POLYGRID 2050: INTEGRATING HYDROGEN INTO THE ENERGY TRANSFER INFRASTRCTURE LANDSCAPE

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Overview

Integrating hydrogen represents a challenge for the established energy network planning processes because there are various means of delivering hydrogen to end-users. Climate-neutral hydrogen can be transported by a dedicated newly build hydrogen pipeline, a repurposed gas network, electricity grids, and existing transportation networks (e.g., truck, rail, marine transport) or even produced on-site. As a result, hydrogen as an energy carrier establishes new linkages between established energy networks and new infrastructures from different sectors as in future end-users can easily switch from one infrastructure to another for delivery of hydrogen. This is a rather new setup for the established energy networks (e.g., gas or electricity) that have traditionally been considered as natural monopolies. This is specifically important because it means future hydrogen-driven investment into these networks should no longer be solely governed by the sector-specific supply and demand, but also coordinate with the production, consumption, and infrastructure developments in other sectors.

In Europe, there are three ongoing policy debates on the integration of hydrogen into the energy transfer infrastructure landscape. This paper reviews proposals made in these debates and finds that each one results in a different institutional environment. For example, the discussion on integrated infrastructure planning is associated with a 'hierarchical governance' approach where a newly introduced central planner- e.g., a new institution or a common stakeholder platform- coordinates the infrastructure expansion across different sectors. As opposed to this, the hydrogen and gas markets decarbonisation package debate emphasizes a 'decentralized market' approach, where most of the hydrogen transport infrastructure is delivered by unregulated private investment. The cross-sectoral coordination is ensured by a decentralized individual stakeholder optimization in response to price signals at energy markets. The 'regulatory network' approach, on the other hand, which emerges out of the debate on energy system integration proposes adjustments to network regulation. The aim of adjustment is to motivate operators of regulated infrastructures to abstain from expanding their networks if other modes of transport are found to be socially more preferrable, resp. to coordinate with providers of these alternatives to achieve socially optimal solution. Hence, at a first sight, there seem to be no convergence emerging at the European level with respect to hydrogen integration within energy transfer infrastructures. Instead, proposals within the three aforementioned policy debates are reminiscent of the classical institutional environments known from the institutional economics- i.e., hierarchy, market, and network.

A suitable institutional environment is the one that is aligned with the technological development of hydrogen transport (cf. Finger et. al. 2005). The difficulty of the task stems from the fact that climate neutral hydrogen can be produced locally or in clusters, transported in larger quantities by a traditionally monopolistic energy networks (e.g., gas network) or traditionally competitive transportation infrastructures (e.g., truck). Each of these technological scenarios requires a different institutional environment. At the same time, future technological development of the different hydrogen transport modes is dependent on the development pace of the respective technologies and local circumstances of the implementing country, i.e. highly uncertain.

Considering the technological uncertainty, the above-introduced European policy debate on hydrogen integration draws a coherent picture of a future hydrogen institutional framework. 'Decentralized market' approach emphasizes that limiting the consumer choice with respect to alternative modes of hydrogen transport or constraining the local hydrogen production is unlikely in Europe. The resulting technology competition might easily turn lumpy irreversible investments of grid-based infrastructures (e.g., power lines, pipelines) planned within the sector-specific energy network planning processes into sunk costs. 'Hierarchical governance' approach highlights that this risk of stranded assets is likely to also limit the hydrogen-driven investment of grid-based infrastructures below the social optimum when infrastructure investment is driven by the individual stakeholder optimization and hence by the price signal of decentralized energy markets (cf. McDonald & Siegel 1986). Furthermore, external network effects among infrastructures from different sectors might occur. Energy network planning processes have been developed to address such problems and hence should be extended beyond the current sector boundaries. 'Regulatory network' approach accepts the capability of planning processes to improve cross-sectoral information exchange among investors and hence the planning results. It however questions the ability of these processes to account for the emerging technology competition in hydrogen transport. Planning processes should hence serve as an investment guideline and not as a fixed investment plan of the regulated infrastructure operators. In this view, technology competition is better accounted for by adjustments to the current regulatory model as it encourages regulated infrastructure operators to consider all available hydrogen transportation modes and thus coordinates their investments with the development in other sectors.

Based on these thoughts, several policy recommendations on a coherent hydrogen institutional framework can be derived. First, technology competition in hydrogen transport is inevitable (at least in Europe). Second, established sector-specific energy network planning processes were not designed for such technological setup. Therefore, these should not decide on the hydrogen-driven investment of the regulated infrastructures. Instead, planning processes should be developed to facilitate cross-sectoral information exchange on infrastructure investment that allows to identify cross-sectoral external effects. Third, lumpy irreversible investment of (regulated as well as competitive) grid-based infrastructure represents a competitive disadvantage in the emerging technology competition. This should be considered in the network regulation and market-design in order to promote optimal infrastructure investment. Fourth, hydrogen-related investment of regulated network operators has a different risk profile against the other traditional activities. Given that network regulation promotes cost reduction in business-as-usual activities, the incentive towards hydrogen investment is likely to be suboptimal (cf. Poudineh et. al. 2020). Therefore, operators of regulated infrastructures need an additional incentive in order to optimally invest into hydrogen transport.

Methods

This paper applies the coherence framework (Finger et. al. 2005) known from the institutional economics on the issue of cross-sectoral infrastructure coordination. Put in a nutshell, coherence framework suggests a network industry delivers good economic, social and technical performance when its institutional environment and technical structure are aligned, i.e. (1) when the scope of institutional control corresponds to the technical boundaries of the system and (2) the institutional and technical organization, be it centralized, decentralized or peer-to-peer/relational, are aligned. A change in technology implies an institutional adjustment and vice versa- i.e., a coevolution of institutions and technology is necessary. Hydrogen as an energy carrier represents a technological change that connects monopolistic power and gas networks with potentially competitive infrastructures from other sectors. Power and gas networks become herewith part of a broader hydrogen transport infrastructure for which technical boundaries go beyond the boundaries of electricity and gas sectors and hence the governance of the current network planning processes. Clearly, this misalignment needs to be addressed by the introduction of cross-sectoral infrastructure coordination mechanisms.

Results

The contribution of this paper is twofold. First, it describes proposals of European practitioners on the implementation of hierarchical, market- and network-based institutional environment with respect to hydrogen transport infrastructure. Second, it combines these proposals in a coherent institutional framework. The results of this study provide valuable insights about an institutional environment that coordinates the development of hydrogen transport infrastructure across different sectors in a country-specific context.

Conclusions

This paper provides four policy recommendations on a framework governing hydrogen transport infrastructure investments

- Technology competition with respect to mode of hydrogen transport is inevitable (at least in Europe);
- Energy network planning processes should not decide the final hydrogen-related investment of regulated infrastructures but be expanded as to identify cross-sectoral external effects;
- Competitive disadvantage of grid-based hydrogen transport infrastructures driven by lumpy irreversible investments should be accounted for by e.g. network regulation and market-design adjustments;
- Operators of regulated grid-based hydrogen transport infrastructures need an additional incentive that accounts for the differences in the risk profile of hydrogen-related and business-as-usual activities.

References

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