ETH zürich

Analyzing Future Market Designs for Switzerland – Results of the AFEM Project

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Energy Science Center

Outline

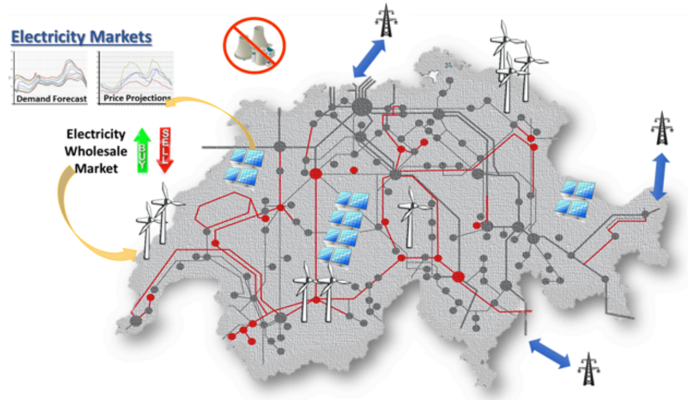
AFEM (Assessing Future Electricity Markets)

- Motivation
- AFEM Project Overview
- Future Market Scenarios
- Baseline Assumptions
- Results: Impact of Nuclear Phase-out
- Results: Renewable Targets
- Results: Other Scenarios
- Summary of Conclusions

Why AFEM?
Modeling the Energy Transition

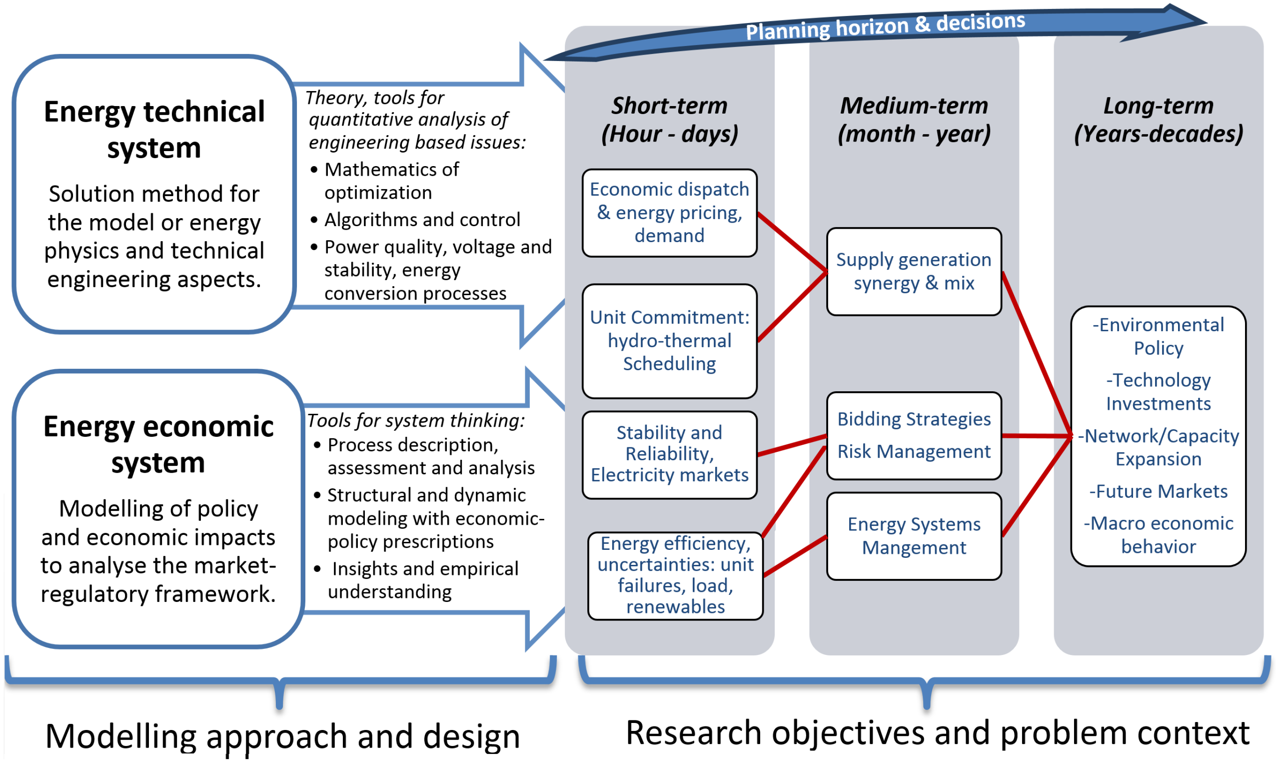
Current Situation of the Electricity Market(s) in Switzerland and Europe:

1. Eroding electricity prices
2. Missing investment incentives (e.g. efficient gas turbines, hydro)
3. Capacity Markets are being evaluated/installed (also strategic reserves)
4. Increasing share of Renewable Energy Sources (RES)
   → Flexibility and/or storage is needed
5. Security of Supply?
   → We need to assess future market designs!

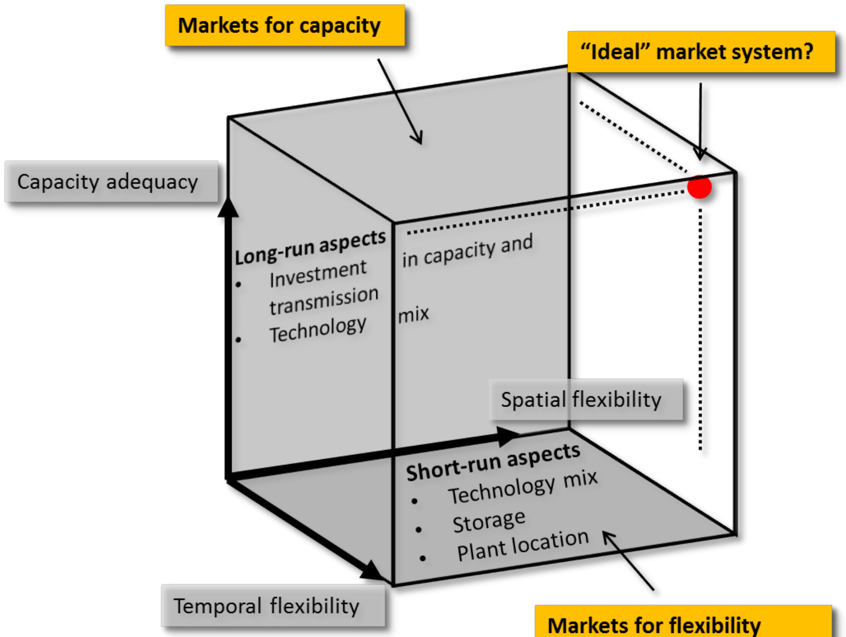


Most energy modelling efforts do not cover a broad/deep scope

- Insufficient interdisciplinary understanding between macro economic-policy and energy-technology disciplines
- Interfaces and model coupling
- Interlinking renewables, economics and security of supply
- Few methodologies that build-up 'whole scope' models by building on the insights of submodels



AFEM couples several dimensions of the energy-economic system to assess future market options



- Provide a model to evaluate and assess electricity market designs
- Present scenarios to reach the goals of ES2050 using market mechanisms
- Determine the renewable source potentials for solar and wind based on geographical location
- Support decision makers in questions regarding market designs, support schemes for RES, maintaining security of supply and grid expansion
- Take uncertainties into account

AFEM research questions

1. **How will the Swiss and European electricity market evolve** if the existing market mechanism (energy only market, reserve market) be perpetuated as is?
2. How will the market evolve if **additional market components** such as capacity markets are introduced?
3. How do **future market models** need to be designed in order to give the "right" investment incentive (e.g. flexibility markets) for an efficient yet carbon-free electricity supply system?

Under the following operational constraints:

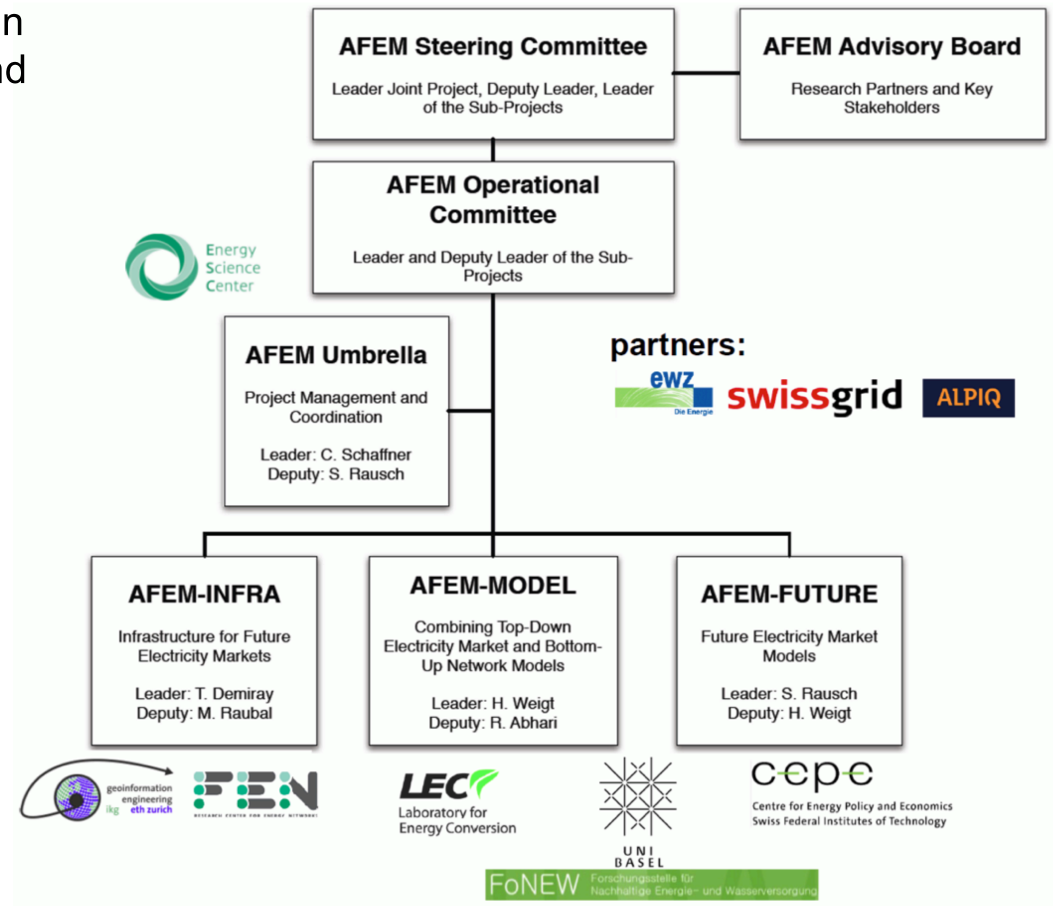
- Defined level of Security of Supply (in relation to the market proposed)
- Reduced CO2-Emissions (market incentives, ES 2050 goals)

Aiming at an increased share of Renewable Energy Sources (RES)

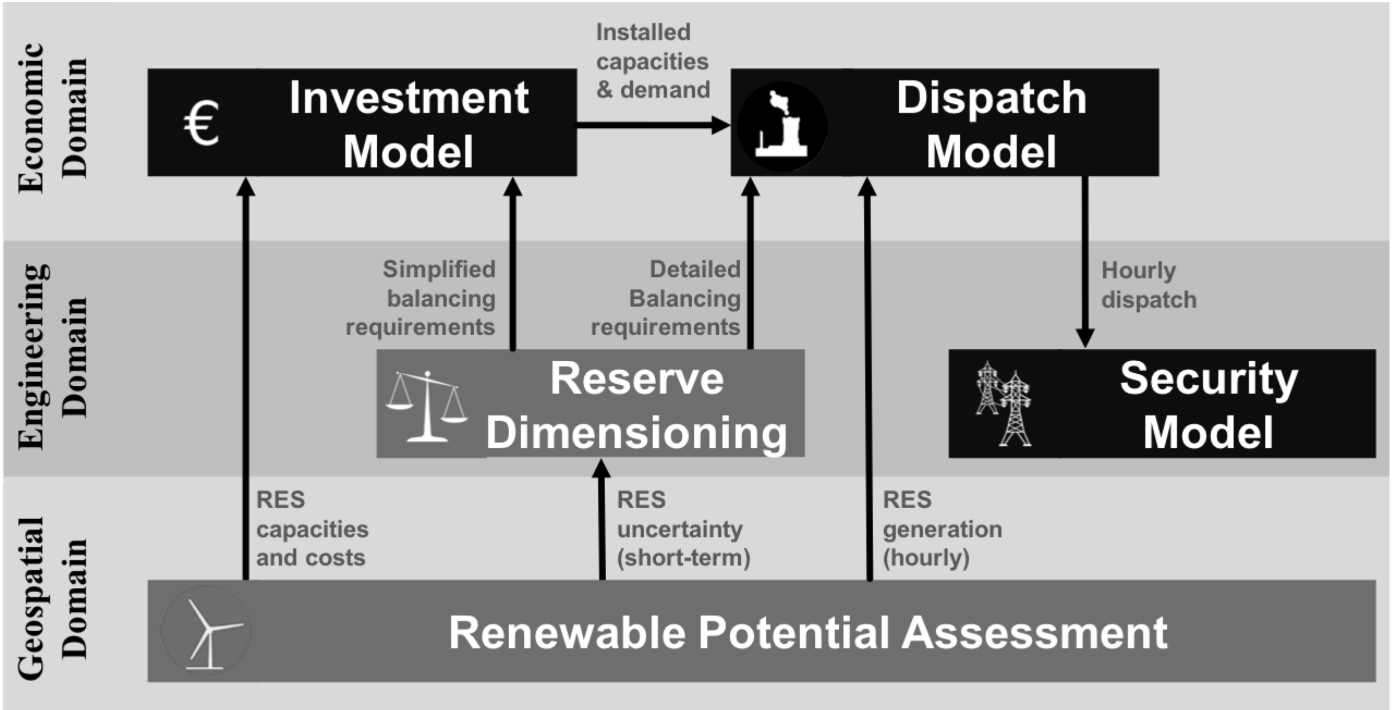
AFEM Project Organization

Joint effort of ETHZ and University of Basel using an inter-disciplinary approach, combined bottom-up and top-down modelling.

- **Energy Science Center:**
  - Christian Schaffner, Lead
  - Pedro Crespo Del Granado, Post-doc
- **Forschungsstelle Nachhaltige Energie- und Wasserversorgung**, **University of Basel:**
  - Hannes Weigt, Lead
  - Jonas Savelsberg, PhD Student
- **Center for Energy Policy and Economics:**
  - Sebastian Rausch, Lead
  - Jan Abrell, Post-doc
- **Forschungsstelle Energienetze:**
  - Turhan Demiray, Lead
  - Jared Garrison, Post-doc
- **Laboratory of Energy Conversion**:
  - Reza Abhari, Lead
  - Ndoana Chokani, Senior Researcher
  - Patrick Eser, PhD student
- **Geoinformation Engineering**,
  - Martin Raubal, Lead
  - Fabio Veronessi, Post-doc
  - Stefano Grassi, PhD student



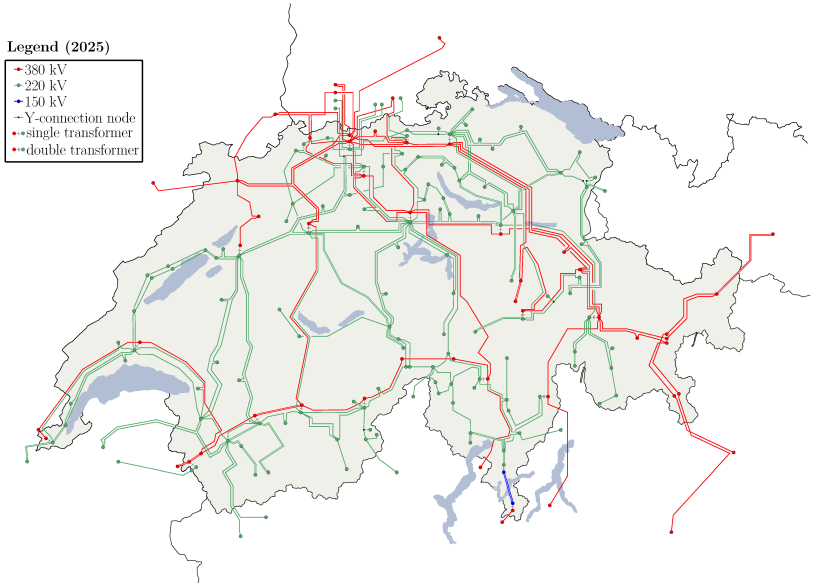
AFEM Modeling Framework



Spatial dimension: Switzerland and first neighbors
Time dimension: Hourly in 5 year steps until 2050

What do we cover (and not cover)?

- Hourly market clearing (uniform within country)
  But: Optimized framework without contract length or lead-times
- Reserve procurement depending on renewables
  But: Optimized as hourly contracts with no lead times
- Spatial dimension
  DC load-flow in dispatch, AC for security analysis
- Hydro power:
  Detailed cascading hydro flows in dispatch model
  Investment model abstracts from cascading hydro
- Detailed assessment of renewable potential/variation
  But: No uncertainty in models



Future Scenarios Overview

<table>
<tr><th>Capacity Mechanism</th><th>RES Policy</th><th>Balancing</th></tr>
<tr><td>None</td><td>None</td><td>Current system
Sizing: Year-ahead
Tertiary/secondary: According to current Swissgrid rules</td></tr>
<tr><td>Strategic storage reserve
Demand: 750 GWh</td><td rowspan="2">RES support
Demand (targets): 4.4, 11.3, 18.4 in 2020, 2035, 2050
Supply: PV, Wind, Biomass</td><td rowspan="2">Maximum flexibility
Renewable generation causes no additional reserve demand</td></tr>
<tr><td>Market-wide capacity market
Demand: Highest hourly demand in each year
Supply: All units in the market according to average availability; interconnectors not eligible</td></tr>
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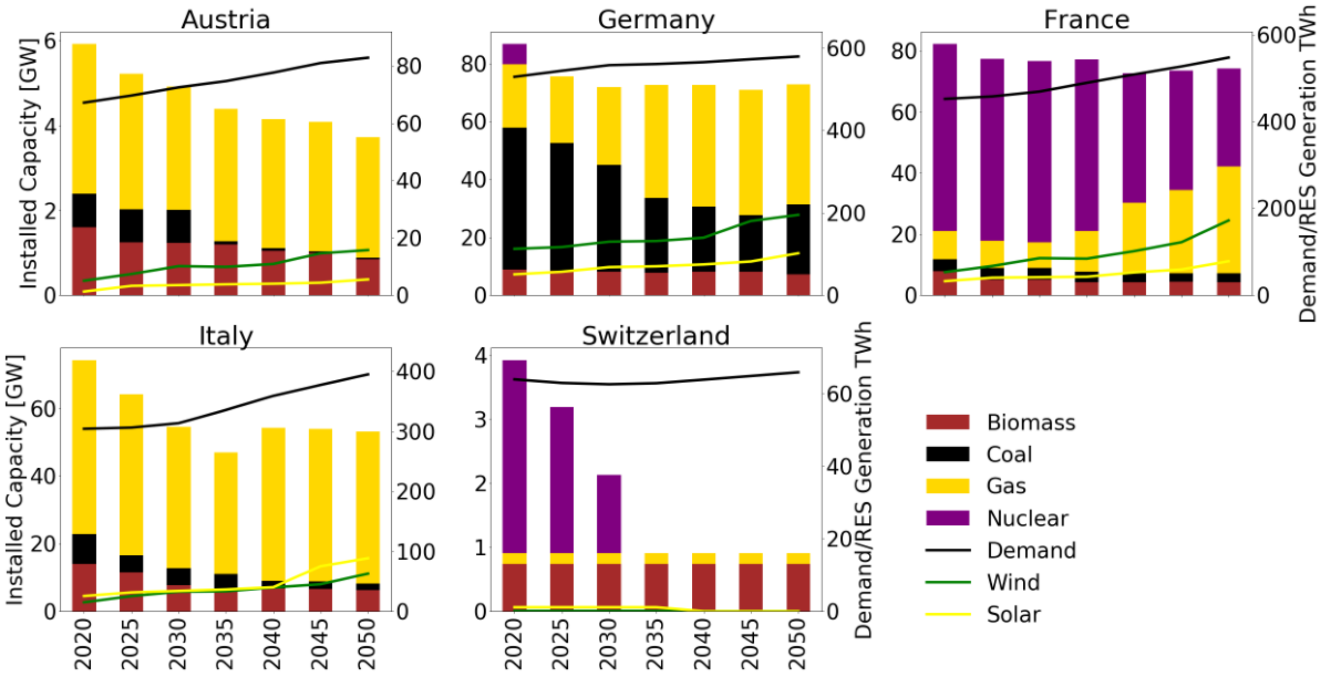
Baseline Assumptions: Capacities

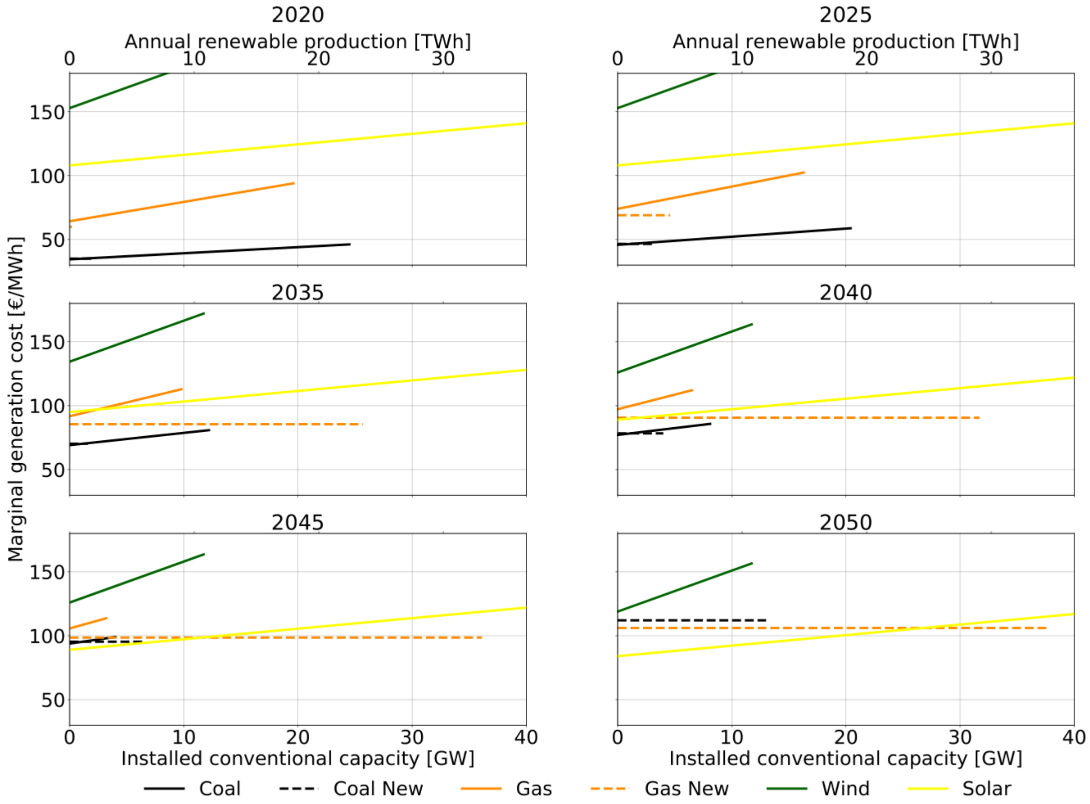
- Switzerland: Nuclear phase-out until 2050; demand according to Energy Strategy
- Capacity development of neighboring countries based on EU energy reference scenario



Notes: The graph shows exogenously imposed changes of installed capacity (left axis, GW), demand, and renewable generation (right axis, TWh). Hydro capacities, modestly increasing over time, are not shown.

Baseline Assumptions: Costs

- Fuel and carbon prices according to EU energy reference and World energy outlook
- Renewable cost based on detailed spatial analysis for Switzerland and neighbors
- Exogenous technological progress for renewable cost (based on EU reference)

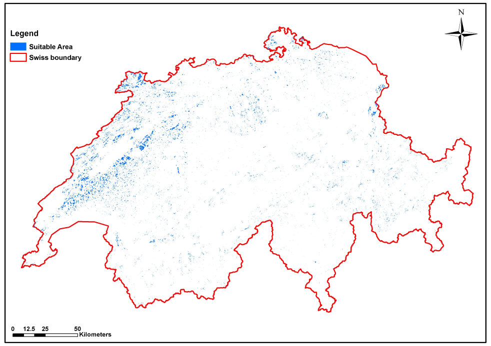


Results

Renewable Potentials are dominated by PV

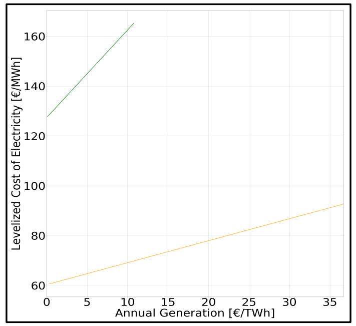
- GIS-based optimization of turbine location and quantity
- Rooftop-based assessment of radiation, installable potential, and energy production
- Potential for PV capacity is both larger and lower cost than for wind power

Wind Potential Assessment

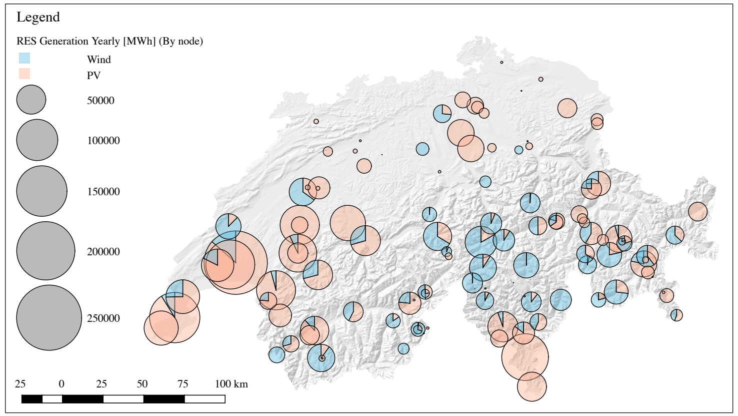


Solar Potential Assessment

Costs



Production



0.7 GW added Wind
3.2 GW added PV
} (Ex. from Prognos)

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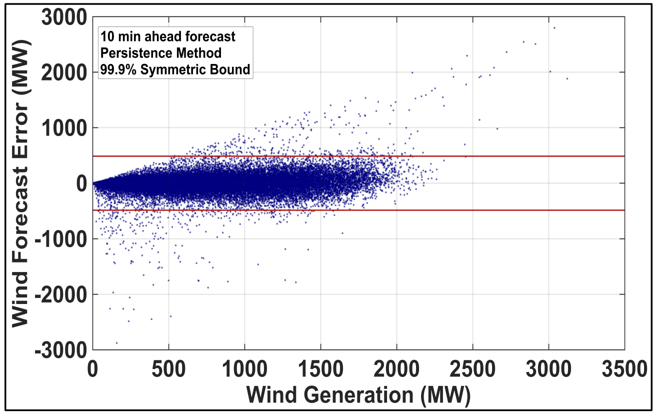
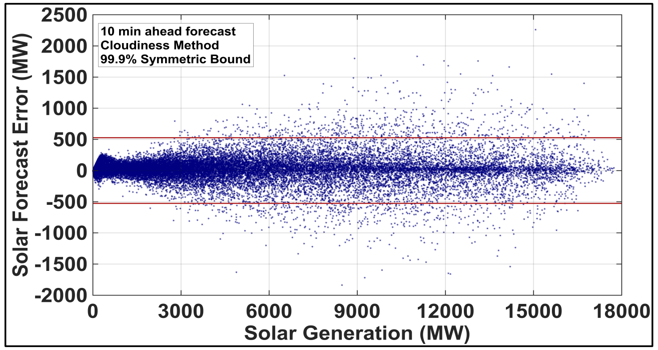
Flexibility needs for renewables is manageable

- Reserve sizing to cover 99.9% of additional imbalance
- Solar utilized clear sky irradiance for improved forecast
- ➢ Uncertainties in Wind greatly exceed PV
- RES additions in AFEM results are mostly PV
- ➢ Only moderate increase in reserves needed (100-150 MW) for case with 12 TWh of RE generated





Year	2020	2050
Tertiary UP (MW)	442	536
Tertiary Down (MW)	227	380

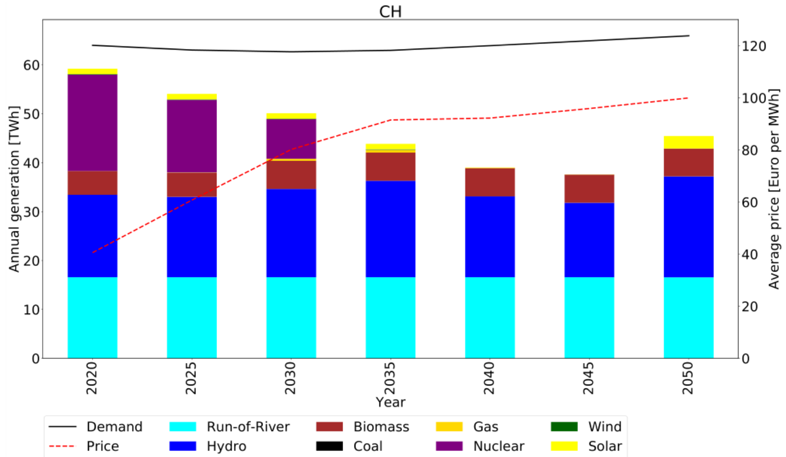
Baseline Scenario Results: The Impact of Nuclear Phase-out

Investments

- Biomass: 130 MW
  (potential exhausted by 2025)
- PV: ~4.3 GW (2.5 TWh)
  most in 2050

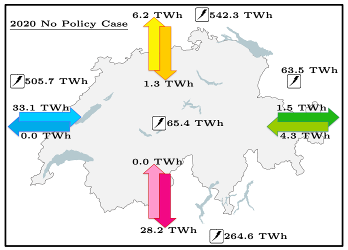
Nuclear phase-out mainly balanced by an increase in net-imports

- Mostly reduced exports to Italy

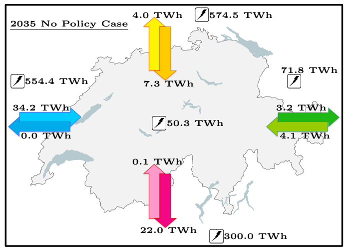


Notes: The graph shows annual generation in Switzerland by generation technology as well as annual demand in TWh (left axis). On the right axis the average electricity price is shown in € /MWh.

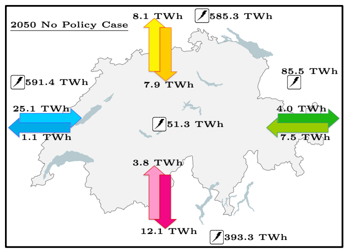
2020 Net-imports = 2.8 TWh



2035 Net-imports = 16.5 TWh



2050 Net-imports = 19 TWh

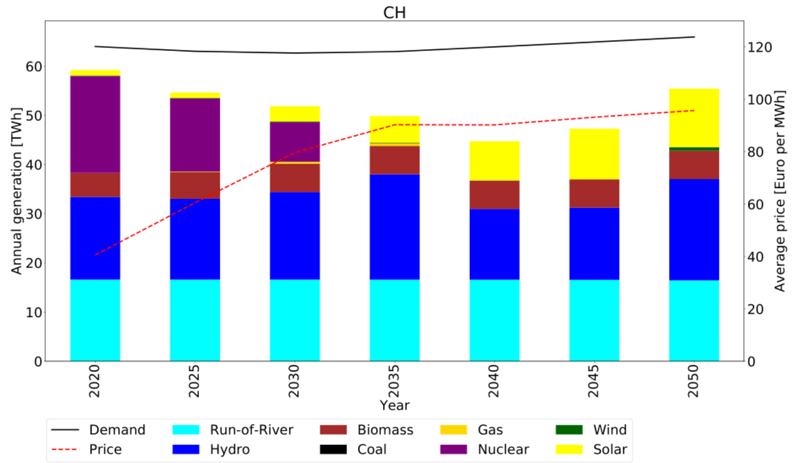


Renewable Target Scenario: achieving 18.4 TWh in 2050

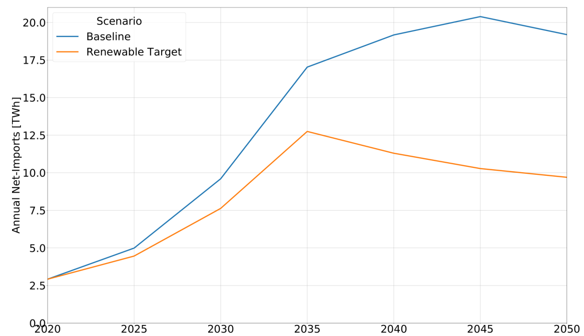
Investments

- Biomass: 130 MW
  (potential exhausted by 2025)
- PV: ~20.3 GW (11.9 TWh)
- Wind: ~0.6 GW (0.7 TWh)

Reduction of net-imports due to renewable support mechanism



Notes: The graph shows annual generation in Switzerland by generation technology as well as annual demand in TWh (left axis). On the right axis the average electricity price is shown in € /MWh.



Renewable Support Premium

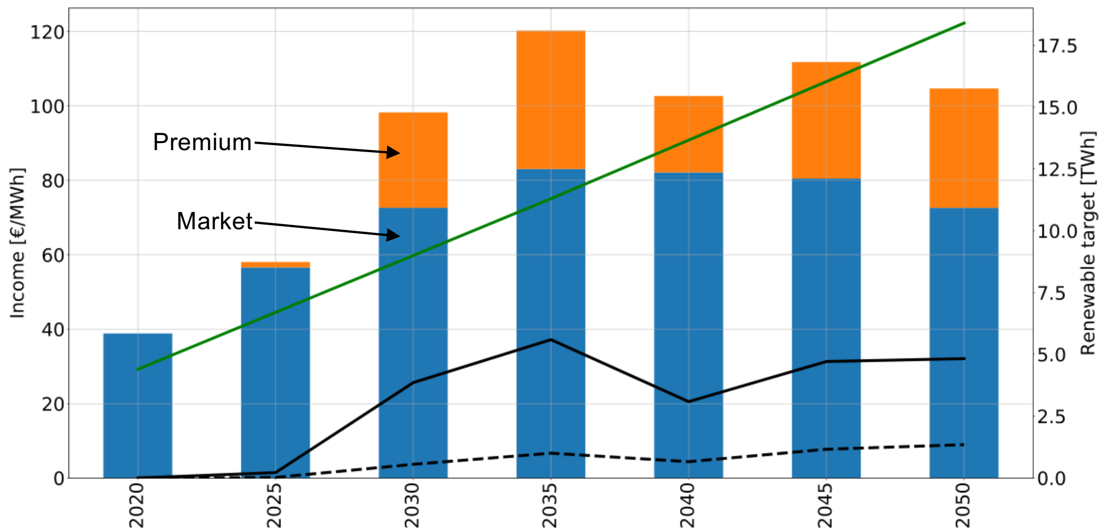
Premium affected by

- Relative marginal cost
- Renewable target
- Marginal cost in subsequent period

- Premium peaks in 2035 (37.19 € /MWh)

- Demand surcharge in 2050: (8.95 € /MWh)

Figure 15: Renewable support premium



Notes: The graph shows the the mean income of solar producers by year (left axis € /MWh). Also shown is the absolute level of the renewable premium (black line) as well as the final demand surcharge to refinance expenses for premium payments (dotted black line; both left axis € /MWh). The demand surcharge is derived as total expenses on renewable support divided by final demand. The right axis measures the renewable target in TWh (green line).

Other scenarios made virtually no impact

Capacity markets

- Virtually no impact as capacity target is already met

Storage reserve

- (minimum requirement of 750 GWh)
- Only slight reconfiguration of storage

Optimal balancing market

- Only slightly favorable for renewables

Capacity Mechanism	RES Policy	Balancing
None	None	**Current system** Sizing: Year-ahead Tertiary/secondary: According to current Swissgrid rules
Strategic storage reserve Demand: 750 GWh	**RES support** Demand (targets): 4.4, 11.3, 18.4 in 2020, 2035, 2050 Supply: PV, Wind, Biomass	**Maximum flexibility** Renewable generation causes no additional reserve demand
Market-wide capacity market Demand: Highest hourly demand in each year Supply: All units in the market according to average availability; interconnectors not eligible		

Table 2: Capacity targets [GW]

Year	2020	2025	2030	2035	2040	2045	2050
Target	10.5	10.4	10.3	10.3	10.5	10.7	10.8

Notes: The capacity target is derived as the annual peak demand of Switzerland. In all years peak demand occurs at February 6 10 am.

Summary and conclusions

Model capabilities: Assessments of the transformation of the Swiss electricity system should be embedded in an integrated modelling framework to obtain consistent results.

Market operation: The existing hydro assets, the projected Swiss transmission network, and the available import and export capacities are well suited to ensuring the stable short-term operation of future electricity markets.

Market dynamics: The price levels and dynamics will be largely shaped by global and European drivers (fuel prices, carbon tax prices). However, the hourly price dynamics may both pose threats and present opportunities for storage and RE operators.

Renewable energy support: Without RE support schemes, only minimal amounts of domestic RE investments are achieved, making Switzerland an annual net importer.

RE potentials: Solar power is a more cost-effective, available and predictable RE resource for Switzerland than wind.

Transmission network reliability: The Swiss electricity grid is sufficient to support the change in flow patterns anticipated in future years.

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Thanks for your attention

Questions?

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http://www.nfp70.ch/en/projects/electricity-supply/future-electricity-markets

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https://ieeexplore.ieee.org/document/8469895