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Energy sustainability, stakeholder conflicts, and the future of hydrogen in Denmark

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ABSTRACT

Denmark spends the most on hydrogen research (in Gross Domestic Product terms) than any other country in the world, which has led to an immense amount of activity related to hydrogen fuel cells within the past decade. However, not all stakeholders in the Danish hydrogen network share the same vision for the technology. This study therefore uses critical stakeholder analysis to first identify the most influential actors involved in hydrogen research before it documents a set of stakeholder conflicts. The study has a threefold conclusion that urges analysts to rethink how they view stakeholder contention within the Danish hydrogen research network. First, the study concludes that hydrogen and fuel cell technologies are still open for interpretation and the application is thus a conflict area between stakeholders. Second, stakeholder conflict can contribute to technical development according to an evolutionary economics perspective. Third, consensus regarding energy system transitions is by nature temporary and, at times, can be counterproductive to the advancement of hydrogen technologies.

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1. Introduction

Denmark, perhaps more than any other country, has attempted to embrace a hydrogen economy. National energy plans call for an ambitious mitigation of CO_2 and a significant acceleration in the use of renewable resources. The goal for 2020 is 50% power production from renewable resources, and 35% of complete energy consumption from renewables, moving to complete penetration of renewables by the year 2050 [1]. Therefore Denmark invests heavily in research and development for renewable energy technologies. For instance, from 2000 to 2012, the Danish government has committed US$280 million of public funding into hydrogen

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research projects, the largest of any other type of alternative energy technology over the 13 year period [2]. Denmark is furthermore the country that spends the most on Hydrogen and fuel cell development worldwide measured against Gross Domestic Product (GDP) [3].

Yet despite these substantial investments, little actual hydrogen infrastructure exists, and hydrogen fuel cells remain only in isolated niche markets where customers are willing to pay a premium for the technology [4]. Even the Danish energy sector, propelled by natural gas and crude oil, retains aspects of "carbon lock-in" [5], and new energy systems, such as hydrogen, face barriers that transcend expectations, markets, institutions, and technology [6–8].

This situation is unfortunate, given that hydrogen and fuel cell technologies can offer a wide range of applications ranging from small scale supply to large scale power plants that can enable Denmark, and other countries, to respond to energy challenges [9]. Compared to the internal combustion engine, fuel cells produce no direct local emissions, are practically noiseless and theoretically more stable due to the absence of moving parts [10]. Compared to batteries, hydrogen systems have faster refueling and higher energy density, meaning they can refuel quicker and travel longer than electric vehicles [11,12].

So why, then, has hydrogen technology not taken off as expected in Denmark? This paper utilizes critical stakeholder analysis to determine how different stakeholders perceive hydrogen technology throughout the country. We define the country's hydrogen and fuel cell network as those actors who are engaged in research, development, production, financing and governing and otherwise supporting hydrogen production and handling and fuel cell technologies. Our research is based on 21 interviews with key stakeholders across 10 institutions in the hydrogen and fuel cell network conducted between September 2010 and November 2013[2]—key details of these interviews are presented in Appendix I—supplemented with a review of the academic literature and policy literature [13].

To make its case, the paper proceeds as follows. It begins by introducing readers to critical stakeholder analysis and then conducting such an analysis for the country of Denmark. Then, it presents a sample of four stakeholder conflicts including hydrogen production and handling, stationary units, mobile applications, and energy utilities. It concludes by calling on policymakers and researchers concerned about hydrogen technology to reconceptualize how they envision stakeholder cohesion and controversy.

The importance of such an inquiry is twofold. First, it has real-world practical value for Danish policymakers, helping to identify the lingering barriers that impede widespread deployment of the hydrogen and fuel cell technology. Second, it has relevance for hydrogen practitioners in any country that must manage competing stakeholder interests in an ever-changing energy technology and policy landscape. This has descriptive as well as predictive value beyond Denmark.

2. Materials and methods

The term "stakeholder" was originally defined as [14]: "Those groups without whose support the organization would cease to exist." The traditional list of stakeholders includes shareowners, employees, customers, suppliers, lenders, and/or society. In this paper we will include the stakeholders mentioned in the citation above, and we will apply a selection criterion where we include those stakeholders who have the power to exert influence over the development of the innovation system.

In addition, stakeholders can be divided into "internal," "external," and "rest of world" categories. The "internal" stakeholders are those directly involved in the utilization of a particular event or technology, whereas the "external" stakeholders are those not directly involved but who still are critical to the development of the technology. Examples include promoters of a competitive technology, educators that may need to teach students about a technology, insurance companies that need to indemnify against liability, and so on. "Rest of world" are actors who cannot influence any meaningful development, meaning they are peripheral and need only be monitored sporadically [15]. Stakeholders can further be classified according to their involvement in the decision-making processes. Mitchell et al. [16] use the three metrics of power, legitimacy and urgency.

The purpose of conducting the stakeholder analysis is to examine relevant stakeholders to a given technological or political field, and subsequently account for their interests and relative power [17]. As Brown and Sovacool [18] write, the process involves:

- Identifying relevant stakeholders to include for analysis.
- Assessing each stakeholder's objectives, interests and beliefs.
- Characterizing stakeholder resources.
- Elucidating the strategies and venues stakeholders use to achieve their objectives.

The purpose of applying critical stakeholder analysis in this manner is to enable a more efficacious management of stakeholder interactions [19,20].

3. Results

Who, then, are the stakeholders within the Danish hydrogen and fuel cell innovation system? The Danish Partnership for Hydrogen and Fuel Cells consists of 15 producing companies, three formal networks of which one is an overall industry association, four universities and three institutional units [21]. In addition to these there are exogenous actors and institutions that have an indirect influence on hydrogen development.

As mentioned in the previous section, stakeholder identification in the broadest sense includes all actors or groups who can affect the objectives of an organization's (or in this case an innovation system's) achievements or can be affected by the objectives of the organization. When applying this perspective the group of Danish hydrogen stakeholders it can expand, arguably, to include all of society, considering that hydrogen and fuel cell technology can revolutionize the entire energy system including power and heat production, transportation and commerce, and household energy use. So a loose definition of a hydrogen stakeholder could encompass everyone. Although there is widespread agreement that the fossil energy system will not be replaced directly by a hydrogen economy [22], the technology can play an important role in the future energy system [9]. To narrow within such a large group, we have therefore in this section included only the actors which we consider most influential for the development of the hydrogen and fuel cell innovation system, and for the development of the energy system. We do this by classifying stakeholders based on their power, legitimacy and urgency, considering a stakeholder salient if they possess at least two out of these three criteria. Only if the

[2] The research has been conducted as a qualitative case study, where data have been gathered through a number of channels. Primary sources of data were gathered through unstructured informal interviewing of key actors within the Danish energy system and hydrogen and fuel cell network. Furthermore, knowledge gathering has been conducted through participation in open meetings at the Danish energy agency and at the Danish Partnership for Hydrogen and Fuel Cells. Lastly, knowledge concerning the Danish competitive capabilities has been gathered through participation in industrial fairs.