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A TOP-DOWN SCENARIO QUANTIFICATION METHODOLOGY FOR ELECTRICITY HIGHWAYS AT 2050

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Overview

The research and development project "e-Highway2050[1] aims at developing a new planning methodology able to deliver a first version of coherent Modular Development Plans of the pan-European power transmission system, going from 2020 to 2050. The resulting pan-European grid is expected to enable electricity market integration and the 2050 decarbonization goals of the electricity system, therefore integrating large quantities of renewables to be transported over long distances from production sites to load centers. The developed modular, long-term planning approach follows five main steps: 1) the development and use of an approach to generate different European *long-term energy scenarios* representing "extreme[2] but realistic" developments of the power system at 2050; 2) the development of *scenario quantification* (definition of generation, consumption, storage and exchange by area); 3) the use of *system simulations* to identify feasible and efficient pan-European grid architectures under each of the above chosen energy scenarios by 2050; 4) the verification that the selected *reinforcement options* and *novel network architecture options* alleviate critical issues focusing on overload problems, and possible voltage and/or stability problems for a given level of system reliability; 5) the development of *grid architectures* from now to 2050 of the pan-European transmission system, covering each of the studied scenario. In parallel, the possibility to mathematically formalize such long-term planning methods is investigated.
The aim of the present paper is to present the methodology developed for the quantification of the long-term energy scenarios illustrated here on one of the five 2050 scenarios selected by the e-Highway2050 project.

Method for the scenario quantification process

A three step top-down approach has been developed to quantify the five e-Highway2050 scenarios.
The calculation and localization of the installed capacities of each generation technology over a geographical zone is a complex problem due to:

- its size and uncertainties due to the long term horizon;
- the need to consider a sufficient level of details in order to take into account distributed phenomena (renewable generation) requiring an hourly basis analysis;
- the need to ensure consistency between national and EU policies;
- and the need to ensure adequacy at each hour.

The process starts with the computation of yearly demand values and of energy targets per generation technology at European level. Then, the installed generation capacities in each macro-area (gathering several countries[3]) are computed (Step 1). The installed capacities of the macro-areas are broken down to country level, where thirty-three countries are considered (Step 2). Finally the installed capacities are distributed across each of the ninety-six clusters[4] into which Europe is split (Step 3).
The installed capacities are first defined in a macro-area based on weighting distribution keys which combine information about potential of generation capacities and demand in a given macro-area. Then a market simulation over Europe without considering internal grid constraints allows tuning the installed capacities to reach a sufficient level of adequacy. A similar approach is repeated at lower levels, where the National Renewable Energy Action Plans at 2020 (NREAP) and other local constraints are taken into account.

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[1]The e-Highway2050 project (http://www.e-highway2050.eu) received funding from the European Union's Seventh Programme for research, technological development and demonstration under Grant Agreement n° 308908.
[2] Extreme scenarios are scenarios which challenge the entire existing European electricity system, not just the grid.
[3] Eight macro-areas are considered. For instance, the North Europe macro-area consists of Norway, Sweden and Finland.
[4] Clusters are based on unified standards and grid characteristics and are scenario independent.

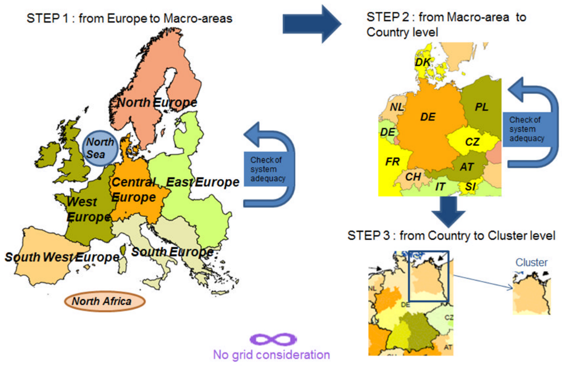

Fig. 1: The e-Highway 3 step top-down approach for scenario quantification

Intermediate results

The application of the above methodology is illustrated for one of the five scenarios: the "*Big and market*" scenario. In this scenario, a global agreement for climate mitigation is achieved. Thus, CO_2 prices are high due to the existence of a global carbon market. Europe is fully committed to meet its 80-95% GHG reduction orientation by 2050; but it relies mainly on a market based strategy. Moreover, there is a special interest on large scale centralized solutions, especially for RES deployment and storage. This scenario has the most diversified energy mix: it includes nuclear, fossil with and without CCS and 60% RES. European demand is 4337 TWh. The two graphs below illustrate energy mixes with loads and imbalances at macro areas (Fig. 2) and installed capacities at country level (Fig. 3) for the same scenario "big and market".

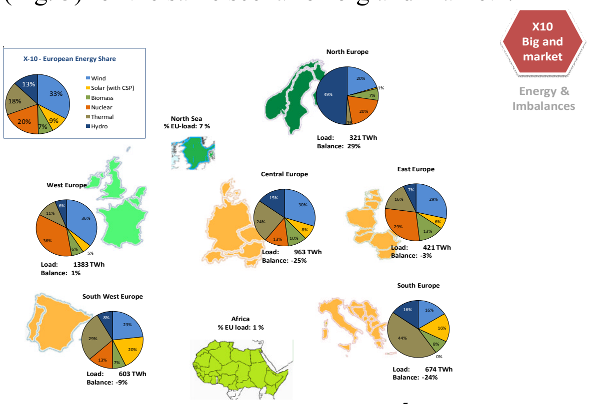

Fig. 2: Energy mix and imbalances[5] per macro-areas (interim results)

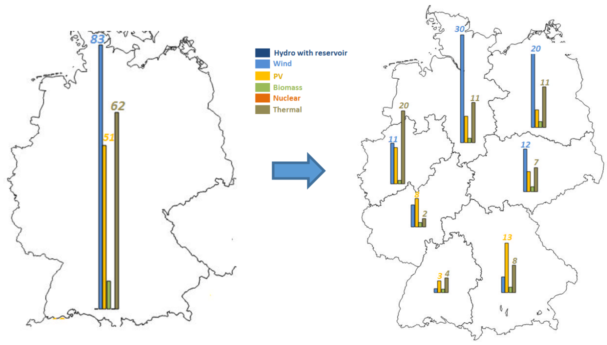

Fig. 3: Installed capacities at cluster level: example of Germany, scenario "Big and market" (GW)

At the macro-area level, the results for the "Big and Market" scenario respect the European energy mix (except from minor deviations). The analysis shows that Central Europe, Eastern Europe, Southern Europe and South Western Europe are the countries with the highest imbalances (highlighted in orange in Figure 2) while Nordic and West Europe are net electricity exporters (highlighted in green in Figure 2). Fig 3 illustrates the breakdown of installed capacities in Germany into its clusters.

Conclusions

At the current stage of the project, the scenario quantification methodology has been validated with respect to the above-mentioned constraints at each geographical scale and has been fully implemented on all the five project scenarios. The outputs of the methodology will be used in the e-Highway2050 grid simulation studies.

Within the future exploitation of e-Highway2050 results, the developed methodology on scenario building and quantification constitutes a key knowledge block for future pan-European network expansion studies by ENTSO-E, European Transmission Network Operators (TSOs) and other interested stakeholders of the electricity value chain.

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[5] Imbalance is defined as sum of yearly production divided by annual consumption.