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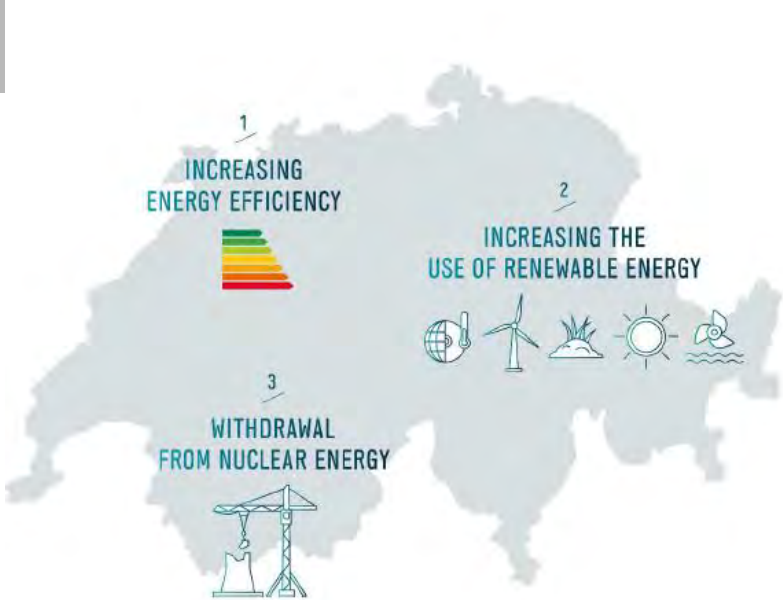
Integration of stochastic renewables in the Swiss electricity supply system

68th LCA Discussion Forum, 16th April 2018, ETH Zürich, Alumni Pavillon

New energy act: Three Strategic Objectives



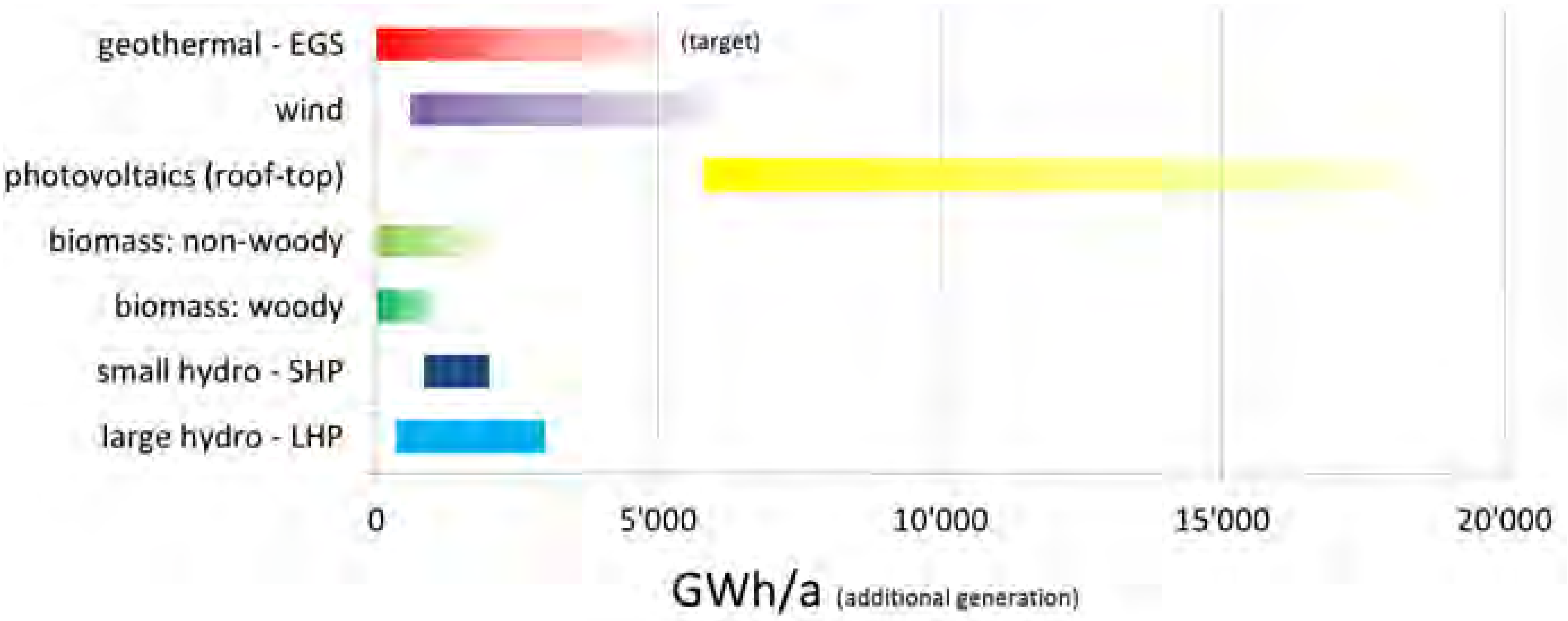
Measures to increase energy efficiency
- Buildings
- Mobility
- Industry
- Appliances

Measures to increase the use of renewable energy
- Promotion
- Improvement of legal framework

Withdrawal from nuclear energy
- No new general licenses
- Step-by-step withdrawal – safety as sole criterion

Source: Swiss Federal Office for Energy

Sustainable renewable potentials for additional electricity generation (from current levels)



Source: Bauer and Hirschberg et al., (2017) Potentials, costs and environmental assessment of electricity generation technologies

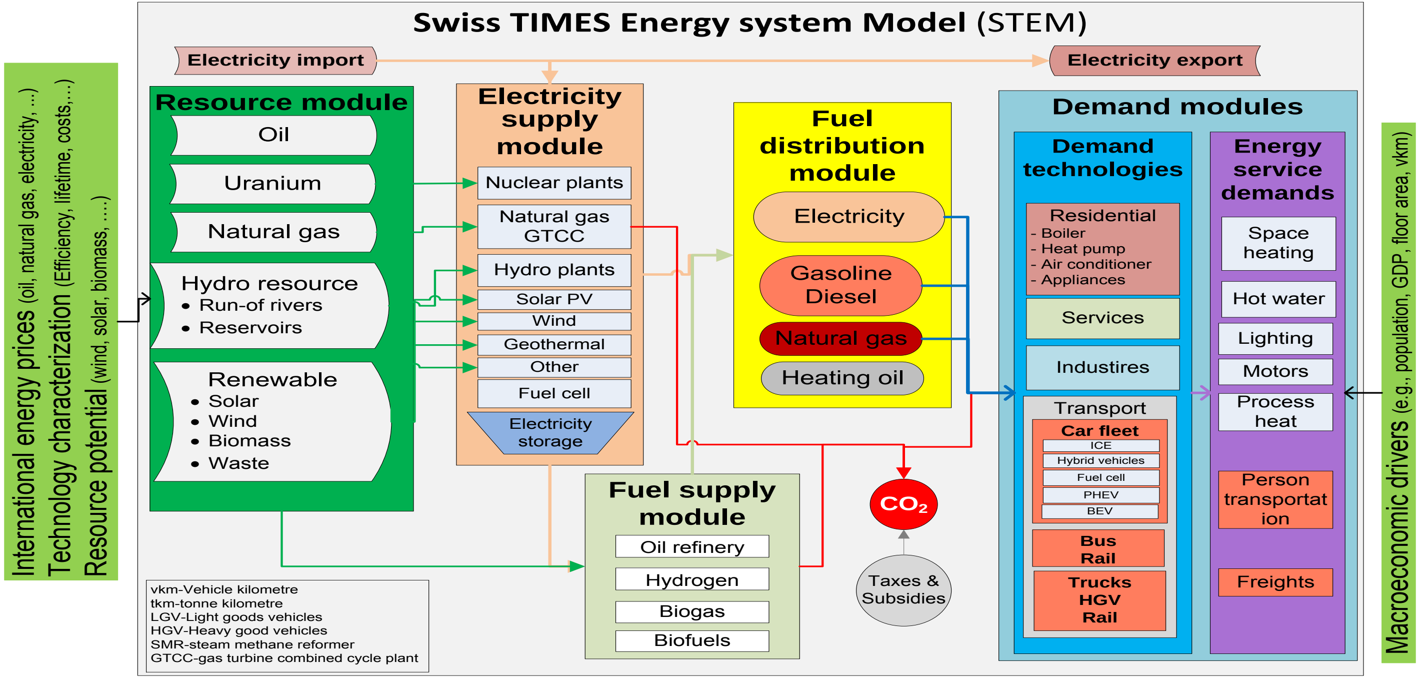
In the context of the ISCHESS project….

- We studied integration measures for variable renewable generation (VRES) from wind and solar PV in Switzerland for the horizon 2015 – 2050, such as:
  - Reinforcing and expanding the **grid network**
  - Deploying local storage, complementary to pump hydro, like **batteries and ACAES**
  - Deploying dispatchable loads such as **P2G, water heaters and heat pumps**

The ISCHESS project was funded by the Swiss Competence Center Energy and Mobility (CCEM) and is a collaboration between the Paul Scherrer Institute and the Swiss Federal Institute of Technology (ETH Zurich)
http://www.ccem.ch/ischess , https://www.psi.ch/eem/PublicationsTabelle/ischess_final_report.pdf

The Swiss TIMES Energy Systems Model (STEM)

- Represents the whole Swiss energy system in a cost-optimisation framework
- Combines long time horizon (>2050) with high intra-annual resolution (288 typical hours)
- Detail electricity & conversion modules, and several end-use sectors

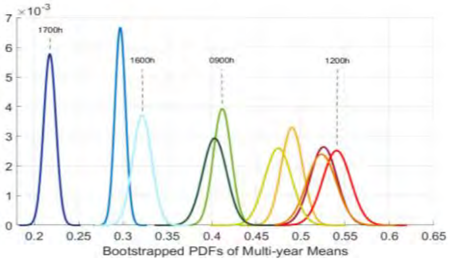


Key storage-related features in the STEM model

01

Representation of RES variability

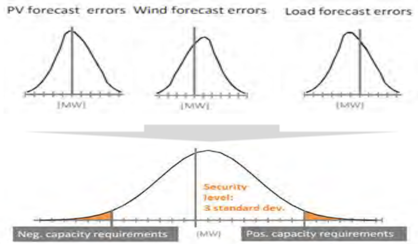
Based on a historical sample of solar and wind generation the model ensures that there is enough storage and dispatchable capacity to accommodate residual load curve variations and curtailment



02

Ancillary services markets

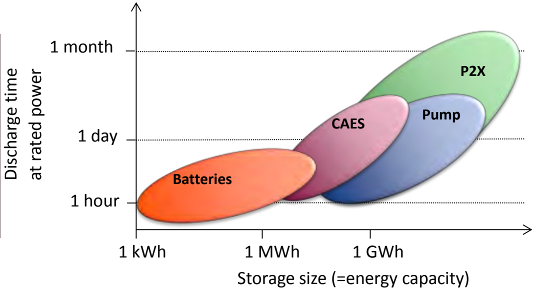
Power plants compete for the supply of electricity and the provision of reserve; storage technologies can participate in ancillary markets by forming "virtual units"



03

Several electricity-based storage technologies

Hydro storage, batteries of different sizes and time scales, technologies and applications, compressed-air storage, power-to-gas pathways

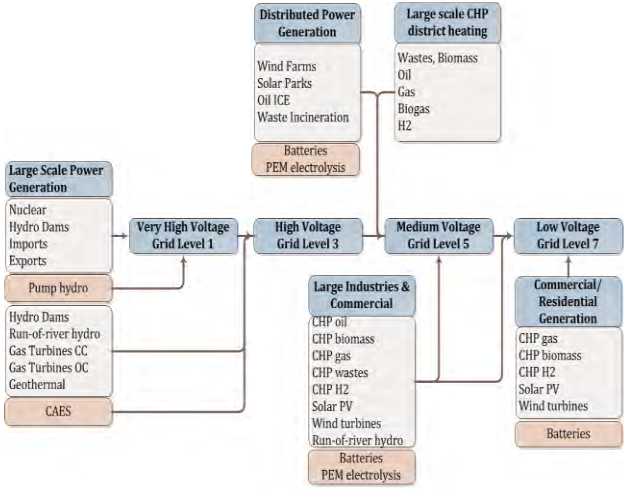


Key grid-related features in the STEM model

01

Representation of the grid levels

The grid levels are differentiated by transmission losses and costs; a set of power plants and storage options can be connected to each level; the dispatching of power plants is subject to operating constraints

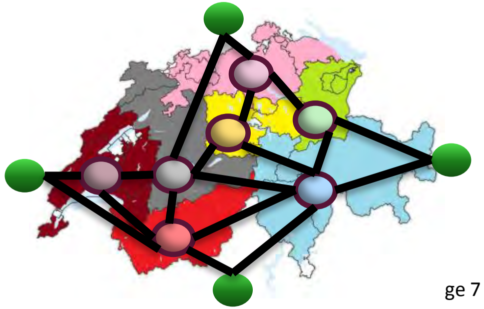


* Grid levels 2, 4 and 6 correspond to transformers

02

Representation of the grid topology

The model represents the transmission grid with 15 nodes and 316 bi-directional lines and busbars; 7 nodes represent different Swiss regions, 4 nodes represent the neighbouring countries, and 4 nodes for current nuclear plants



Long term energy scenarios analysed with STEM

About 100 what-if scenarios were assessed along **three main dimensions:**

1. **Future energy policy and energy service demands:**
   - Energy service demand growth: low growth **vs** high growth
   - Electricity imports: allowed **vs** self-sufficiency
   - Climate change mitigation policy: mild policy **vs** 70% reduction in CO_2 by 2050

2. **Grid expansion:** Grid-2025 **vs** restriction

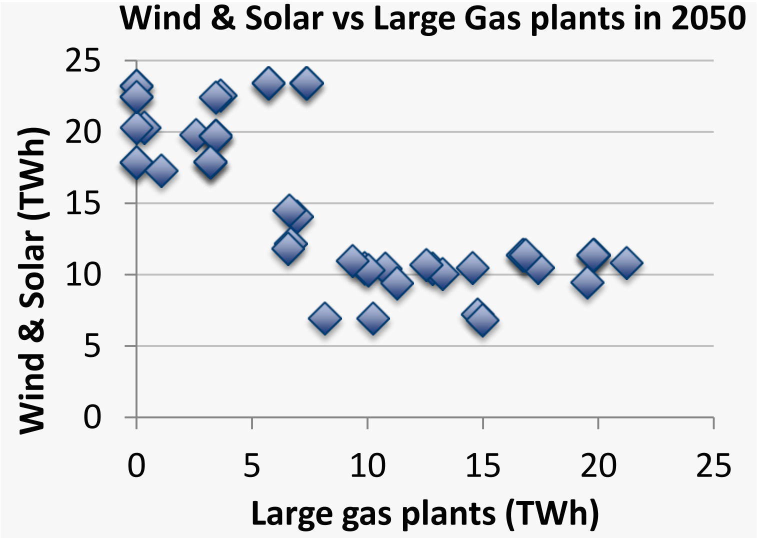
3. **Location of new gas power plants and capacity (% of total at the national level):**

	Corneux (NE)	Chavalon (VS)	Utzenstorf (BE)	Perlen (LU)	Schweizerhalle (BL)
Case 1	20.0	20.0	20.0	20.0	20.0
…	…	…	…	…	…
Case 11	0.0	33.3	33.3	33.3	0.0
…	…	…	…	…	…
Case 26	33.3	33.3	0.0	0.0	33.3

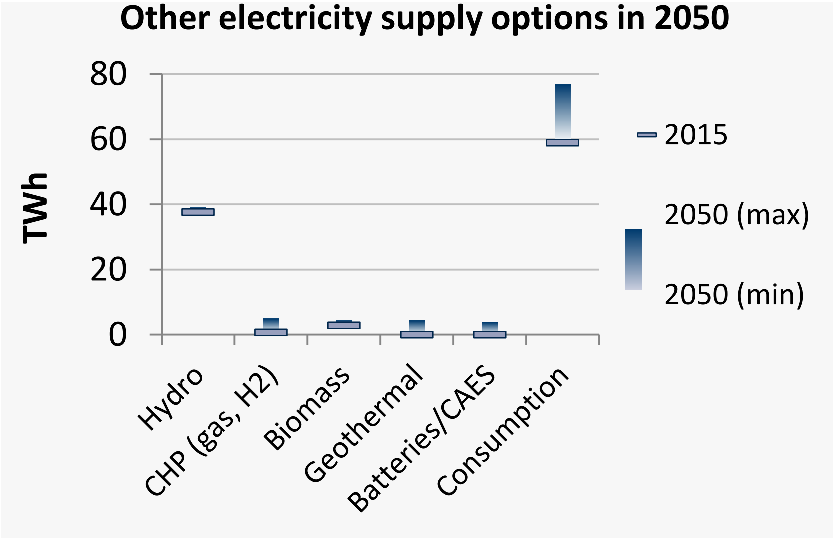
Results: Electricity Sector in 2050

- New gas plants replace phased out nuclear capacity
- Under stringent climate policy VRES provide up to 28% of the supply

- Limited expansion of hydro and biomass
- CHPs gain share in electricity production
- Geothermal competitive under stringent climate policy or under grid congestion
- Batteries could provide up to 4 TWh electricity



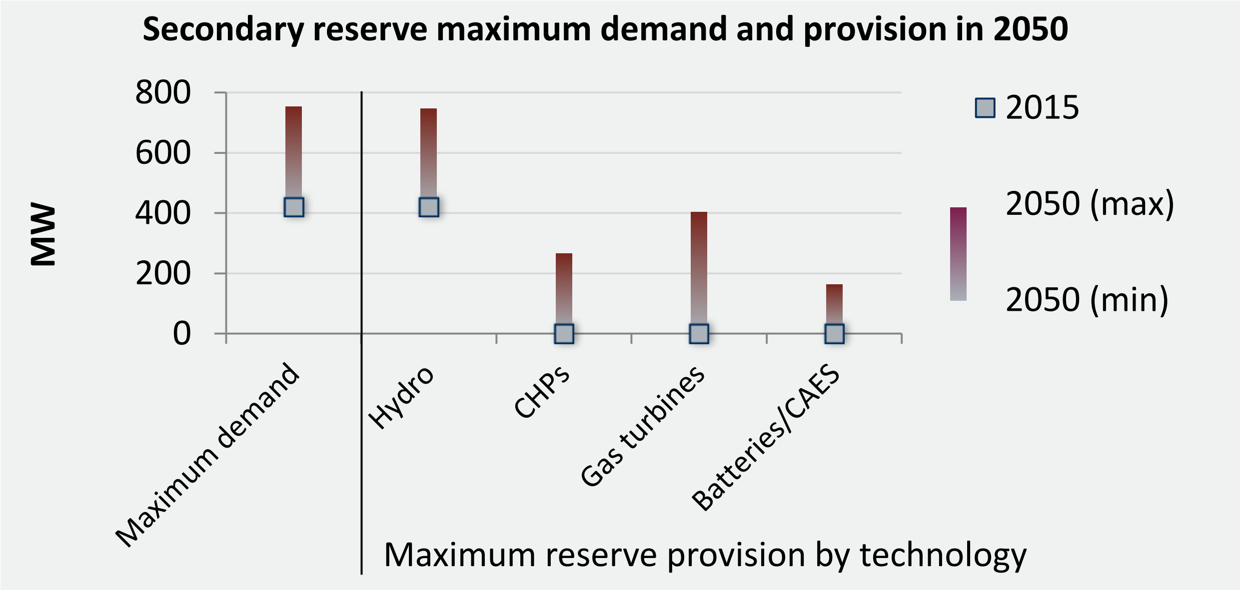
Markers correspond to a scenario



Ranges across the different scenarios

Results: Secondary Reserve Provision in 2050

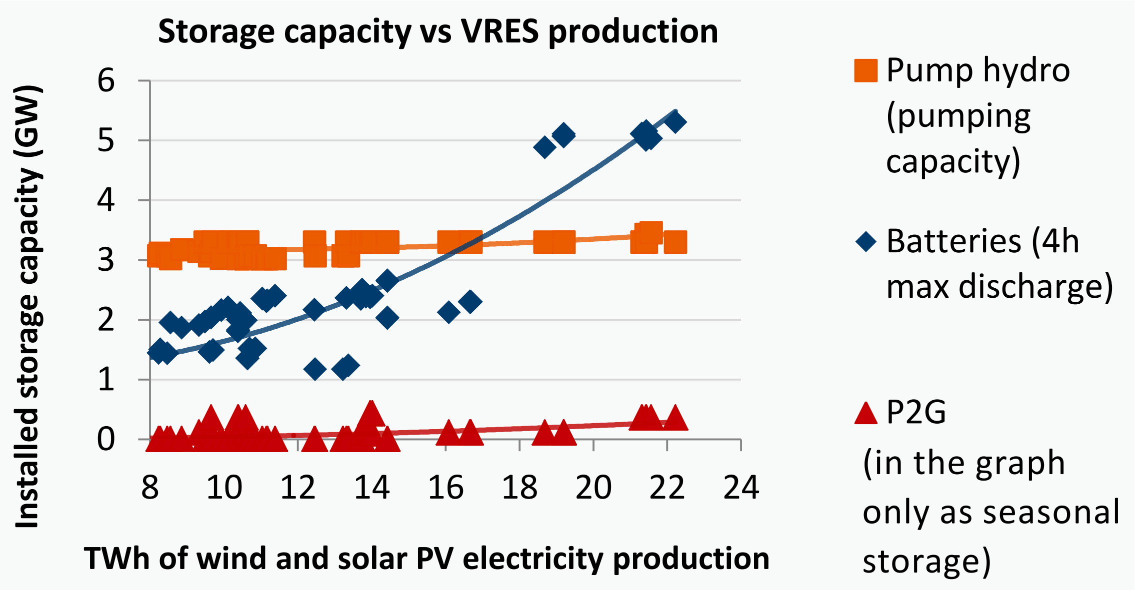
- The secondary reserve requirements almost double in 2050 from today's level and peak reserve demand shifts from winter to summer
- Hydrostorage remains the main contributor for reserve provision
- Flexible CHPs and batteries enter in the reserve provision market by forming virtual plants



Ranges across the different scenarios

Results: Stationary Electricity Storage Needs

- High shares of VRES require electricity storage peak capacity of ca. 30 – 50% of the installed capacity of wind and solar PV (together)
- About 13% of the excess summer VRES production enters in P2G pathway (~ 1-2 TWh_e) and it is seasonally shifted



Small scale batteries (>50% of total) are driven by solar PV

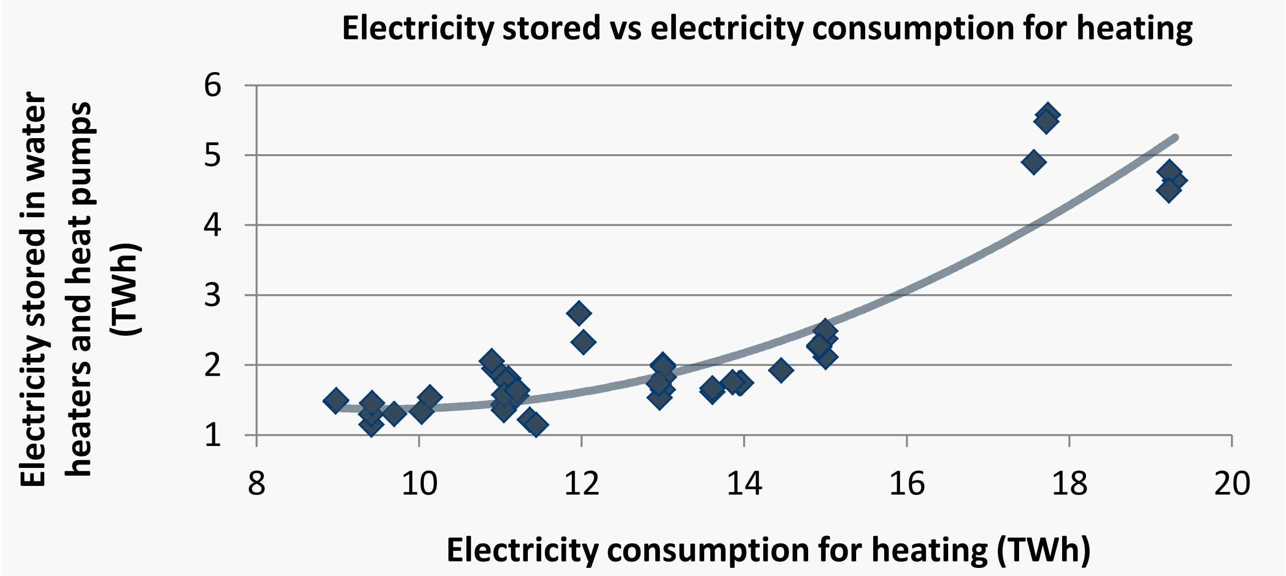
Medium scale batteries (~40%) are driven by large VRES and CHP

Large scale batteries (~10%) complement hydrostorage

Markers correspond to a different time period and scenario

Results: Electricity stored in water heaters and heat pumps

- Electricity storage in water heaters and heat pumps could represent up to 25% of the total electricity consumption for heating
- Large potential for load shifting is in water heating followed by space heating in buildings (>90% of the total shifts occur in the buildings sector)

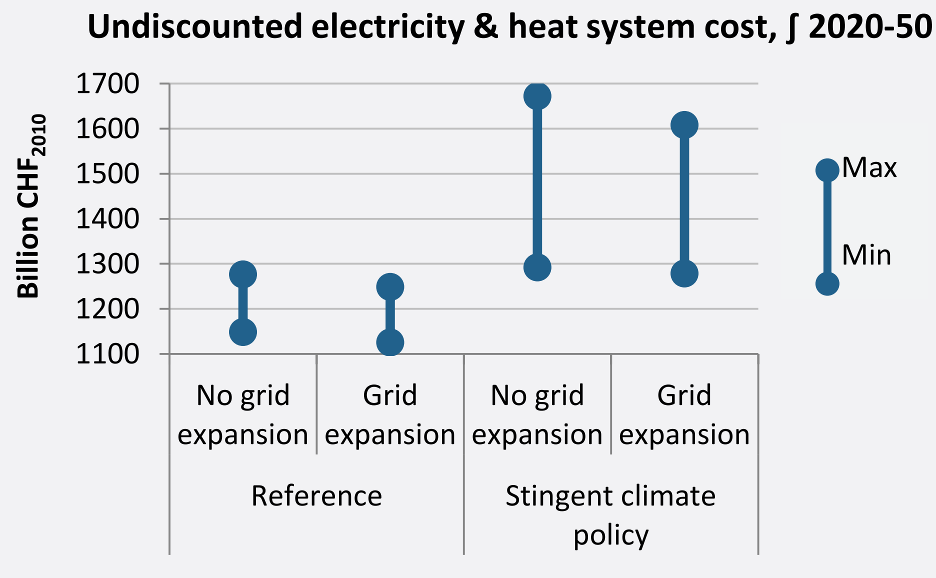


Markers correspond to a different scenario

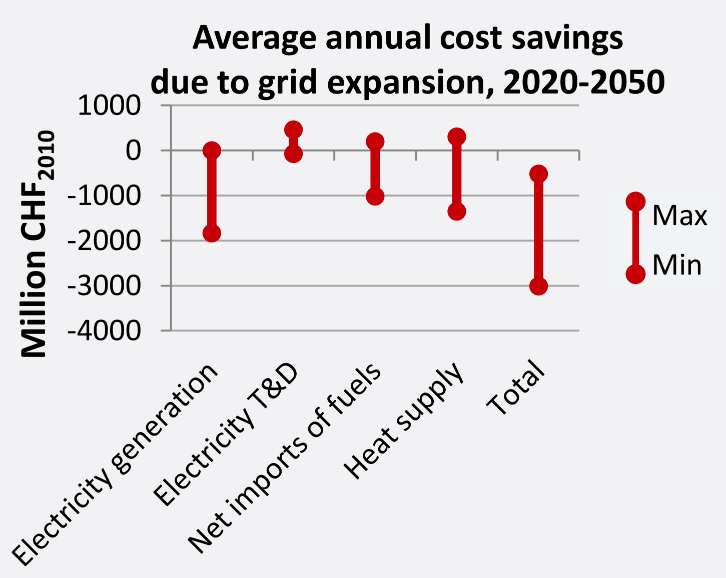
Results: Electricity Grid Expansion Benefits

- Restrictions in grid expansion results in higher system* costs (up to +90 BCHF) due to the non cost-optimal deployment of electricity supply options and reliance of demand on fossil fuels

- Grid expansion results in cost savings due to fuel switching (higher electrification of demand) and less imported fuels



Ranges across the different scenarios

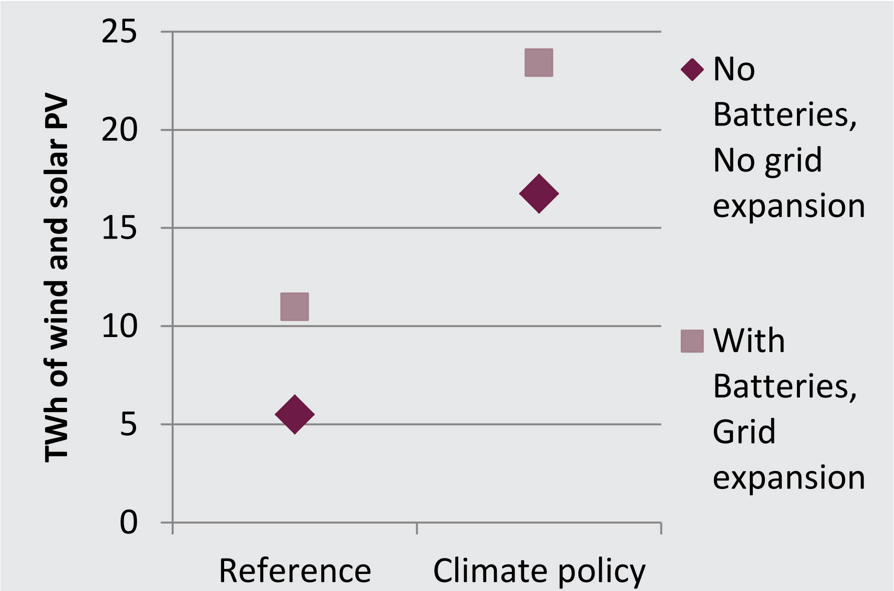


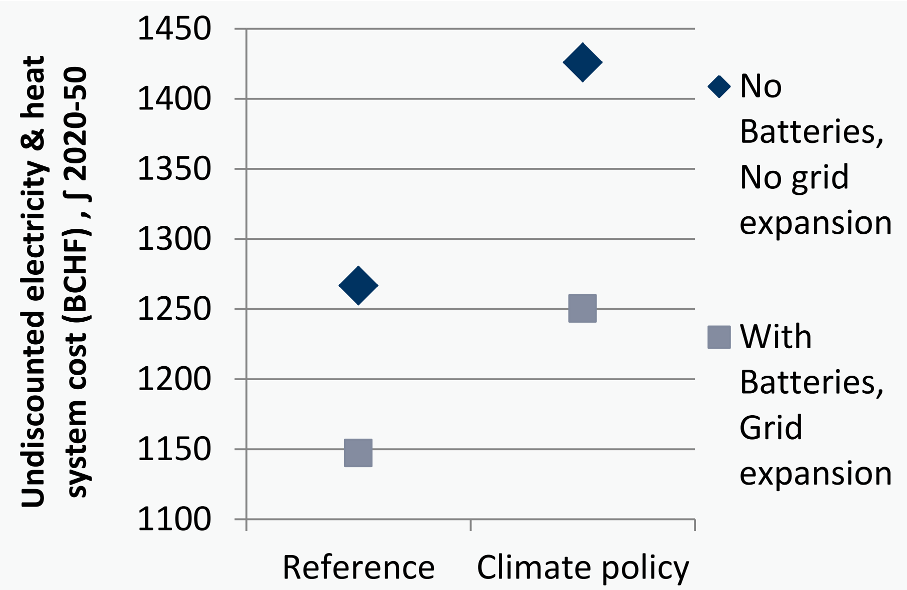
Ranges across the different scenarios

* The system cost (CAPEX, OPEX, fuel costs, etc.) refers to the supply and consumption of electricity and heat in stationary applications

Results: Synergies among the flexibility options

- Batteries are important to cope with the intra-day variability of RES
- Grid expansion enables further electrification of demand and indirectly more RES deployment
- Without batteries and grid expansion, there can be 30-50% less deployment of wind and solar
  – …. while system* costs can be 10-14% higher (and climate policy costs** increase >50%)



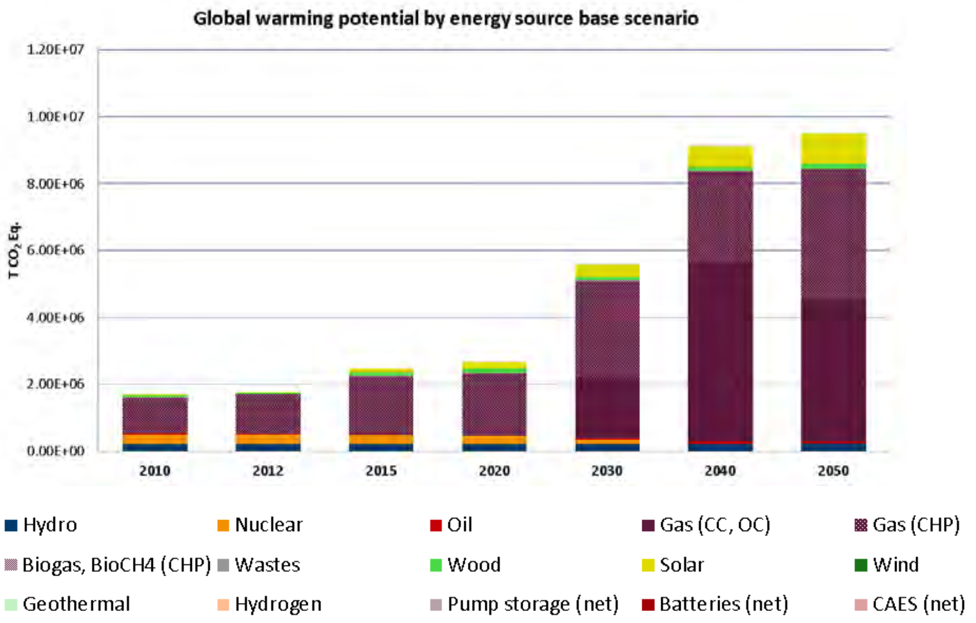


* The system cost (CAPEX, OPEX, fuel costs, etc.) refers to the supply and consumption of electricity and heat in stationary applications

** The climate policy cost is calculated as the difference of the system costs between the Climate policy and the Reference scenarios

Integrating LCA into energy systems models

- A current PhD thesis integrates LCA in the STEM energy systems model, by:
  - Introducing constraints on LCA indicators, which are then accounted in the cost optimisation
  - Modifying the objective function of STEM to be a weighted sum of LCA indicators and system cost



Vandepaer Laurent, Panos E., Bauer C. and Amor B. (2017)**.** Prospective environmental assessment of stationary batteries and their consequences in energy systems: the case of Switzerland., *23rd SETAC Europe LCA Case Study Symposium*, Barcelona, Spain

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Conclusions

- **Role of storage increases** in the long term both for electricity and heat supply in the Swiss energy system:
  - Integration of generation from renewable energy
  - Back-up power and reserve
  - Load levelling and peak shaving
  - Seasonal energy shifting
- **P2X as an option** to deal with power surplus and to partly decarbonise energy demand
- **Short-term storage requirements are up to four times more than the seasonal storage**
- **Besides investment costs, efficiency as key factors for storage**, because low efficiencies translate into extra generation capacity to satisfy demand and into extra storage capacity to satisfy the systems balancing needs
- **Multiple flexibility options** (network expansion, storage, Demand Side Management) have synergistic and complementary effects

My thanks go to the whole ISCHESS team:

- Kannan Ramachandran
- Tom Kober
- Christian Bauer
- Warren Schenler
- Peter Burgherr
- Stefan Hirschberg
- Alexander Fuchs
- Turhan Demiray