SUPPORT HYDROGEN FOR TRANSPORT: A COMPARISON OF INCENTIVES FOR PRODUCERS AND CONSUMERS IN EUROPE AND THE US

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Abstract
Large scale demonstration projects ‘Lighthouse projects’ are an important step towards commercialisation. However, costs for disruptive technologies such as hydrogen, are high in the first phase of the innovation trajectory. Therefore, technology specific policy support is needed to facilitate the introduction of hydrogen. But, how can the government support and stimulate (early) market introduction and use of hydrogen in the transportation sector? What kind of policy instruments are needed in what phase of the introduction trajectory? And what are the current instruments in the EU and US? Can these affect the introduction of hydrogen in transport?

Generally, the hydrogen chain can be stimulated by providing an investment subsidy, production subsidy, tax exemptions and a (production or sales) obligation. Technology specific configurations of these support mechanisms for the diverse technologies in the hydrogen chain have to be taken into account. Besides that, the support measures have to be able to adapt to the rapid changing (improving) competitiveness of the hydrogen technology as deployment goes up.

A comparison of the EU and US policies shows differences in the approach of bringing the hydrogen vehicles to the market. The amount of support differs. The US funds RD&D 50% and stimulates the market by obligating sales (ZEV obligation) and procurement, while the EU funds R&D 50%, demonstration 35% and is now looking into large scale demonstration projects, after which the commercial market introduction of hydrogen vehicles is envisaged.

1. Introduction
Being a disruptive technology that is still in the early phase of market introduction, hydrogen in transport can yet not compete with the conventional technology. Large scale demonstration projects ‘Lighthouse projects’ are an important first step towards commercialisation. The role of early markets is described in more detail in (Bunzeck et al., 2008)..However, costs for new technologies, and specifically for disruptive technologies such as hydrogen, are high in the first phase of market introduction. Therefore, policy support is needed to facilitate the introduction of hydrogen.

This article outlines possible policy support mechanisms for large scale demonstrations projects for hydrogen in transport. In order to identify and make recommendations for suitable support schemes for innovations, a distinction needs to be made with respect to (1) the innovation stage of the technology and (2) the specific characteristics of the technology. This is specifically of relevance in the case of hydrogen in transport. Barriers have to be overcome in all parts of the energy chain

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and on top of that the performance of the technology improves rapidly when deployment goes up.

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2. Policy support in the innovation cycle

New technologies face a number of barriers after their technical feasibility has been demonstrated. Potential barriers comprise not only technological and economic aspects such as high(er) investments and operational costs, infrastructure needs, slow capital stock turnover, but also other aspects such as market organisation, regulations, codes and standards, end-user behaviour and (lack of) information. By means of (temporary) support by a policy framework, these barriers have to be overcome in order to pass the various stages of the innovation trajectory.

Large scale demonstration projects are the first step within the trajectory towards mass market deployment. After a series of large scale demonstration projects has been completed, the next steps towards mass market can be made by entering early markets with increasing economic and technological demands. The effectiveness of a policy support framework in these early phases of technology introduction depends on the ability to adapt to these various transition trajectory phases. Such a policy support framework can include various types of instruments, such as regulation and financing. However, the impact of a policy support instrument differs for the market stage of the technology. The aim of the policy support scheme remains the same: to increase the competitiveness of the technology at minimum costs. When the competitiveness of the innovation improves the innovation is able to enter the next phase. The competitiveness is determined by both the costs of the option as well as the technical performance (and also end-user preferences). Two distinctions can be made in policy support framework:

- A policy support framework contributing either direct or indirect to the competitiveness
- A policy support framework for a specific technology or supporting a generic policy goal

2.1 Direct and indirect support schemes

A direct impact on the competitiveness is obtained through changing the price level of the reference technology (e.g. by taxation) or decreasing the price level of the innovation (i.e. by subsidising or tax exemptions). These type of instruments aim to decrease costs by increasing the deployment of the technology (‘learning by doing’). Regulation (i.e. minimum shares or exclusion) is another way to improve the competitiveness of the innovation in a direct way.

The cost competitiveness can also be improved by means of indirect instruments such as R&D schemes (‘learning by searching’). R&D expenditures will lead to an increase in performance and a decrease in costs.

The policy support framework is most effective in case both direct (deployment related - learning by doing) and indirect (R&D related – learning by searching) support mechanisms are combined. The balance between learning by doing and learning by searching depends on both the type of technology as well as the market stage (Sagar, A.D., B. van der Zwaan, 2006).

2.2 General versus technology specific support schemes

A further characterisation of support schemes can be made by making a distinction between technology specific and general support schemes. The aim of general support schemes is for example to support sustainability. All options that offer an advantage in comparison to the non-sustainable reference technology are supported. This type of instrument focuses on cost-optimisation and relies on the optimal functioning of market forces. The incentive is based on the current contribution to policy goals. The long term potential, or more important: the lack of a long term potential, is not taken into account. Short term optimisation, as induced by the general support schemes, may lead to serious and undesirable lock in effects. Examples of general support schemes are CO_2-trading schemes, CO_2-taxation and internalisation of external costs. Obviously, these schemes will reduce the attractiveness of the reference options, but the incentive for high potential long term innovations is lacking, since the focus is on maximising emission reductions at the short run at minimum costs. So, on top of these general instruments, technology specific support is needed in order to ensure that high potential innovations will be developed.

A support scheme can also be technology specific, supporting only specific renewable energy production methods such as wind energy, solar and biomass each with a tailor made incentive. This offers the opportunity to support options with a higher long term potential with stronger incentives. On the short term, a less cost-effective solution is obtained due to the higher initial costs. On the long term, lock in effects can be avoided, ensuring that also future long term policy goals can be achieved at acceptable costs. Due to its larger emission reduction potential and cost reduction potential, on the long run the cost effectiveness of hydrogen in transport is favourable over competing options (HyWays, 2008).

By means of implementation of a general support framework, the competitiveness of hydrogen in comparison to the reference (non-sustainable) technology will improve. However, since this instrument basically focuses on short term cost effective optimisation hydrogen will be at a (relative) disadvantage in comparison to competing incremental innovations (e.g. biofuel blending), implying that its introduction is likely to be delayed. Only after the failure of the incremental innovation to reach future policy goals at acceptable costs, market prospects of ~~the~~ hydrogen improve. This does not mean that the incremental innovations should not be supported. They do offer valuable benefits at the short and medium term, but their potential to meet long term more ambitious policy goals is lacking. The temporary solution offered by these incremental innovations should be used to further develop the disruptive technology.

Both disruptive as well as incremental innovations will benefit from general support schemes. In addition to this, disruptive technologies such as hydrogen need a technology specific support scheme that enables them to compete with incremental innovations. In the first market phases, the disruptive technologies need protection to be able to increase its competitiveness. In time however, the support scheme needs to shift from protection to competition. At the end, the market forces will determine the market shares of the various technologies. Without being able to make the first steps in a protected environment (so technology specific support schemes), disruptive technologies will only reach the stage where they can compete with incremental innovations with severe delay.

2.3 Flexibility of the support schemes

In order to remain effective, the policy support framework has to be able to adapt to changing conditions in time. The required need for flexibility of the policy support scheme as well as the need to specifically support the reduction of various barriers in each part of the hydrogen energy chain imposes a major challenge in the design of an effective support scheme for hydrogen in transport. Policy schemes which are low in detail with respect to technological detail are more flexible. They are however not able to handle the time and energy chain specific barriers appropriately.

More complex policy support schemes with high technological detail need often more time to adapt to change. The past has shown that specifically detailed regulatory measures such as minimum performance standards are in practice quite inflexible. If the standards are set too ambitious, they can only be met at excessive costs (assuming they can be met at all). If the standards lack ambitions, there will be no response at all within the market. Given the rapid change of market conditions, it is very complicated to set the standards at the right level and they may be outdated within months, or prove to be to ambitious.

Support schemes need to be designed in way that the height of the incentive can be changed. When market conditions change rapidly and deployment increases fast, e.g., subsidy budgets may explode. To prevent this one option is to limit the total number of applicants for the subsidy. A second option is to make the applicants tender for the subsidy.

Taxation schemes have the advantage that unforeseen circumstances lead to higher income. Tax exemptions, just as subsidies, may lead to unforeseen debits in case of inappropriate monitoring. Taxation and tax exemption schemes can be coupled to a budget neutral support scheme, although also in this case proper monitoring is required. All options have different side effects and no ‘one size fits all’ solution exists.

3. Lessons learned from the renewable electricity framework

A comparison with the renewable electricity framework can provide some learning for hydrogen in transport. This has to do with a number of renewable energy options that have already passed the innovation phase that now is being entered by hydrogen in transport. The question arises if and how the support schemes for renewable energy can be translated to the case of hydrogen in transport.

The renewable electricity framework

The use of (an increasing share of) renewable electricity basically only requires changes in the production part of the electricity chain. The properties of renewable electricity do not differ from conventional electricity produced from fossil fuels or nuclear energy and the existing distribution grid can be used. Also, no changes are required for the end-use applications (dish washers, washing machines, lighting etc.).

The production of renewable electricity can be supported both at the level of the end user or at the production level. At the level of the end-user, renewable energy can be supported by means of tax exemptions (in €ct/kWh) bringing down the price level to a level comparable to the conventional electricity price. This type of support scheme supports renewable electricity in general without making a distinction between the various production sources. It's up to the market to choose the most economic way to provide the renewable electricity demanded at the end-user level.

Renewable electricity can also be supported at the production side of the chain. This can be done by providing incentives on the investment for the production facility (e.g. the wind mill, the pv panel, e.g. in €/MW) or by means of an incentive on the renewable energy production (e.g. in €/MWh). Examples are an investment subsidy for wind mills or purchase subsidies for pv panels. Also, production subsidies are commonly used. An example of such a production subsidy for renewable electricity is feed-in tariffs, which guarantee a minimum price for every unit of green electricity produced. In the case of providing incentives at the production level, it is possible to tailor the support to the needs of the specific technology.

Instead of providing a subsidy on either investment or production, also regulation can be implemented. The most common way to do this is by setting a minimum share of renewable electricity (%, in MWe), although also obligations for a minimum amount of capacity (in MW) are used.

3.1 Comparison with the hydrogen framework

For hydrogen to enter the mass market a whole chain has to be set up, from production, distribution to end-use. In all these parts of the hydrogen chain policy support is possible. In contradiction to the case of renewable electricity, barriers do exist at the end-user level. At the end-user level, hydrogen can be supported by either incentives on the investment costs of the vehicle (€/vehicle) or by incentives on the fuel costs (€/GJ or €/kg). Purchase subsidies for the vehicle, tax exemptions on excise duty or vehicle purchase tax are possible ways to support hydrogen at end-use level. The combined effect of the investment costs and fuel costs determine the overall costs and can be compared to the cost of the reference option. The end-user will respond differently to each of the measures. High investments and low fuel prices may cause different market behaviour in comparison to low investment costs and high fuel prices, even if the net effect over the (economic) life time of the vehicle is the same.

3.2 Support at the production level

At the production level, the case of hydrogen differs not that much from the case of renewable energy. Specific barriers at the production level have to be overcome, either by incentives on investments (€/unit) or by incentives for hydrogen production (€/GJ). Again, at this level incentives can be, and usually are, applied in a technology specific way. A subsidy on production costs of hydrogen also positively influences the total costs for driving a hydrogen fuelled car, because the fuel price is lower(ed), but barriers are most effectively tackled at the level where they occur (which may be the car in stead of the fuel).

3.3 Support at the infrastructure level

An important barrier in the introduction of hydrogen in transport is the absence of a hydrogen infrastructure (distribution, storage, fuelling stations). Infrastructure funding has no value of its own, since nobody buys a hydrogen vehicle just because of a station nearby, but without stations no one buys a hydrogen vehicle. Hence, the infrastructure support needs to be orientated at the production and end-use development and cannot be seen as autonomous parameter.

Different kinds of infrastructures can be distinguished for hydrogen. There can be an infrastructure which can be easily expended (liquid hydrogen trucks and storage tanks at the refuelling station) and an infrastructure that needs to be designed to meet long term specifications (e.g. pipelines). A key issue in this aspect is the design of the capacity of the infrastructure. Pipeline infrastructure has a very long life time and preferably should be designed based on the potential demand on long term and not on the expected demand in the next three to five years. In case long term expectations are taken into account, severe underutilisation will occur for a long period of time, leading to negative cash flows.

In the past, the build up of (pipeline) infrastructure belonged to a large extent to the responsibilities of a public body. The market is insufficiently able to take into account the long term demands on pipeline infrastructure since their investments need to meet specific cost criteria. Total costs for society can however be lower in case these future aspects are taken into account. Due to factors such as market liberalisation and globalisation, it’s unlikely that public bodies will become responsible again for building up a large scale pipeline infrastructure. However, it is still possible by means of the right incentives to steer the market into a direction where the long term requirements on infrastructure are (to some extent) taken into account. Such incentives need to be aimed at risk reduction for the investor. This might even be important in the early phase of introduction of hydrogen in the transport system, since the design of the first user centres may already predetermine (or influence) the design of the hydrogen infrastructure in the following decade.

3.4 Concluding

In the case of support of renewable electricity, incentives can be provided at the end-user level and production level. These incentives have the aim to overcome (cost) barriers at the production level. In the case of hydrogen, incentives can be provided on the end-user level and the production level as well as on the infrastructure level. The main difference, however, is that not only barriers have to be overcome at the production level, but also at the level of infrastructure build up and end-user application (the hydrogen vehicle). This makes the hydrogen policy scheme way more complex than the support scheme for renewable electricity.

A major question in the design of a hydrogen support scheme is whether it specifically should support hydrogen production from specific sources (e.g. renewable energy; differentiate the support depending on the pathway), or just hydrogen in general. In case of support of renewable hydrogen, this can both be done by a general support of renewable hydrogen (leaving it open to the market which renewable technology to use) as well as by technology specific support (e.g. ensuring that renewable technologies that are at the moment less cost competitive but which have a high future potential are already being developed).

4. The current policy support framework for hydrogen

In this chapter, a brief overview of the current and foreseen support schemes for the support of hydrogen in transport is given as well as a brief comparison with the hydrogen support scheme in the US. The analysis is restricted to initiatives on the EU level [2].

4.1 Comparison between the EU and the US – a different philosophy?
In addition to the support scheme for hydrogen in transport in the EU, an overview of the support mechanisms in the US has been made. In figure 1, the incentives in place in the US and the EU are compared.

At the R&D stage, the incentives are comparable. However, at the demonstration level, conditions in the US seem to be more favourable due to the higher subsidy rate (50% in the US vs. 35% in the EU). Moreover, in the US a number of other financial incentives have been implemented. The most striking difference between the US and the EU however is obligation for deployment of hydrogen fuel cell vehicles through the Californian ZEV mandate. Large automotive manufacturers are obliged to deploy (and operate) an increasing number of ZEVs in time. Within the EU, a joint technology framework (JTI) for hydrogen and fuel cells is under preparation. Within the JTI, funding conditions for (large scale) demonstration projects may differ from the current EC conditions.

The philosophy with respect to how innovations have to be stimulated seems to differ between the EU and the US. In Europe, the innovation trajectory usually exists of a phase of technology protection with limited selection up front of which technology is the ‘best’, followed by a phase of competition, finally leading to obligations (e.g. by excluding old technology). In the US (in fact: California), already in the first phase of technology introduction, a clear choice has been made for hydrogen and fuel cell vehicles by setting obligations. This obviously imposes very strong incentives for technology development and deployment but also imposes major risks. Technology improvement is a non-linear process. Setting obligations too ambitious will lead to excessive costs, assuming that the target level actually can be met. This can have a very negative impact on the support and acceptance of a new technology, leading to a hampered deployment.

It is concluded that the current incentives for the deployment of hydrogen vehicles in the US are stronger than the incentives in Europe due to more favourable financial support schemes (e.g. higher subsidy rate) as well as the obligatory deployment through the ZEV mandate. This disturbance of the level playing field may lead to a delayed deployment in Europe. This does not mean, however, that the incentives that are currently in place in the US should be copied to Europe. Setting obligations on the deployment of a new (disruptive) technology that is in an early phase of introduction imposes high risk and may lead to severe negative side effects such as excessive costs or a loss of public acceptance. However, opportunities exist to increase the effectiveness of the (financial) support schemes, by designing it in a way that it tackles the technology specific barriers at the part of the energy chain where they occur.

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Figures

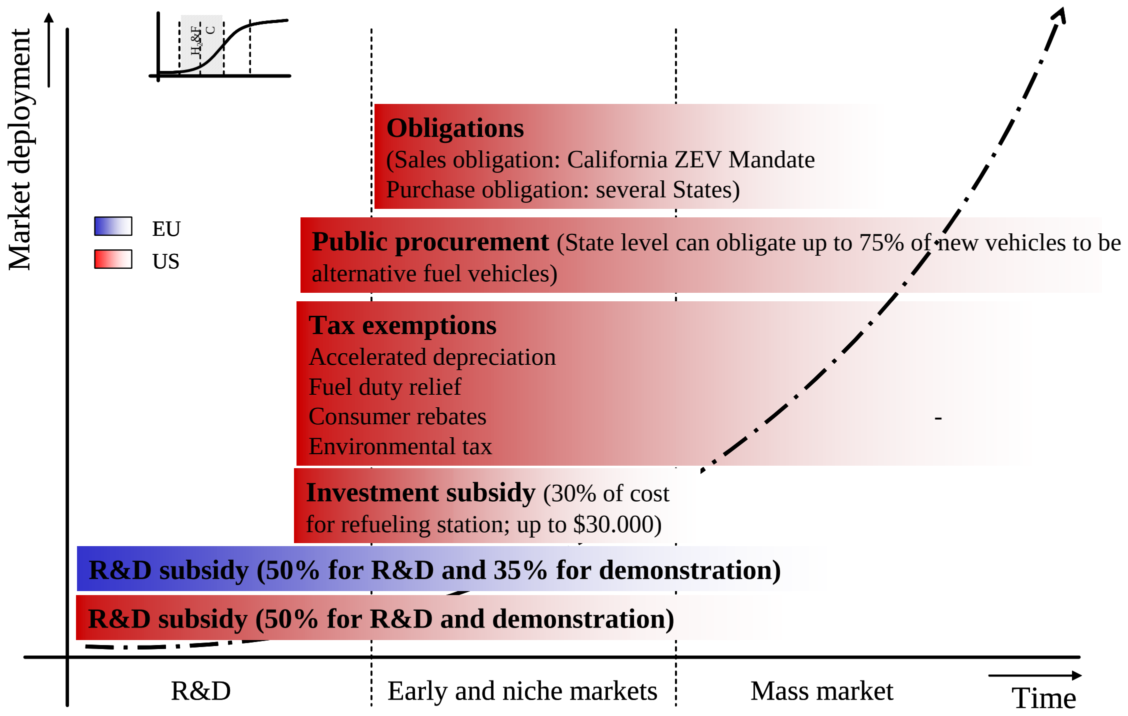

Figure1 *Comparison of the incentives for hydrogen in transport for the US and the EC-level*