<u>**Impact of Hydrogen on Power System Adequacy. Application to the Belgian System in 2030.**</u>

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Hydrogen is foreseen to be part of our future energy systems as Europe has the ambition to be a carbon-neutral continent by 2050. Given that the energy sector is responsible for a significant portion of European GHG emissions, its transition is key. Green hydrogen − produced through electrolyzers powered by low-carbon electricity −is under the spotlight as various studies claim that it can be used as a feedstock for the industry, and as an alternative fuel for heavy transportation and future back-up generation units which are hard-to-electrify sectors. These studies also state that hydrogen deployment will consist in the development of a future hydrogen network.

As the grid undergoes significant changes, such as shifting to intermittent renewable energy production and increasing the electrification of various end-use demands, probabilistic adequacy studies that assess whether a power system can meet consumers' demand at all times and in all locations becomes essential. Integrating electrolyzers into the power system introduces an unconventional and variable electrical demand. Indeed, to assess green hydrogen production, electrolyzers will primarily consume when renewable energy sources are producing. Furthermore, the hydrogen system comprising a pipeline network, storage facilities, import points, and hydrogen-to-power units may influence electrolyzer consumption.

The primary objective of this work is to quantify the impact of this unconventional demand on power system adequacy. Specifically, we aim to answer the question: What is the impact of e-hydrogen and e-fuels on the adequacy of the Belgian power system? To address this, we developed a probabilistic adequacy tool capable of analyzing large and complex systems, such as a country, while considering the coupled operation of electricity and hydrogen systems. This framework includes an economic dispatch model that minimizes load shedding and operational costs. It incorporates network constraints via DC-OPF formulation, and integrates the interdependencies between the electricity and hydrogen systems. The hydrogen system encompasses electrolyzers, storage units, pipelines, hydrogen-to-power units, import points, and an annual hydrogen demand. From this model, key adequacy indicators such as Energy-not-served (ENS) and Loss-of-load (LOL) are derived. This model is integrated into a sequential Monte Carlo process to obtain expected values for these indicators (EENS and LOLE). The process also accounts for yearly un certainties, including renewable energy production variability and technology outages.

After testing the tool on smaller systems, it is applied to a coupled electricity-hydrogen system representative of Belgium in 2030. Various scenarios reflecting current uncertainties, such as grid and offshore wind farm expansions, and different flexibility means were analyzed.

Key findings for the Belgian system in 2030 include the crucial role of flexibility, which significantly reduces adequacy indicators across all scenarios, highlighting its importance in such studies. Given the model's assumption of unlimited hydrogen imports, the system does not experience energy deficits due to hydrogen demand. Therefore, hydrogen integration, under these conditions, does not negatively impact power system adequacy. Assessing the impact of constraining hydrogen demand requires setting limits on local production. In the scenario considering offshore wind farm and grid extension, as well as all flexibility means, constraining electrolyzers up to a 90% annual load factor does not compromise Belgium's adequacy with 447 MW of electrolyzers. This suggests that local hydrogen production, if managed flexibly, will not affect system adequacy. Despite incorporating flexibility and 447 MW of electrolyzers, curtailment peaks remain high, reaching values of 6-7 GW, indicating the system's limited capacity to absorb very high renewable energy peaks.

In conclusion, this study demonstrates that while the integration of green hydrogen into the Belgian power system introduces new challenges, particularly with respect to managing the variable demand from electrolyzers, it does not inherently compromise system adequacy when flexibility measures are in place.