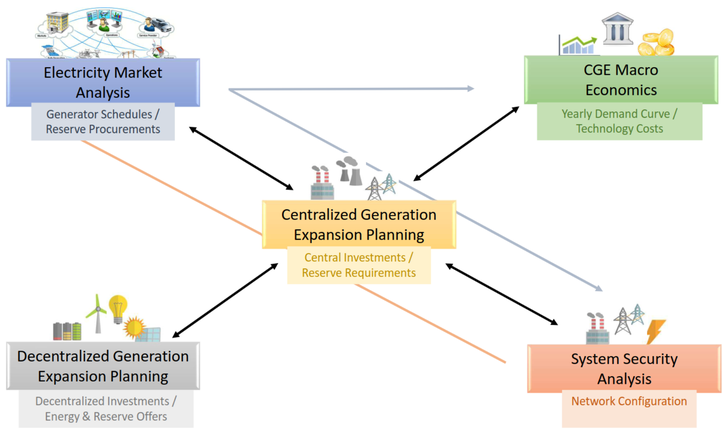
ETH zürich

Nexus Energy System Modeling Platform

Energy Science Center | PSL Power Systems Laboratory | FEN Research Center for Energy Networks / Forschungsstelle Energienetze | cepe Centre for Energy Policy and Economics | RRE Reliability and Risk Engineering

Nexus, the integrated modeling platform

Climate change induced policies impose wide-ranging implications throughout the whole energy system and influence various sectors of the economy. To analyse different decarbonization pathways for the energy system, existing models have traditionally focused on specific energy sectors, adopted specific research perspectives, assessed only certain technologies, or studied isolated components and factors of the energy system.



Nexus is an integrated energy systems platform linking top-down and bottom-up models to represent centralized and decentralized generation and demand, operations of electricity grids, infrastructure investments, generation dispatch, energy markets, macroeconomic interactions, and system security.
Nexus is a long-term project at the **ETH Zurich** and integrates by integrating knowledge across disciplines such as economics, system engineering, power system modeling, and risk assessment. In its first phase (ending soon), it will deliver a platform for the electricity market consisting of five modules and their interfaces (see figure to the left).

The modules of Nexus

- **Centralized generation expansion planning (cGEP)**: a centralized generation expansion planning model that determines the optimal generation investments at the transmission level, while satisfying the demand and reserve requirements over a specific planning horizon. It is formulated as a mixed integer linear programming (MILP) model, investments are optimized by minimizing the total system costs consisting of both investment and operational costs that calculated using representative days.
- **Decentralized generation expansion planning** (**dGEP**): The dGEP model has similar ideas as cGEP. It is a decentralized generation expansion planning model that determines the optimal generation investments at the distribution level. It is formulated as a mixed integer linear programming (MILP) model, investments are optimized by minimizing the total system costs consisting of both investment and operational costs while considering the participation of the decentralized generation units in the energy and reserve markets.
- **Electricity markets**: The electricity markets module consists of a futures, a spot and a balancing market model. The market clearing is achieved by a social welfare maximization based on marginal cost curves. A heuristic bidding strategy is used for bidding in the markets. The module can deal with zonal aggregated, disaggregated, or mixed power unit and grid configurations. Different market coupling modes are available.
- **Macroeconomic top-down model** (**CGE**): a recursive-dynamic single country model for Switzerland with government, households, and around 60 production sectors modeled as a system of non-linear equations.
- **System security analyses** (**SSA**): This module assesses the security of the supply by testing the capability of a power system to withstand sudden changes, and provides a transmission system expansion plan if the predefined level of security is not satisfied. The SSA module consists of two models, a cascading failure analyzes model and a transmission expansion planning model.

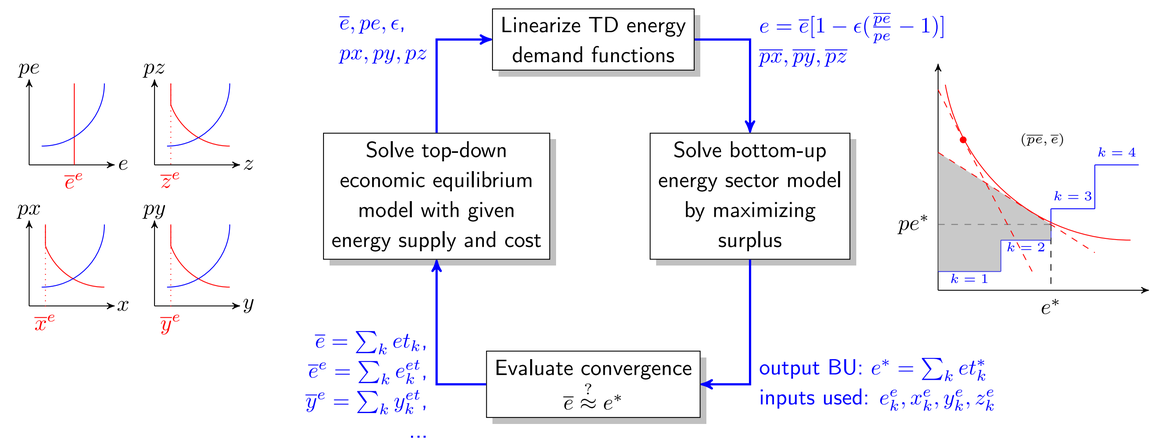
Interfacing

Developing interfaces between models is an opportunity to extend each single model's capabilities. The Nexus platform contains interfaces between the modules that not only provide a distinctive methodology to couple different parts of the energy system, but also enhance the scope of each separate module.

Example

The figure on the right shows the interface between the CGE and the decentralized generation module. It is an extension of the work done by Böhringer and Rutherford (2008). They combined a CGE model and a simple economic dispatch model in the same programming environment without investment decisions. The Nexus interface is between two modules in different programming languages (GAMS and Matlab) with a more realistic bottom-up model, and solves additionally the investment decision.

Example of an interface: dGEP-CGE



Research questions Phase 1

Research questions in Phase 1:

- Develop the platform for the electricity system.
- Run scenarios:
  - What are the needs with respect to flexibility options in a scenario with high RES deployment? Are decentralized flexibility providers (e.g., battery storage and demand-side management) an alternative to hydro storage?
  - What are the parameters influencing the investment decisions for hydro storage vs. decentralized flexibility providers? What is the optimal mix of flexibility providers when assessing different policy designs (e.g., impact of subsidies)?

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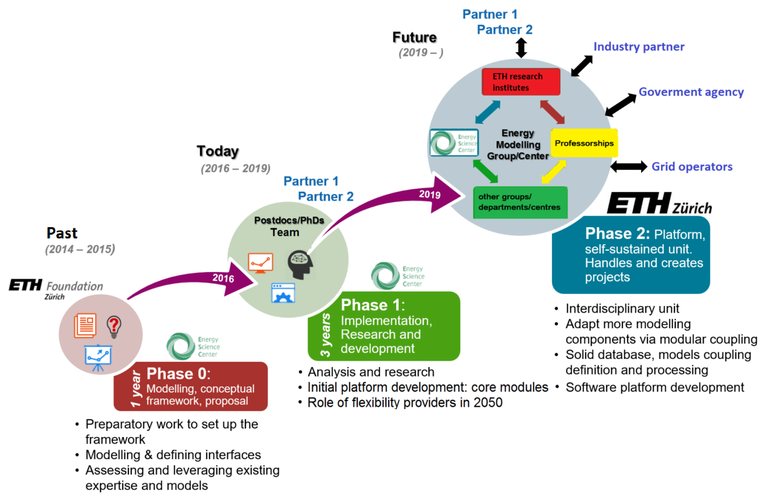
Nexus Planning



Nexus Energy System Platform

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