Which way to choose?
Technical, economic and environmental evaluation of different hydrogen production pathways

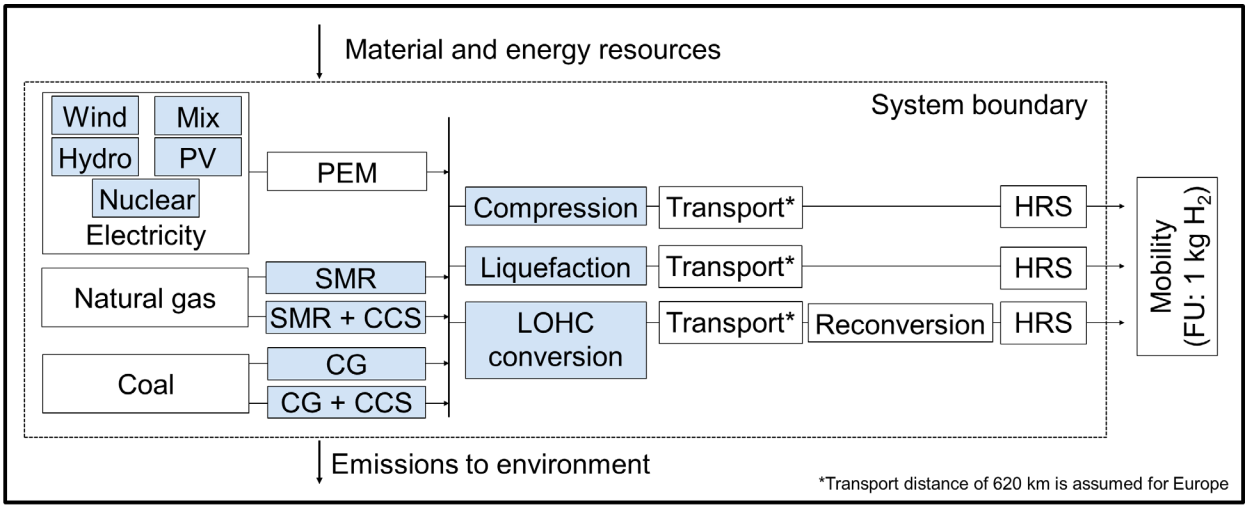
Jakob Kulawik[1], +49 241 80 49875 , jakob.kulawik@eonerc.rwth-aachen.de
Christina Kockel[1], +49 241 80 49845, christina.kockel@eonerc.rwth-aachen.de
Prof. Dr.-Ing. Aaron Praktiknjo[1], +49 241 80 49691, apraktiknjo@eonerc.rwth-aachen.de
[1]Chair for Energy System Economics, RWTH Aachen University

Overview

Hydrogen will play an important role as an energy vector in future energy systems. Possible applications include use in industrial processes, in building heat, in the mobility sector or as a storage for renewable energy. However, there are many unanswered questions regarding future production systems, as well as the transportation and storage options for hydrogen, which open up a multitude of possible pathways. To develop a targeted strategy for integrating hydrogen into existing energy systems, an environmental and techno-economic evaluation of individual production pathways is required. Therefore, in our research we ask the question: *What are the life-cycle emissions and costs of hydrogen production and distribution pathways in different countries and which are the critical factors driving the results?*

Methods

We carry out a life cycle assessment (LCA) and an investigation of the levelized costs of hydrogen in order to evaluate the environmental and economic potential of the identified pathways. Within the system boundary we have defined, different production processes for hydrogen, including material input for required technologies and the energy demand, are taken into account. The respective production processes are then combined with corresponding transport routes and storage options, to be able to draw conclusions about the total emissions and costs of the functional unit under consideration - one kg of hydrogen at its place of use. The respective investigation framework for our analysis is shown below.



Investigation framework for the evaluated hydrogen systems

A weakness in many of the existing LCA literature is the strong dependency of results on individual factors and assumptions within the study framework, which are often very difficult to comprehend in retrospect. In order to address this issue, our methodology includes a tool that simplifies the procedure of performing various sensitivity evaluations. This allows us to identify the most important drivers behind our results, and to better understand the reasons for the discrepancies between different hydrogen production and distribution pathways.

Results

Our results show that there is a high potential of renewable energy-based pathways to reduce the GWP of the produced hydrogen compared to fossil-based pathways, but currently still at significantly higher costs. A high potential is also attributed to the CCS technology to reduce the GWP of the fossil-based pathways at lower costs than in the renewable energy-based pathways.

In terms of conversion and transport of hydrogen, compressed hydrogen has a higher potential for shorter road transport distances (< 200 km) and liquefied hydrogen has a higher potential for longer distances (> 500 km) from an environmental and economic point of view. However, the evaluation of conversion and transport pathways is highly dependent on the characteristics of the hydrogen economy.

Regarding hydrogen-based fuels, the highest potential is seen in the synthesis of ammonia. However, the costs of renewable energy-based pathways are considerably higher than the current market prices of the fuels investigated.

Conclusions

Our analysis shows that there is a great variability between the economic viability and environmental impact of different hydrogen production pathways. As the integration of hydrogen within existing energy systems progresses, LCA methods can provide valuable, comprehensive insights into the advantages and disadvantages of different pathways and allow for an easier comparability of economic and environmentals goals.

Our enhanced methodology for conducting sensitivity analyses helps to more clearly identify the key drivers behind our main outcomes and can contribute to making future LCA research more accessible and comparable.