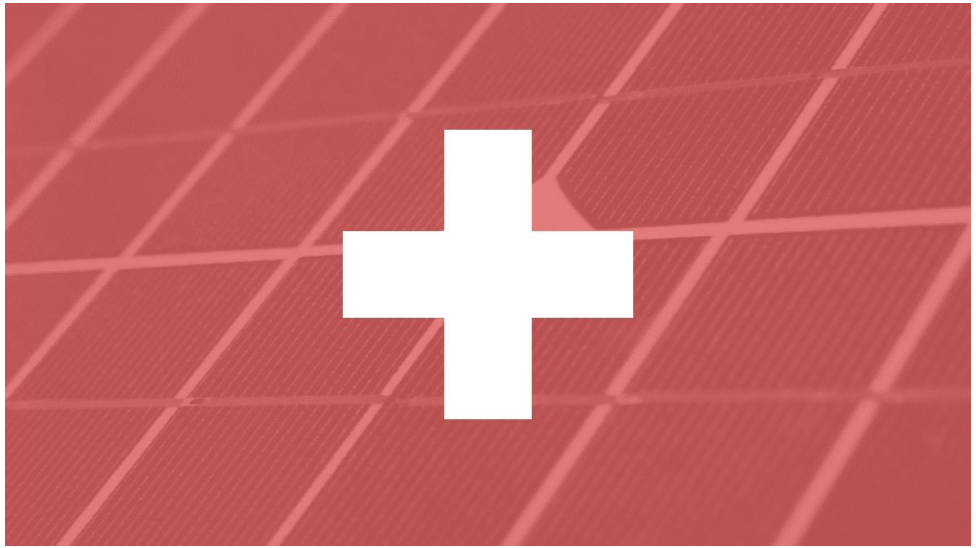
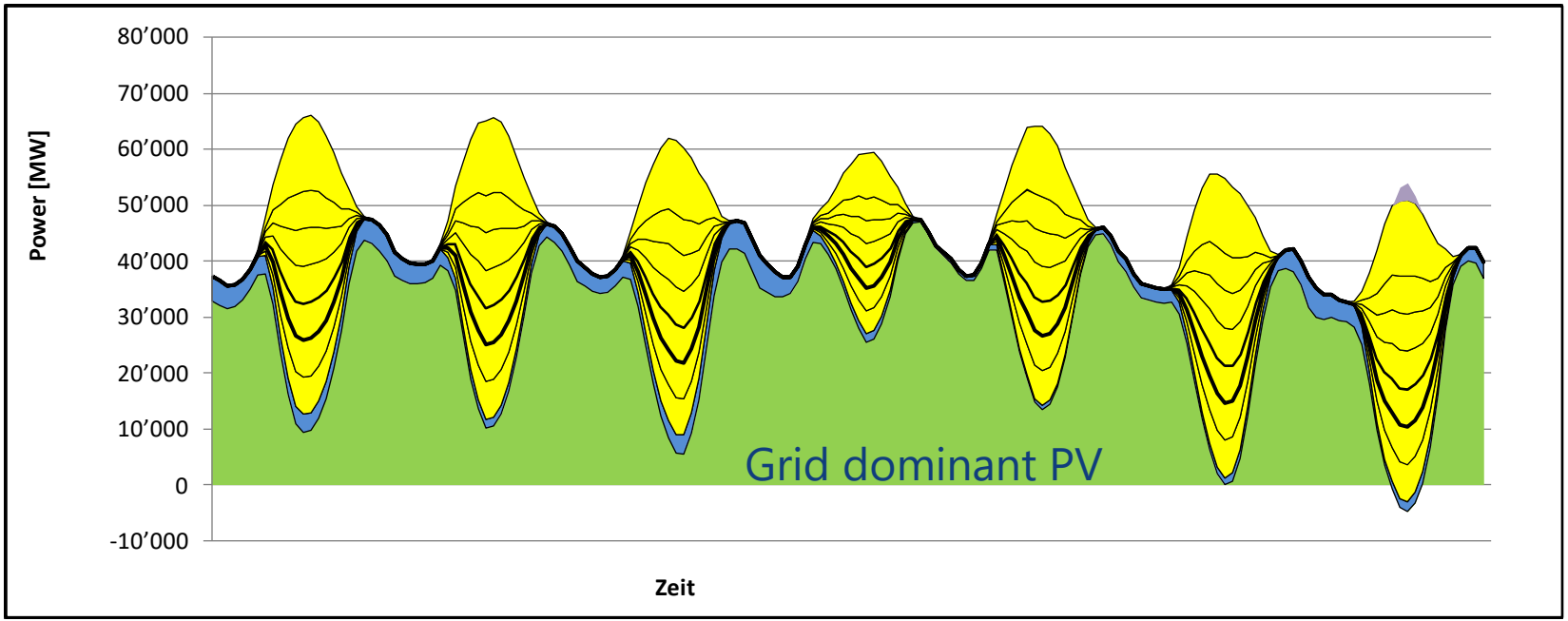


Firm PV Power Switzerland

Jan Remund, Meteotest AG, IEA PVPS Task 16 / Marc & Richard Perez

WCPEC-8, Milano, 28.09.2022

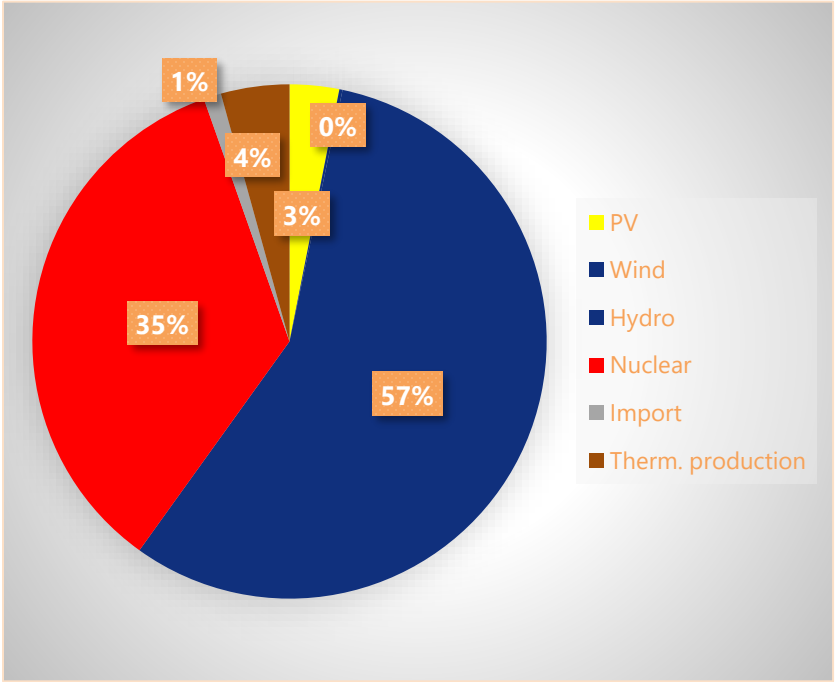
The reason behind Firm PV Power concept



→ How to deliver cost optimally 100% Renewable Electricity

Electricity production today

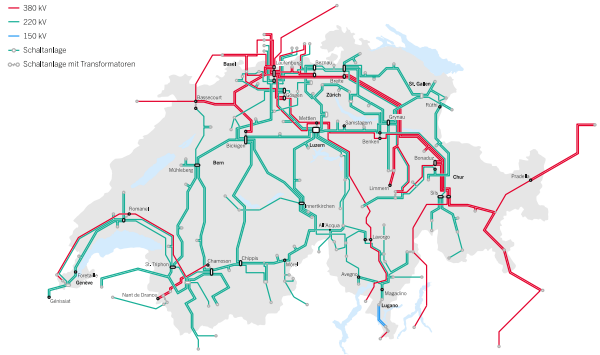
- PV:
  - Share is small: 3% (2018-2020)
  - but growing strongly: 30% / year
    - share is 5% in 2021, 3.7 GWp
    - assumed installation 2022: 1 GWp
- Consumption trend: stable (60 TWh)
- Hydro: 57%
  - Run-of-river, pumped hydro and seasonal storage lakes

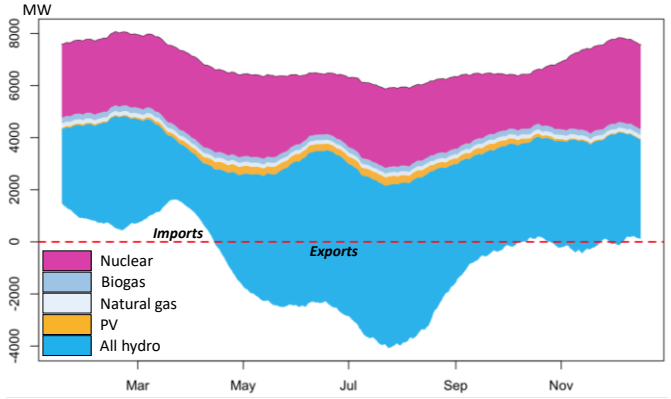


Swiss case

- Not coupled to EU market system any more
  - missing framework & electricity agreement “in the centre – but left out”

  → scenarios with autonomous grid and restricted import (“stand alone”)
- Historically strongly integrated in Europe
  - Import during winter, export during summer
  - Very small net import/export annually
- Notice: No grid modelling, no P2X, no climate change taken into account





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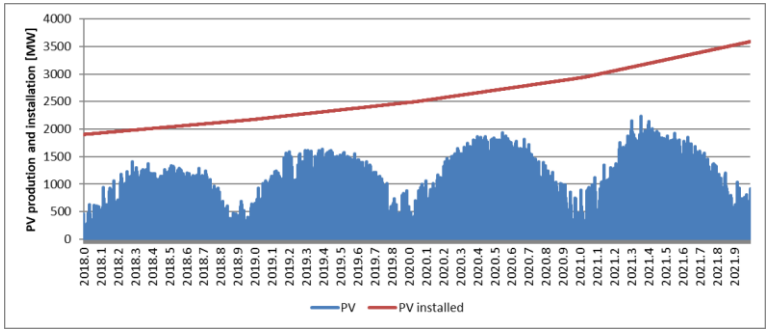
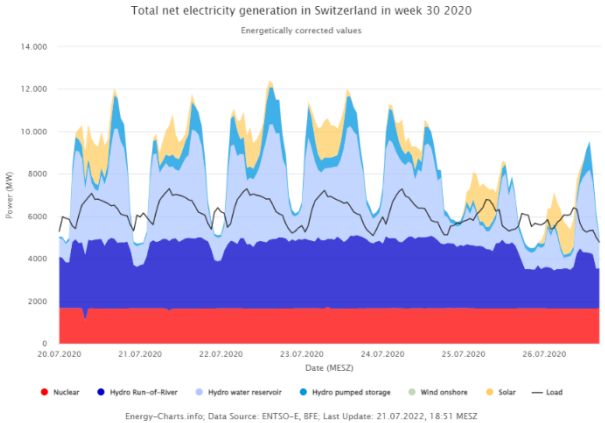
Input data: Time series

- Based on ENTSO-E hourly time series[1] 2018 – 2020
- Corrections:
  - Correction to annual production data of Swiss Fed. Office of Energy (SFOE)
  - One hour gaps: filled linearly
  - Longer Gaps:
    PV filled with average GTI (15°S) of Swissmetnet
- Scaled up linearly to 2050 scenario levels





[1] https://transparency.entsoe.eu

ENTSO-E is the European association for the cooperation of transmission system operators (TSOs) for electricity

Cost levels: CH and USA (2050)

Two assumptions:

- US: **optimistic**, large scale: installation costs:
  PV: 390 CHF/kW & Battery storage: 45 CHF/kW
- CH: **conservative**, small scale:
  PV: 860 CHF/kW & Battery storage: 330 CHF/kW

Source: NREL ATB: https://atb.nrel.gov/electricity/2021/data

Current price levels much higher:

- Electricity: 40 cts/kWh
- Gas: 20 EU cts/ kWh

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https://www.zeit.de/wirtschaft/energiemonitor-deutschland-gaspreis-spritpreis-energieversorgung

24 varieties

- Energy perspectives 2050+, Net Zero (CO2) “Basis”, state of **2050**
  - Growth: +30% till 2050 (to 85 TWh)
  - Nuclear: phased out (power stations would be 66-83 years active in 2050)

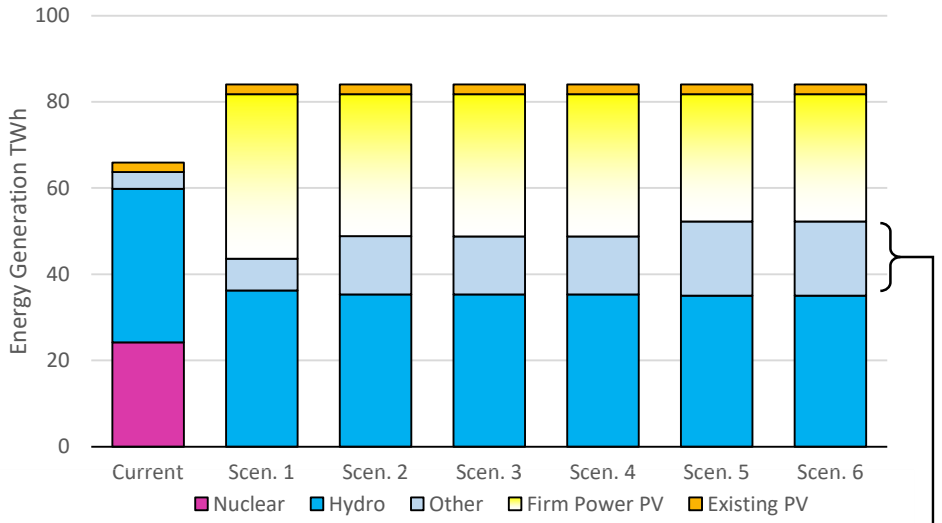
  → **Exchange of nuclear with PV**
- 6 sub-scenarios (→ next slide)
- 4 options:
  - CH as an island (“stand-alone”/autonomous) or linked to the EU electricity market
  - CH or USA cost levels

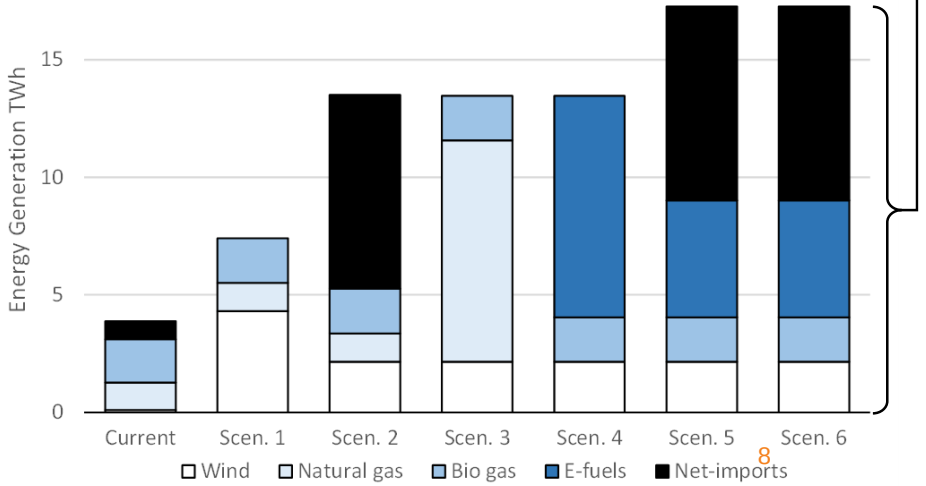
  → **24 scenarios**

* https://www.bfe.admin.ch/bfe/en/home/policy/energy-perspectives-2050-plus.html/

Six main Scenarios

1. E-Perspectives, zero net import
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





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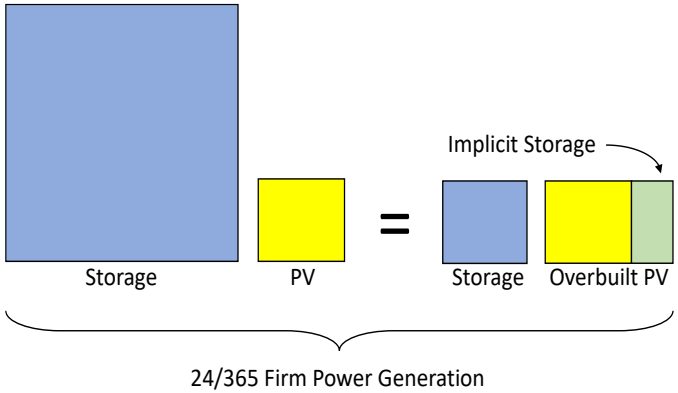
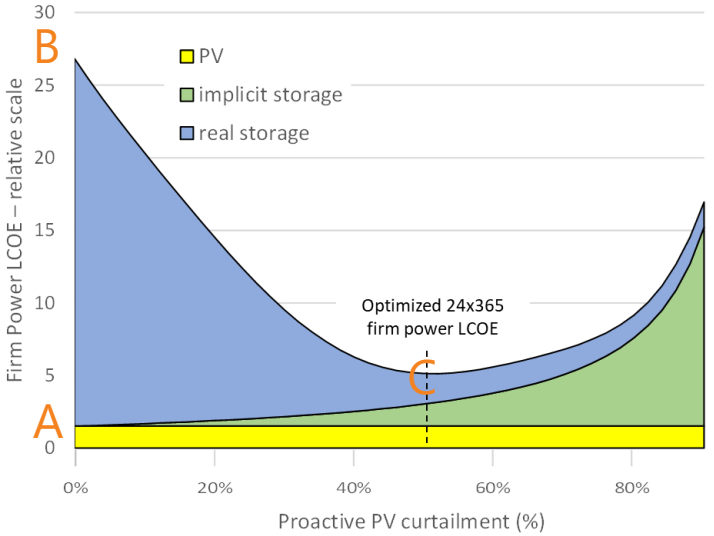
Method: Energy storage & implicit storage

- Asumption: s > p (storage costs are higher than production costs)
- Optimisation of LCOE based on installation costs



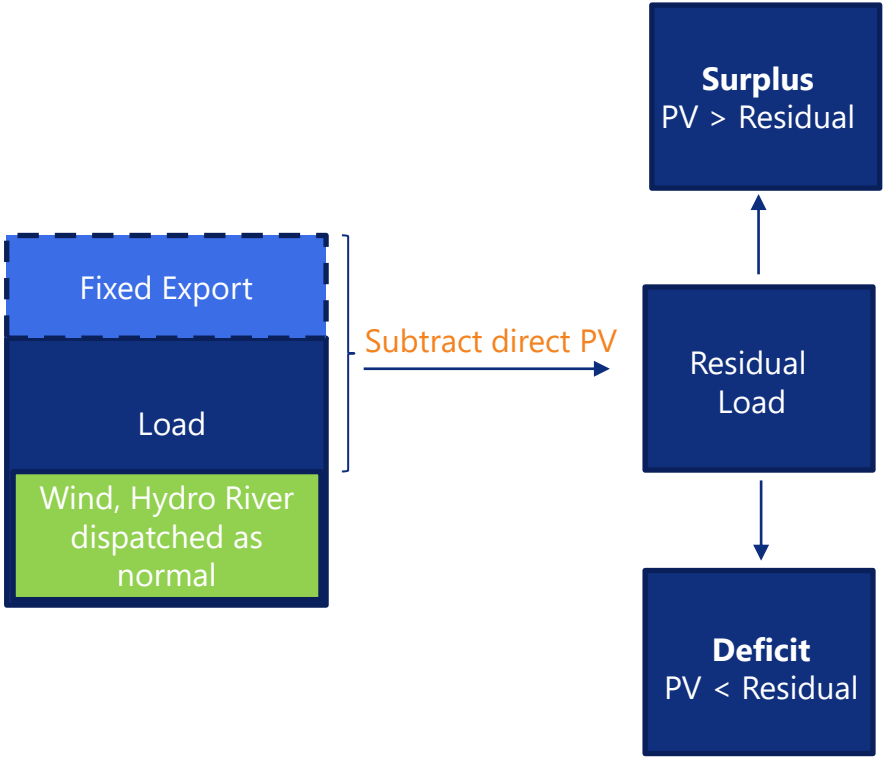


(A) LCOE of uncurtailed PV

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

(C) Sweet spot

Dispatch model



1. Fill storage: PSH → batteries electrochemical within cap. limits
2. Curtail if additional excess

1. Discharge storage: PSH → batteries
2. Discharge dispatchable resources: hydro storage, natural gas, biogas and/or e-fuels

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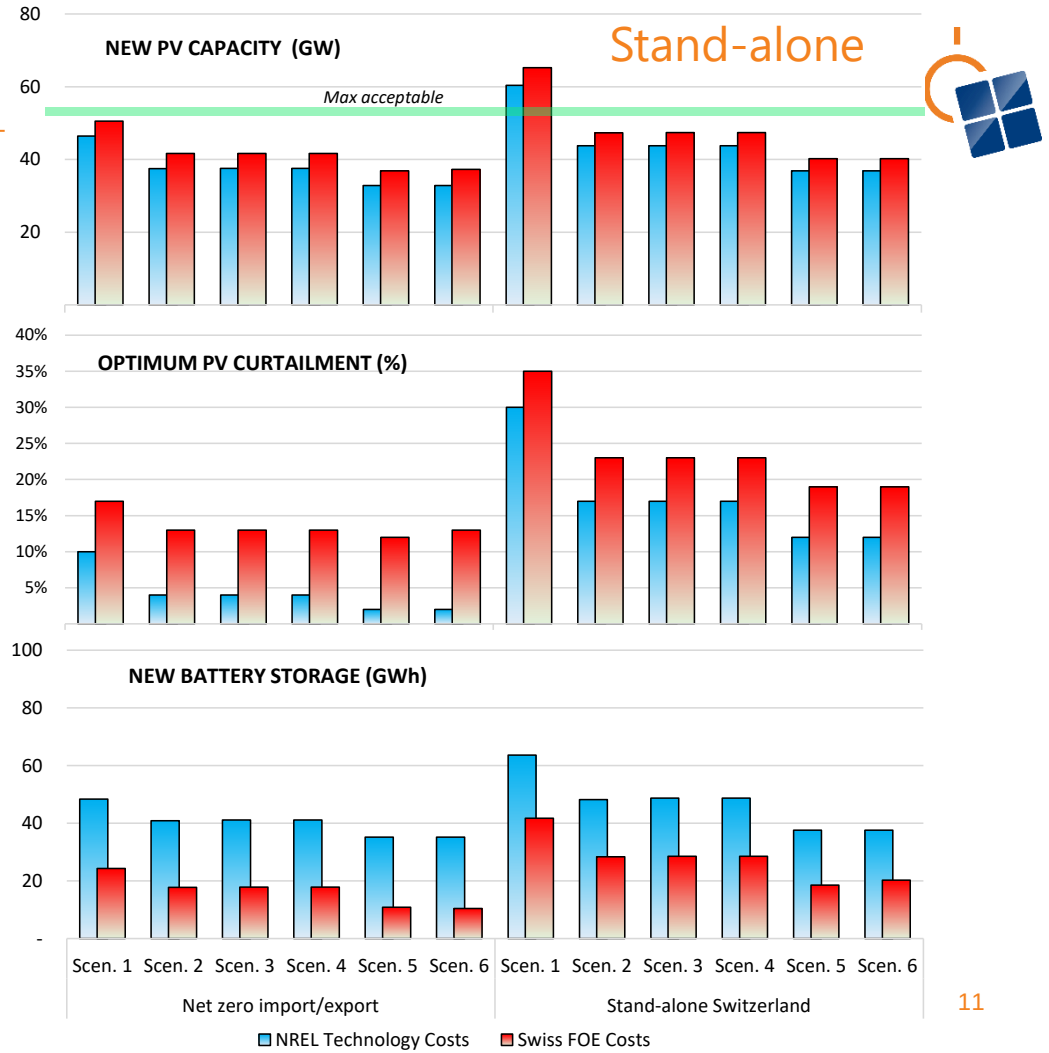
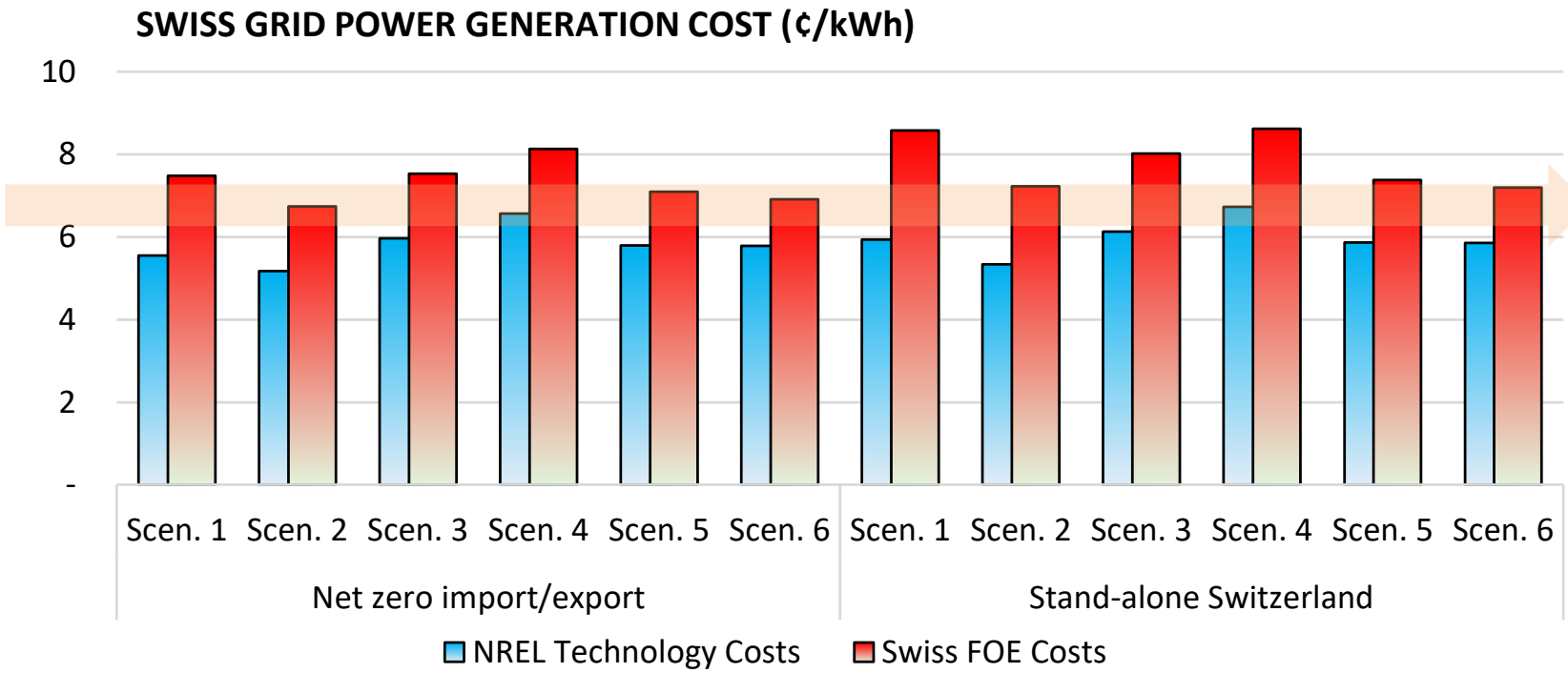
Results

- New PV capacities
- Optimum curtailment
  - 15 % curtailment = peak load * 0.45
- New battery storage



Generation costs for all scenarios

Cost level 2015-19



Stand-alone

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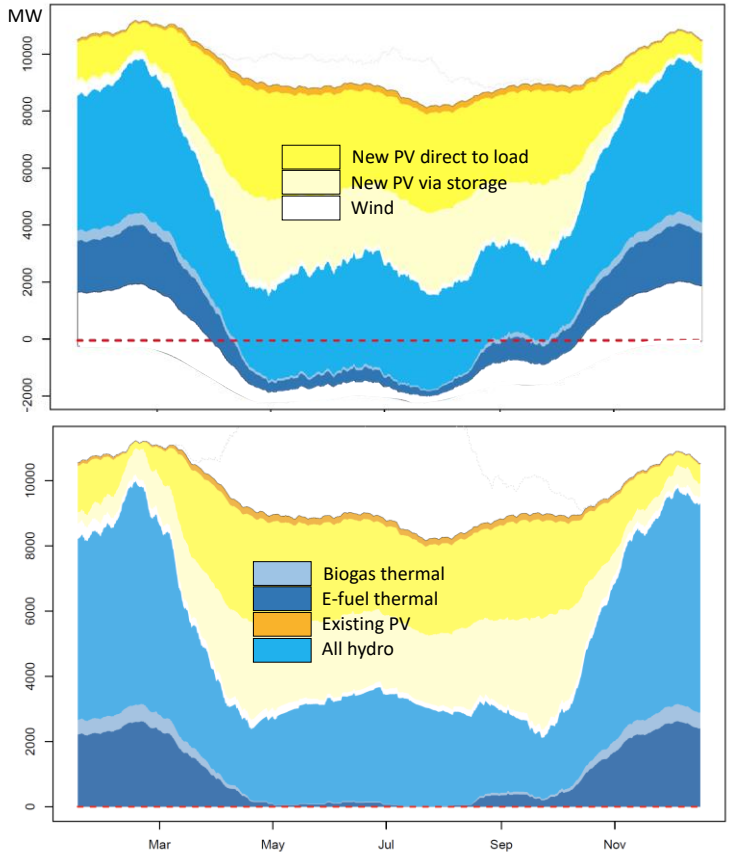
Seasonal Production (Scenarios 4 / 4a)

Production: integrated / autonomous

- With import/export (4)

- No import/export (4a)

Stand-alone



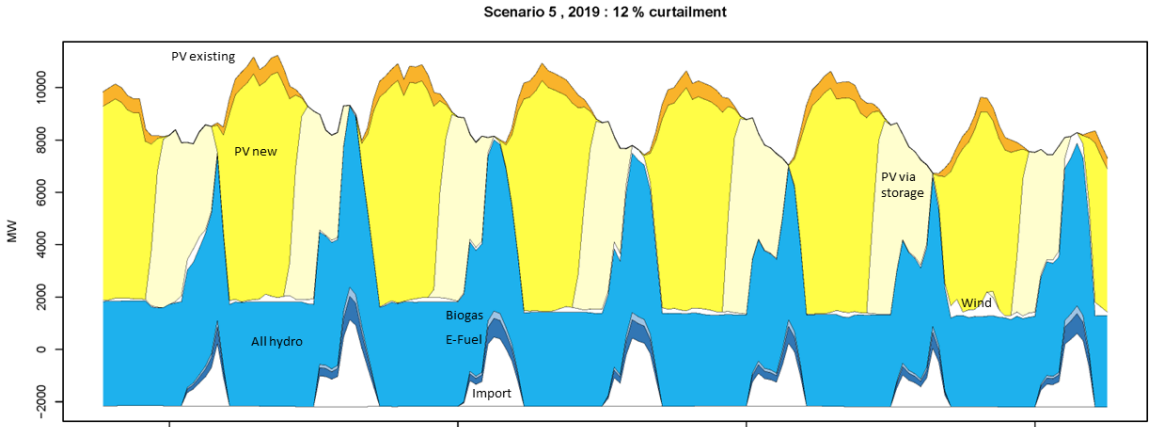
Hourly production patterns (Scenario 5)

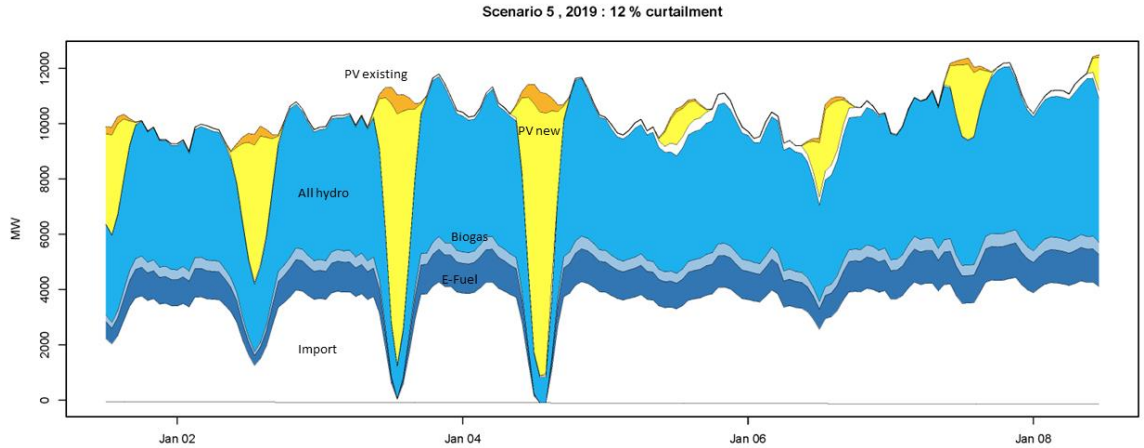
Summer:

- PV at day
- Batteries in evening
- Hydro at night
- Export at day

Winter:

- PV at day – when sunny
- Hydro all day
- E-fuels all day
- Import (if not sunny)





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Curtailment reduces costs (scenario 1a / 2a)

No curtailment → (no import)

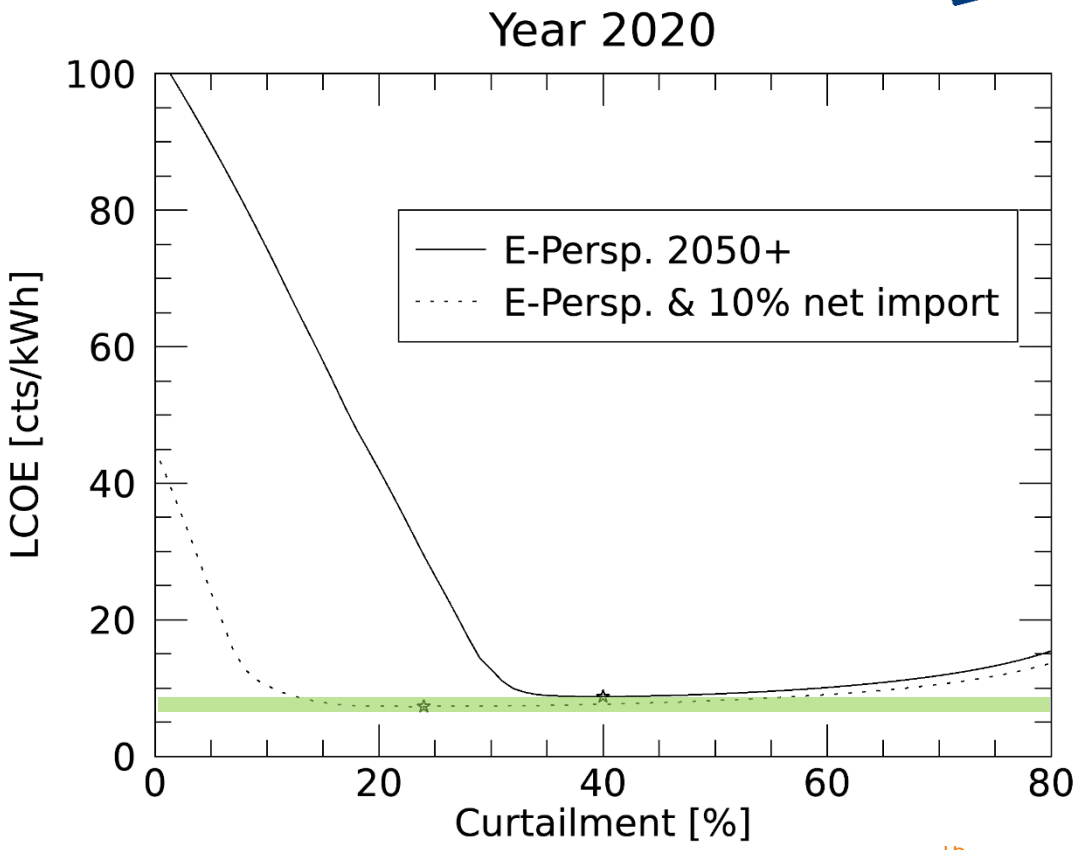
No curtailment → (with 10% import)

With curtailment →

100 cts/kWh

40 cts/kWh

7



Price levels: 2015-2019

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Conclusions

- 10–85 GWh of batteries are feasible compared to the expected electrical vehicle batteries (about 200 GWh of battery storage)
- Stand-alone grid operation would increase these costs by an average of 7%
- Curtailment lowers production costs by 63% for import/export configuration, and 450% for stand-alone
- Overbuilding and curtailment of PV is “the enabler” of the energy transition
- Curtailment has to be taken into account for all net zero modelling

Take home messages & outlook

- **Renewables are securing costs and climate and energy reliability**

  → The quicker we get to 100% renewables, the stabler the system and the less it depends on imported energy

- There is no fast track:
  - It will take 20 years with 2 GW installed / year to achieve 40 GW
- Current support and market system have to be re-modelled to obtain the optimum for the economy
  - A market system based on marginal costs seems unlikely to fit
  - Incentives to build renewable energy capacities have to be changed
  - Switch from energy to capacity (power) renumation

Report: https://www.aramis.admin.ch/Default?DocumentID=68985&Load=true

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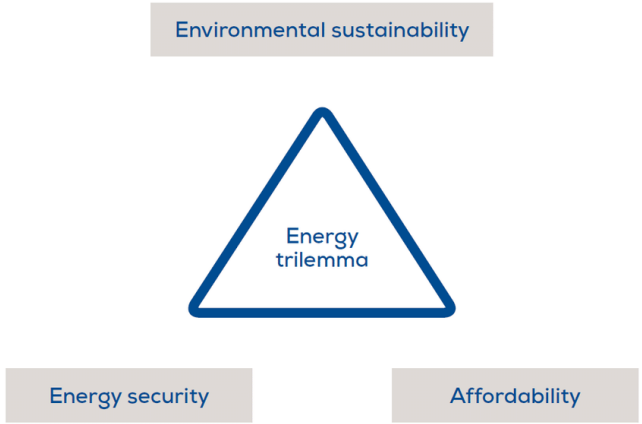
Firm PV concept solves energy trilemma

- Firm PV power concept eases heavily the energy trilemma:
  - Affordability → all scenarios show low prices
  - Sustainability → net zero is possible
  - Security → scenarios with and without import show low price

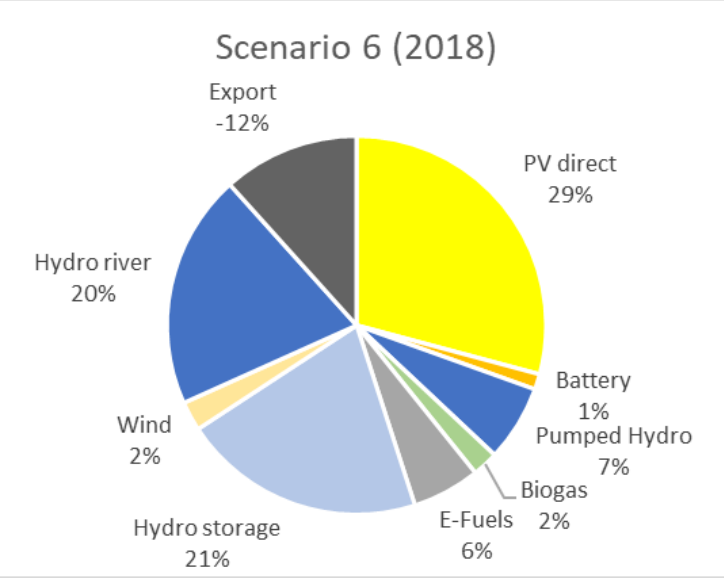


Energy trilemma according Gove et al., 2016

Different levels of security of supply can be reached without neglecting the net zero CO2 targets and still keeping electricity costs affordable.
The higher the level of security the higher the installed PV and the higher the share of curtailment is needed

Capacities and production

Share of electricity production



Installed capacities (CH cost levels)

	CH integrated						Stand-alone
Parameter	**Sc. 1**	**Sc. 2**	**Sc. 3**	**Sc. 4**	**Sc. 5**	**Sc. 6**	**Sc. 4a**
PV installed capacity [GW]	50.1	41.0	41.0	41.0	36.6	37.0	48.1
PV curtailment [TWh]	7.9	4.7	4.7	4.7	4.1	4.5	11.1
LCOE [cts/kWh]	7.5	6.7	7.5	8.1	7.1	6.9	8.6
Battery Capacity [GWh]	24.8	19.8	19.9	19.9	11.9	11.6	26.6
Imports [TWh]	10.0	18.3	10.0	10.0	18.3	18.3	0.0

Sensitivity to meteo

Low sensitivity of meteo years 2018, 2019 and 2020