Modelling of hydrogen production technologies in an integrated energy system at different carbon constraints

(3) Sektorkopplung und Flexibilität
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Motivation and the central question

The rapid decarbonization of the power sector, combined with a progressive electrification of multiple sectors represent a global challenge. The increased share of variable renewable technologies will require the development of new flexibility and storage resources to ensure the system reliability.
Hydrogen is widely seen as a key technology to provide the storage and flexibility required by a low carbon system, as well as an energy vector to decarbonize hard to abate sectors.
The central question of this study is to analyze under which conditions hydrogen is competitive and which hydrogen production technology is most economic given stringent carbon constraints.

Methodology

The study aims at establishing the long-term optimal combination of generation sources to satisfy a given demand for power and hydrogen at the minimal economic cost. This optimization is performed by a linear programming optimization tool PowerInvest for a reference year with hourly resolution. Power demand and production profiles of renewable sources have been obtained from real country data. The tool has been developed at the IAEA to support interactive capacity building sessions and is currently being expanded for analysis purposes.
Generation of electricity is provided by a combination of technologies: fossil fuels (gas and coal power plants) and low-carbon technologies such as nuclear, solar photovoltaic, wind and hydroelectric sources. Flexibility and storage are provided by demand side management and batteries. The generation of hydrogen consists of technologies such as steam methane reforming, with and without carbon capture and storage, and electrolysis. The hydrogen can also be used to produce electricity in dedicated power plants, thus ensuring a full coupling between the power and industry sector.
Several sensitivity analyses are performed to investigate the impact of changes in key study parameters, such as the overall carbon constraint, the level of hydrogen demand, as well as cost of main economic inputs.

Results and implications

The main objective of the study is to investigate how the energy mix and hydrogen production evolve at different levels of carbon intensity, hydrogen demand and when changing economic assumptions on low-carbon technology costs. The study aims also at understanding under which conditions hydrogen can be economically used as seasonal storage and flexibility provider to compensate for the variability of renewable sources. With gas prices averaged over the past 10 years, costs of low-carbon hydrogen production from electrolysis are 2 to 4 times higher than the ones of steam methane reforming [1], the latter will dominate at a loose carbon constraint while the former will prevail at more stringent one establishing a coupling between the power and industry sector.
Next to the carbon constraint, it will be shown that the gas price will have the biggest impact on hydrogen production as steam methane reforming becomes less attractive with soaring and volatile gas prices as it was the case in the recent years.

Literature

[1] “The Role of Nuclear Power in the Hydrogen Economy”, OECD (NEA), 2022

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