does not have to be fail-safe
- Is fail-save: In the event of a communication failure, it goes to a fixed value released by the DSO with the connection request (e.g. 30% of the DC nominal power)

- ▶ Outlook: The same principles apply to flexible loads and storage





Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

Thank you for your Attention!

Prof. Dr. Christof Bucher