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Pivotal Questions for the Market Design of a Hydrogen Market

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The development of a hydrogen economy is a crucial element of the energy transition towards climate neutrality. A key aspect of the hydrogen economy is a suitable market design. However, the discussion of the implementation of the hydrogen market lacks the consideration of the aspired final market state. This brief will explore the crucial elements of the market and raise seven pivotal questions that serve as cornerstones for further discussions.

Hydrogen Market Design

The public debate and research focus mostly on aspects like generation, consumption sectors, and infrastructure when addressing the transition to renewable hydrogen. Aspects of direct vs. indirect electrification, the alignment of the power and gas sector for the integration of renewable energies or the climate impact of hydrogen sources are part of the discussion. Most energy system studies do not consider the market design or focus on specific measures to improve the economic situation of renewable hydrogen. In this context, the overview of crucial elements of the hydrogen market design and the configuration of the elements for different market conditions is of high relevance.

Niedrig et al. (2024) identify key elements of a hydrogen market design combining a literature review with expert interviews. First, the identification of the market design options uses a two-step approach. A morphological analysis and literature review of the power and gas market identify the basic elements of energy markets and represent the solution space for the hydrogen economy. Expert interviews with stakeholders of the German energy and hydrogen sector enable the evaluation of the design options for three scenarios. The scenarios represent different states in terms of infrastructure coverage from local, island networks to some interconnections of hydrogen centres and closely, meshed grids. The different states can also be considered as successive phases of market development.

The analysis shows seven elements that are crucial for the future hydrogen market design: marketplace, trading period, price formation,

cost components, price orientation, prequalification's, and geographical coverage. The results indicate a distinguishable market design and show a huge impact of the infrastructure coverage on the configurations of the hydrogen market. Individual hydrogen regions that are not interconnected result in markets with only local geographical coverage. In contrast, the creation of national and international exchange capacities is the foundation to enable a dynamic and liquid market environment.

Element	Value						
Commodity	Hydrogen						
Marketplace	Over the Counter	OTC + Stock Exchange	Stock Exchange				
Trading Period	Long-term Trading	LT + Day Ahead	LT + DA + Intraday				
Price Formation	Bilateral	Bilateral + CT	Bilateral + UP	Bilateral + Pay as bid	Bilateral + Fixed Price		
Cost Components	Extraction	Generation	Transport & Distribution	Storage	Sales	Taxes, Duties, Levies	
Price Orientation	Cost	Demand	Supply	Competition: Competitors	Competition: Substitutes		
Pre-qualifications	No Requirements	Minimal Supply Volume	Energy Carrier	Emissions	Reaction Time	Quality	
Geographical Coverage	Local	Regional	National	International			

OTC – Over the Counter
 LT – Long-term Trading
 CT – Continuous Trading
 UP – Uniform Pricing

Figure 1: The elements and configurations for the hydrogen market design options

The analysis shows that in small market areas trading is organized bilateral over the counter with long-term contracts. Aspects like short-term trading and auction systems play a rather minor role. Securing financing for electrolyzers and production is of high importance, as generation is the most relevant cost component combined with the risk and low liquidity in the local markets. Additionally, taxes, duties and levies are expected to have a significant impact on the cost. However, scarcity of suppliers could result in a seller's market. In the case of larger regional clusters competing hydrogen producers can be an important orientation for the price. Hydrogen emissions are the relevant prequalification criterion for market participation.

In contrast, the case of extensive infrastructure coverage enables a more liquid and dynamic market. The analysis shows that the market

benefits from the implementation of a stock market and various trading products and periods such as intraday or day-ahead trading or continuous and pay-as-bid price formation. Hydrogen transportation becomes a relevant cost factor in this scenario and the impact of taxes, duties and levies is reduced compared to smaller, independent market areas. The price formation shows the pattern of a broader and more liquid market, and all configurations of the element might have an impact. In line with more trading options, the prequalification aspect of reaction time gains in importance and the quality (e.g., purity) of hydrogen becomes relevant as production conditions differ regionally. The final geographical coverage of the market area depends on the international exchange and can reach from national to international areas.

Given the urgency of the market ramp-up of hydrogen, short-term measures shouldn't compromise the target for the medium and long-term framework. The different states of the market design raise seven questions that need to be considered by policymakers and decision-makers on the national and international levels when developing the hydrogen market. This is relevant as the scenarios can also be seen as a development path from local hydrogen grids to a European infrastructure in the long term.

Pivotal Questions of the Market Development

The first question concerns the impact of the extent of trading and transport of hydrogen and hydrogen derivatives: **What is the impact of the use of hydrogen derivatives on the trade of pure hydrogen?** The answer to this question is affecting several elements of the market design such as marketplace and period or geographical coverage. The higher the extent of hydrogen derivatives the lower the need for pure hydrogen. This impacts aspects such as the market size, market liquidity and the required infrastructure.

The second question concerns the size of market areas: **Is the target market state conform to the infrastructure and vice versa?** This aspect primarily concerns the geographical coverage of a market. The questions tackle the alignment of market area with network capacities. In this context, the European Hydrogen Backbone currently represents the political goal that Europe has a continental coverage with hydrogen infrastructure. A further benefit of both questions is the critical review of infrastructure plans and a reduction of the risk of building oversized hydrogen infrastructure.

The organization and planning of a hydrogen grid relate to the third question: **Do nationally different approaches have an impact on the market and compatibility between EU member states?** A first step on the European level was realized by the national gas TSO with the publication of the vision of the European Hydrogen Backbone. The national and international exchange capacities are necessary to enable a larger market area and a more liquid and dynamic market. A second step is the recent PCI list to support key cross-border hydrogen infrastructure projects. However, the legislation and regulations related to infrastructure development are still developing. As the conversion of network elements is a promising option, the operation of the existing gas grid, initial funding (e.g., initial funding by governments can affect EU state aid rules) and aspects like third-party network access involve regulatory institutions. This is the case, for example, with the Natural Gas Directive, which provides that geographically limited hydrogen networks are exempt from some of the unbundling requirements. However, a later market integration can be problematic if the target is a national or European market area.

The fourth question is: **How do different national developments in terms of infrastructure, production, and consumption affect the trading volume?** For instance, a differently organised structure of grid tariffs can eventually impact the exchange between countries and there is a need for European mechanisms to promote and share investment in hydrogen projects and infrastructure (e.g., cost-sharing). The update of the German hydrogen strategy shows another aspect of this issue. The strategy update also considers hydrogen for decentral heating applications in the long term meanwhile the Danish strategy focuses on sectors where direct electrification is not possible or causes very high costs. Such aspects do not only complicate a common European path but also impact the alignment of relevant market components like relevant cost components or price formation.

The next question is: **What standardization and harmonization are necessary?** For instance, the quality of renewable hydrogen might become more relevant in the case that different sources supply one area. In the case of island grids, this can be determined bilaterally. Larger markets require harmonized standards like for natural gas. Guidelines provided on the European and national levels will provide a framework that economic associations and industry certifiers can further develop standards for elements such as prequalification, price formation or trading periods. The goal is to create international standards that ensure

smooth trade and interoperability between different countries and markets.

This aspect is linked to another question: **What type of trade agreements are required to facilitate cross-border trade in hydrogen?**

This question is primarily related to the promotion of the hydrogen economy at the international level. Furthermore, it helps to create sustainable and efficient supply chains for hydrogen that are aligned with the long-term goal for the hydrogen market.

The last question concerns the structure and implementation of market elements: **What is the risk of creating today's framework conditions for the long-term goal?** An example is the component marketplace. Even with a long-term goal of a comprehensive hydrogen market, an early commitment to today's products and market players may result in a lock-in. Furthermore, the implementation of financing mechanisms in the market ramp-up phase of a domestic market and for establishing import structures requires an analysis of the compatibility of the EU and national approaches to market compatibility.

Outlook

This brief raises seven pivotal questions related to the market design and development of the future hydrogen market. Aspects, such as the hydrogen use in different sectors, imports of hydrogen or derivatives (and their submarkets), infrastructure availability and extent, and the timeline of the hydrogen implementation influence the market organization. The implementation of hydrogen and derivatives requires the alignment of the target market state with the infrastructure development, framework conditions and industrial standards on the European and national levels. A thoughtful and adaptable approach is crucial to managing the complex task of market development. Considering the raised questions can ensure that the evolving hydrogen market is in line with long-term goals and includes harmonisation, standardisation, and strategic planning for sustainable and efficient development.

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