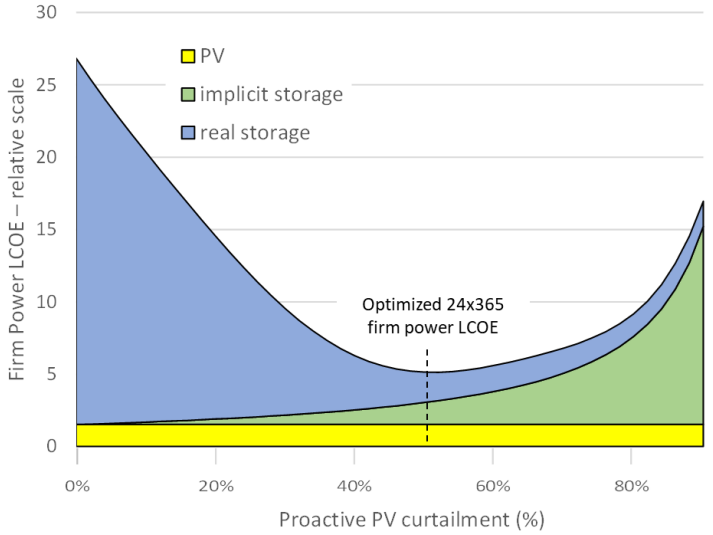


Firm Power Generation

Jan Remund, Richard Perez, Marc Perez

ICEM 2023, June 28th 2023

Contents

- IEA PVPS
- Firm Power Generation Concept
- Results of different studies
- Conclusions
- Effects and regulations and market (design)

What is IEA PVPS?

- The International Energy Agency (IEA), founded in 1974, is an autonomous body within the framework of the Organization for Economic Cooperation and Development (OECD).
- The **Technology Collaboration Programme (TCP)** was created with a belief that the future of **energy security and sustainability starts with global collaboration**.
- The Photovoltaic Power Systems Programme (PVPS) is one of the TCPs established within the IEA in 1993.
- The objective is to facilitate the role of photovoltaic solar energy as a **cornerstone in the energy transition.**

Current status of team

50 institutions

Science (labs and universities)

Met Services / utilities

Data providers

PVPS

Meteotest

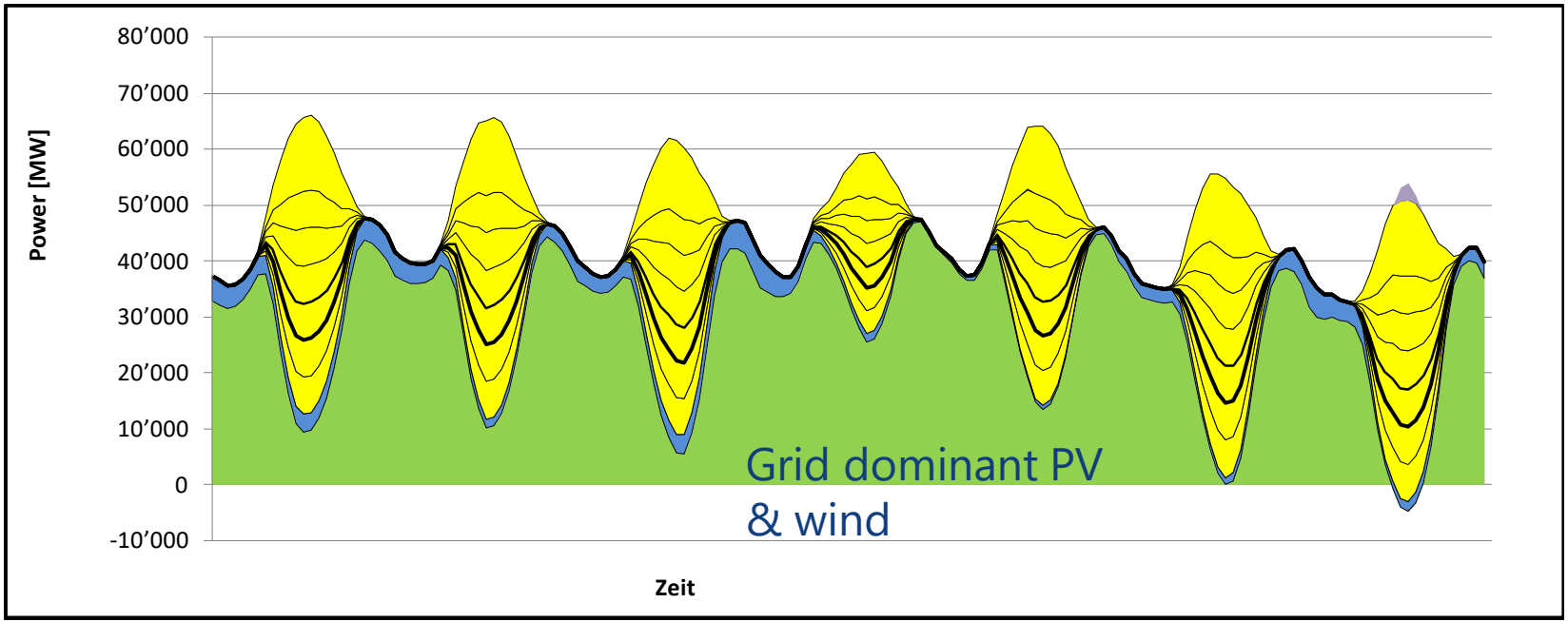
Founded: 1981
Staff: 35
Berne, Switzerland
www.meteotest.ch
solar.meteotest.ch

PVPS

Firm Power Generation

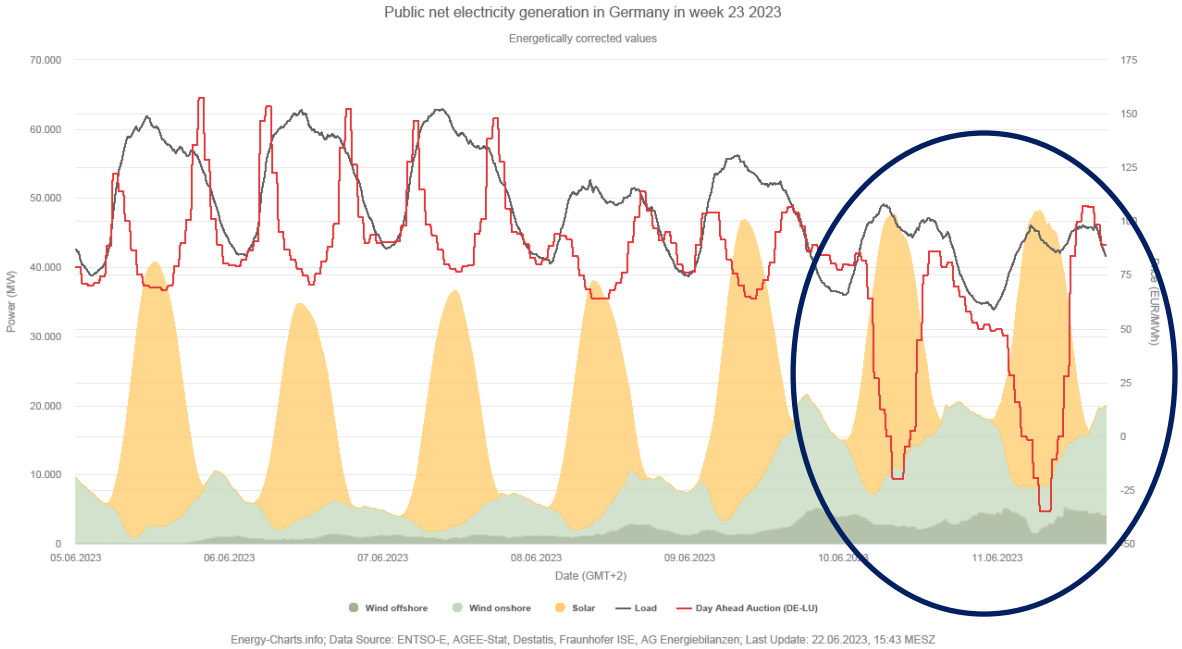
- Main question: how to secure (cost efficiently) seasonal and daily imbalances with renewables?
- Report published in January 2023:
  - https://iea-pvps.org/key-topics/firm-power-generation/
- Covering 14 studies in Europe, Australia and USA

Renewables from margin to core



PVPS

Situation in Germany (2023)



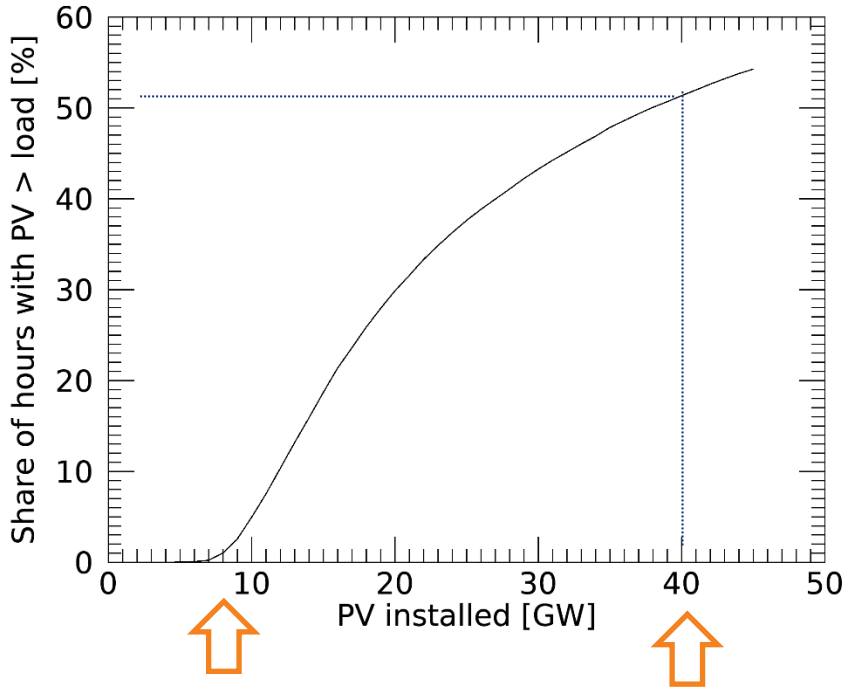
PV & Wind larger than load in Germany June 10 – 11 2023

- Negative prices
- Current solution: export (as Poland and France are behind in PV)

PVPS

Situation in Switzerland

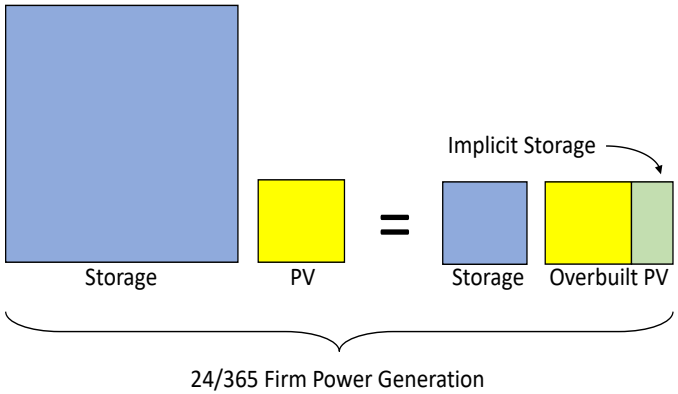
- Curtailment question will get a hot topic soon

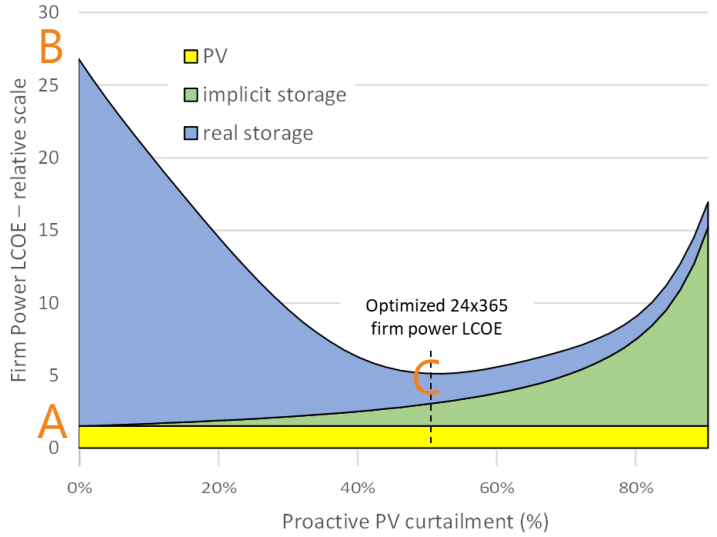


- Today: approx. 5 GW
- Growth 2022 in CHE: 1 GW/year
- > 7 GW issues start
- In 2 years PV production > load

Firm Power Generation principles

- Assumption: storage costs are higher than production costs
- Optimisation of LCOE based on installation costs





(A) LCOE of uncurtailed PV

(B) LCOE without any curtailment (all is stored)

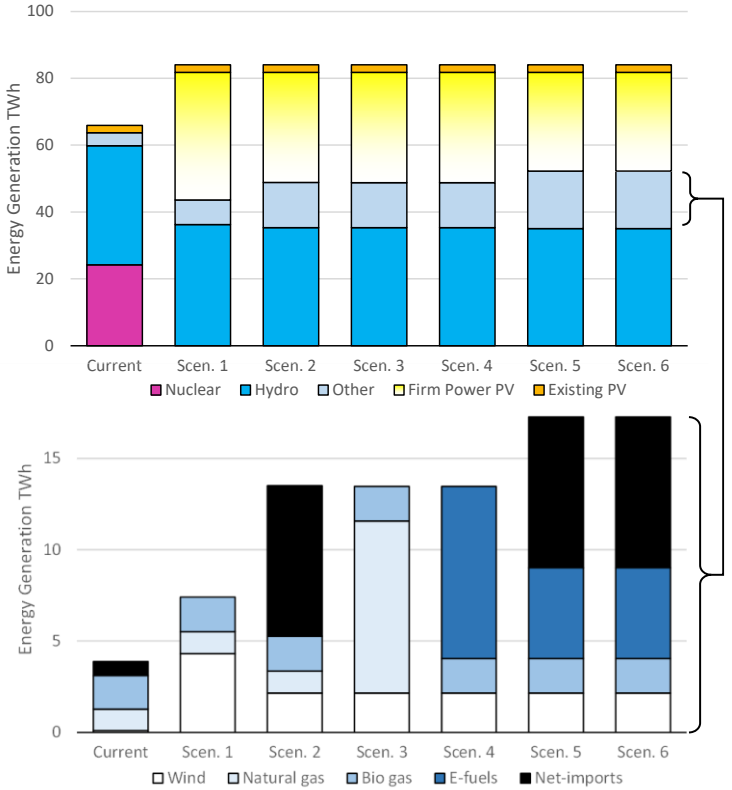
(C) Sweet spot

PVPS

Swiss Case 2050: growth & nuclear → PV

1. Official E-Perspectives, zero net import
   ENTSO-E time series 2018-2020 scaled up
2. 10% net annual import
3. 10% renewable gas power plants, restricted import (3 GW)
4. 10% e-fuels power plants, restricted import (3 GW)
5. 10% net annual import, 6% e-fuels power pl.
6. 10% import, 6% e-fuels pp., agri-PV
7. High prices (CHE) – low prices (USA)
8. Import / no import (“a” = autarky)

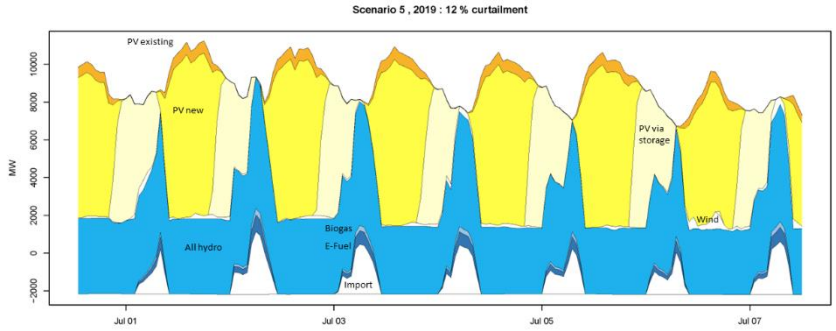
→ 2023: new study including scenarios with extended lifetime or new nuclear and more wind energy



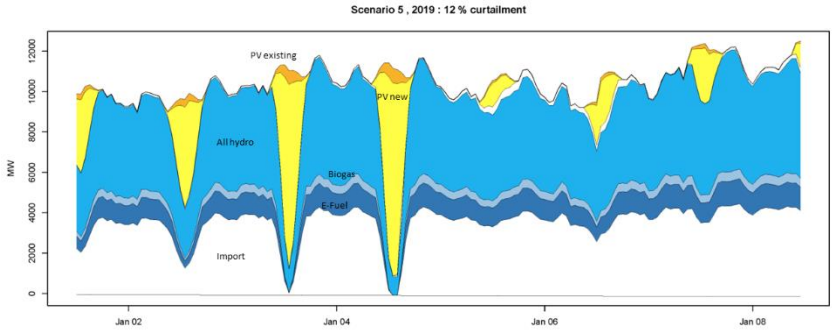
PVPS

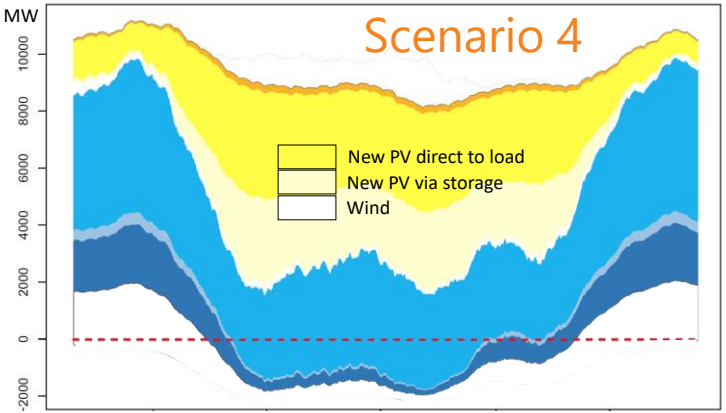
Production patterns (Switzerland: 2050)

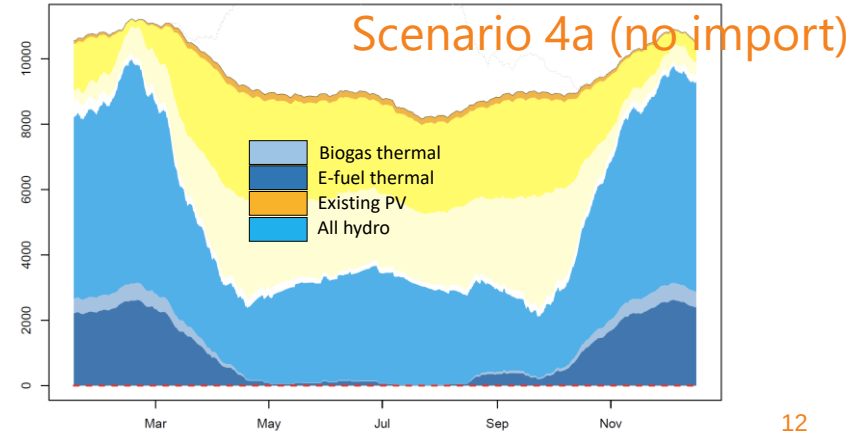
Summer week (scen. 5 with import)



Winter week (scen. 5 with import)



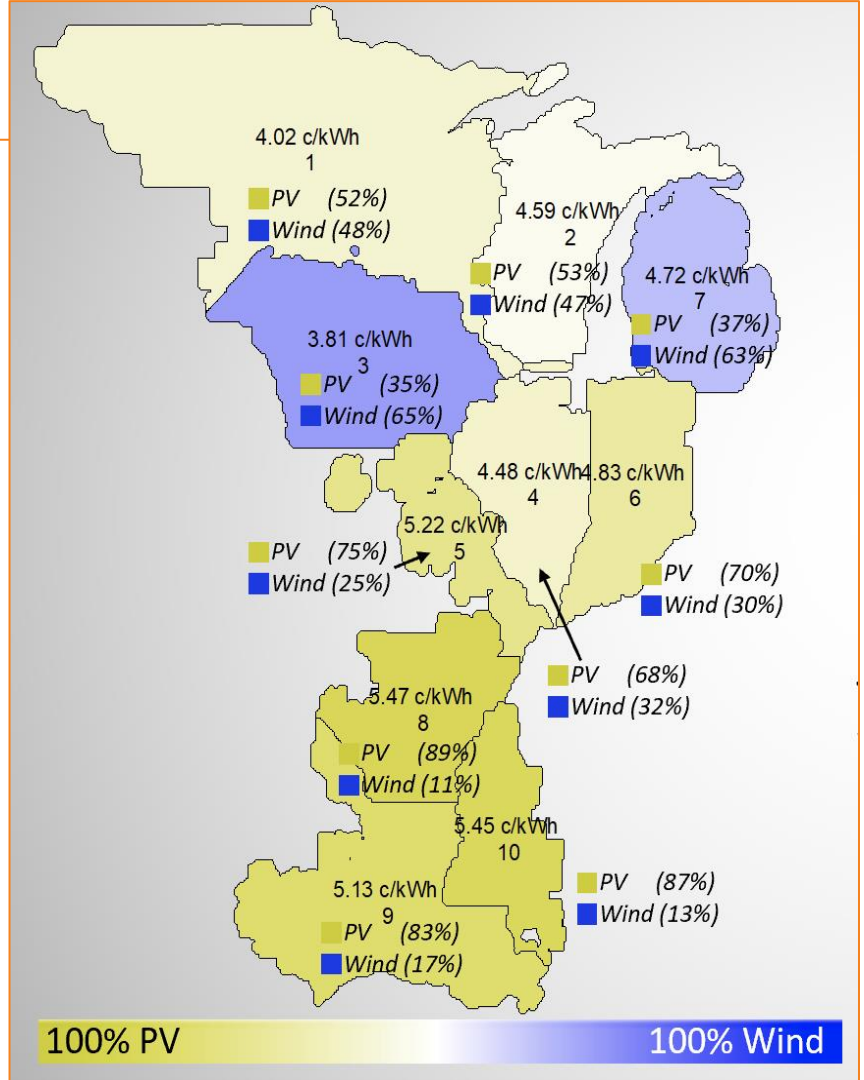




PVPS

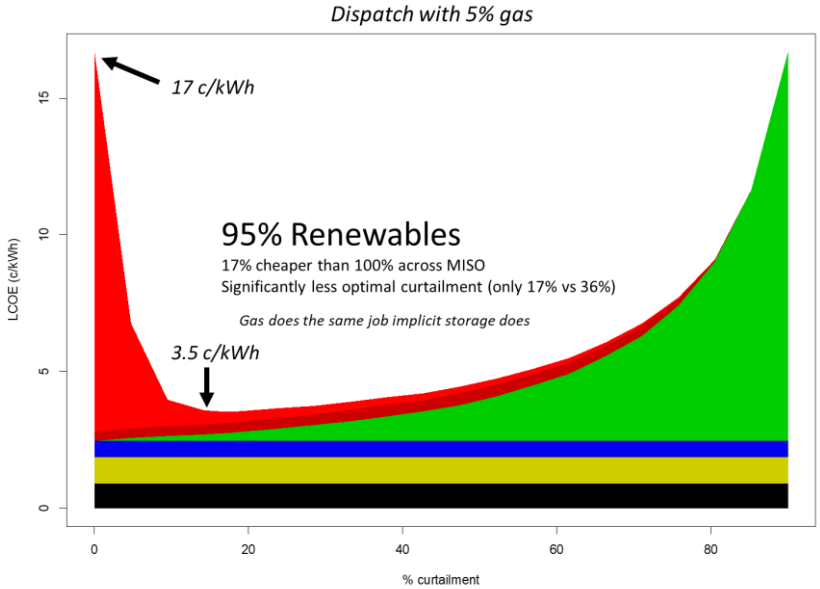
Firm Power Generation: MISO

US Midcontinent System

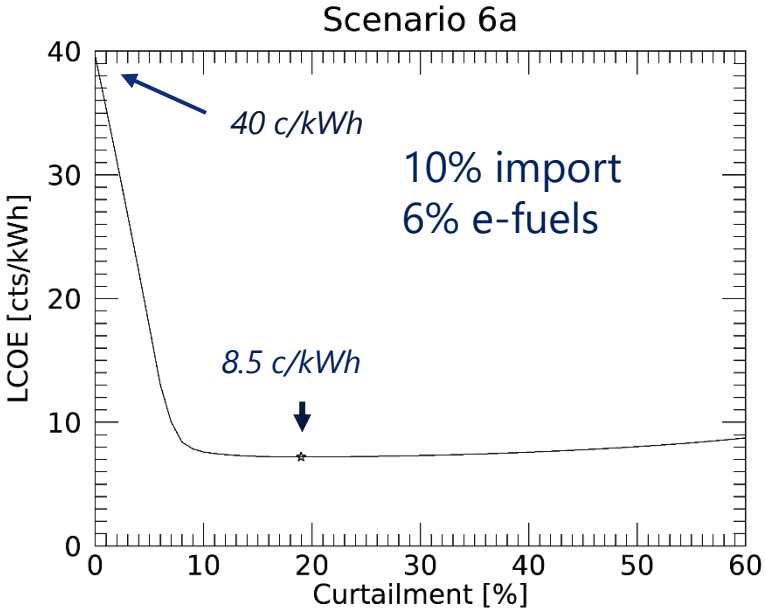


Firm Power Generation: MISO and Switzerland

US Midcontinent System



Switzerland



→ No curtailment is always expensive

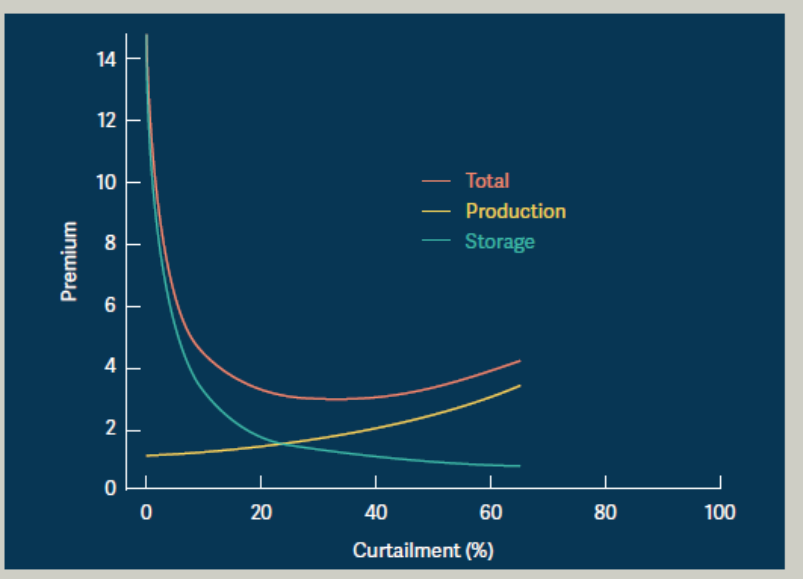
→ 5-6% of expensive e-fuels are useful (and don't enhance the average price levels)

PVPS

Firm Power Generation: Europe

- Example of a pan-European study from Univ. Utrecht (incl. H2 storage and Li-Ion batteries (Master thesis of R. van Eldik*)
- Input data are crucial (future cost levels) → ATB NREL / ENTSO-E
- 29% curtailment optimal
- Average LCOE of 93 EUR/MWh

	Solar PV	Onshore wind	Offshore wind	Li-on	Hydrogen
Economic life	30 years	30 years	30 years	15 years	18 years
WACC	4.4%	4.4%	4.4%	5.0%	5.0%
CAPEX	700 k€/MW	760 k€//MW	1945 k€//MW	243 k€//MW 81 k€/MWh	1300 k€//MW 1 k€//MWh
O&M	10 k€//MW/y	33 k€//MW/y	71 k€//MW/y	2.5% capex/y	2.5% capex/y
SoCmin				20%	0%
SoCmax				100%	100%
Efficiency				85%	40%



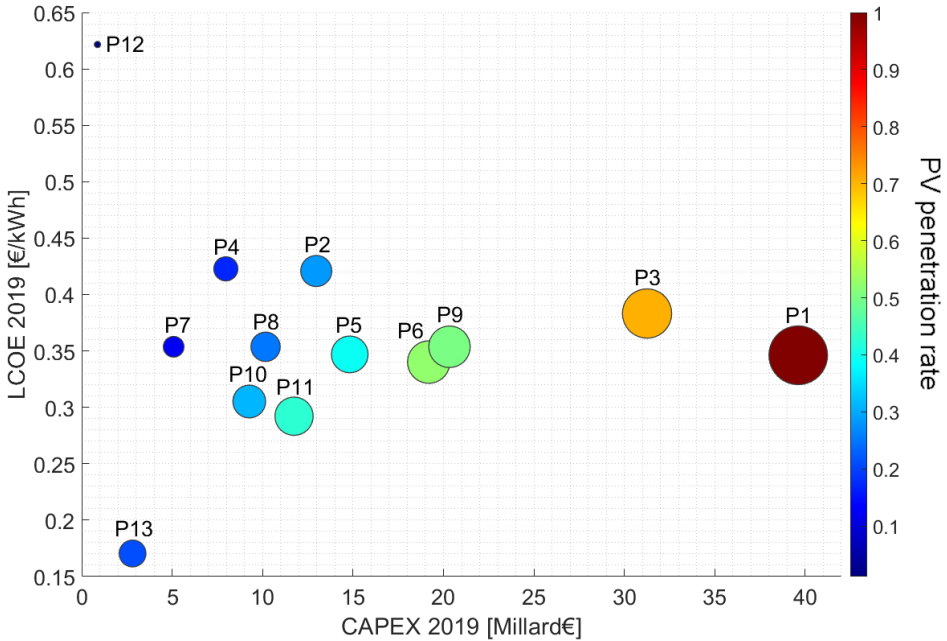
Premium: Firm / unconstrained

* https://studenttheses.uu.nl/handle/20.500.12932/43991

Firm Power Generation: La Reunion

- Example of a study on a remote Island without connection to continent
- Modelled with rather expensive PV and storage prices of 2019

- P1 scenario corresponds to 100% firm power PV penetration
- P2- substituting diesel plants
- P3-subsituting coal plants
- P4-supplying cooling demand
- P5-supplying the tertiary sector
- P6-supplying tertiary and industrial sectors
- P7 to P9-supplying constant load at 50, 100 and 200 MW,
- P10-meeting a trapezoidal day-time load peaking at 300 MW,
- P11-meeting 100% demand during daytime only
- P12-meeting evening peak demand only
- P13-meeting firm day-ahead solar forecasts



Firm Power Generation: Conclusions

- Curtailment & Overbuilding lowers average LCOE significantly
- PV Magazine report in February 2023 («Curtailment is not the enemy»)
- Curtailment is part of the solution aside
    - energy storage
    - optimum blending of VREs
    - geographic dispersion and
    - supply/demand flexibility

Results have multiple effects on…

- Power system modelling
  - e.g. how much rotating mass is needed?
  - what kind of additional (e.g. ancillary) services are needed?
- Grid modelling
  - how much of grid enhancement costs can be reduced? (→ in the range of 50% / SFOE*)
- Optimal dynamic curtailment
  - how to regulate curtailment?
  - New rules for grid operators?
  - DSO/TSO most likely should get additional regulations (and power) for optimal curtailment

* https://pubdb.bfe.admin.ch/de/publication/download/11205

Effects on market design

- Effects on market regulations
  - how optimal (market) system for 100 RES systems can look like?
  - Are models based on marginal costs viable? (with 100% RES without marginal costs)
- Effects on regulation of supporting schemes
  - how to secure enough income with significant curtailment (e.g. for PPA)?
- Suggestions:
  1. value firm power generation, and
  2. reflect the physical characteristics of the VREs,
  3. recognize that optimum firm power results from the concerted operation of several resources that cannot be treated independently (e.g., wind+storage+PV)
  4. Switch from renumeration of energy to capacity

https://iea-pvps.org/research-tasks/solar-resource-for-high-penetration-and-large-scale-applications/

Thank you

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