

Impact of self-consumption on regional PV power feed-in

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IEA PVPS Task 16 parallel event: Regional PV power modelling and forecasting

15.09.2026, Rotterdam

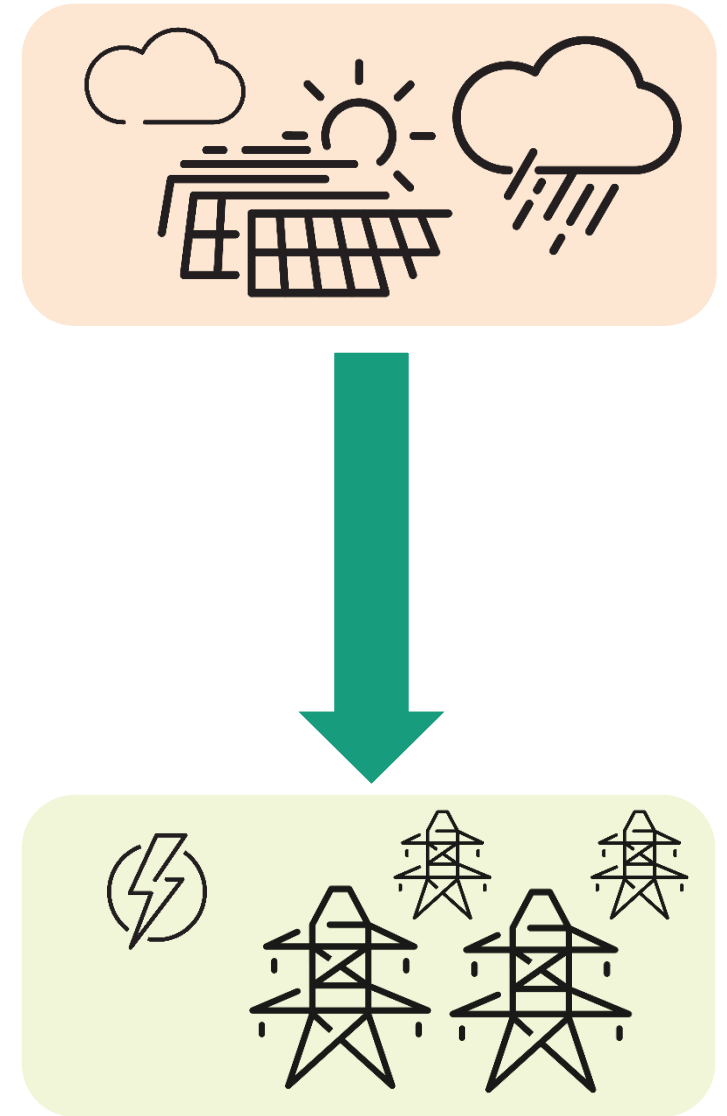
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Motivation

Grid integration of PV power

Patterns of PV power feed-in are changing

PV generation



Motivation

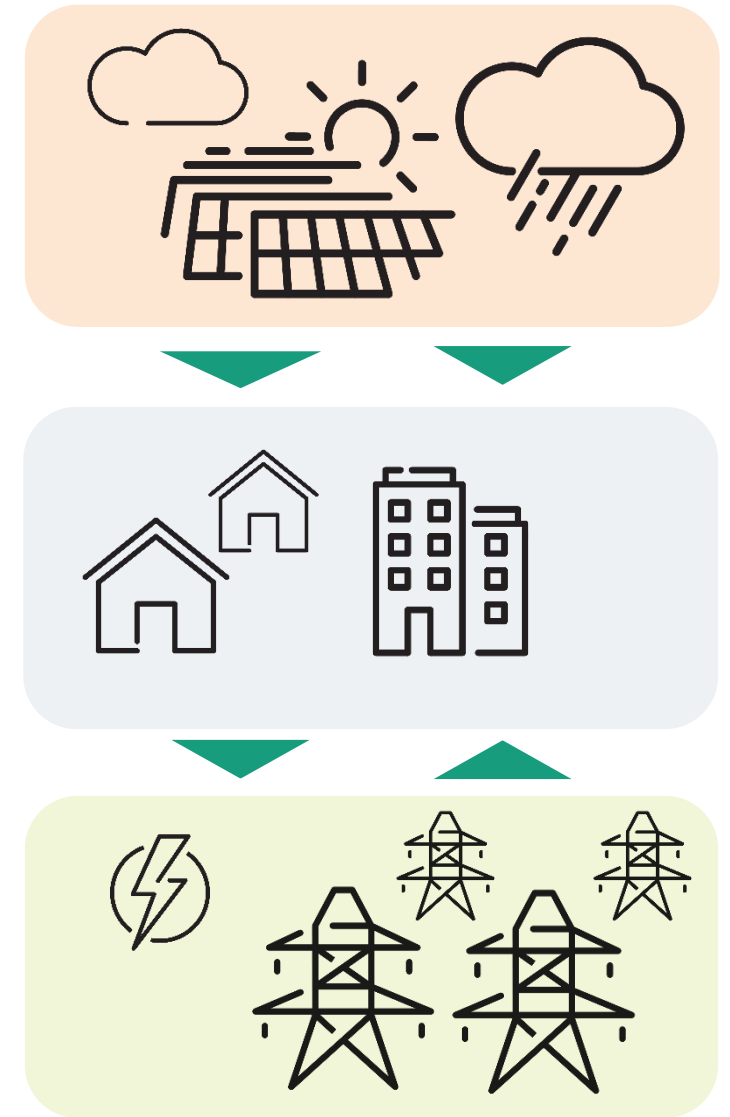
Grid integration of PV power

Patterns of PV power feed-in are changing

PV generation

PV self-consumption:

PV generation minus local consumption



Motivation

Grid integration of PV power

Patterns of PV power feed-in are changing

PV generation

PV self-consumption:

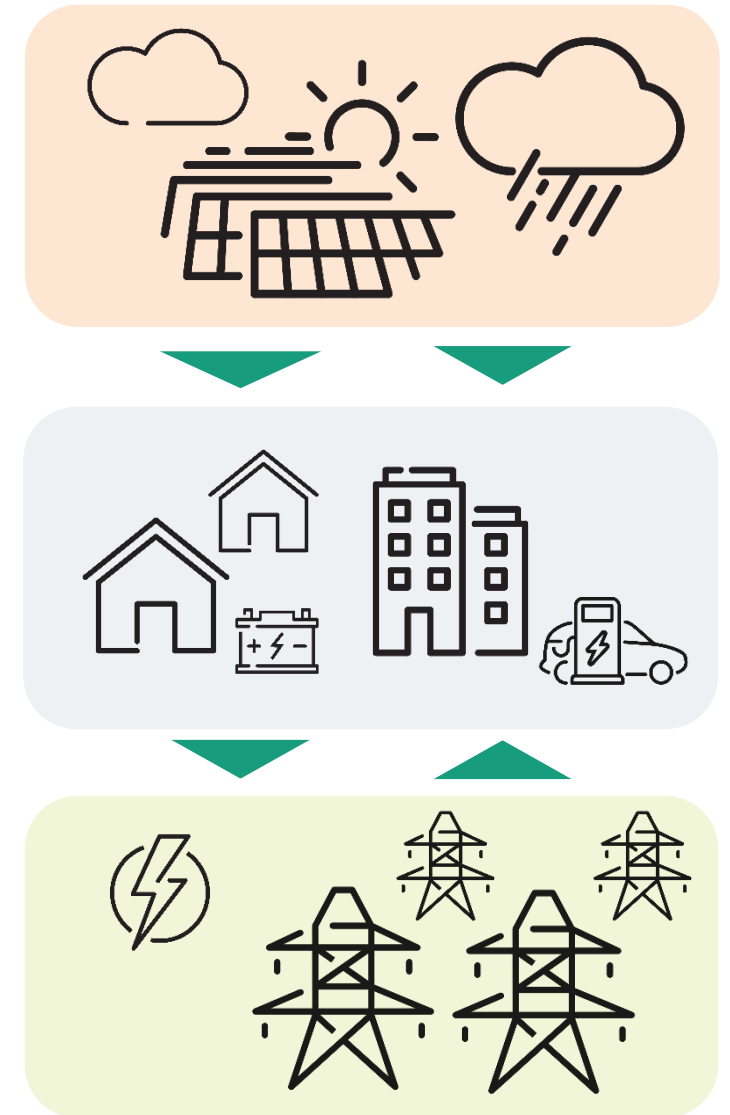
PV generation minus local consumption

PV self-consumption with local energy management:

Modification of PV power feed-in with battery storage and flexible consumption

Feed-in limits/curtailment

➡ **New models for estimating regional PV Power feed-in necessary for marketing and reliable operation of electricity grids**



Regional PV-Power estimation with self-consumption

Project PVEV

Aim PVEV

Development of models for estimating regional PV Power feed-in

- Understanding of behaviour and influencing factors
- Operational estimation of regional PV Power feed-in
- Future scenarios with increasing share of batteries and additional electrical loads (e.g. heat-pumps and e-mobility)

Supported by:



on the basis of a decision
by the German Bundestag



Agenda

How to model regional PV power feed-in with self-consumption?

How are regional PV feed-in patterns changed by PV self-consumption for different consumption categories?

How well does our model capture actual PV power feed-in?

Approach PVEV

Constraint: Data availability

Measured time-series of local **PV-generation, consumption, and PV power feed-in** available for few PV prosumers only

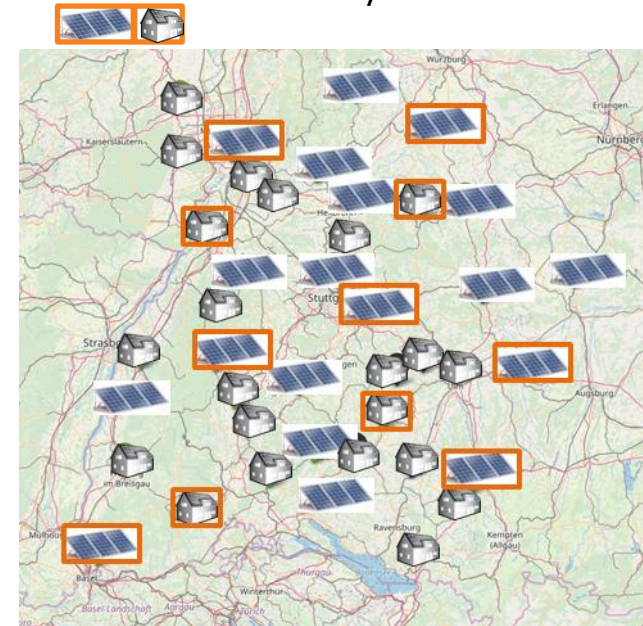
Challenges

- Daily, weekly and annual patterns change in dependence of weather conditions → complex
- Measurements are available mainly for larger systems → not representative for all systems

Approach

- Bottom-up simulation of PV power feed-in

PV and PV prosumer reference systems



Model system PV self consumption

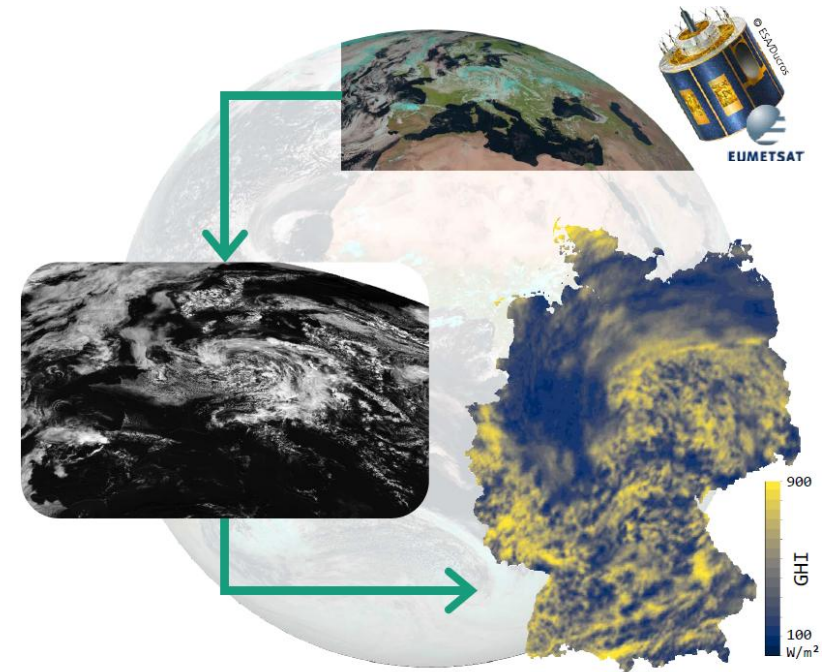
Bottom-up approach

- PV-generation and consumption at individual system level
- Modelling of PV generation
 - Satellite based modelling of solar irradiance
 - PV simulation

-> Needs PV system information

Meteosat Second Generation Satellites

resolution: 15 min. / $\sim 1.3 \text{ km} \times 2.2 \text{ km}$ (BaWü)
Cloud index based version of Heliosat method*



*Hammer A, Heinemann D, Hoyer C, et al., Remote Sens. Environ. 86, 423–432 (2003).

Model system PV self consumption

Bottom-up approach

- PV-generation and consumption at individual system level
- Modelling of PV generation
 - Satellite based modelling of solar irradiance
 - PV simulation
 - > **Needs PV system information**
- Modelling of consumption
 - Residential buildings SynPro*
 - Commerce, trade and services, industry SynGHD**
 - > **Needs information on buildings and their usage**

People and Housing types



Activities and Devices



Data



Individualized Load Profiles



Electric



Domestic Hot Water



Space Heating

* Fischer et al., *Energy and Buildings* 92 (2015), 170

** Wille-Haussmann et al., *Fraunhofer-Institut für Solare Energiesysteme, Tech. Rep.* (2020)

Model system PV self-consumption

Characterisation of PV self-consumption portfolio

Historic data set for model development

- Control area of transmission grid operator TransnetBW (South of Germany) / year 2022
- Approx. 17 thousand systems with measured PV-power feed-in („SOL“)
 - Data available for this study: aggregated on distribution grid level, available to TSO: around 2 months later
 - Mostly large PV systems

PV-prosumer data

- „EEG“-register“ of TransnetBW*
- Basic information on location, installed PV power, designed for PV self-consumption

➡ Additional information necessary!

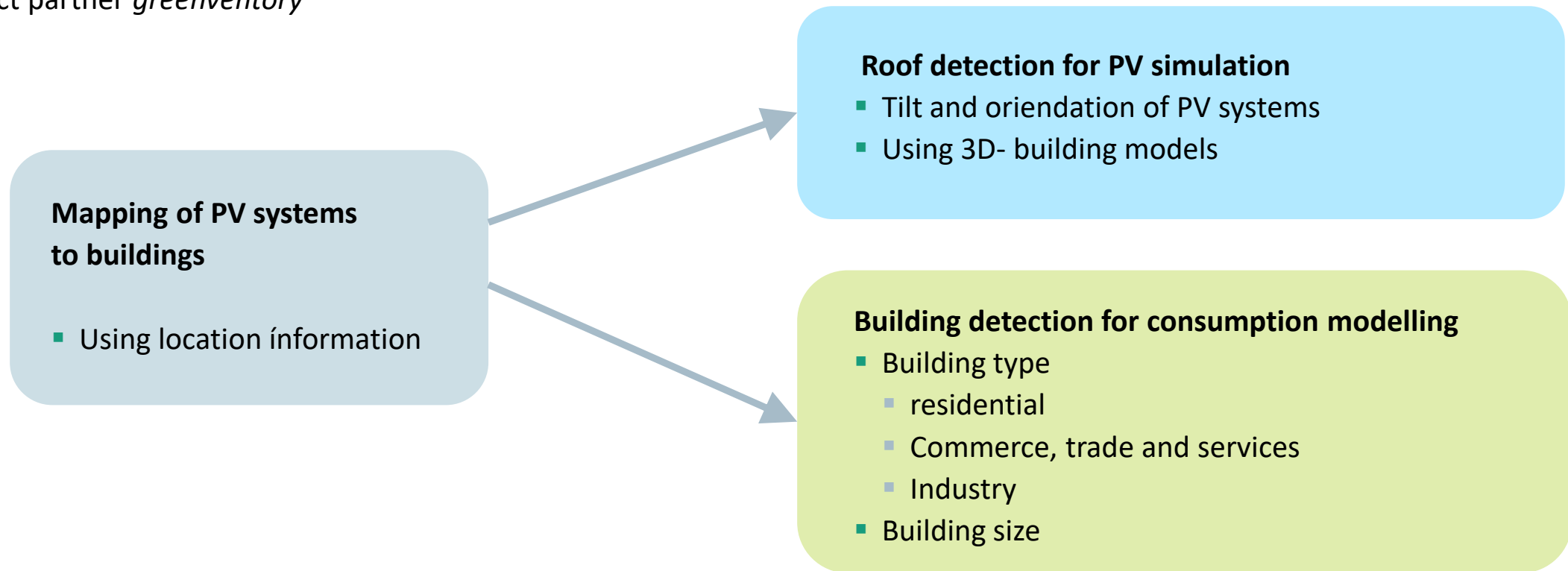
*EEG: German renewable energy sources act

Model system PV self-consumption

Characterisation of PV self-consumption portfolio

Additional information based on geomapping

Project partner *greenventory*



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Analysis of PV self-consumption

Influencing Factors

- Ratio of PV generation to consumption
- Consumption type

Examples shown here

- Case study: residential PV systems with batteries
- Different consumption categories for SOL portfolio TransnetBW (2022)

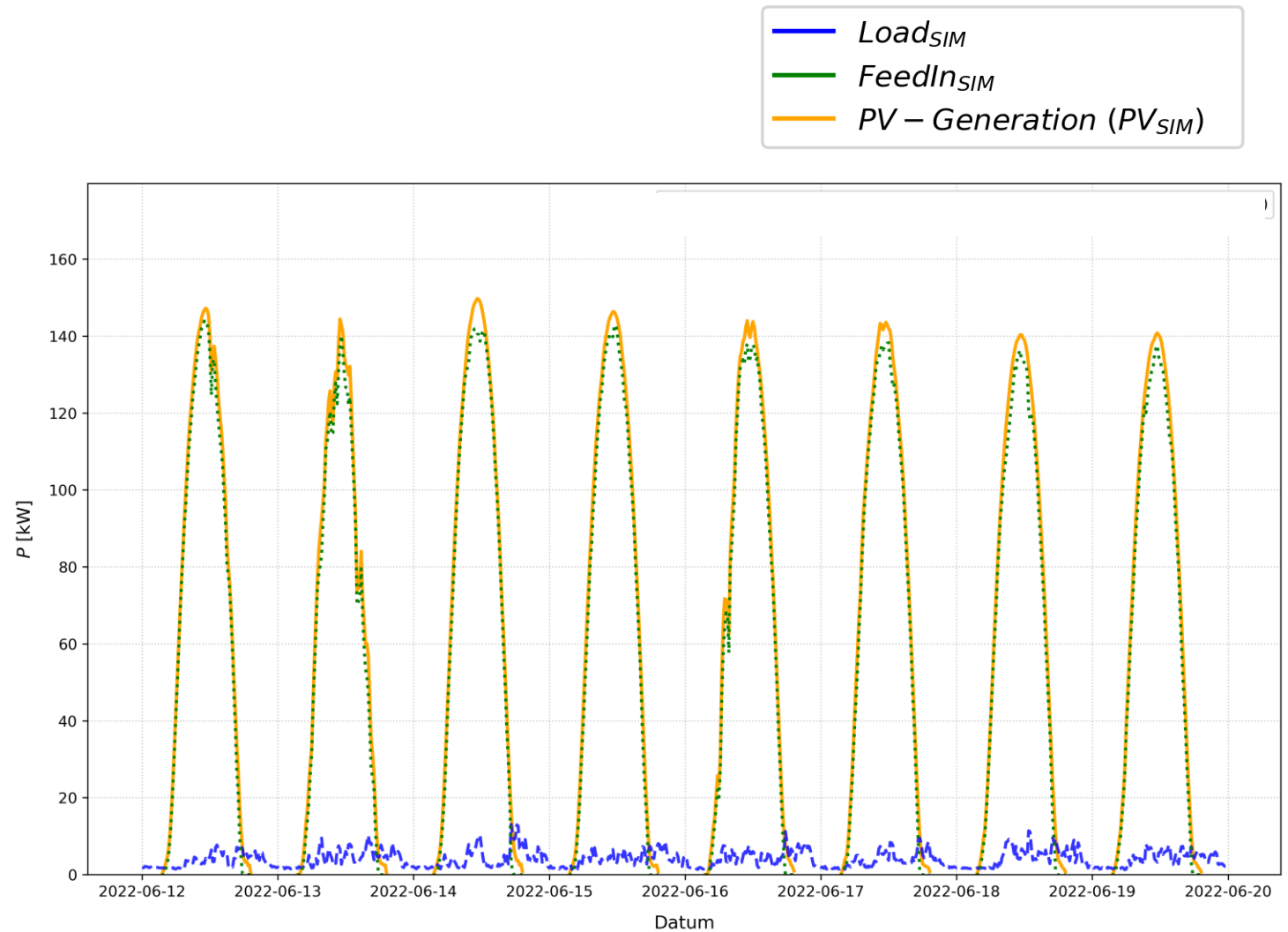
Impact of PV self-consumption

- Daily, weekly and annual patterns change in dependence of weather conditions
- [Focus on daily and weekly patterns here](#)

Analysis of PV self-consumption

Simulation for individual systems

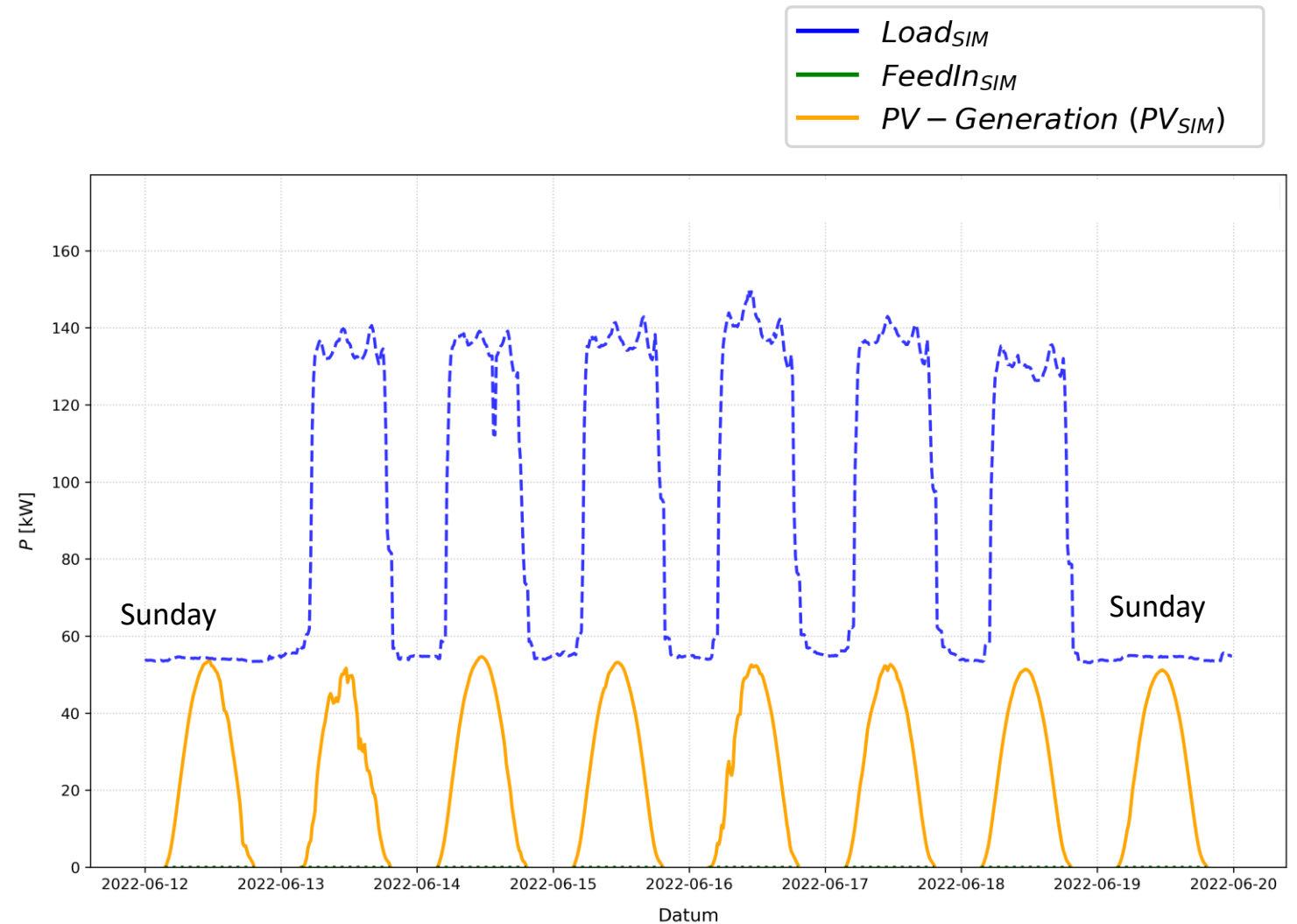
- PV-generation >> consumption
 - PV power feed-in only slightly reduced compared to PV generation



Analysis of PV self-consumption

Simulation for individual systems

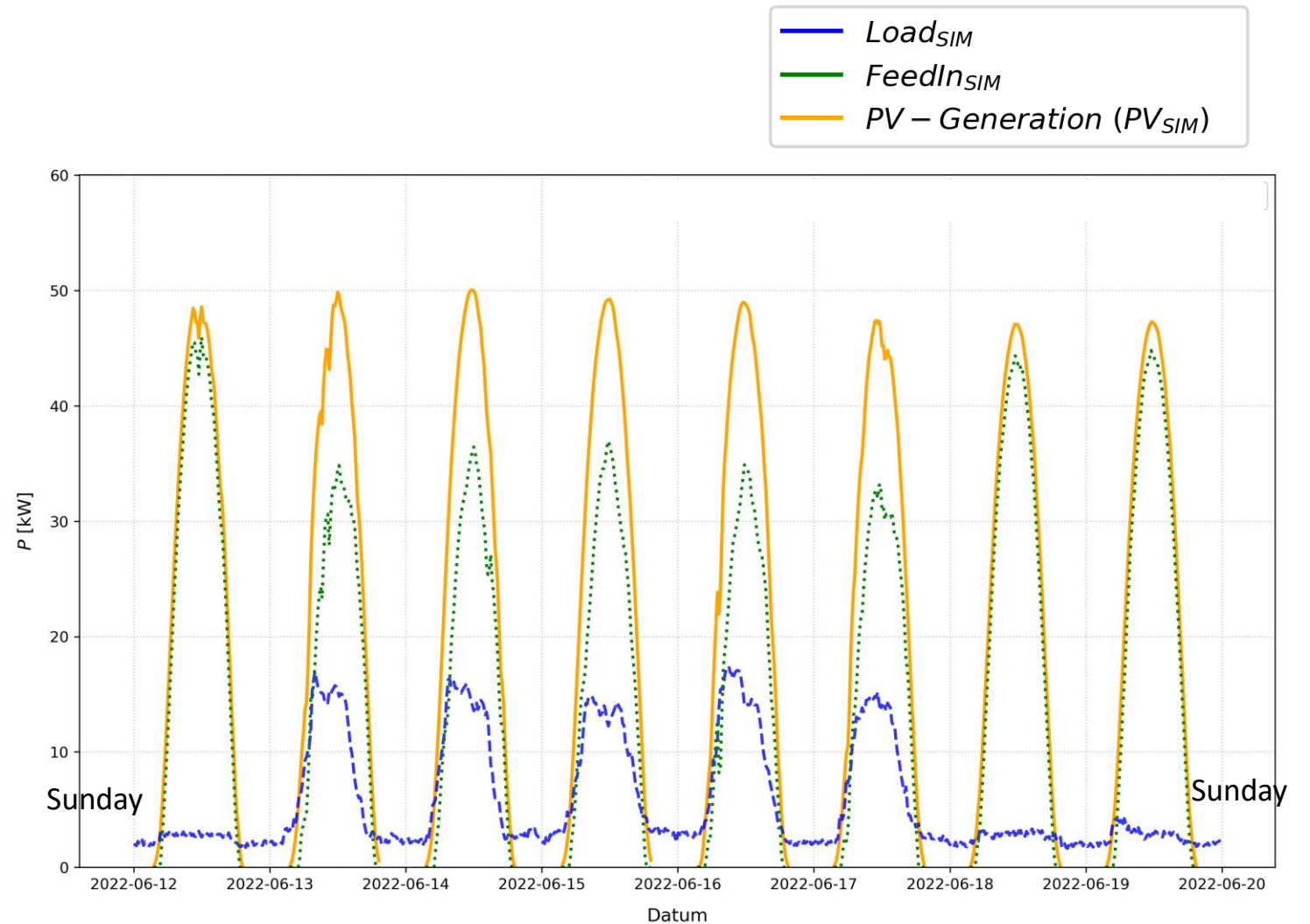
- PV-generation >> consumption
 - PV power feed-in only slightly reduced compared to PV generation
- Consumption >> PV-generation
 - Almost no PV-power feed-in



Analysis of PV self-consumption

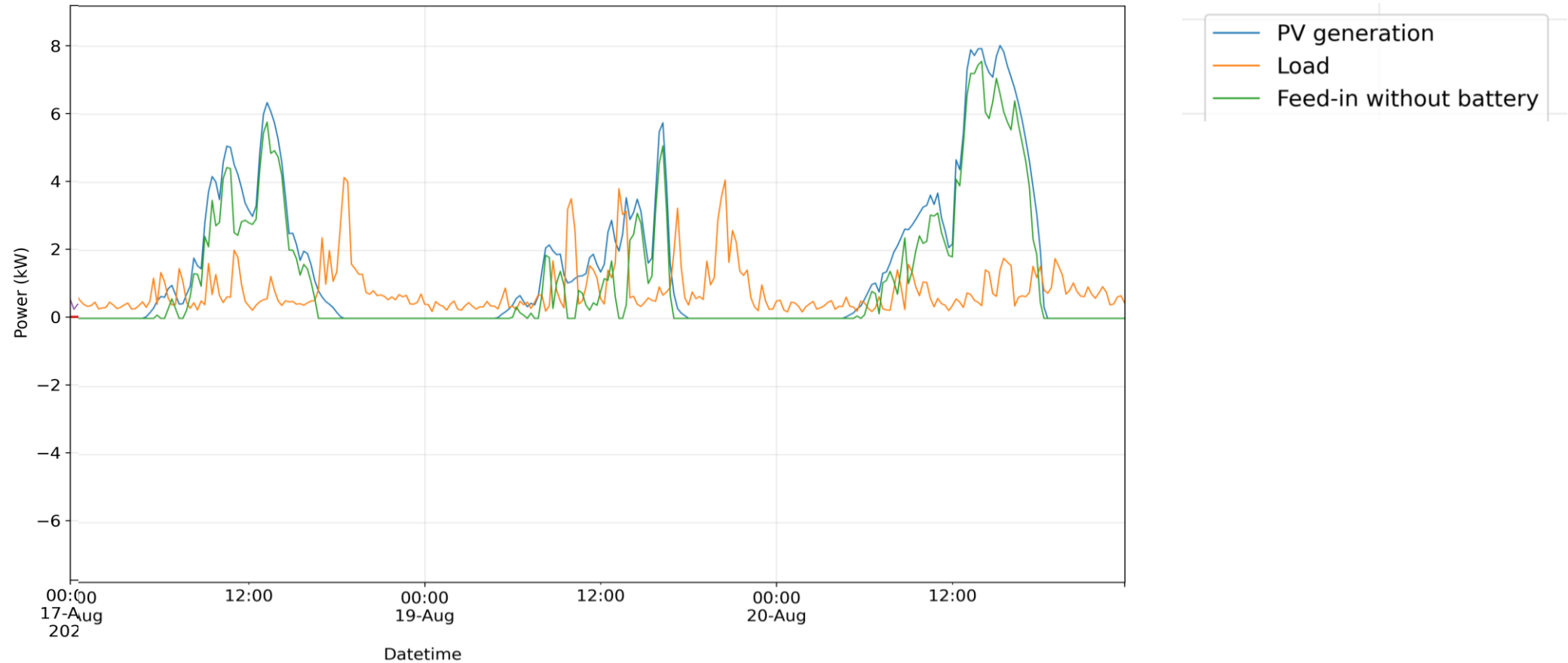
Simulation for individual systems

- PV-generation >> consumption
 - PV power feed-in only slightly reduced compared to PV generation
- Consumption >> PV-generation
 - Almost no PV-power feed-in
- PV generation ~ consumption
 - PV power feed-in strongly reduced compared to generation and influenced by consumption patterns



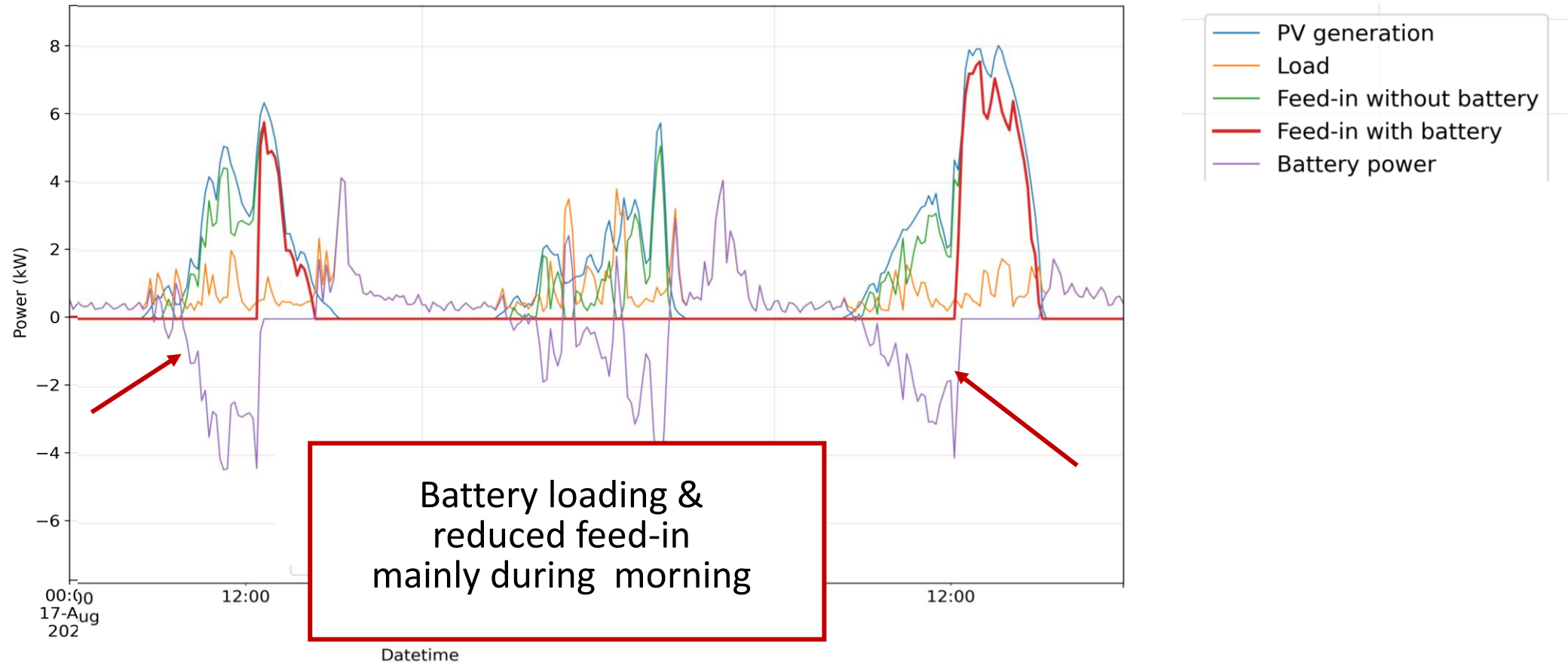
Analysis of PV self-consumption

Simulation for individual systems with battery (small residential systems)



Analysis of PV self-consumption

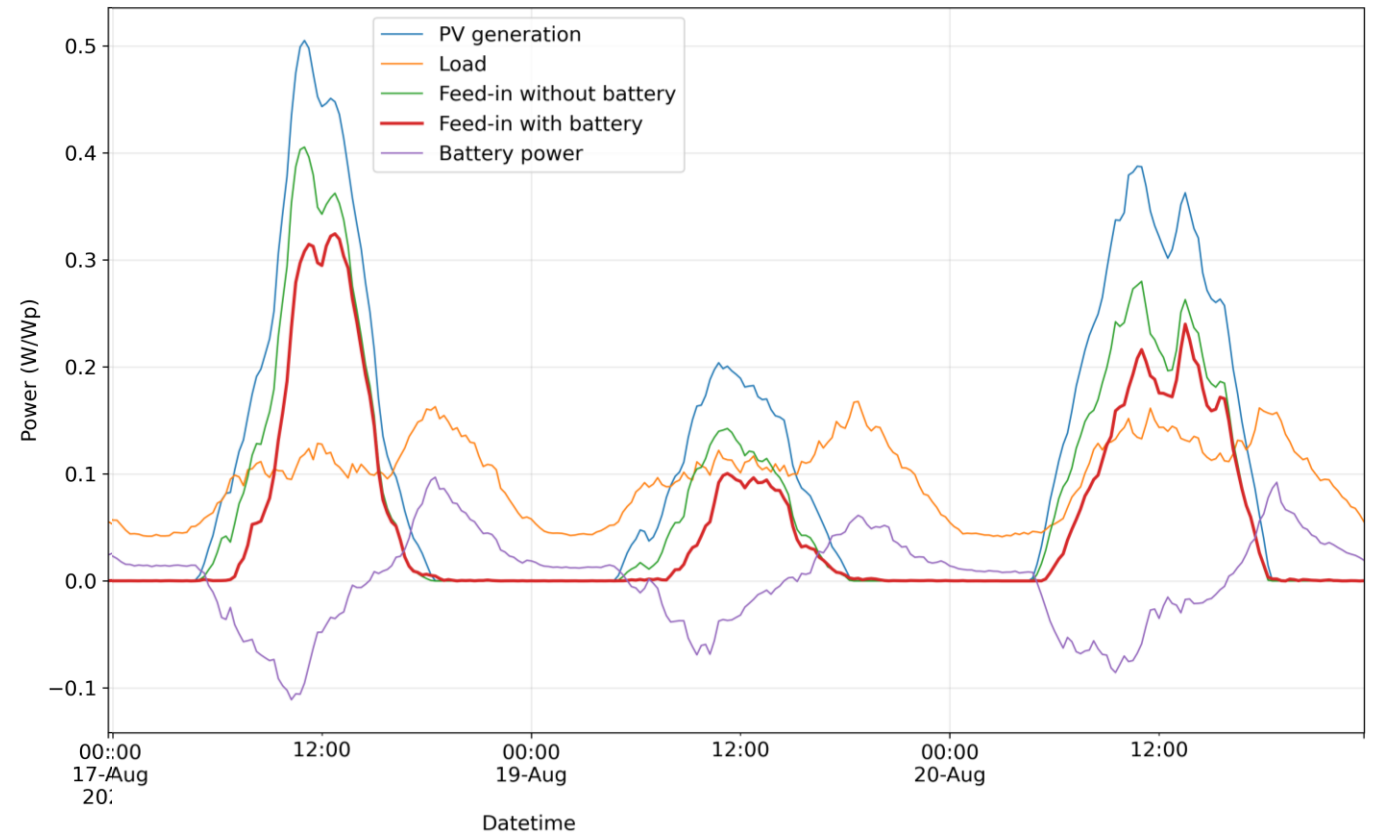
Simulation for individual systems with battery (small residential systems)



Use case residential PV battery systems

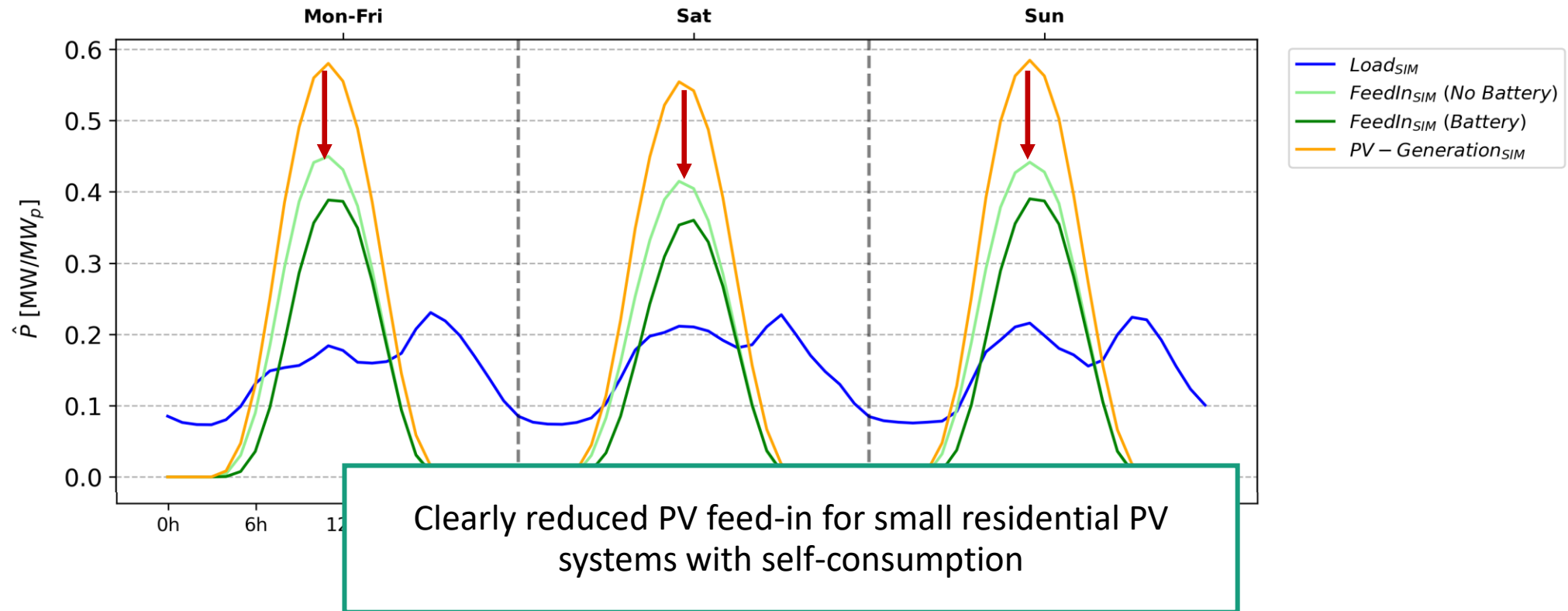
Regional feed power feed-in

- Portfolio of 120 residential PV systems:
Nominal power < 20 kW_{peak}
- Smoother curves due to regional averaging
- PV power feed-in clearly reduced during morning hours



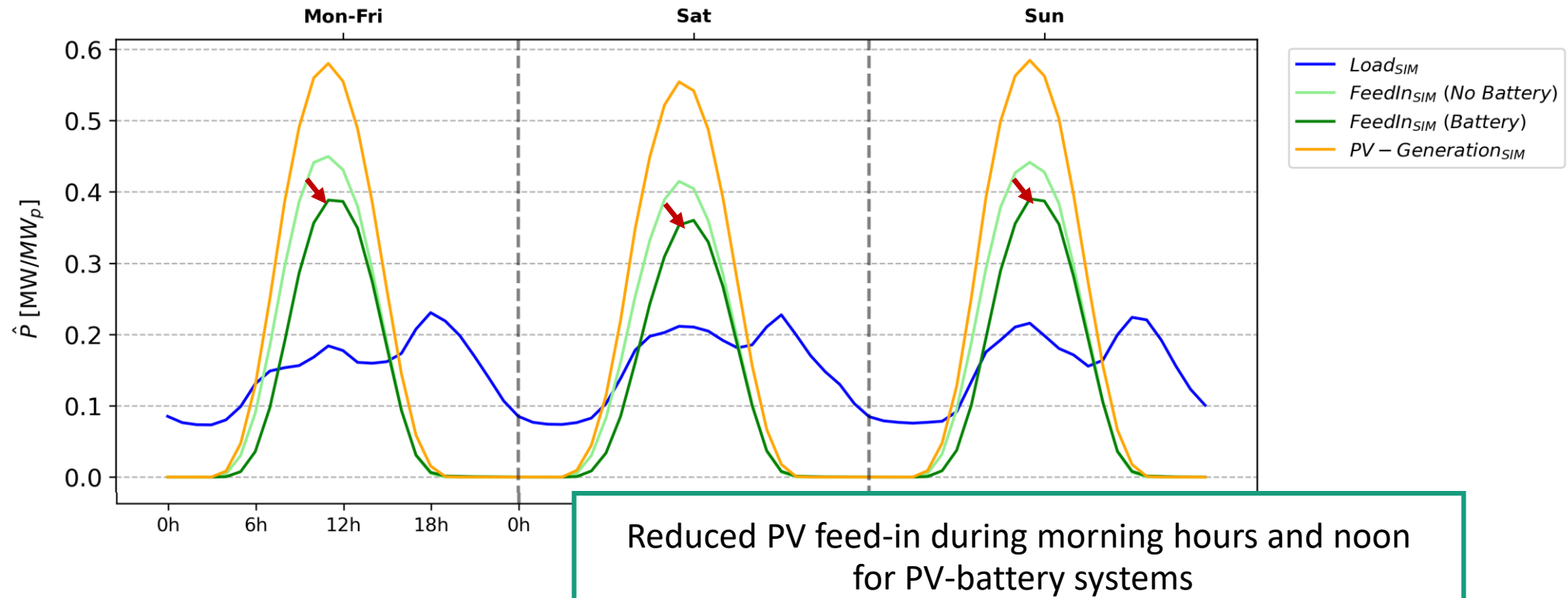
Use case residential PV battery systems

Typical daily profiles of regional PV power feed-in



Use case residential PV battery systems

Typical daily profiles of regional PV power feed-in



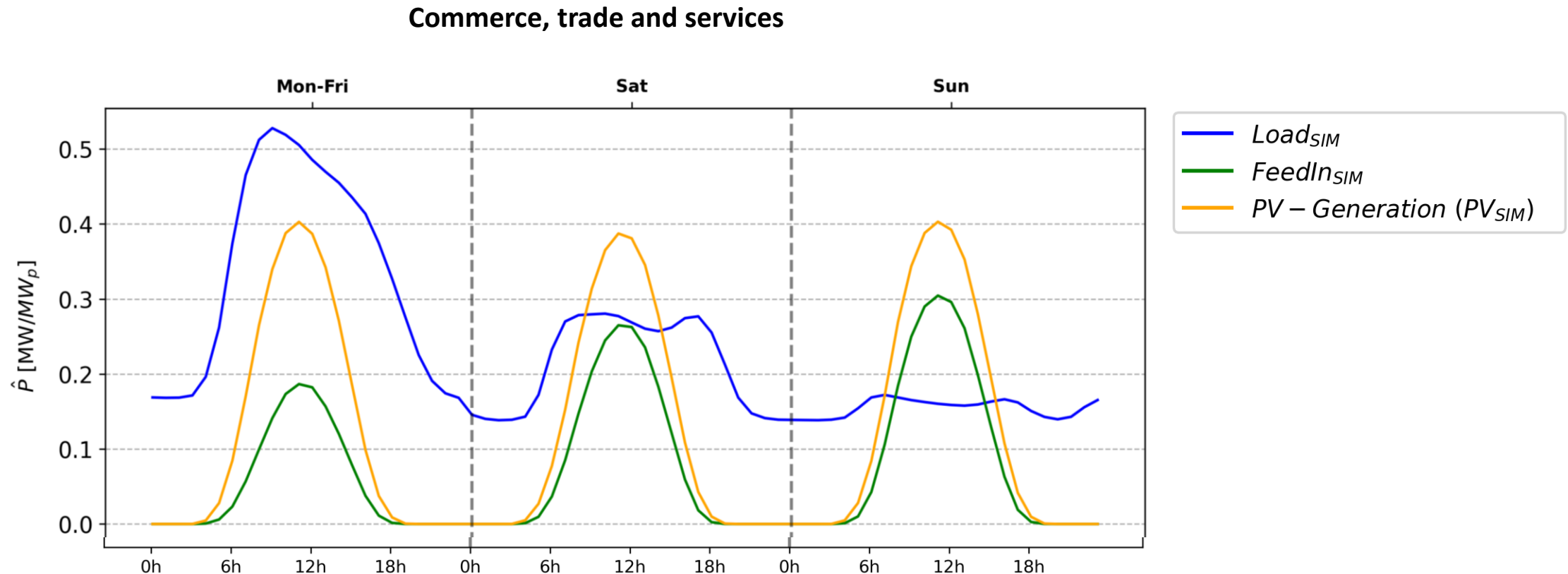
Analysis of PV self-consumption

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Analysis for different consumption categories (SOL portfolio 2022)

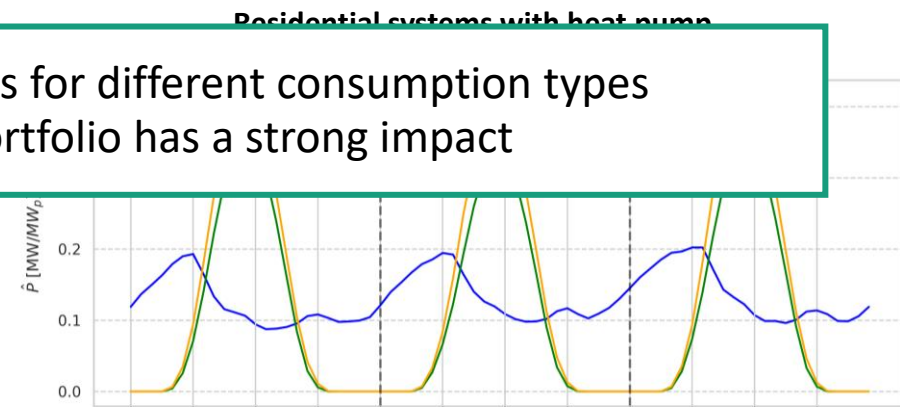
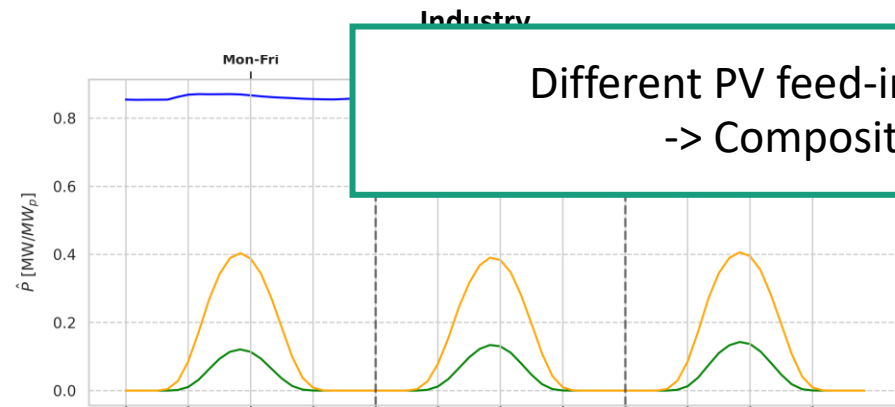
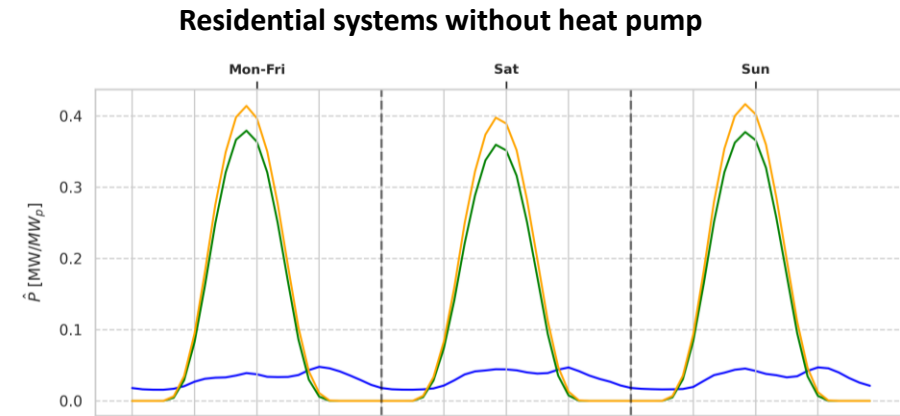
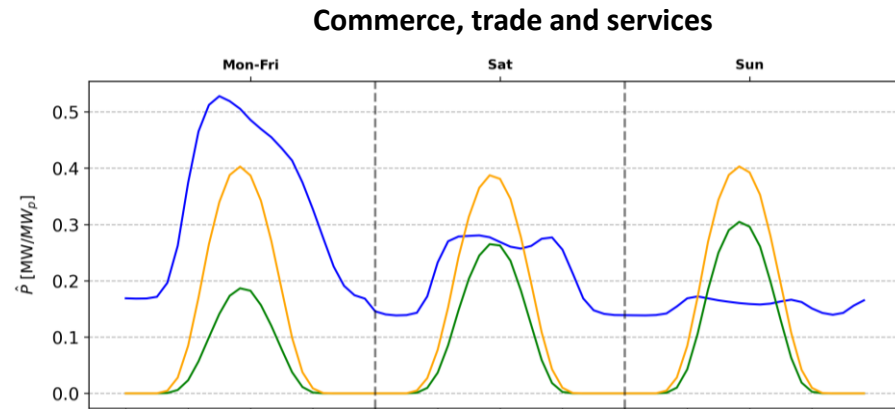
Typical daily profiles of regional PV power feed-in



High consumption during the working days -> strongly reduced PV feed-in
Less consumption on weekends -> more PV feed-in

Analysis for different consumption categories (SOL portfolio 2022)

Typical daily profiles of regional PV power feed-in



Different PV feed-in patterns for different consumption types
-> Composition of portfolio has a strong impact

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How to model regional PV power feed-in with self-consumption?

How are regional PV feed-in patterns changed by PV self-consumption for different consumption categories?

How well does our model capture actual PV power feed-in?

Evaluation of modelled PV self-consumption

Data set

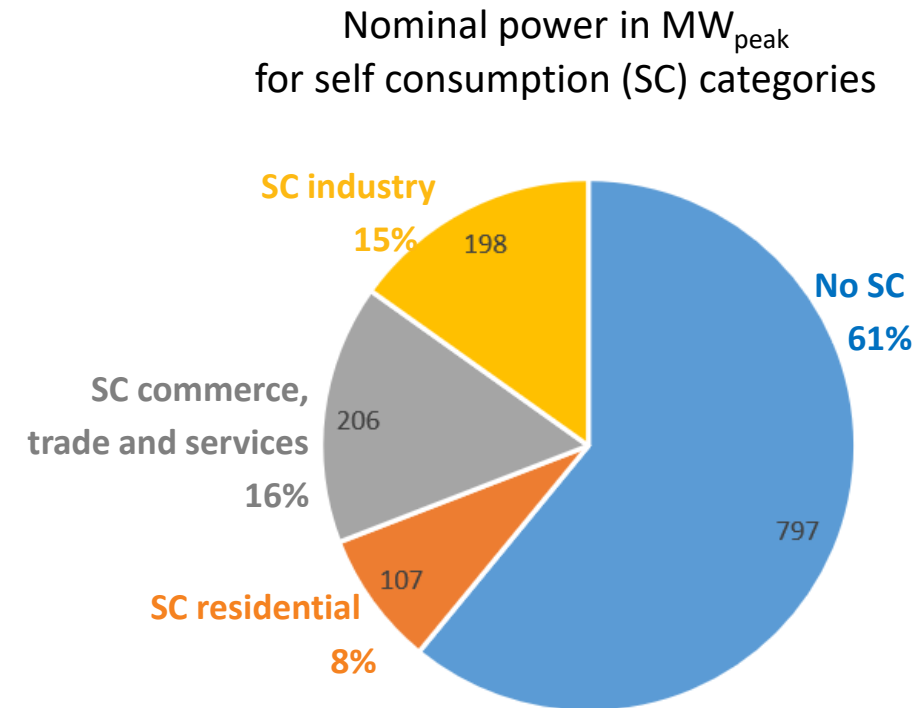
Control area of TransnetBW / year 2022

- Overall:
 - > 500 k PV systems
 - Nominal PV power: ~ 6.9 GW_{peak}
- “SOL” systems with measured PV-power feed-in:
 - 17 k PV systems (3.2 %)
 - Nominal PV Power: ~1.3 GW_{peak} (19%)
 - Regionally aggregated values
 - > Basis for this study and for model validation

Characteristics

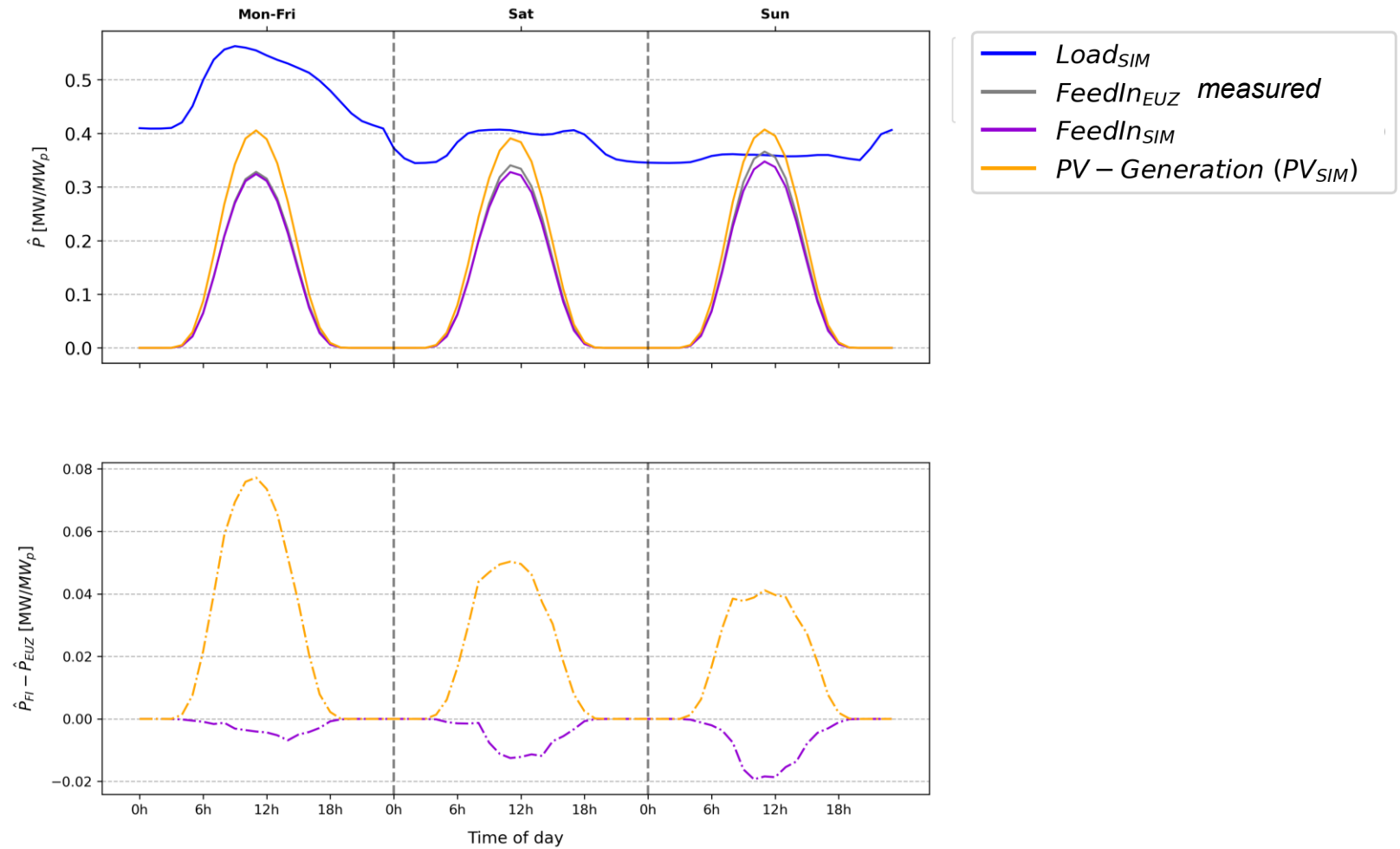
- Mostly large PV-systems
- 39 % self-consumption*
- Very small share of PV battery systems and heat-pumps

*normalized to nominal power



Modelled and measured PV feed-in for 2022 portfolio feed-in

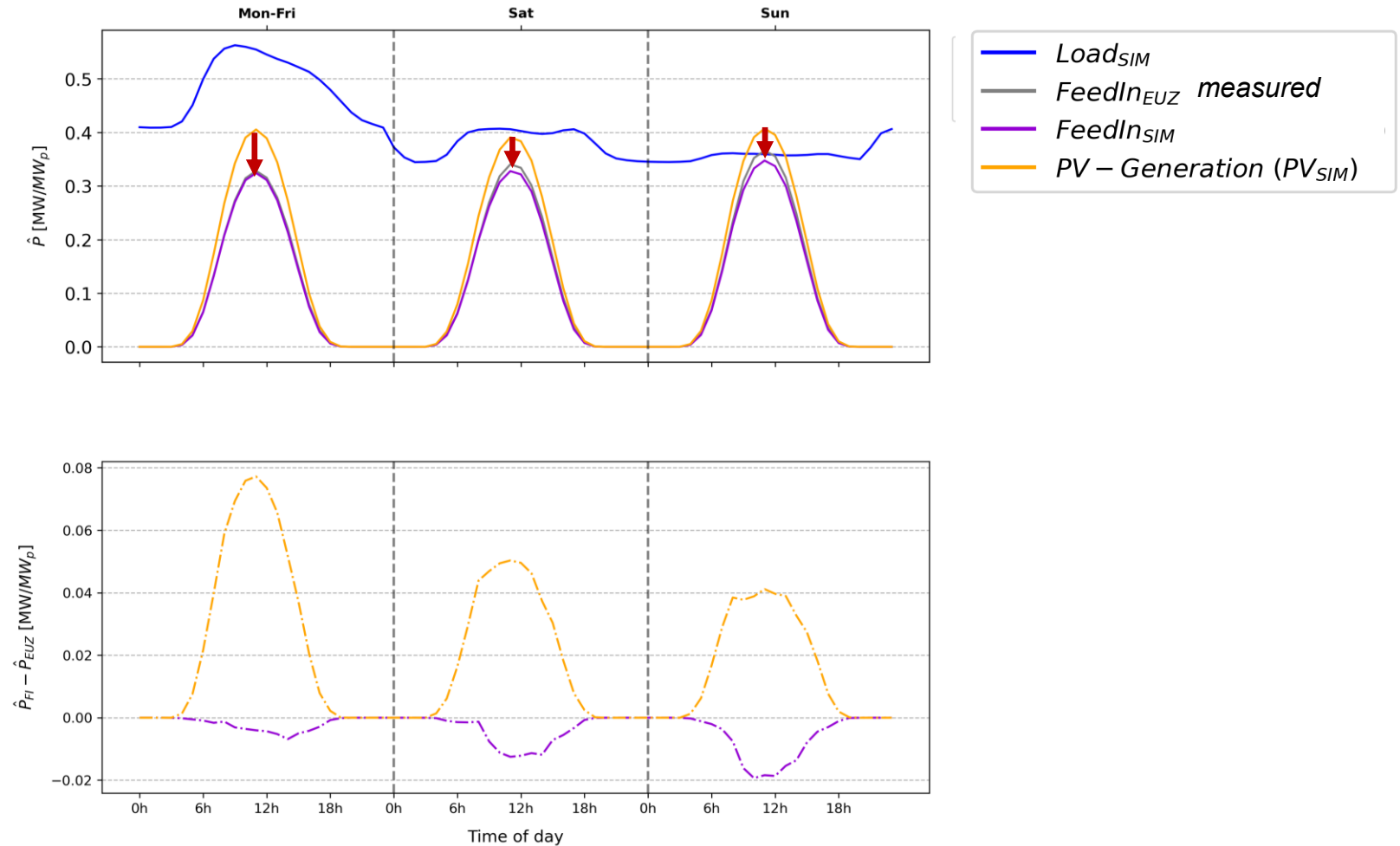
Typical daily profiles



Modelled and measured PV feed-in for 2022 portfolio feed-in

Typical daily profiles

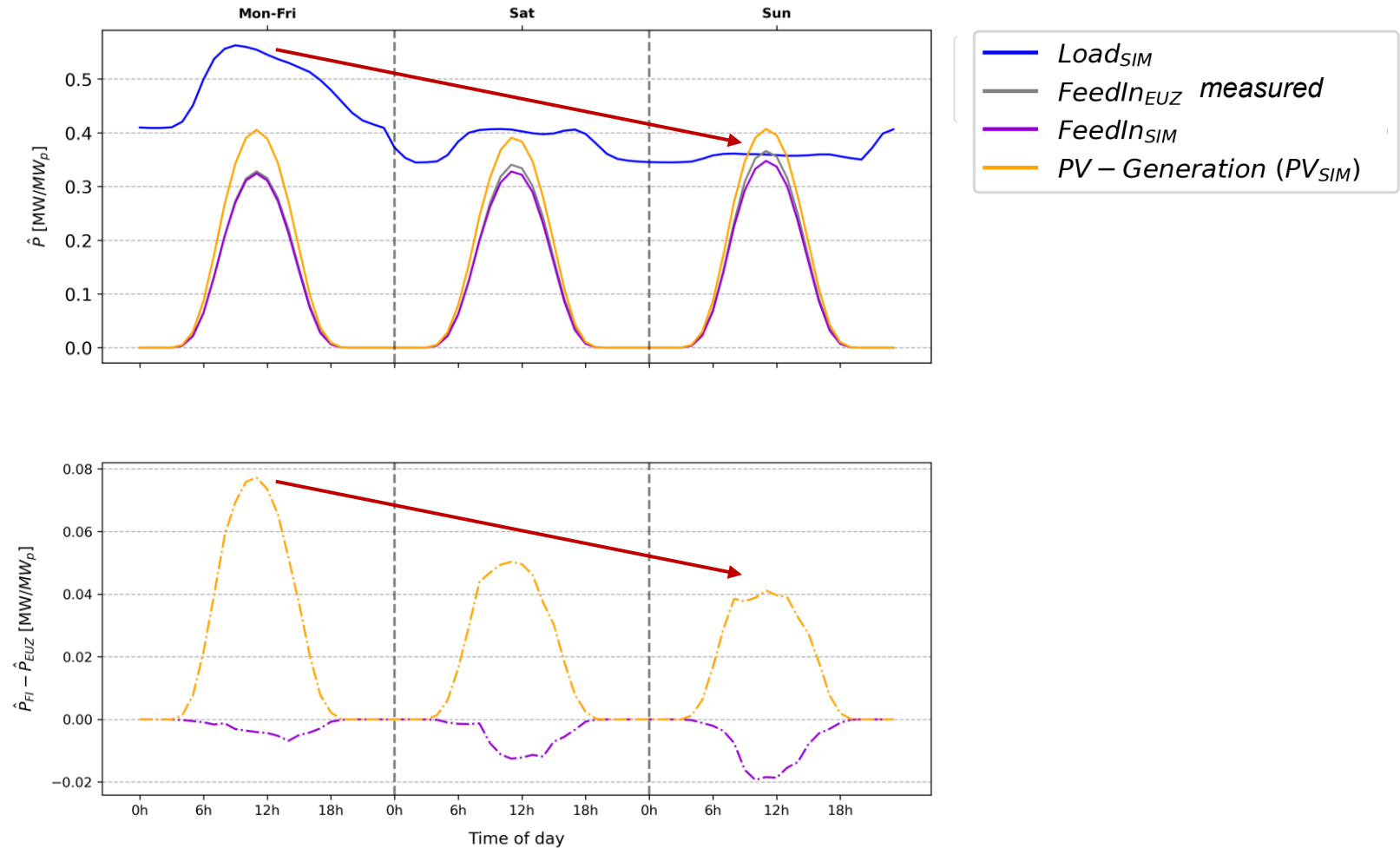
- Clearly reduced PV power feed-in due to self consumption
-> overestimation, if not considered



Modelled and measured PV feed-in for 2022 portfolio feed-in

Typical daily profiles

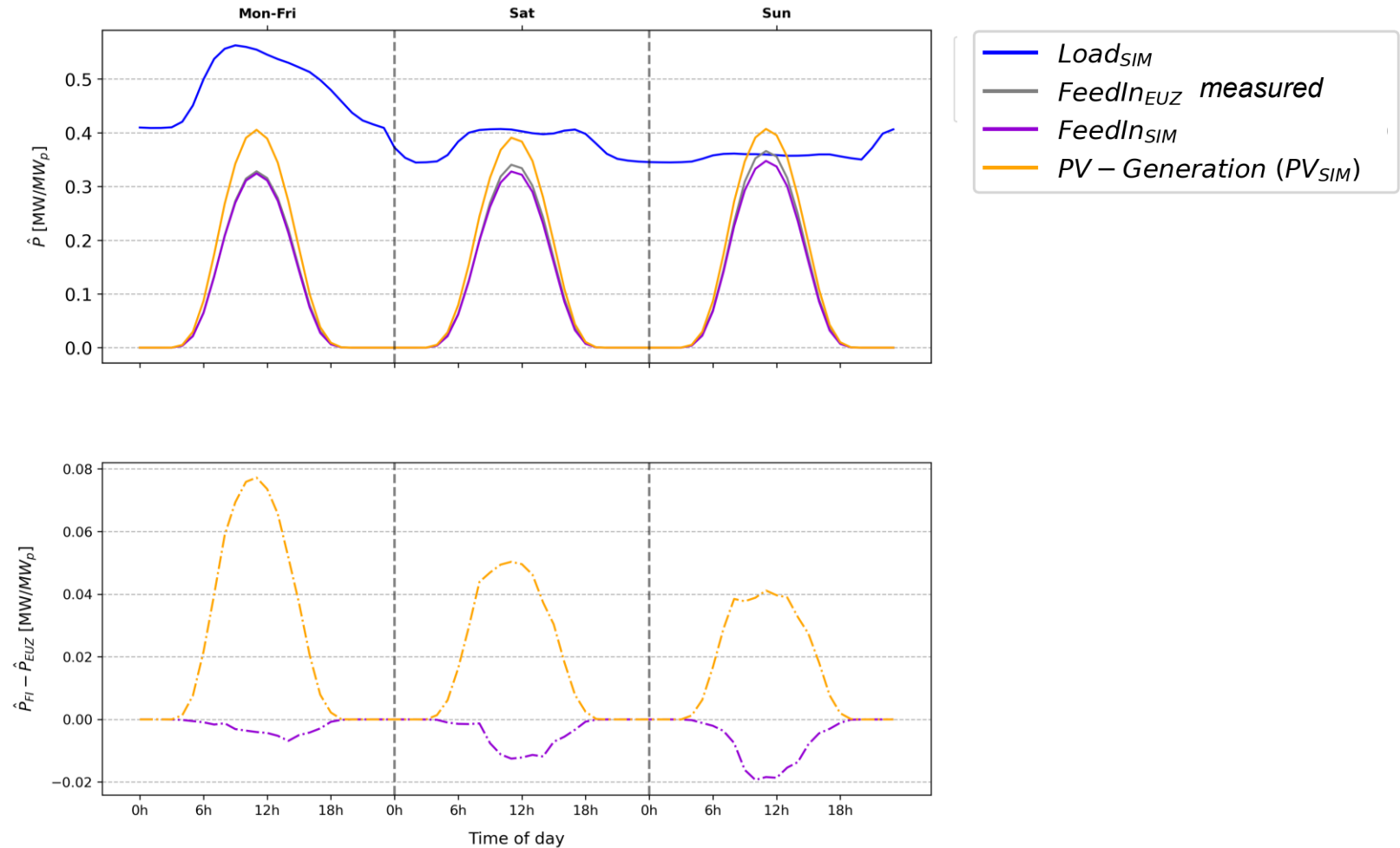
- Clearly reduced PV power feed-in due to self consumption
-> overestimation, if not considered
- Lower consumption on week-ends impacts measured feed-in (EUZ)
-> larger overestimation during working days



Modelled and measured PV feed-in for 2022 portfolio feed-in

Typical daily profiles

- Clearly reduced PV power feed-in due to self consumption
-> overestimation, if not considered
- Lower consumption on week-ends impacts measured feed-in (EUZ)
-> larger overestimation during working days
- Self-consumption model describes
 - overall reduction
 - weekly patterns



Summary

- How to model regional PV power feed-in with self-consumption?
 - Bottom-up modelling approach in combination with meteorological data
 - Information on PV systems and consumption categories combining register information and geomapping
- How are regional PV feed-in patterns changed by PV self consumption?
 - Strong reduction of PV power feed-in with self-consumption
 - Very different patterns for different consumption categories (e.g. daily and weekly profiles)
 - PV power feed-in is changed by self consumption considerably already today
- How well does our model fit actual PV power feed-in?
 - Impact of self consumption on measured feed-in is captured with bottom-up modelling approach

Outlook:

**Strong future changes of PV feed-in patterns are expected
with increasing share of batteries and additional and flexible electrical loads**

Thank you for your attention!



TRANSNET BW



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on the basis of a decision
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