PATHFNDR project

Nexus-e: Integrated Energy Systems Modeling Platform (ETH Zurich)

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Agenda

I. What is Nexus-e? A model overview.

II. How can Nexus-e be used? Selected Case Study.

III. How does it work exactly? Model processes.

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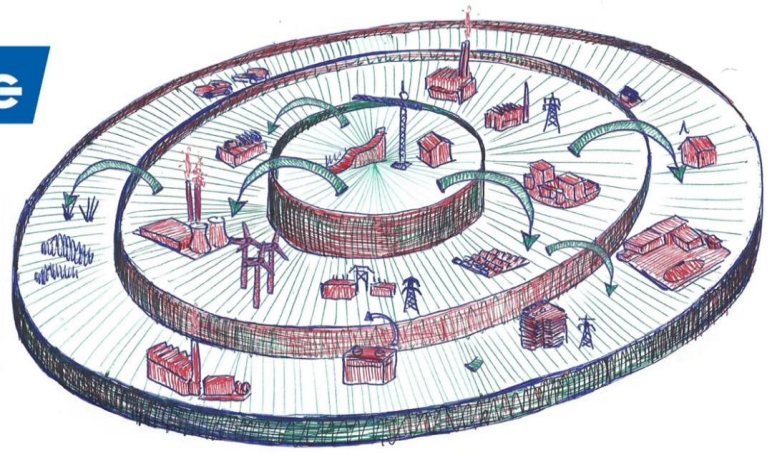
Purpose

- Assessing the the development of energy systems
- Combining macroeconomic and energy system optimization modelling approaches
- Offering a Platform architecture



Modularity:

- Integrate models through a modular structure
- Interact with existing projects to capture know-how

Defined interfaces:

- Identify, define and implement interfaces to connect modules
- Facilitates exchange of existing modules with new ones

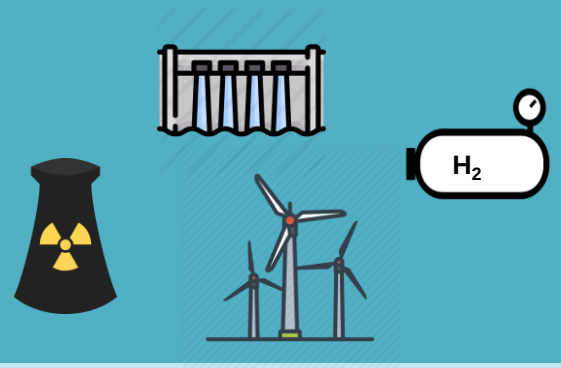
Transparency:

- Be a transparent and well-trusted platform
- Harmonize research viewpoints, data and assumptions

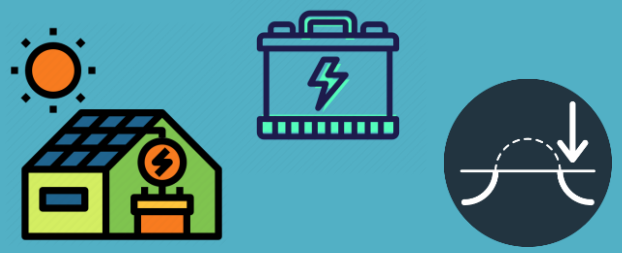
Features

Electricity System Optimization

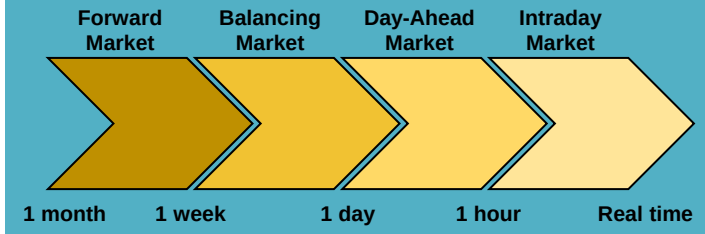
Centralized System



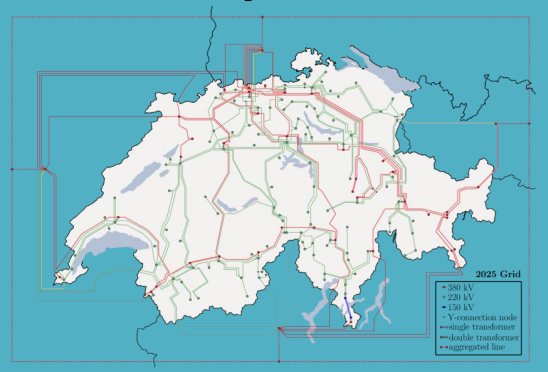
Decentralized System



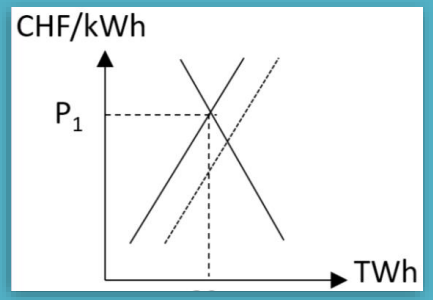
Electricity Market Optimization



Grid Security Assessment



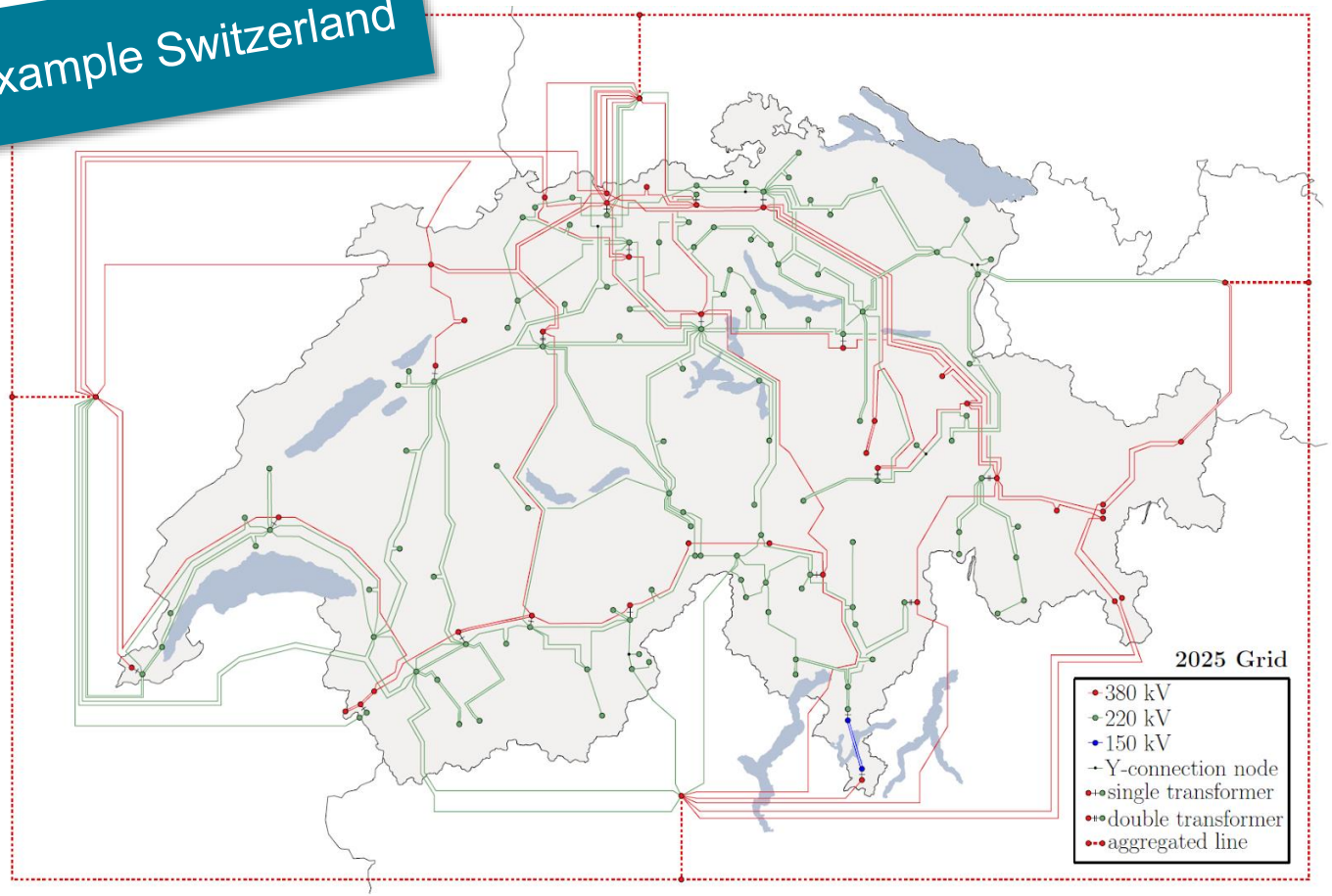
Macroeconomic Assessment



5 Core Features of Nexus-e

Scope

Example Switzerland



- Electricity systems in full detail on transmission level
- Countries either represented in full detail, aggregated, or as fixed electricity flows
- Temporal coverage unlimited, including path dependency
- National, cantonal, and nodal resolution
- Hourly temporal resolution
- Account for NTC or flow-based cross-border limits

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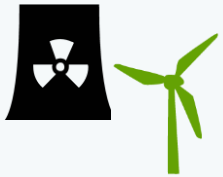
Case study: The role of flexibility providers in shaping the future energy system

Energy Strategy 2050



- Nuclear phase-out
- Renewables
- Demand reduction
- Deep decarbonization

- Security of supply
- Investment and incentives

Energy Transition in other European Countries

Renewables cause higher variability and uncertainty and needs to be matched with **increased flexibility**.

- Short-term flexibility
- Long-term flexibility

1. What are potential pathways for the future Swiss electricity system?
2. What is the need for flexibility in the projected Swiss electricity system?
3. Who provides the required flexibility?
4. What are the macroeconomic and environmental impacts of the future Swiss electricity system?

Scenario Overview

Baseline

- Projected development of input parameters
- Represents the policy status quo

Nuclear 60

- Discusses the nuclear power phase-out
- Assumes a lifetime of 60 years for nuclear power plants (instead of 50 years)

High Flexibility

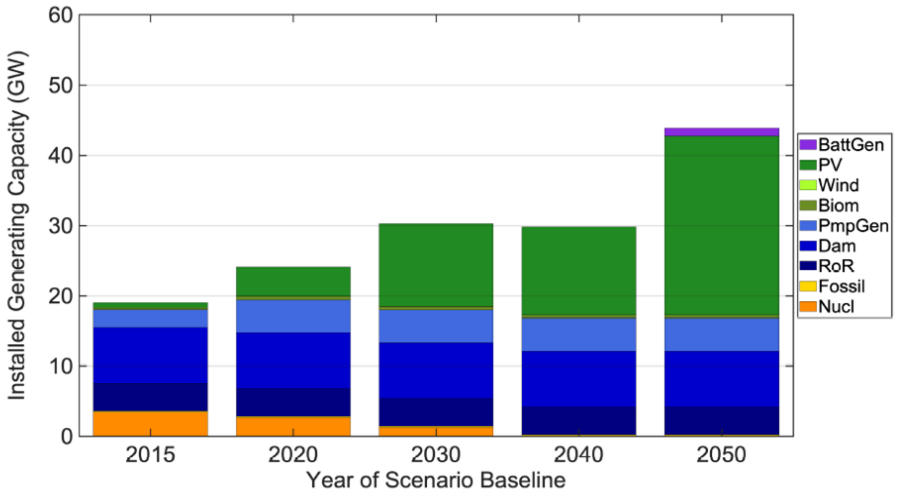
- Discusses the impact of more distributed flexibility in the power system
- 50% lower battery costs
- 100% higher demand-side management potential

Table 6: Overview nuclear power phase out under 50 and 60 years of lifetime

Nuclear power plant/reactor	Capacity	Operation since	Phase-out in year (runtime 50 years)	Phase-out in year (runtime 60 years)
Beznau 1	365	1969	2019	2029
Beznau 2	365	1972	2022	2032
Mühleberg (KKM)	355	1972	-	-
Gösgen (KKG)	1060	1979	2029	2039
Leibstadt (KKL)	1220	1984	2034	2044

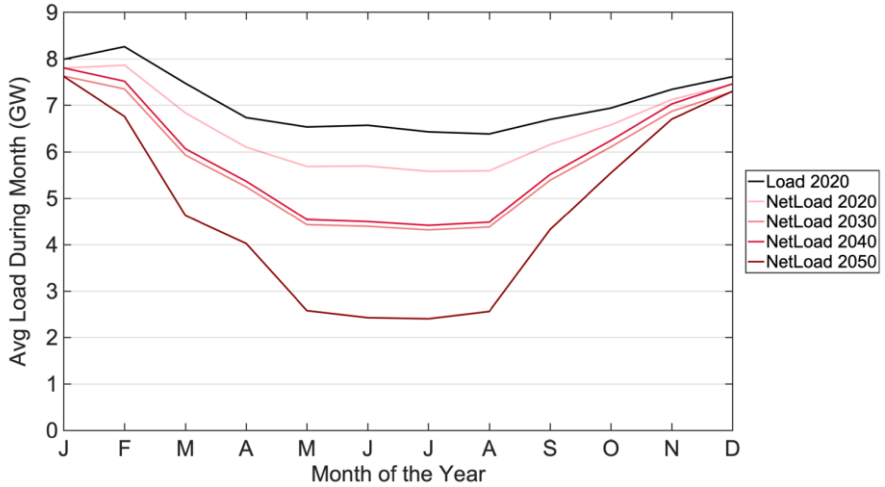
Results Summary I

- What are the potential **pathways** for the future Swiss electricity system?



- PV installations replace nuclear capacity to a large extent, no investment in wind, minor investments in biomass.
- PV installation stagnates between 2030 and 2040 because of decreasing subsidies and it rises again by 2050 because of decreasing PV costs.
- RES targets are achieved in all scenarios and years.
- As nuclear gets phased out, imports become a large electricity supplier.

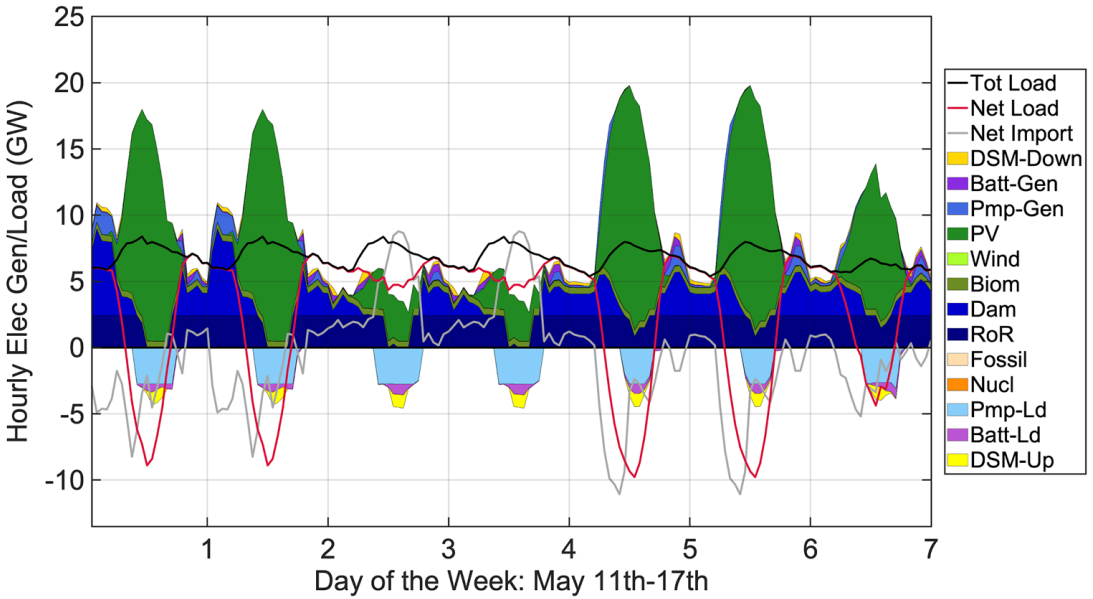
- What is the **need for flexibility** in the projected Swiss electricity system?



- The seasonality of the net load increases in all future years, especially in 2050, which calls for seasonal flexibility (e.g., hydro storage, import/exports).
- The hourly net load changes also substantially over a day/week/month, which calls for fast-ramping flexible capacities (e.g., hydro dams, battery).
- To cope with sub-hourly forecast uncertainty, tertiary reserve requirements increase by almost 100% (upward) and 50% (downward) by 2050.

Results Summary II

- Who **provides** the required flexibility?



- Seasonal flexibility is mainly provided by imports/exports and hydro dams.
- Hourly flexibility is mainly provided by adjusting the operation of the existing generators, import & exports, and PV-batteries & DSM.
- The increasing requirements of the tertiary reserves are supplied by the existing dispatchable capacities.
- In all scenarios, the risk of systemic failures are addressed by upgrading one transmission line.
- PV-batteries and DSM strengthen system security.

- What are the **macroeconomic** and **environmental** impacts?

- The differences between the scenarios for GDP, gross investments and CO2 emissions are minor.
- The varying scenario inputs do not introduce substantial macroeconomic and environmental differences.

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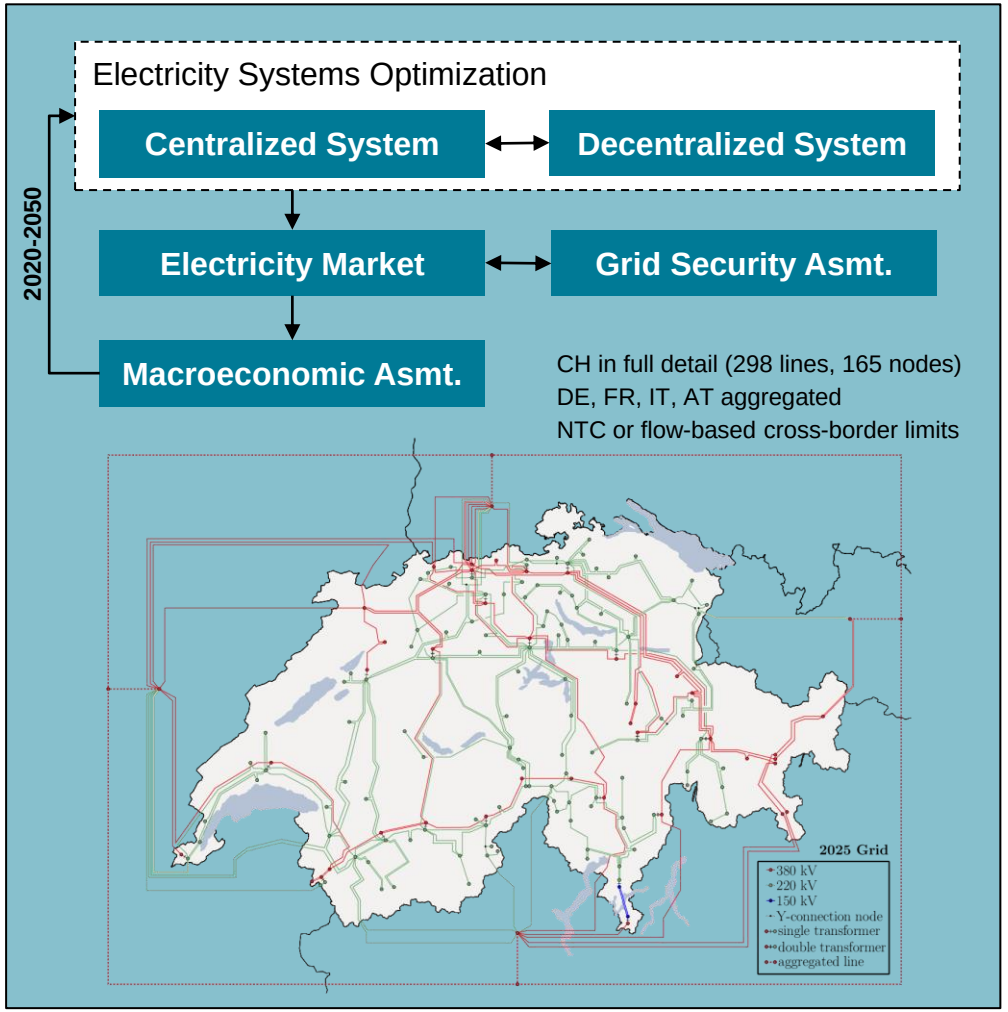
Process (Example Switzerland)

Model



Process (Example Switzerland)

Input

Techno-economic

Electricity demand [GW]

Transmission network [lines, nodes]

Generators (existing, potentials, outlook) [GW]

Generator and fuel costs [CHF]

Weather [Wind, Irradiation]

Policies

PV investment subsidies [CHF]

Injection tariff [CHF]

CO_2 tax [CHF]

Model

Electricity Systems Optimization

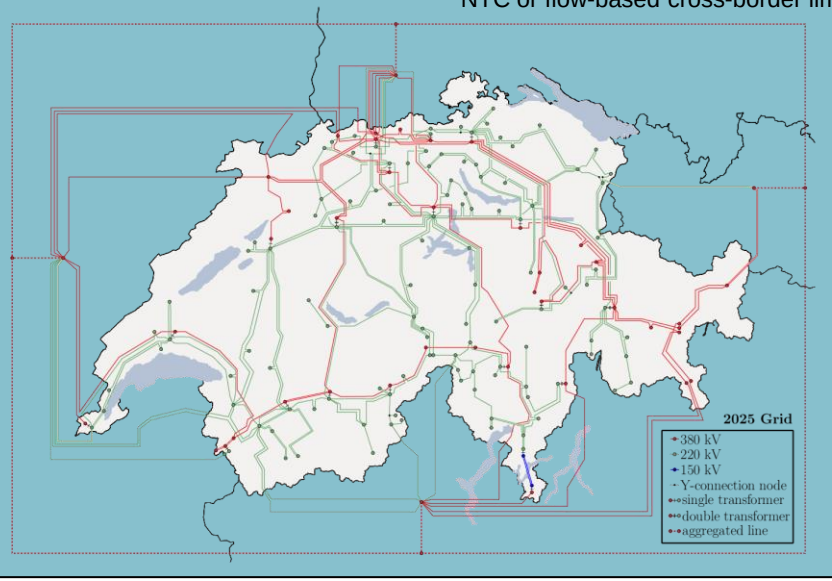
Centralized System ↔ **Decentralized System**

2020-2050

Electricity Market ↔ **Grid Security Asmt.**

Macroeconomic Asmt.

CH in full detail (298 lines, 165 nodes)
DE, FR, IT, AT aggregated
NTC or flow-based cross-border limits



Process (Example Switzerland)

Input

Techno-economic

- **Electricity demand** [GW]
- **Transmission network** [lines, nodes]
- **Generators** (existing, potentials, outlook) [GW]
- **Generator and fuel costs** [CHF]
- **Weather** [Wind, Irradiation]

Policies

- **PV investment subsidies** [CHF]
- **Injection tariff** [CHF]
- **CO_2 tax** [CHF]

Model

Electricity Systems Optimization

Centralized System ↔ **Decentralized System**

↓

Electricity Market ↔ **Grid Security Asmt.**

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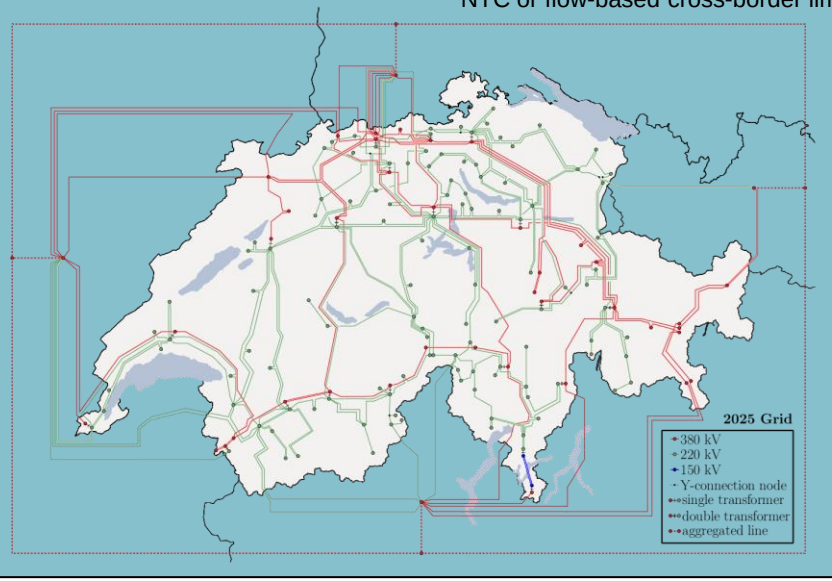


Output

Electricity System

- **Installed Capacity** [GW]
- **Capacity Distribution** [GW]
- **Electricity Generation** [GWh]
- **Prices** [CHF/MWh]
- **Import / Exports** [TWh]

Grid Security

- **Demand not served** [expected outages]
- **Grid expansion** [lines]

Social & Environmental Impacts

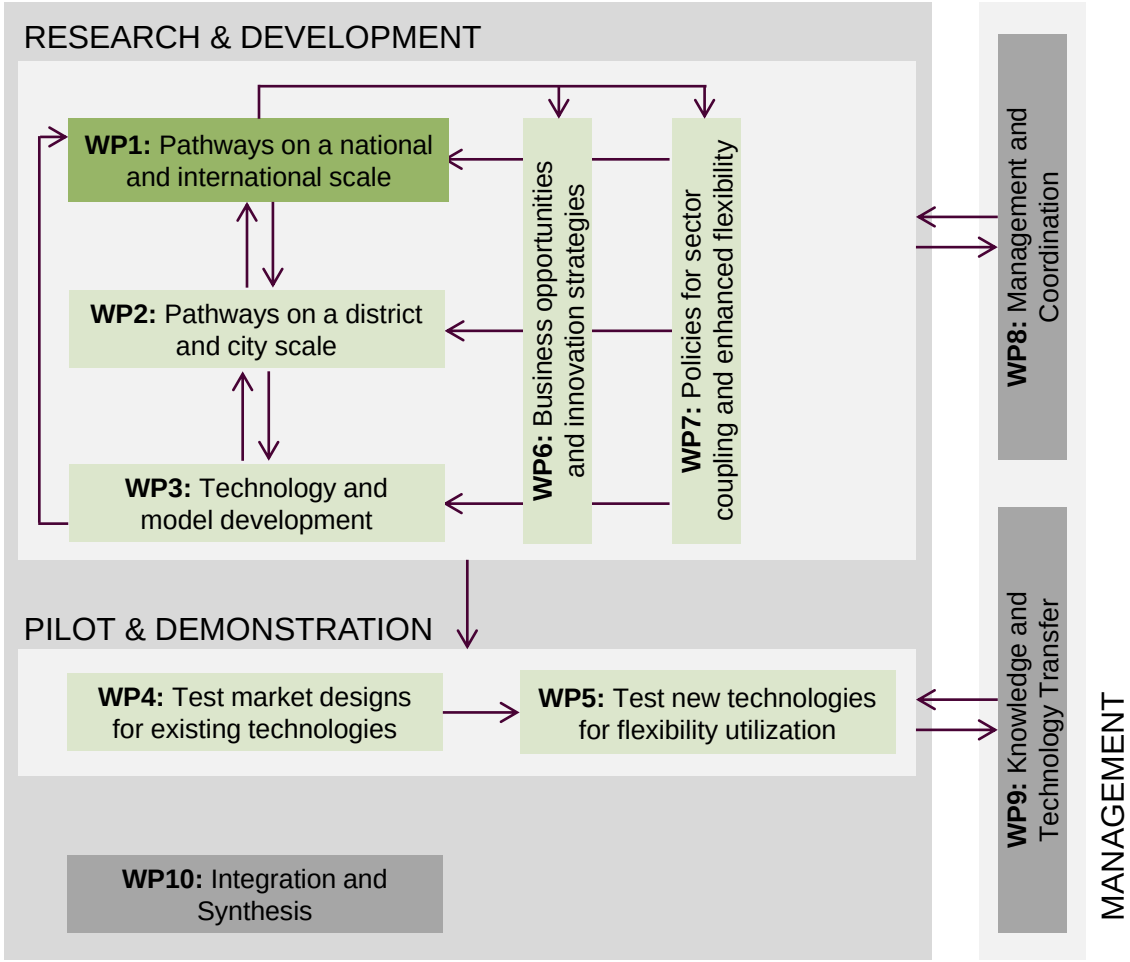
- **Investments & GDP** [CHF]
- **Carbon emissions** [tCO_2]

Future development under the PATHFNDR project

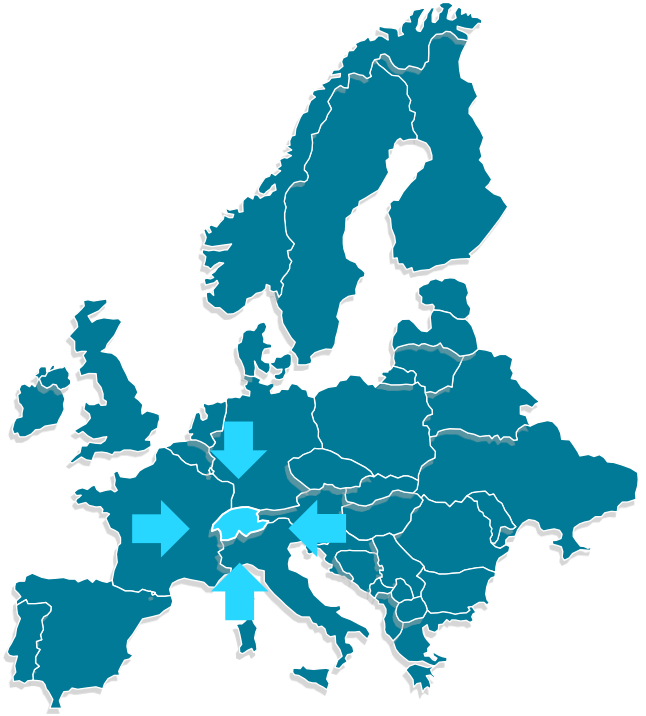
I. Transforming Nexus-e from an electricity system to an energy system model
   - Modeling the Heating and industrial sector
   - Modeling the transportation sector
   - Modeling the gas network

II. Assessment of Swiss energy system pathways

III. New methods to link models and depict cross-scale interactions



Linkage to other tools of the PATHFNDR project

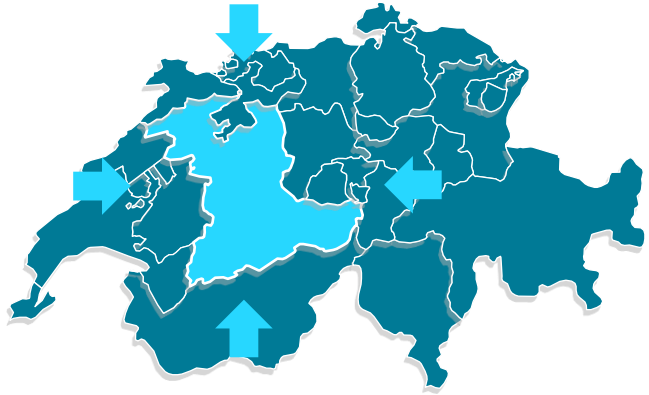


Nexus-e & Euro-Calliope

- Calliope provides the developments of the European energy system; Nexus-e uses these developments as boundary conditions for a more detailed assessment of the Swiss energy system.

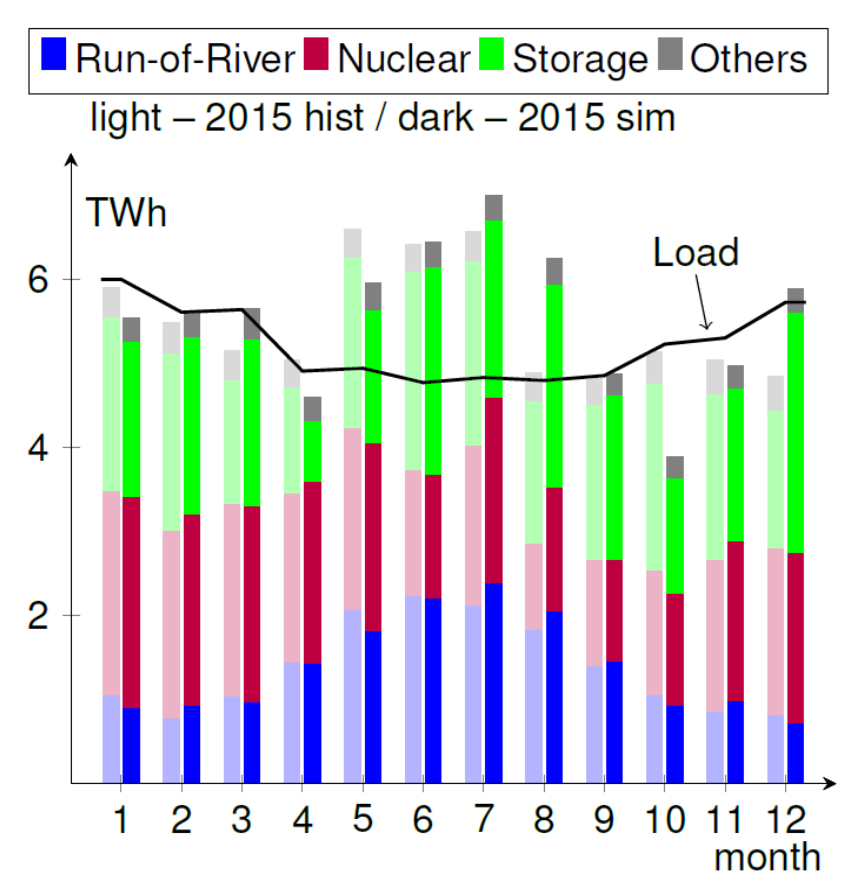
Nexus-e & EXPANSE

- Nexus-e provides the developments of the Swiss energy system; EXPANSE uses these developments as boundary conditions for an assessment of the Swiss energy system with a higher spatial resolution.

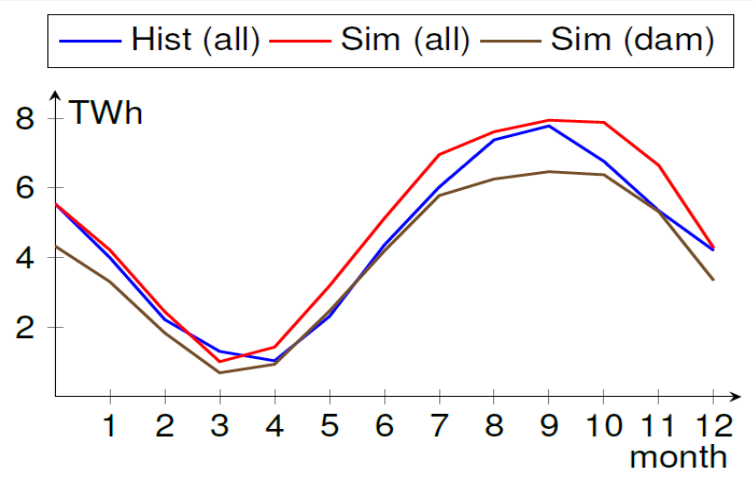


Validation

Calibration Example 1:
Monthly dispatch per technology type



Calibration Example 2:
Comparison of hydro storage levels

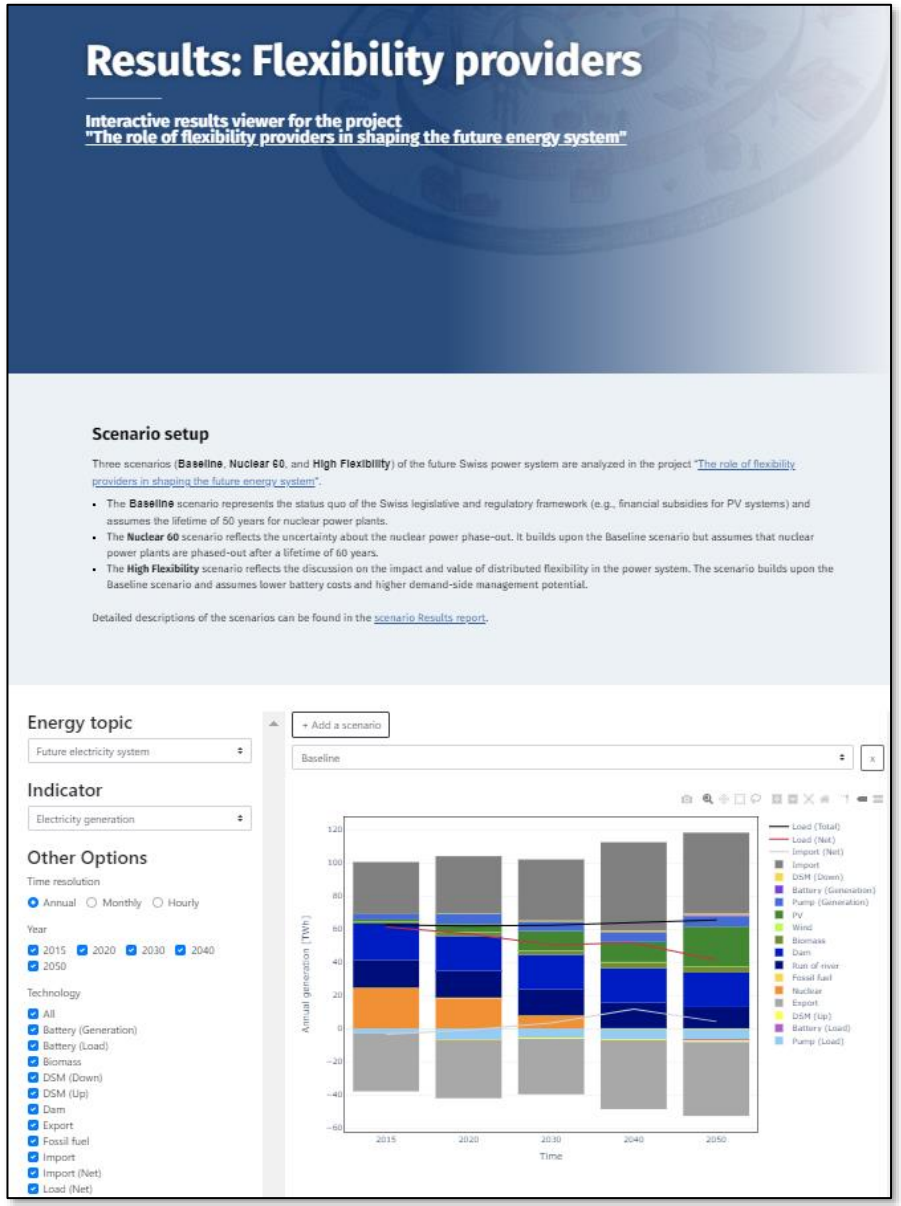


Calibration Example 3:
Comparison of net Swiss cross-border exchange

Net Export (From - To)	Hist. [TWh]	Sim. [TWh]
AT - CH	6.7	4.9
DE - CH	13.1	9.0
FR - CH	5.3	4.3
CH - IT	25.4	21.0

User interfaces

- Webviewer provides a more detailed assessment of scenario results
- Model Code on GitLab and accessible on request (Plan to go fully open-source second half of 2021)
- All input and output data in one database to ensure coherent set of inputs across the platform



Limitations

I. Neglect sector-coupling with the heating and transport sector (only included as DSM potential). No net-zero scenarios.

→ Addressed in PATHFNDR and other ongoing projects (e.g., CH 2040)

II. Current focus on Switzerland with an aggregated representation of surrounding countries

→ In planning, open proposals and discussions with industry partner to use Nexus-e for other countries

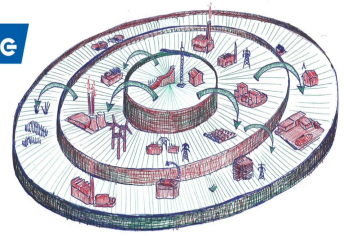
III. High spatial and temporal resolution renders Nexus-e very computational heavy

→ Feasible but not planned yet

sweet swiss energy research for the energy transition

PATHFNDR

Nexus-e



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