Overview - Scope of Case Study 1

Objective of the Horizon2020 project plan4res is to provide a well-structured and highly modular modelling framework to enable consistent insights into the different needs of future energy system. Three case studies will highlight the potentials of this framework by dealing with different aspects of a future energy systems (compare [1]).

Case study 1 will focus on a multi-modal European energy concept for achieving COP 21 goals with perfect foresight, considering sector coupling of electricity, heat, transport and gas.

Overall Objective

What is the optimal transformation pathway for the European energy system to meet the COP21 targets in 2050?

- **What will the optimal future energy mix look like?**
- **How can we reach the COP21 goal with a cost-effective investment pathway?**
- **What impact has sector coupling on the future generation fleet, e.g. the potential role of emerging technologies like Power2Heat, eMobility and Power2Gas?**

Further objectives within plan4res are to assess the tool's adequacy and relevance to analyse:

- **The investment trajectory for an integrated energy system for a set of countries**
- **The impact of extended pan-European cross-border energy exchange**
- **The impact of sector coupling on the future multi-modal energy mix**
- **The impact of promising emerging technologies on the integrated energy system**

The case study is studied in two consecutive steps (compare Figure 1).

Step 1 focuses on the optimal investment pathway using an aggregated view and providing the optimal energy mix per year.

Step 2 refines these results for specific focus years by using a detailed bottom up approach including a breakdown of installed capacities to higher spatial resolution and consideration of technical constraints (e.g. minimum up-/downtimes) for power plants.

Additionally, flexibility potentials of Power2Gas are considered in the electricity system and validated by means of a gas flow grid model.

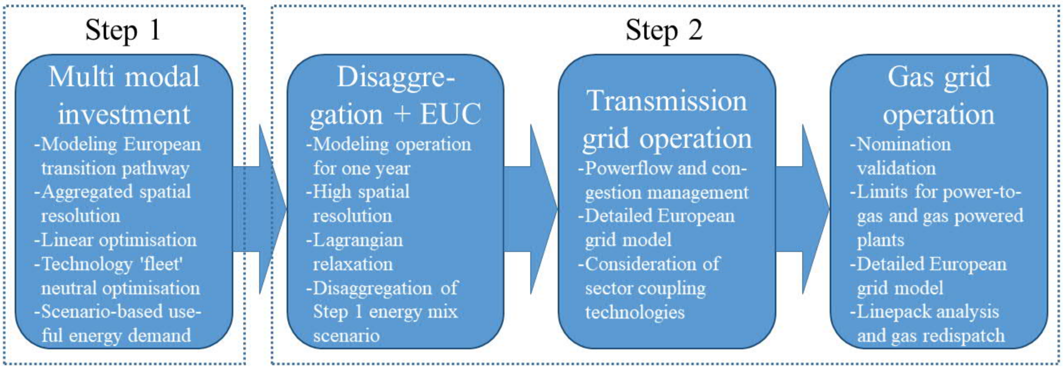

Figure 1: Case Study 1 workflow and coordination

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 773897

Target Users

Case study 1 provides an integrated system approach, which will be useful for

- **Energy System planning**, including sector coupling
- **Optimization of the energy mix** of multi-energy resources (electricity, heat, gas) including contributions from distributed energy resources.
- **Operational planning,** performing cost-benefit analysis, testing new flexibility services or emerging technologies or analyse market revenues**.**

With the tools developed as a result of case study 1 the following target users are addressed:

- **National and European authorities**
- **Operators and utilities**
- **Energy system researchers and analysts**

Methodology

The case study is performed in two consecutive steps. Figure 1 gives an overview of the modelling interactions and data transfer in the different modules.

Step 1 optimizes the entire investment pathway with an aggregated view and provides a scenario definition for each year, which is input to the second step. This represents a macroeconomic view on the energy system and uses a relatively low resolution, but already on sub-country level. Focus is on installed capacity in an optimized energy mix including optimal investments along the pathway and considering technology fleets and not individual plant operation.

In step 2 these results are refined for specific focus years. To get a more detailed view on the energy system a detailed bottom up approach is used distribute installed capacities to higher spatial resolution and optimize power plant operation on higher regional resolution considering technical constraints. Using the operation schedules of central and decentral generation units, electricity grid analysis are performed using power flow and congestion management tools.

Additionally, the aspect that regions are coupled not only by the electric transmission grid, but that constraints from the existing gas transport network have to be considered, too. The results of Step 1 are further evaluated using a stationary gas network optimization model based on physical flows. Flexibility potentials of Power2Gas in a coupled energy system and its constraints are assessed, too.

Detailed Description

Key aspects of CS1

Case study 1 focuses on the incorporation of different energy sectors to reduce the overall CO_2 emissions of the energy system and increase the flexibility of the energy system

The key aspect of case study 1 is a **projection of the multimodal multi-regional energy mix** plus the **investment trajectory along the entire pathway**, providing a detailed view on the overall energy generation and demand, including **electricity, gas and fuel, thermal heat, cold and mobility.**

Modelling approach used in CS1

- aims at **optimizing the investment trajectory** which is necessary to establish a future European energy concept for achieving the COP 21 goals.
- uses perfect foresight and optimisation algorithms for linear problems searching for a **cost-effective pathway** to establish this new energy world. Thereby it provides the **optimal energy mix** and a simplified (fleet) dispatch **schedule for each year along the pathway**.
- uses mixed integer linear problems and a detailed bottom-up modelling approach to determine optimal energy system operation and electricity grid congestion management for specific focus years.
- explicitly includes **sector coupling technologies** to capture the impact of interacting multi-modal energy systems (→ **multi-modal energy concept**).
- challenges future energy mix results, especially Power2Gas topics, using a **gas grid model.**

Expected results

Step 1:

For each simulated year along the pathway step 1 can provide the optimized energy mix, early retirements and new installations of capacity per year, hourly generation and load profiles for each technology implemented, as well as macro-economic cost estimations and price levels for the used energy types (compare e.g. [2]).

This includes the resulting demand or generation per energy type, e.g. electricity generated, gas (H_2) produced, gas consumed. In addition, it provides an estimated tonnage for expected CO_2 emissions operating the projected energy mix.

Step 2:

Step 2 uses the results from step 1 to perform a detailed bottom up modelling for further analysis of single years of the pathway.

The detailed modelling will provide operation schedules for power plants, storages and distributed generation units (by means of an aggregation) including technical constraints like ramping and minimum up/downtimes (see e.g. [4]). Resulting schedules are not only dependent on the electric demand, but generation of distributed and central units have to meet thermal demand too.

A subsequent electricity transmission grid operation model provides results regarding line utilizations and congestion management on a detailed European level.

A gas grid interconnections study provides a gas transport network dataset that is used to test previous results using a physical flow-based gas network model, with a special focus on appropriate allowed hydrogen volumetric share level in the gas grid. The model is used to evaluate feasibility of decisions provided by the case study. Thereby Power2Gas technology is evaluated in interaction with the electricity grid and gas transport grid.

Scope of Technologies

The multi-modal investment model considers a consistent set of technologies relevant to the sectors industry, CTS, residential and mobility, covering the energy modes electricity, heating and cooling and transport in different characteristics. This includes central generation technologies, central storages (pumped hydro, battery, thermal), and distributed generation technologies and storages. Further, flexibility-providing technologies (e.g. Power2Gas, Power2Heat, demand side management or eMobility) are considered. The European energy system is spatially resolved using regional cells with sub-county resolution and considering net transfer capacities for electricity exchange simplified between these regions.

In step 2, distributed technologies (e.g. heat pumps, CHP, boilers, solar thermal power, electric/thermal storages) are considered in a bottom-up approach per household/business. Their operation is determined in an aggregated manner within a European unit commitment model. Further, central generation units (power plants, storages, Power2Gas, Power2Heat) are considered as well as the European energy exchange. Within the electric transmission grid operation, the European extra high voltage network and the high voltage network of selected countries are considered. The network topology is modelled then in higher detail using classical AC components as well as power flow controlling devices as HVDC systems and phase shifting transformers which are optimized within the grid operation to reduce overloads. Congestions are resolved by redispatching power plants and pump storages as well as RES curtailment. Power2Gas and Power2Heat units provide further flexibilities for redispatching resulting from the coupling of the electricity sector with other energy vectors.

Gas grid operation involves a detailed gas transport grid model comprised of entry/exit nodes, pipelines and compressor stations is established using open data sources. The nomination validation (NoVa) problem [4] solved to verify gas transport demand resulting from case study via schedules resulting from the electric transmission operation model. In addition, extensions to NoVa are studied in order to compute allowable transport limits for the gas network to evaluate Power2Gas.

References

[1] Horizon 2020 project plan4res, 2018, “Deliverable D2.1 Definition and requirements of three case studies”; pdf downloadable at www.plan4res.eu

[2] Siemens AG, “Siemens' Position on Decarbonization and Energy Transition in Germany”, Munich, 2017

[3] C. Müller et al., “Integrated Planning and Evaluation of Multi-Modal Energy Systems for Decarbonization of Germany,” Energy Procedia, vol. 158, pp. 3482–3487, 2019.

[4] T. Koch, B. Hiller, M. E. Pfetsch, and L. Schewe, Eds., Evaluating Gas Network Capacities. Berlin, 2015.