Determining the Maximum Feasible Amount of Photovoltaics in the European Transmission Grid Under Optimal PV Utilization

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Agenda

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1. Introduction
2. Methodology: Grid Model and PV Placement
3. Calculation Results: Whole-Year Scenarios
4. Conclusions

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Introduction

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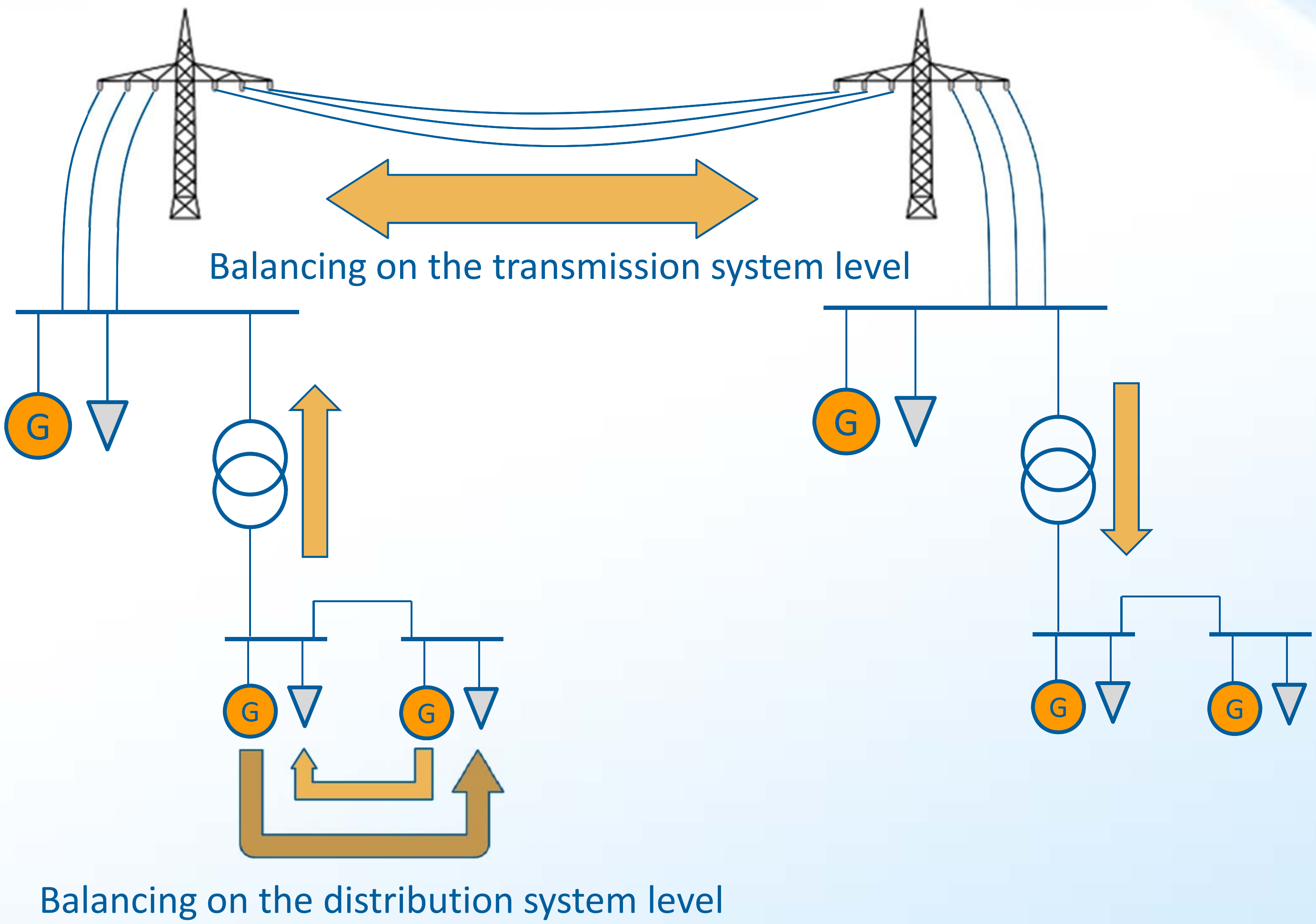
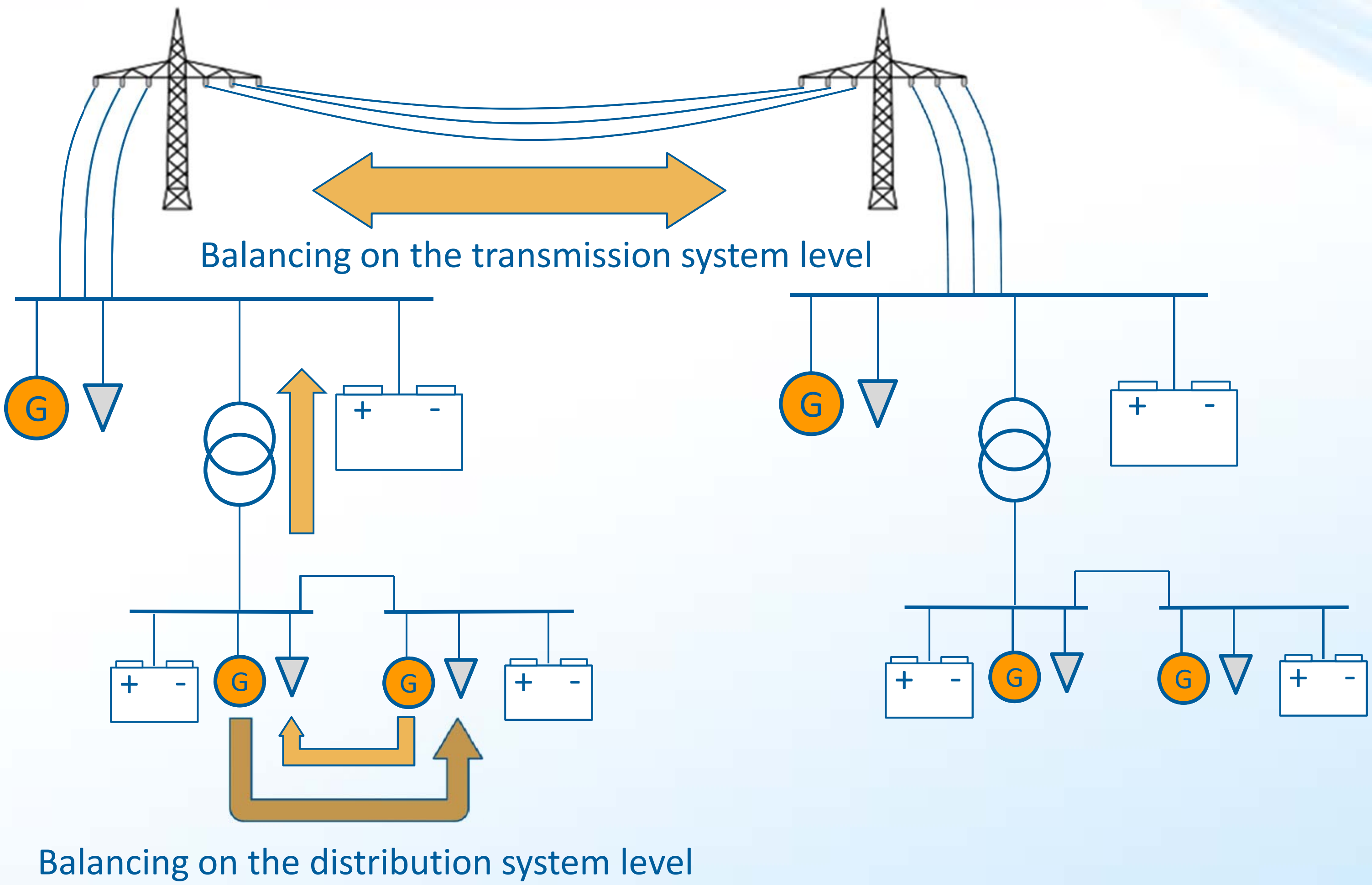
Background:

- Significant growth of the number of photovoltaic systems in recent years
- Introduction of incentives for PV usage in many countries
- Grid parity can be reached even in regions with less favorable irradiation conditions
- Further decline of PV system prices and increase of electricity prices anticipated

Balancing of PV electricity



Balancing of PV electricity



Introduction

In this study:

- Consideration of a large PV capacity addition in the future decades in Europe
- How much demand in Europe can be supplied by PV?
- How much curtailment would PV suffer due to its massive expansion and bottlenecks associated with the transmission grid?
- What is the role of storage?

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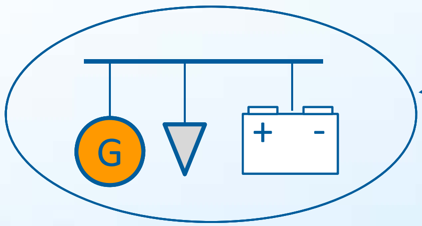
Methodology: Grid Model

Energynautics' European Transmission Grid Model:

- Validated European network model in DIgSILENT PowerFactory
- Consists of 400+ aggregated lines (≥ 220 kV) and 200+ aggregated nodes
- Contains both HVAC and HVDC lines
- Here conducting DC Optimal Power Flow (OPF) simulations
- Grid fixed at predicted 2020 state



Source: ENTSO-E, adapted by Energynautics

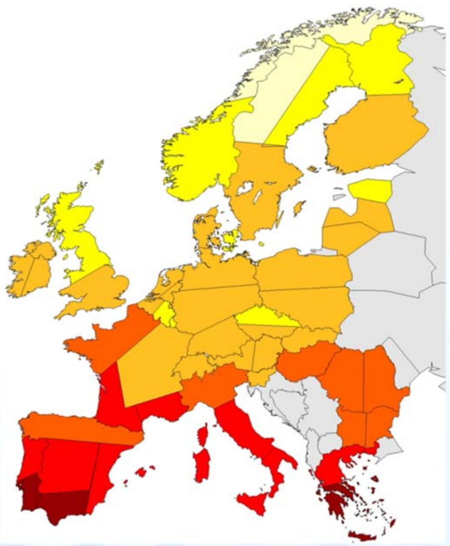
Methodology

Approach steps:

- Dimensioning and distribution of minimum PV capacity in Europe
- Projections concerning PV capacity growth in the future
- Dimensioning and placement of different amounts of storage
- Calculations of a complete year in several scenarios related to the amount of available storage capacity

Methodology: PV dimensioning & placement

- Minimum PV capacity amount: cover complete demand in the system on a clear summer weekend day at noon (base case)
- Load projections for 2050 as a target year
- PV capacity distribution through OPF simulation in accordance with region-specific irradiation conditions respecting grid's thermal limits



Source: EWI

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Country	Installed PV, %	Demand, %
Austria	1.6	1.9
Belgium	1.3	2.7
Bulgaria	1.1	1.1
Czech Republic	0.9	2.3
Denmark	0.7	0.9
Estonia	0.0	0.3
Finland	2.1	2.1
France	13.4	14.1
Germany	11.8	12.7
Great Britain	9.0	9.5
Greece	2.7	2.4
Hungary	2.8	1.5
Ireland	1.0	0.9
Italy	12.9	11.7
Latvia	0.6	0.3
Lithuania	0.0	0.4
Luxembourg	0.0	0.2
Netherlands	5.4	3.2
Norway	1.3	2.5
Poland	6.4	5.6
Portugal	2.5	2.1
Romania	1.9	2.4
Slovakia	0.9	1.0
Slovenia	0.0	0.4
Spain	13.1	12.9
Sweden	4.6	3.7
Switzerland	2.1	1.3
Total	100	100

Base case: 770 GWp PV

Methodology: Calculation Scenarios

- Calculation of a complete year in hourly resolution
- Hourly demand and irradiation data for all nodes
- Output presents PV energy used, stored and curtailed due to grid or storage restrictions
- Storage (short-term only) placement and dimensioning according to curtailed PV energy on a day in spring

Scenarios:

Installed PV in GWp	**Total storage capacity in Europe in GWh**		
	Scenario 1	*Scenario 2*	*Scenario 3*
770; 1155; 1540; 1925	none	290	1540

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Calculation results: Scenario 1: no storage

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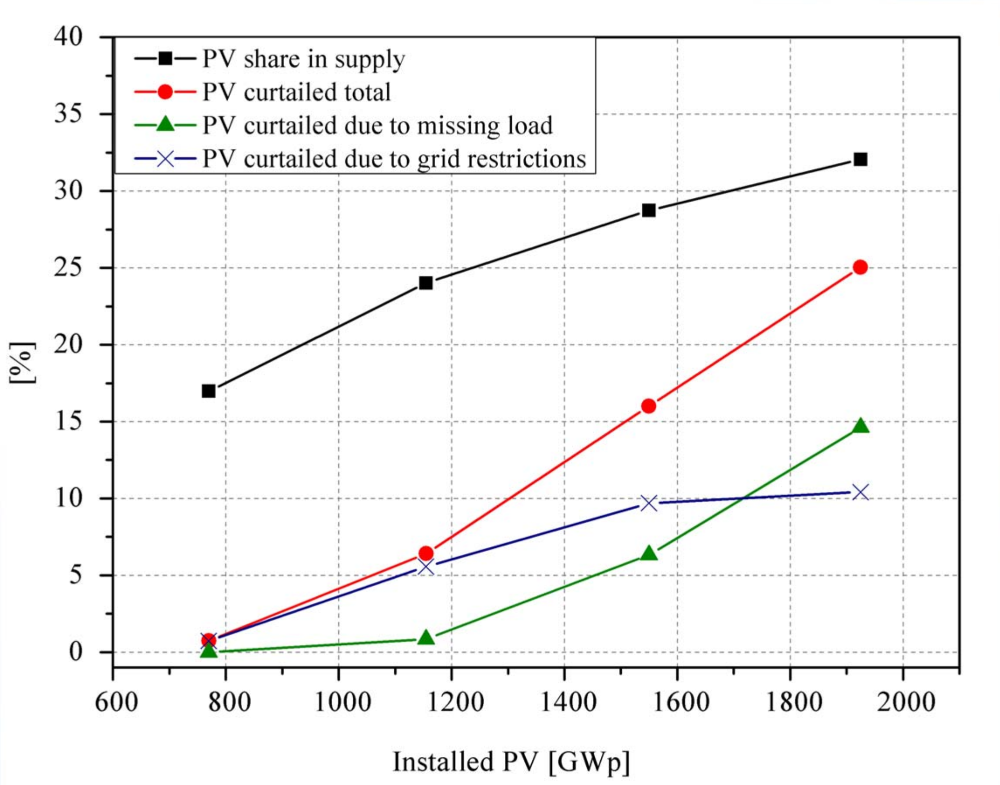
- Up until 1155 GWp of installed PV no significant excess of PV in the system
- Role of the grid clearly visible
- At about 1700 GWp of PV in the system amount curtailed due to excess PV overtakes
- 1925 GWp installed PV in Europe would result in a loss of 25% of available PV energy



Calculation results: Scenario 2: 290 GWh storage

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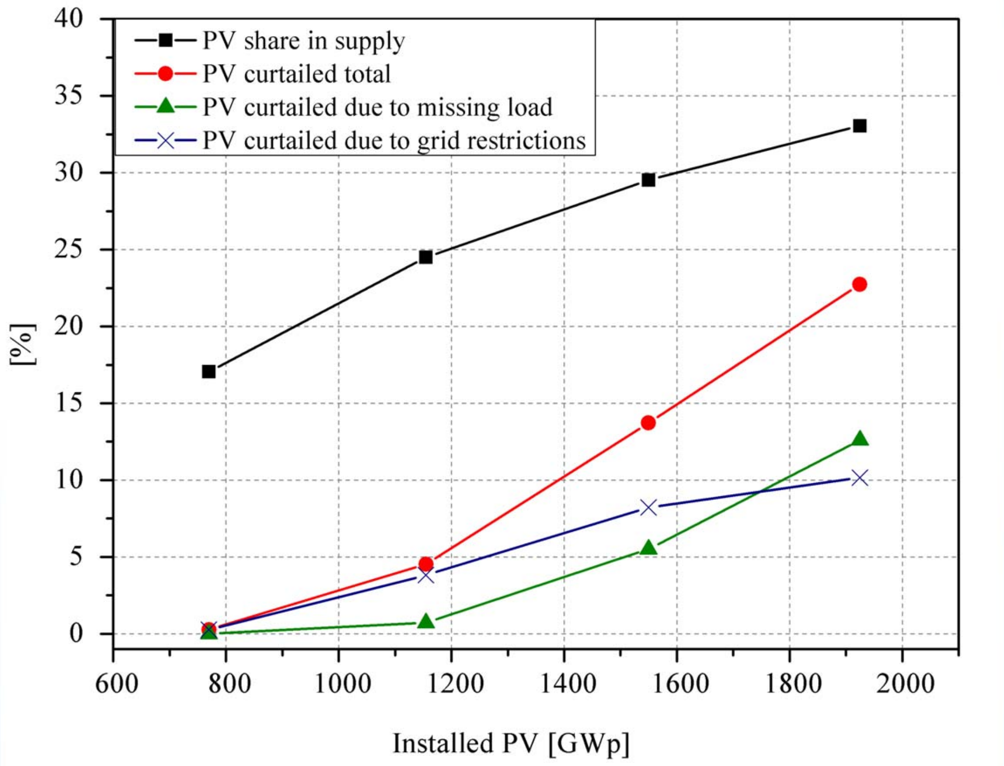
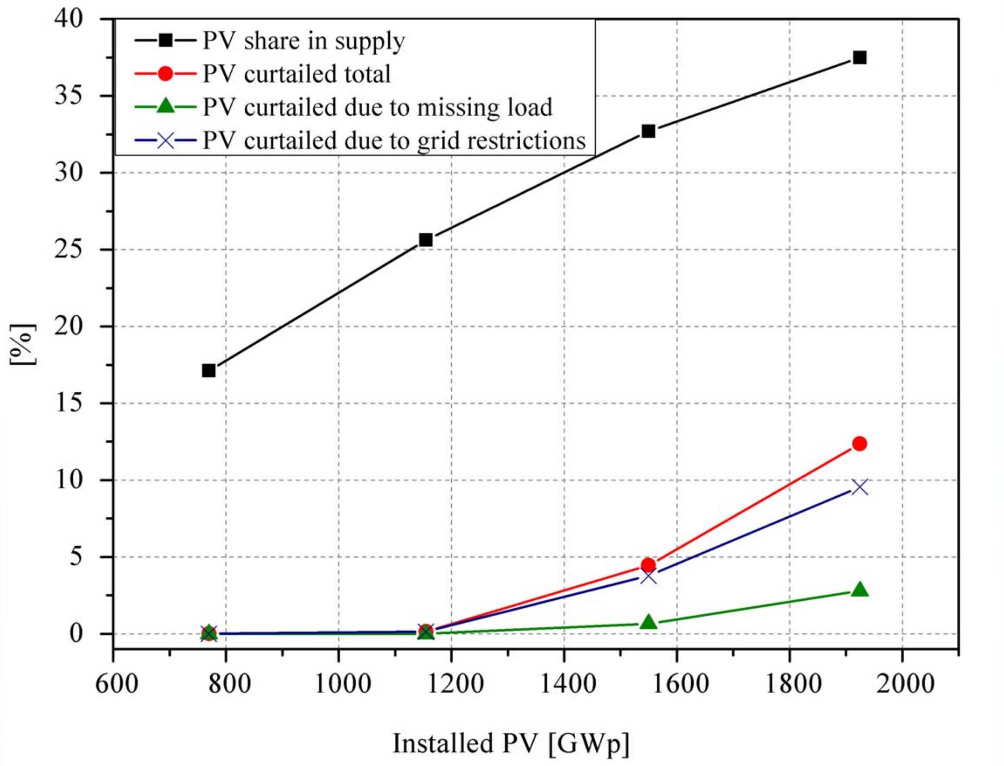
- Storage dimensioned for 770 GWp PV in Europe
- Storage fixes curtailed PV caused by grid restrictions and excess PV generation in relation to load
- Curtailed PV energy is reduced from 25% (scenario 1) to 23% for 1925 GWp installed PV

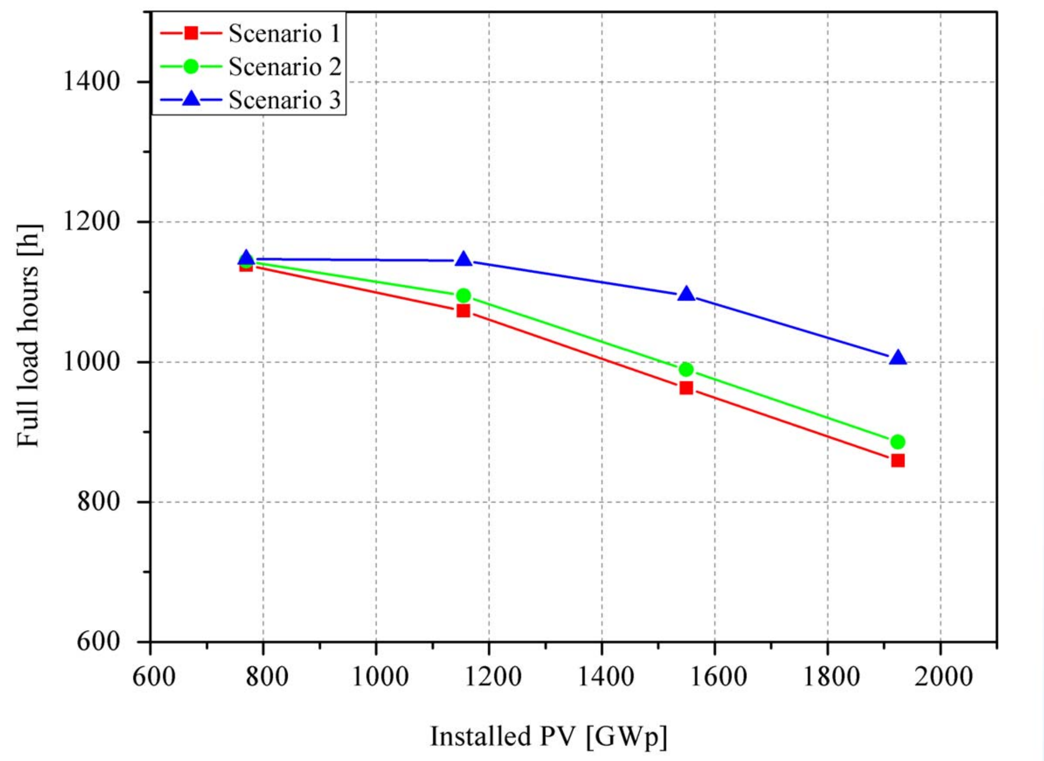


Calculation results: Scenario 3: 1540 GWh storage

- Storage dimensioned for 1155 GWp PV in Europe
- Storage capacity equivalent to a full capacity of about 31 million electric vehicles
- 12% curtailed PV with 1925 GWp in the system supplying 38% of demand
- Appropriate grid enforcement would contribute to further reduction of curtailment



Calculation results: full load hours



- Larger storage in scenario 3 considerably raises the number of PV full load hours

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Conclusions

- Consideration of grid restrictions and irradiation conditions leads to well-distributed PV placement close to demand
- PV curtailment can be reduced significantly if distributed storage is dimensioned and placed strategically according to accruing curtailment
- 30% to 40% of annual demand in Europe can be covered by PV with low to moderate curtailment and feasible amount of storage
- Appropriate grid enforcement would further reduce the amount of curtailed PV energy
- Any further expansion of PV capacity is likely to carry a high economic burden owing to the disproportionately high amount of required storage capacity

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Thank you for your attention!

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