Policy support for large scale demonstration projects for hydrogen use in transport

Deliverable D 5.1 (Part B)

M.E. Ros

H. Jeeninga

P. Godfroij

ECN-E--06-064

December 2006

Acknowledgement
In the framework of the ‘HyLights’ project of the EU this study presents an overview of policy support mechanisms for hydrogen for transport. It takes into account the co-evolution of technology development and policy mechanisms such as financial and other incentives, resulting in an overview of ways to support and accelerate technology development for hydrogen in transport. Herewith this report pays attention to the specific parts of the hydrogen chain (production, distribution and end-use). The project is registered at ECN under project number 7.7700.

Abstract

This research addresses the possible policy support mechanisms for hydrogen use in transport to answer the question which policy support mechanism potentially is most effective to stimulate hydrogen in transport and especially for large scale demonstrations. This is done by investigating two approaches. First, by investigating the possible policy support mechanisms for energy innovations. Second, by relating these to the different technology development stages (R&D, early market and mass market stage) and reviewing their effect on different parts of the hydrogen energy chain (production, distribution and end-use). Additionally, a comparison of the currently policy support mechanisms used in Europe (on EU level) with the United States (National and State level) is made.

The analysis shows that in principle various policy support mechanisms can be used to stimulate hydrogen. The choice for a policy support mechanism should depend on if there is a need to reduce the investment cost (€/MW), production/use cost (€/GJ) or increase performance (€/kg CO_2 avoided) of a technology during its development. Careful thought has to be put into the design and choice of a policy support mechanism because it can have effects on other parts of the hydrogen energy chain, mostly how hydrogen is produced. The effectiveness of a policy support mechanism greatly depends on the ability to adapt to the developments of the technology and the changing requirements which come with technological progress. In time different policy support mechanisms have to be applied.

For demonstration projects there is currently the tendency to apply R&D subsidies in Europe, while the United States applies a variety of policy support mechanisms. The United States not only has higher and more support the demonstration projects but also has stronger incentives to prepare early market demand (by for instance requiring public procurement and sales obligations). In order to re-establish the level playing field, Europe may also need to start applying a combination of production subsidies, investment subsidies, tax exemptions and public procurement in order to successfully start large scale demonstration projects and increase the chance of early market demand and leadership in the hydrogen for transport field. This however does not mean that the incentives that are currently in place in the US should be copied. Setting obligations on the deployment of a new technology that is in the 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 mechanisms. By designing the support in a way that it tackles the technology specific barriers at the different parts of the energy chain, by keeping in mind the flexibility of policy support mechanisms and by providing industry with a long term security of support Europe can create an attractive climate for the introduction of hydrogen in transport.

Contents

List of tables

List of figures

Summary

New technologies have to go through several technology development stages in order to reach the mass market and provide revenues to counterbalance initial R&D and deployment investment. Especially disruptive technologies, like hydrogen, tend to have many barriers, one of which is high initial cost, which has to be overcome to successfully enter the mass market. Policy support is one of the options helping to overcome this barrier.

Europe is currently looking into large scale demonstration project for hydrogen in transport. Here also the question rises which kinds of policy support mechanism can be used to support further technology development. Therefore, the aim of this research is to explore the possible policy support mechanisms and relate these to the different stages of technology development, especially focussing on the impact and possibilities for the different technologies in the hydrogen energy chain (production, distribution, storage and end-use) related to transport during the demonstration phase.

This is done by using two approaches. First, by briefly outlining the various support mechanisms for energy innovations. Second, by investigating policy support mechanisms during the different technology development stages (R&D, early market and mass market stage) and review which policy support mechanisms can help overcome the changing requirements. For this last approach helpful insights can be gathered by reviewing the effect of policy support on different parts of the hydrogen chain is done and review current support in Europe and the United States.

The analysis shows that different policy support mechanisms can be used to stimulate hydrogen in transport. These are R&D and demonstration subsidies (or investment subsidies), low interest loans and loan guarantees, production subsidies (like feed-in tariffs and fixed premium systems), tax exemptions, quota obligations, emission trading, tendering and bidding, environmental standards or regulation, voluntary agreements and public procurement. Depending on the technology development stage the policy support mechanism should be chosen. Firstly the focus should be on reduce the investment cost (€/MW), hereafter the production/use cost (€/GJ) should be reduced and finally the performance (€/kg CO_2 avoided) should be increased.

The choice, design and target of the policy support mechanisms however also have effects on:
- Competition between technology options, namely the conventional technology and/or other technologies contributing to sustainable transport.
- Supply or demand of hydrogen for transport.
- Other parts of the hydrogen energy chain, mostly how hydrogen is produced.

Careful thought has to be put into the design and choice of a policy support mechanism. The effectiveness of a policy support mechanism greatly depends on the ability to adapt to the developments of the technology and the changing requirements which come with technological progress. In time different policy support mechanisms have to be applied.

Currently in Europe there are subsidies for R&D and demonstration projects, while the United States applies a variety of policy support mechanisms. By for instance requiring public procurement and sales obligations the United States not only supports the demonstration phase but also starts to prepare early market demand. In order to maintain a level playing field, Europe may need to reconsider its approach and start to apply not only R&D subsidies and subsidies for demonstration, but also a combination of production subsidies, investment subsidies, tax exemptions and public procurement in order to successfully start large scale demonstration projects and increase the chance of early market demand. This however does not mean that the in-

centives that are currently in place in the US should be copied. Setting obligations on the deployment of a new technology that is in the 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 mechanisms. By designing the support in a way that it tackles the technology specific barriers at the different parts of the energy chain, by keeping in mind the flexibility of policy support mechanisms and by providing industry with a long term security of support Europe can create an attractive climate for the introduction of hydrogen in transport.

1. Introduction

New technologies are constantly developed with the aim that they one-day will be able to enter the mass market and provide revenues that counterbalance the R&D and deployment costs. For new technologies it is hard to enter the market and compete with the existing technology. High initial cost, start up problems and lock-in are just some barriers which have to be overcome for the new technology to succeed. This specifically holds for disruptive technologies such as hydrogen.

One of the options to overcome the initial barriers is the implementation of policy support schemes. Policy support schemes can be designed to directly stimulate specific policy goals. This goes for biofuels (directive 2003/30/EC) for transportation purposes and renewable electricity (directive 2001/77/EC). Policy schemes can also indirectly contribute to policy goals by means of i.e. incentives for development or deployment of more efficient technologies.

In the EU different support schemes are in place, but their effectiveness depends on several factors, like the context and technological maturity. Over the past years, a lot of experience has been gained with a spectrum of policy instruments for the stimulation of renewable energy, legislation and regulation regarding renewables (Haas, 2001). However, although the effectiveness of these policy instruments have been studied extensively (ex-ante and ex-post studies), there are hardly any studies available clearly indicating what kind of policy support schemes are most effective for a specific technology at a certain market stage. Technology characteristic barriers have to be overcome. This holds specifically for disruptive technologies such as hydrogen applications. In addition, the technology evolves through time, the policy support mechanisms should adapt to the changing market phase.

The HyLights project specifically focuses on the design of large scale demonstration projects for transport applications. The aim of this research is to explore the possible policy support mechanisms and relate these to technology development especially focussing on the impact and possibilities for the different technologies in the hydrogen energy chain (production, distribution, storage and end-use) related to transport during the demonstration phase. This is done by a two step approach. First, briefly the various support mechanisms are categorised for each of the market stages a technology has to pass in the trajectory towards full market maturity. In a second step, the support mechanisms reflecting the characteristics of the upcoming market phase (large scale demonstration projects) are investigated. This is done by:
1. Investigating support mechanisms for technology at a market stage comparable to where hydrogen has to go to in order to cover market size specific aspects.
2. Investigating the past and current support mechanisms for hydrogen in transport in order to cover technology chain specific aspects.

The research questions to be answered are therefore: ***what are potentially the most effective policy support mechanisms stimulating hydrogen technology development in the different phases in time and which are specifically suitable for supporting large scale demonstration projects for hydrogen use in transport?***

The main research question is broken down in a number of sub-questions:
- What are the different technology development stages and what are their characteristics?
- Which policy instruments are most effective to stimulate technology development at the various market stages?
- How can the technology development be supported in the hydrogen and fuel cell field (what are the technology specific barriers in time)?

- Which policy support mechanisms are currently in place for the development of hydrogen and fuel cells?
- Which policy support mechanisms can be used for supporting hydrogen and fuel cell demonstration projects?

In order to answer these questions, Chapter 2 starts with giving an overview of the technology development trajectory outlining the different stages and their characteristics. Chapter 3 provides a general description of different policy support mechanisms, followed by Chapter 4 linking policy support mechanisms to the different technology development stages. Hereafter, the focus will be more on hydrogen and fuel cell technology development. In Chapter 5 specific difficulties with supporting hydrogen and fuel cells will be outlined taking into account the whole hydrogen energy chain and comparing this to the renewable energy system for electricity. After this an overview of current policy support mechanisms for hydrogen and fuel cells will be given in Chapter 6, while Chapter 7 provides an overview of different support mechanisms for hydrogen in transport giving first insight into possible ways to support large scale demonstration projects.

It should be noted that this study is the first and more general study conducted in order to derive recommendations for a support framework for large scale demonstration projects for hydrogen in transport. This report serves as background report, a short summary of results of phase I of the project can be found in (Jeeninga, 2006) In the second phase of the project, the study will solely focus on support schemes (financing issues) for large scaled demonstration projects for hydrogen by building upon the results from the study carried out in the first phase of the project.

This study focuses on support schemes, including financing. In the next steps, the focus will be on what part of the hydrogen energy chain have to be support by what means and to what level. Legal aspects of e.g. how the funds can be transferred between the various stakeholders are outside the scope of this study and will be covered by (Kellen, 2006).

2. Technology development

A future hydrogen based transportation system depends not only on the development of new technologies for end-use applications (e.g. fuel cells or H_2 ICE), but also on technologies for hydrogen production and infrastructure development. In general, each technology has to go through different technology development stage before it becomes market mature. This chapter provides an overview of the different technology development stages and their barriers.

2.1 Technology development stages

There are several stages in the life-cycle of a technology. It starts with the creation of an idea, or *invention*. This invention is researched, developed and demonstrated. During the *innovation* stage the first practical application is introduced. After RD&D the first practical application enters the *niche markets* - specialised markets where the technology has performance advantages - and *early markets* and further improvements are made to cost and performance due to 'learning by doing' and 'learning by using' [1,2]. After successful introduction in niche and early markets the novel technology is introduced to a wider market in the *pervasive diffusion* stage. *Saturation*, the following stage, occurs when this market is exhausted. When a (new) competitor takes a big market share or redefines performance requirements *senescence* occurs (Grübler, 1999). Table 2.1 provides an overview of the different technology stages and Figure 2.1 shows the technology development stages in time.

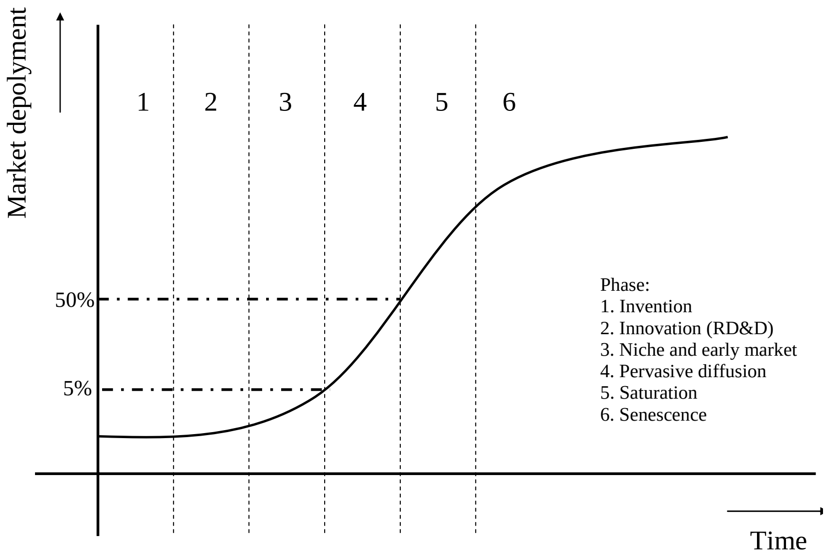

Figure 2.1 *Technology development phases and market deployment in time*
Source: Grübler, 1999.
Note: see also Table 2.1.

The technology development phases should not be interpreted as a linear process. For example, information from demonstration projects in the niche and early market phase feeds back to R&D for further research and to match the technical possibilities to market opportunities. There-

[1] A niche market is a defined as a specialised market of limited size, where an early market is a part of the mass market with more favourable (technological and economic) conditions. For fuel cells in transport, fork lifts may act as a niche market, where city busses or captive fleets may act as an early market.

[2] Learning is an aggregate term that may involve many different mechanisms that contribute to cost reduction over time in producing and deploying new technologies (Sagar, 2006).

fore, it is difficult to determine in which phase the new technology is and if a support scheme for a specific phase can be terminated, legislation can be made, or a new support schemes has to be set up.

In many cases government involvement is justified and desirable since the required changes towards a more sustainable energy system, being a public goal, may not take place by itself. The government can also help reduce (financial) barriers so the new technology can be deployed and compete with the conventional technology, but each technology development stage has its own barriers.

In the *invention stage* the greatest barrier is investment in basic R&D. Universities and industry face high investment costs in R&D and there are no revenues. Outcome of basic R&D is unpredictable, because it is not certain if the technology can be applied in a product during this basic research stage, first the basic science and laboratory tests have to turn out if the technology would work.

The next step is applied R&D and first product development during the *innovation stage*. Innovator firms develop technologies because they believe a market exists for the new technology. The new technology is demonstrated and tested in real life conditions at pilot plant or prototype scale. Demonstration includes early prototypes and during this phase technology has to be developed to the point where full-scale working devices are installed, but only in single units or small numbers. The ultimate goal of development programs is to bring technologies to markets, and this can be done in a number of ways which in practice usually are jointly utilised: through 'learning', through elimination of market barriers, and through targeted programs of market transformation. The scale-up of new technology from laboratory scale to demonstration scale carries significant risks of failure and, even if technically is successful, historic analysis show that this stage tends to cost more than originally anticipated (OECD, 2003). The main problem is the high costs and investments and lack of revenues.

New technologies face a number of barriers after their technical feasibility has been demonstrated. This holds for incremental innovations, as well as disruptive technologies. For example, an incremental innovation like clean coal technologies fits well in the existing energy system but still has a disadvantage with respect to investment costs compared to existing technological options. Disruptive technologies such as hydrogen require changes in the whole energy system and therefore have even higher barriers for introduction. Potential barriers comprise not only technological and economic aspects such as high(er) investment and operational costs, infrastructure needs, slow capital stock turnover, but also other aspect such as market organisation, regulations codes and standards, end-user behaviour and (lack of) information. The first barrier - cost - is by far the most important in the niche and early market stage since most technologies are deployed through markets and cost is the key variable in this area (Sagar, 2006). In this stage of technology development there is limited production and the production process is labour intensive. This leads to high cost for both the producing company and its suppliers. However, depending on its characteristics and conditions the new technology may provide advantages compared to the conventional technology. Niche and early markets can exist because the new technology has technological, environmental or financial advantages compared to the conventional technology. Utilising these advantages creates an early market, where the characteristics of the technology determine its seize. The government, for instance by introducing a favourable tax regime, can create or improve these favourable financial advantages. In these niche and early markets learning-by-doing (deployment) further reduces cost of the technology.

Commercially oriented companies start to roll out the technology in substantial numbers during the *pervasive diffusion phase*, because investments, economies of scale and standard setting lead to (further) cost reductions and market prospects improve. Imitation and adoption leads to a wider array of settings for the new technology. By building on network effects[3] the new technology can gain further market share. The conventional technology slowly phases out, but does not exit the market without a struggle. The technological and/or environmental performance of the conventional technology also (but sometimes slowly) increases, delaying the phase out of the technology (this is called 'sailing ship effect'[4]). See for example the clean diesel which potentially has improved its performance (efficiency, emissions) considerably over the last decade but may on the long run be overtaken by hydrogen fuelled vehicles. Nevertheless, lock-in and low running costs of the conventional technology compared to the (relatively) high investment cost of the new technology are the biggest barriers during this stage.

In the *saturation phase* new and more competitors enter the market and redefine the performance requirements. The market penetration reaches its upper threshold and the technology improvement potential becomes exhausted. Eventually - during the senescence phase - superior competitors dominate the market.

This report will use more general terms for the different technology development stages. R&D, early markets and mass market are used to describe the most important phases in the innovation cycle (see Figure 2.2). The R&D phase covers the invention and innovation stage. The term early market phase will be used to indicate the niche and early market stage[5]. The mass market phrase refers to the pervasive diffusion stage and beyond.

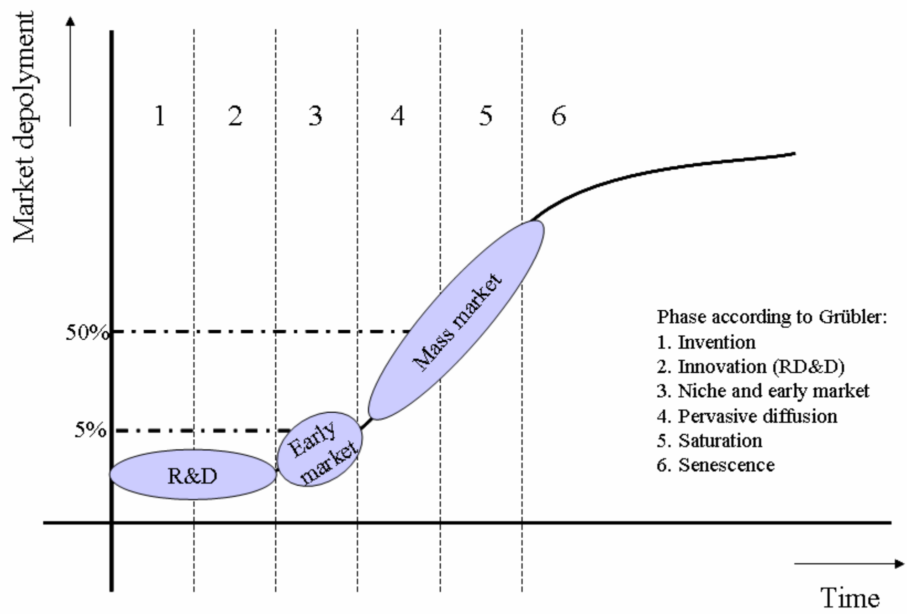

Figure 2.2 *Technology development phases in time and definitions used in this report (in grey)*

3 Network effects are benefits a user derives from a good if other user uses the same good, for instance a fax machine becomes more valuable if there are more owners and users.

4 Sometimes the advent of a new technology stimulates a competitive response. For example, in the 50 years after the introduction of the steam ship, sailing ships made more improvements than they had in the previous 300 years. Hence, 'The Sailing ship effect'. But these efforts are doomed, as the new technology has much more potential for improvement. These efforts can hold off phasing out for a while, but eventually fail.

5 Niche markets are defined as specialized markets (e.g. forklift trucks), while early markets are applications which lead to commercialisation of main stream technologies (e.g. passenger cars). An example is passenger cars in captive fleets.

Table 2.1 *Overview of the different mechanisms, costs, market share and learning rates of technology development stages*

Stage	Mechanisms	Cost	Financial barrier	Commercial market share	Learning Rate
Invention	Creation of new idea; basic research	High, but difficult to attribute to a particular idea or product		0%	Unable to express in conventional learning curve
Innovation	Applied research and demonstration projects (RD&D); learning by learning; learning by searching	High, increasingly focussed on particular promising ideas and products	No revenues	0%	Unable to express in conventional learning curve; high (perhaps > 50%) in learning curves modified to include RD&D
Niche market commercialisation	Identification of special niche applications; investments in field projects; 'learning by doing'; close relationship between suppliers and users	High, but declining with standardization of production; technology offers performance advantages	Start of turnover	0-5%	20-40%
Pervasive diffusion	Standardization and mass production; economies of scale; building of network effects	Rapidly declining;	High investment and running cost, but also high revenues for first movers	Rapidly rising 5-50%	10-30%
Saturation	Exhaustion of improvement potentials and scale economies; arrival of more efficient competitors into market; redefinition of performance requirements	Low, sometimes declining	Revenues depend on market share due to high competition	Maximum (up to 100%)	0% (sometimes positive due to severe competition)
Senescence	Domination by superior competitors; inability to compete because of exhausted improvement potential	Low, sometimes declining	Revenues depend on market share	Declining	0% (sometimes positive due to severe competition)

Source: Grübler, 1999 (except financial barrier column).

3. Policy support schemes

This chapter describes the potential policy schemes that can support innovation and technology deployment. Policy support mechanisms can be defined as a collection of support instruments applicable to enable RD&D, market introduction and commercial market deployment of a technology. Policy support systems are mostly categorised in price-driven models and quantity driven models (Dijk, 2003). Price driven support systems have an effect on the price i.e. the production costs of renewable electricity or subsidies on investments. Quantity driven support systems affect the amount such as a mandatory share of renewable electricity. This section provides an overview of the different support systems, based on this categorisation.

3.1 Price driven technology support models

Price driven support gives a financial incentive to cover the additional costs of new technologies compared to its conventional alternatives. The financial incentive can either cover the additional investment costs (in €/MW production capacity), or the additional operational/exploitation costs (in €/GJ clean energy produced). Price driven support can be investment and production subsidies, fiscal exemptions, and zero or low interest loans. The following sections will briefly discuss all these options.

3.1.1 R&D subsidy

An R&D subsidy covers all cost involved in conducting R&D. This includes labour cost, cost related to the purchase of new equipment and dissemination cost.

National programmes mostly directly support R&D, and the EU has additional short, medium and long-term research programmes for different technologies (the Framework Programmes). R&D programmes are used to stimulate the development and deployment of renewable energy technologies that are far from commercial implementation, so focussing on basic research. There are some limitations to subsidy support formulated in the EU Community guidelines on State aid for environmental protection. These state the total co-financed projects may not exceed 100% of the eligible cost, meaning the total amount of subsidies may not lead to any profit for the technology developer.

An advantage of a R&D subsidy is the relatively low cost. Technologies in this stage of development are still being researched in laboratories and the subsidy has to cover labour cost and sometimes investment cost in new equipment. The government can provide R&D subsidies to a broad range of technologies which have the high potential in becoming the technology of the future.

3.1.2 Investment subsidy

Investment subsidy is a grant, which can help to overcome the barrier of a high initial investment. Subsidy is commonly used to stimulate investments in less cost-effective technologies and varies between 20-50% of eligible investment (and demonstration) costs. The investment subsidy is mostly dependent on the installed capacity (i.e. the amount of MW installed) and mostly purely covers the capital cost (not the labour, fuel cost, etc.). There can be a distinction in amount of subsidy for different technologies installed and even the amount of subsidy in time.

An advantage of the investment subsidy scheme is it allows government to guide the direction of the technology development and deployment. However, in real live, technological progress is hard to predict and the right balance between endurance and making choices between various new technologies has to be found. The government should avoid picking one winner and not subsidizing competing new technologies, however letting market forces decide the technological preference without subsidy can hamper the introduction of new technologies.

3.1.3 Production subsidy

A production subsidy is also a grant supporting additional operation/exploitation cost of for instance clean energy production. Feed-in tariffs and fixed premium systems are different ways of a production subsidy. The level of the tariff is usually set for a number of years to give investors security on income for a substantial part of the project life.

(Fixed) Feed-in tariffs are a system where the producer receives a fixed price per unit, like produced kWh. Feed-in tariffs can have diversified tariffs for different technologies, location, size and time. Different technologies do not have to compete against each other to get the production subsidy, but for a specific technology the tariff may change for large and small sites, or decrease during the years. Diversified tariffs - decrease both with site productivity and over time - in a feed-in system provides incentives to technical improvement (OECD, 2003).

With a fixed premium system the producer receives a fixed premium that covers the difference between the actual production cost and the cost of the reference technology. For instance with electricity production the difference between market price and production price of a renewably produced kWh added on the market price of a kWh.

An advantage of a productions subsidy is its flexibility to adjust the percentage of subsidy and the possibility to make distinctions between height of support for different technologies as well as the possibility to lower the support in time. The ability to alter the amount of subsidy and follow technology development could make this an effective support mechanism.

3.1.4 Zero or low interest loan (debt financing)

Worldwide, one of the major barriers of renewable technologies is the high initial capital cost of renewable energy projects. Thus, the cost of borrowing money plays a major role in the viability of renewable energy markets. Financing assistance in the form of low-interest, long-term loans and loan guarantees can play an important role in overcoming this obstacle. Lowering the cost of capital can bring down the average cost of energy per unit and reduce the risk of investment (Sawin, 2004). Based on (government) funds the banks can give low-interest loans and guarantees. There are generally two types of funds, investment and guarantee funds.

Investment funds (e.g. European Investment Fund (EIF), European Investment Bank (EIB) and FIDEME) can share project risks by providing (zero or low interest) loans. Direct public intervention from government (agencies) is not required in the allocation of the fund and the selection of investors. Often a fund is based on private and public money, government participation is justified, because (private) investments can offer high social benefits.

The EIB is currently thinking of a new investment fund of which the setup is rather unconventional. Organisations can use the fund to lend money, but the interest rate is based on a benchmark and has a certain range. For instance, an organisation lends money to produce a product, depending on the sales of their product they have to pay interest. Meaning if the sales are higher then expected they have to pay a higher interest rate, while in the case of lower sales then expected the interest rate goes down.

Guarantee funds (e.g. FOGIME) loans money (in-) direct to companies. It guarantees the bank the loan will be reimbursed. The only risk the government has is they have to stand in when a loan is not reimbursed.

A key prerequisite for a loan is that it implies the borrower must have revenues to repay the principle (initial amount of money loaned) and interest to the bank, otherwise the bank will not provide the loan. Therefore, demonstration project financing with a loan (dept financing) will not be possible, while no revenues are generated.

Advantages of funds are:

- For organisations the involvement of organisations such as the World Bank in a structured finance arrangement for project financing can often clear the way for project developers to raise additional sponsorship from other sources.
- For the government the leverage of a fund is higher in comparison to subsidies. Assuming a reasonable interest rate, the risk for the government is basically limited to loans that cannot be repaid.

3.1.5 Fiscal system/(Eco) tax exemptions

Renewable energy can also be promoted by means of the fiscal system via tax incentives. Tax incentives can help promote renewable energy development by reducing the costs of investment, or by accounting for the external benefits of renewable energy. The latter include eco- or carbon-tax exemptions but also refer to inclusion of external costs for non-renewable sources. A reduction of investment costs can be obtained by accelerated depreciation, relief from taxes on sales and property, value-added tax (VAT) exemptions, and reduction or elimination of import duties on renewable energy technologies or components (Sawin, 2004).

Reducing costs of investment by allowing accelerated depreciation results in an attractive investment climate. The cost of investment can for instance be depreciated much quicker, resulting in earlier revenues. Another tax incentive is allowing carry forward of losses. By allowing this companies can book their loss costs whenever they start generating profits. This gives them tax advantages, because in the years when they start making profits, after deducting their losses it may be the case no tax on income has to be paid.

Promoting the external benefits of renewable energy with eco- or carbon-tax exemptions result in a cost advantage of clean energy on the demand site, which means the producer can (and has to) recover his costs completely on the market instead of requiring a direct subsidy. With rebates, VAT exemptions and tax relief on sales and import duties the demand site can also be promoted. For investors however the promotion of renewable energy demand via the fiscal system does not reduce the project risk and can result in a negative investment decision.

Possibilities especially for transport related tax exemptions are fuel excise reduction, reduced road tax, reduced purchase tax, parking fee exception, reduced road toll and congestion pricing, etc.

A disadvantage to use the fiscal system is the predictability of the market response based on the height of the exemption. Over stimulation or under stimulation may be the case if the tax advantage is not set at the appropriate level, leading to a low effectiveness. Setting the tax advantage therefore should be handled with great care. Also, if the government decides to abandon giving the tax advantage a high last minute response to make use of the tax exemption may occur. An example here of is the abandonment of the stimulation of PV in the Netherlands. Sales of PV panels increased greatly when the government announced they were abandoning the tax advantage within six months.

3.2 Quantity based technology support models

Quantity driven support aims at achieving a certain amount of clean energy production, e.g. a quantity of an energy carrier expressed in GJ. The most straightforward instrument is an obligation, either placed on the producers directly or on consumers or retailers. This is no direct financial incentive, except when linked to a certain production quantity, as in a tendering system. Setting environmental standards, making voluntary agreements, public procurement and emission trading are also quantity based support methods. All these methods will be discussed in the following sections.

3.2.1 Quota obligations

While pricing systems establish the price and let the market determine capacity and generation, quota obligations work in reverse. The government sets a target and lets the market determine the price. Typically, governments mandate a minimum production, distribution or consumption share of renewable energy. The obligation can be placed on producers, distributors or consumers and often increases gradually over time, with a specific final target and deadline. The implementation of an obligation system usually involves a penalty for non-compliance to ensure that involved parties meet their obligations. Mostly, also a (tradable) certification system is put into place.

Certificates do not form a separate instrument, but can be used to administer whether the obligation can and is met. Often it is allowed to trade surplus certificates resulting in a bit of flexibility for the obliged actors. Tradable certificates prevent disruption of the market. The certificate price reflects the difference between the market price of the conventional product (like electricity) and the cost (i.e. environmental benefits) of renewable product.

Examples of obligations and certification are the EC Directive on the promotion of electricity produced from renewable energy sources for the internal electricity market (directive 2007/77/EC). All countries are obliged to have a system in place for ‘Guarantees of Origin’ for all renewable energy production by October 2003. These Guarantees of Origin do not have to be tradable. If they are made to be tradable, they will have the function of a green certificate. In countries with a green certificate system already in place, it is likely that the system will be used for Guarantees of Origin (Dijk, 2003).

Also the directive on the promotion of the use of biofuels or other alternative fuels for transport (directive 2003/30/EC) is an example of an obligation. With this directive the European Commission obligates European countries to mix a certain amount of biofuel to the diesel and gasoline. There is also a possibility to reach the targets by using renewable hydrogen.

An advantage of obligations is the government is (almost) certain they will reach their policy goal related to the obligation, because an obligation not voluntary. However it is difficult to apply and can cause for resistance against imposing.

3.2.2 Emission trading

An emission-trading scheme is based on creating a price for certain emissions. By setting a target (cap) on emission, defining who has to comply with the target and giving out certificates an emission trading market is created.

Certificates give the pollutants a choice of paying the bill or implementing a new technology. It also gives a financial incentive to diminish all emissions even beyond the emission standards. A disadvantage is this approach should be applied transnational, but should not put national industries at a serious competition disadvantage (Kemp, 2005). Critical in this system is the price (or the cap) of emissions. If this is too low (or the cap is too high), nothing will happen.

In the EU an emission trading scheme is set up for CO_2 as part of the Kyoto protocol. The US has a trading scheme for sulphur dioxide (SO_2) and oxides of nitrogen (NO_x). Also, the Netherlands also has a NO_x trading system.

The advantage of using an emission trading scheme is that it is a market based instrument with the aim to minimise reduction costs at the short term. By applying a cap and tradable emission certificates a new market is introduced. The difficulty with this policy instrument is setting the height of the cap. If the cap is too low it will not stimulate the uptake of technologies which are more expensive (in €/tonne CO_2 avoided) will not be implemented. This specifically may have a negative effect on disruptive technologies such as hydrogen. Also the predictability of the height of the cap during the years in future years could cause for uncertainty for stakeholders.

3.2.3 Tendering and bidding

Bidding procedures can be used to select beneficiaries for investment support or production support, or for other limited rights e.g. sites for wind energy production. The criteria for the evaluation of the bids are set before each bidding round and potential investors/producers who comply with the criteria are invited to the bidding. These actors have to compete through a competitive bidding system, meaning they compete against each other based on their bid. In each bidding round the most cost-effective offers will be selected to receive the subsidy, or use licence. The mechanism therefore leads to the lowest cost options. The bidding procedure can be accompanied by a contract and fine (penalty system), to secure the bid is valid and economical feasible.

Tendering is also a competitive way of providing subsidy support. Unlike the bidding procedure there are few criteria set up front, although the objective is set e.g. hydrogen demonstration in transport. Tendering can for example be used in case of public transport within a specific area (city, region, or route). In procedures where proposals are compared to each other, obtaining the best results with a tender procedure is not merely a matter of selecting the offer with lowest costs, but moreover making the biggest contribution to the objective set upfront (i.e. contribution to reduction of particulate matter or greenhouse gas emissions). Based on submitted proposals from beneficiaries, the government decides to whom to allocate the money.

Tendering and bidding procedures have the advantage to be highly flexible. The focus and amount of money available can vary per round. This however causes for uncertainty for the stakeholders. Nevertheless this system, when applied correctly, can minimise over stimulation and can create potential early markets.

3.2.4 Environmental standards/regulation

Standards can be set in different ways. First of all, a standard can mandate a technology requirement, like a maximum emission level or minimum performance level. Secondly a standard can mandate information provision (on for instance efficiency) to consumers via labels. This latter approach does not affect the producer of a good directly but leaves it to the market (consumers) to decide if they purchase a cheaper, but less efficient product instead of a pricier but more efficient product. The idea of this standard is the consumer buys the most efficient product, sweeping the least effective technology from the market and triggering producers to bring more efficient products to the market.

With respect to regulations of performance levels, research shows that the price structure of a technology determines the effectiveness of this support mechanism. Technologies dominated by operating cost are more sensitive to emissions standards than technologies dominated by capital costs (Pembina Institute, 2004).

Setting mandate technology (environmental) requirement standards affects the producer of a product directly. If their product does not meet the standard they cannot sell it in the market. Therefore it is important in using standards that the regulator gives industry enough time to develop solutions that are environmentally benign and meet important user requirements.

An objection to standards is that they are often set at a more stringent level for instance for new plants than for existing ones, hereby companies prolong the lifetime of older plants in stead of building new ones. This however does not hold for the emission standards for newly produced cars. Companies also often anticipate that political authorities will waive target if technological improvements are insufficient, particularly if the consequences of a full enforcement would be very costly and/or politically difficult. This is manly because a standard is inflexible.

Another difficulty with standards is they are hard to set. On the one hand, the standard should be strict enough to speed up the innovation process in stead of supporting normal technology development speed. On the other hand short term standards could already be outdated by the time they are applied. Also standards are difficult to set because it requires detailed technological insight. And because they are usually set by law they it may be time consuming to change.

3.2.5 Voluntary system/covenants

Voluntary agreements between the government and industry can vary from voluntary non-binding agreements on reporting emissions and progress to self-defined targets to negotiated agreements that are legally binding and have sanctions in the case of non-compliance (OECD, 2003). Voluntary agreements are commonly preferred to gain involvement and commitment of main actors, without the necessity of regulations. The success of voluntary agreements depends totally on the willingness of the involved stakeholders and their ambition and goals as well as on potential sanctions in case the objectives of the voluntary agreements are not met.

Voluntary agreements are often used in policy packages with one or several other instruments such as regulations, tradable permit schemes, taxes or other (OECD, 2003). Voluntary agreements in combination with regulations seem to enhance the dissemination of a technology compared to regulations used in isolation.

The advantage of voluntary agreements is they mostly apply to industry that is willing to change, but because they are not binding so the outcome is uncertain. However the government may pressure the industry to make a voluntary agreement by saying it wants to set a standard or obligation seducing the industry to come up with own proposals for a voluntary agreement.

3.2.6 Public procurement and co-operative private procurement

Public procurement means the government tenders its demand for a product or service. With public procurement the government becomes a customer and thus raises the demand on the market. By purchasing renewable energy technology (for buildings, public spaces and car parks) the government creates advantages for the supplier (like higher production volumes, technological learning) and sets an example, increases public awareness, reduces perceived risks associated with renewable technologies, etc. Organisations can also bundle their demand the same way the government can. This is called co-operative private procurement.

Using their purchasing power the government can not only raise the demand on the market but also quick start the clean energy markets, like the hydrogen vehicle market, giving the suppliers the security there is demand (and turnover) for their product. Just to give a rough feeling for the magnitude of public spending in Europe, public authorities spend some 16% of the EU’s Gross Domestic Product (half of Germany’s GDP).

Because the government is such a big consumer there are certain regulations for public procurement. The EU public procurement directive (directive 2004/17/EC and directive 2004/18/EC) nevertheless has environmental considerations in technical specifications selection and award criteria.

The advantage of public procurement is that it creates early market demand. However, this stimulates the front runners and not necessarily the whole industry involved with the new technology. The success also depends on if the good example of the government will be followed by others.

3.3 Summarizing

There are several possibilities to support technologies by applying different policy instruments. The general distinction between price and quantity driven support is analysed in this chapter. The advantage of using quantity driven support systems is the government has a low chance of over subsidising and has the most certainty of reaching its targets. The advantage of using price driven support systems is the more positive approach, because it creates chances and financially support for desirable behaviour. There however is no ‘silver bullet’ for the support of a certain technology. The effectiveness of the chosen policy support mechanism depends on the ability to follow technology development and this may imply several policy support mechanisms having to complement each other (in time) or a flexible design of a support mechanism. This will be further discussed in the next section.

4. Policy support mechanism and technology development

In the previous chapter, a general overview of policy support schemes is given. This chapter focuses on the role of support schemes in the various stages of technology deployment. This is useful, because policy support is needed for initial R&D activities, as well as further stages of development where the technology is proven on a larger scale, ultimately leading to large-scale demonstrations and if successful mass market introduction. At each of these technology development stages, appropriate funding is required, although the actual sources may change with the different stages. By tailoring policy support schemes the development and deployment of these technologies can be accelerated speeding up the transition towards a hydrogen based transport system. As an indication, the past has shown for large technological systems to diffuse will take six to eight decades (Grübler, 1999).

This chapter provides insight in the policy support mechanisms (as described in Chapter 3) related to the technology development stages (see Chapter 2). The categorisation between price and quantity driven support mechanisms will be used firstly, but further categorisations will be made in order to describe the evolution of technology development and policy support.

4.1 Investment, production/use or environmental performance focus

A definition of the price and quantity driven categories is given in Chapter 3. This categorisation makes a distinction between policy support mechanisms driving the price/cost down or increasing the capacity/amount. This section will elaborate on these basic support mechanisms by making a further categorisation by looking at the different stage of the technology development cycle and how policy support mechanisms can be applied to increase technology development, installation, use and performance of a technology.

As described in Chapter 2, technology development starts with R&D phase. The main barrier here is the cost of the R&D activities and equipment, because the outcome of R&D is uncertain and does not (immediately) lead to the generation of revenues or profits. Therefore, R&D subsidy is the best policy support mechanism because it reduces the investment cost.

As soon as the technology is ready for demonstration or proof of concept the cost usually becomes even higher for organisations. Also in this stage there are no revenues or profits. The best policy instrument to reduce the cost in this stage and stimulate further development is an investment subsidy. Also in this stage of technology development, the success of the demonstration is uncertain and the costs of prototype(s) are high because due to labour intensive production. By providing an investment subsidy the investment risk of an organisation is lowered. This policy support mechanism also falls into the price driven category and can reduce the investment cost considerably.

After a successful demonstration the technology can be tested under real life circumstances. These pilot projects face high cost, not only because the investment in the new technology is high, but also because a lot of unforeseen circumstances can arise. However, the projects may lead to revenues. In general, the revenues will be small and insufficient to counterbalance the investments, let alone the payback of the R&D cost. To stimulate organisations to invest in the new technology policy support should focus on increasing the competitiveness of the technology. This could be done by an investment subsidy, zero or low interest loan or tax exemptions (in the form of accelerated depreciation and loss carry forward), which all reduce the investment risk. For example, some organisations may need funds for investing in new production facilities realising economies of scale. By supplying low interest loans or loan guarantees the government or other capital investors can enable these organisations to borrow funds for their investments.

Because the prospects of the new technology are good the organisations who borrow funds are (in term) able to repay their loan with the revenues they generate. All these mechanisms reduce the cost and price considerably and give organisations the chance to begin installing capacity because the support reduces the amount of €/MW investment. Loans and tax exceptions are also useful policy support mechanisms during the early market stage.

The early market stage (the next step in technology development cycle) arises under certain circumstances and investments in the new technology may be commercially feasible. Please note that obligations, such as limited city centre access, can be one of the measures to create these early markets. The focus during this stage will shift from building up capacity to scaling up and using the new technology. By providing a production subsidy or user subsidy the technology becomes more attractive for early adopters. Due to 'learning by using' induced by these early adopters the technology develops further and cost decrease. By providing a production or user subsidy the €/GJ or €/unit produced are reduced and the quantity in which the technology becomes available gets accelerated (and higher). This could give organisations the change to build economies of scale.

Because production subsidy is usually only from temporary character and the technology becomes more market ready the government can swap to a tendering and bidding system for the limited rights or funds available. The tendering or bidding system however still increases the quantity of the technology, because the technology is now developed to a stage where it becomes commercially attractive under almost every condition.

In this stage the government can also play an active role as early adopter by buying or using the new technology via public procurement. In this stage the technology has to be competitive with the conventional technology and/or other technologies that also have certain advantages in terms of performance. By buying the new technology the government starts mass market demand, gives a good example and shows the technology really works. With also providing tax exemptions (e.g. fuel duty relief and rebates) for buying or using the new technology, also other adopters are triggered to buy the technology and demand will rise. This will increase the quantity in which the technology is used and produced and economies of scale start to arise.

Also in the phase where mass market is entered, policy support can further stimulate market penetration. Due to the high deployment rates, financial support mechanisms are in general very costly even though the additional investment is low. At this stage, support schemes promoting sustainability rather than specific technologies can play an important role. Because the new technology provides environmental benefits it can be coupled to an emission trading scheme accelerating implementation. This is due to the valuation of the externalities and provides benefits to the producers or users. When the critical mass is gathered on the mass market the government may even decide to obligate the use of the new technology.

4.2 Linking the technology stages to policy support schemes

The previous paragraph shows policy support mechanisms change during the technology development stages. The effectiveness of the chosen policy support mechanism depends on the ability to follow technology development and tackle the barriers in each technology development stage. This may imply several policy support mechanisms having to complement each other (in time) or a flexible (design of a) support mechanism. Hereby the ability to follow technological change is greater. This paragraph will make some general suggestions on categories of policy support instruments able to support technology during different stages of technology development. The categories used in this paragraph are investment focussed, production focussed and performance focussed. Investment focussed support mechanisms reduce the investment or €/MW. The production focussed support mechanism reduce the use/exploitation or €/GJ of a technology, while the performance focussed support mechanism reduces the €/kg CO_2.

As said before, technology development of disruptive technologies start by conducting R&D. During the R&D stage the main barriers lie in the field of R&D costs and investment costs (of the first prototypes). The support schemes should aim at counterbalancing the high R&D and investment cost and thus be investment focussed (reducing the €/MW), hereby stimulating the capacity build-up. Investment subsidy and (low interest) loan (guarantee) can be added to this category, since they reduce the investment cost.

When the concept of the new technology is proven the aim is at achieving a certain amount of clean energy production, e.g. a certain amount of GJ. As deployment increases, the operation/exploitation cost of the technology starts to become the barrier. The supporting policy framework should adept to the changing market conditions and thus focus more on reducing the use/exploitation (or €/GJ) of the technology. Support schemes reducing the production costs are production subsidies and public procurement. Also obligations and tax exceptions (like accelerated depreciation, fuel duty relief and rebates) give an impulse to production of clean energy technology.

The final push in the market place can be given by supporting the environmental benefits of the technology. This can be done by policy support mechanisms stimulating technologies with the best environmental performance, by subsidy of emission reduction (or €/kg CO_2). The focus on the environmental performance can be stimulated by applying emission trading or setting environmental standards/regulations.

An overview of the policy support mechanisms is given in Table 4.1. This table shows a division by price or quantity driven and investment, production or environmental performance focus. Exception is the voluntary agreement, which has no specific focus. Agreements can be reached on the production, and/or on the environmental performance.

The distinction between the various technology development stages of technology is not always clear in time. It is hard to tell when exactly a technology enters the next phase. Therefore, there are (perhaps unavoidable) overlaps in policy support mechanisms in time. Policy support mechanisms have to be phased out gradually, based on appropriate monitoring of their effectiveness, when new mechanisms are introduced (see Figure 4.1).

Table 4.1 *Classification of different financial support systems*

		Price driven	Quantity driven
Investment focussed	[€/MW]	Investment subsidy (zero or low interest) loans Tax exemptions (accelerated depreciation and loss carry forward)	
Production focussed	[€/GJ]	Production subsidies Ecotax exemptions	Obligations (possibly with certificates) Public procurement Voluntary agreements on production/consumption clean energy
Environmental performance focussed	[€/tCO_2]		Environmental standards Emission trading system Voluntary agreements on environmental standards

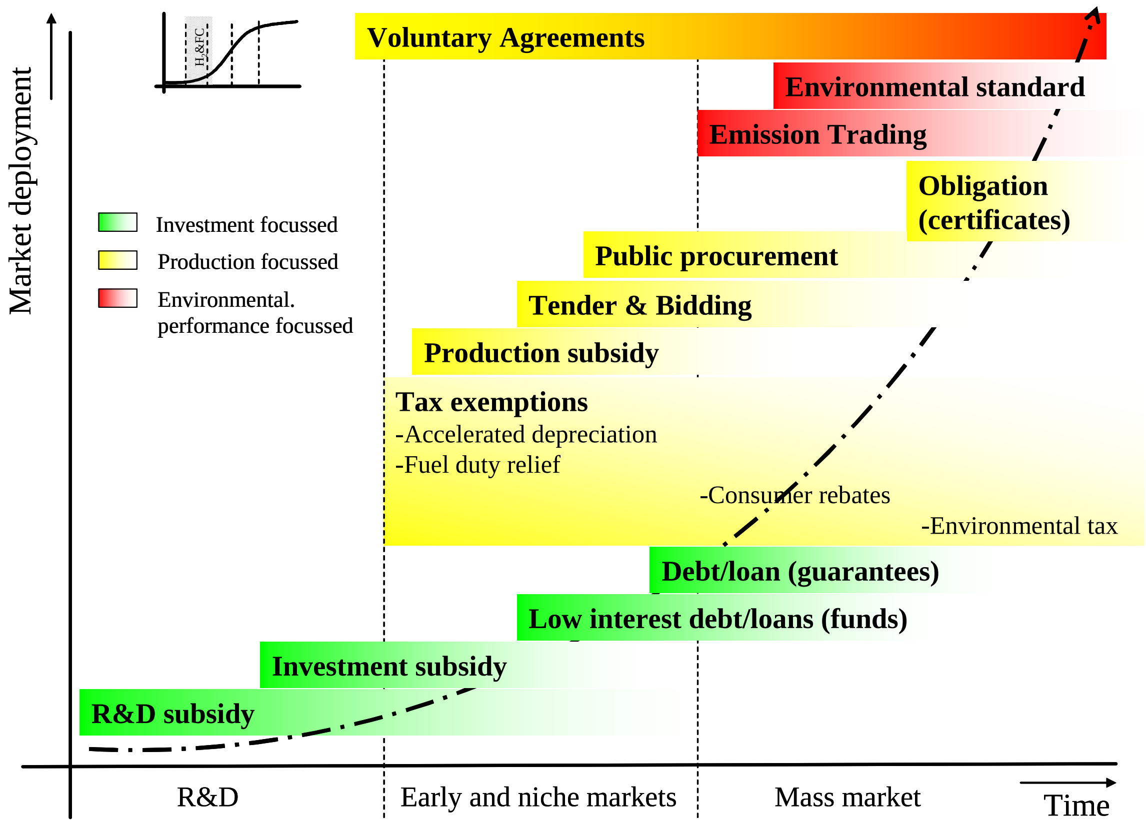

Figure 4.1 *Policy support mechanisms in time, divided by their focus on reducing investment, production or performance cost*

4.3 Technology specific versus generic support

Technology never develops in a vacuum, but has to compete with existing technologies and other alternatives. This section gives more insight in how and whether policy support mechanisms focus on a specific technology, or act upon several competing technologies. For example, different policy support mechanisms can specifically focus at a specific technology like FCs. They can also support all technologies which contribute to the same goal (such as energy efficiency or sustainability). Emission trading schemes are for example not technology specific but support technology that can contribute (most effectively) to obtaining the emission cap.

In these early stages of technology development, competition with the conventional technology on costs is hardly possible. The conventional technology has already entered the mass production stage for years and production costs are low. It is still uncertain if the new technology will be the key option to replace the reference technology, because there are also competing technologies. In general, making a clear choice between the various competing options is not trivial and in this phase several competing options can be supported, each having their own specific advantages. Technology development in the early stages needs to be supported by technology specific mechanisms addressing the technology specific barriers. In practice, this means that some options get (e.g. in absolute terms) a higher support than others, due to the fact that (other) more severe barriers have to be overcome.

When the technology is getting nearer commercialisation and cost competitiveness has increased the support should become more generic. Competing technologies all contributing to the same goal get the same support and the market can decide which technology is preferred. So applying technology specific or generic policy support also depends on the technology development stage of a technology.

Some policy support mechanisms specifically support a technology. A major drawback is that it may have negative effects on the market competition by disturbing the level playing field between the competing options. In addition, when applied during the wrong stage of technology development certain policy support mechanisms support further developed of the competing technologies in stead of the targeted technology. For instance, an obligation cannot be applied to a specific technology without severely hampering the development and use of competing technologies. Obligations need to be set to reach a certain goal independent from a technology preference.

Other policy support mechanisms have a more hybrid approach and can both support specific technologies as well as generic (sustainable) technologies. Production subsidies (i.e. in €/GJ) can be applied to all options, but may differ in tariff. One could for example introduce a general production subsidy on hydrogen (i.e. by means of a feed-in tariff) but also specifically promote the production of hydrogen from renewable or sustainable resources. Such policy support mechanisms have to be designed with highest care. For instance, if the goal is to support renewable hydrogen production the production subsidy for these options may be higher than for non renewable hydrogen production technologies.

To summarise, taking into account the different technology development stages, too severe competition between different options has to be avoided in the early stages. Specifically the development of disruptive technologies which have to overcome more severe barriers will be hampered it they already have to compete with incremental innovations in an early stage of development. In time, when the disruptive technology has improved cost effectiveness, and the early markets are entered, policy instruments that induce competition with alternative options and the reference technology can be introduced. In practice, it is very difficult to decide whether a technology is ready to make the step from protection of competition. Careful monitoring is needed in order to ensure that the policy framework is applied effectively. Over-stimulation has to be avoided (not to waste public money) but the support should also be sufficient (otherwise the technology might die out). The actual situation is even more complicated since competition between innovations also implies that some of the new technologies will not make it. Table 4.2 gives an overview of how policy support mechanisms can be divided into technology specific or generic instruments. Figure 4.2 shows the application of policy support mechanisms in time.

Table 4.2 *Technology specific or generic policy support mechanisms*

	Price driven	Quantity driven
Technology specific	Investment subsidy Production subsidies Tax exemptions (low interest) loan (guarantee)	Tender & bidding
Technology generic	Tax exemptions	Obligations (possibly with certificates) Public procurement Environmental standards Emission trading system Voluntary agreements Environmental tax

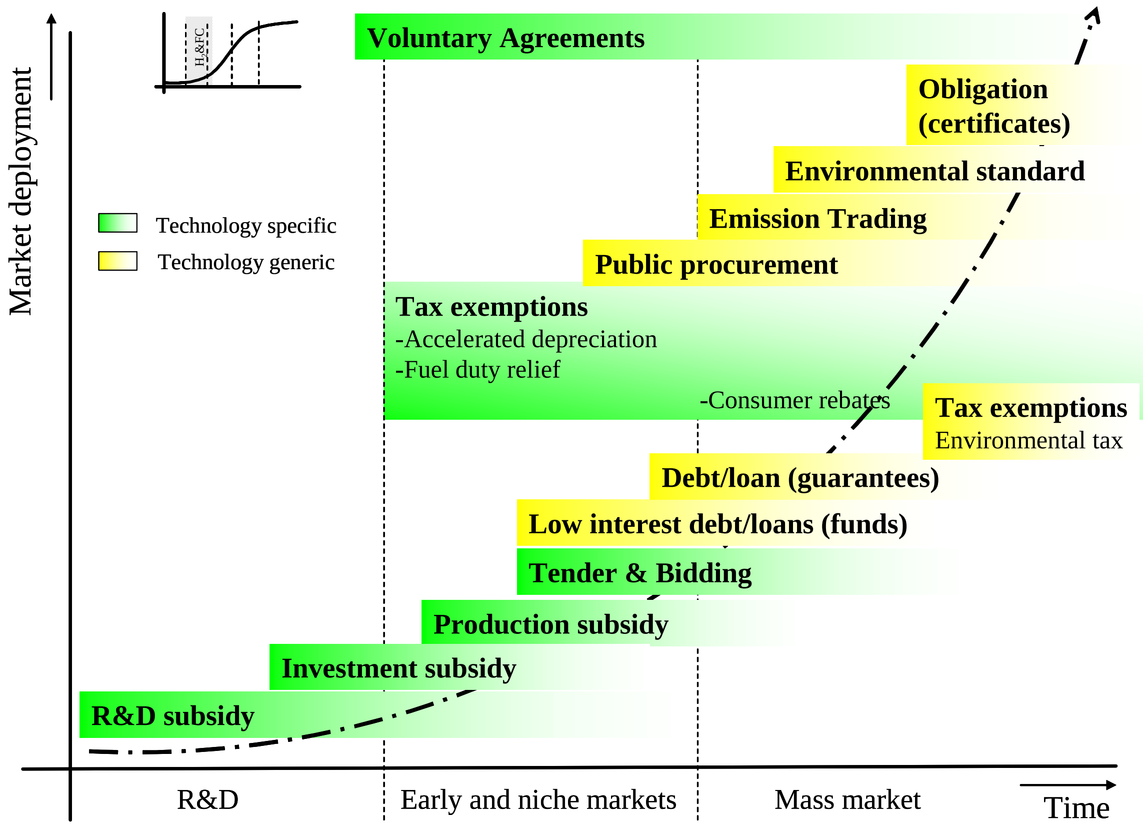

Figure 4.2 *Overview of policy support mechanisms in time, categorised by technology specific and generic impact*

4.4 Support of supply versus demand

A further distinction between the various support mechanisms is whether they support supply or production or a growth of the demand. In a perfect market, the effect will be the same. Production will follow the demand. In practice, stakeholders will respond differently to these incentives. For disruptive technologies, both barriers in supply and demand may have to be overcome. In short, instruments targeting consumption, like public procurement, tax exemptions for consumers, stimulate the demand. Supporting the cost of investment or exploitation/operation of production options with for instance subsidies stimulates the supply (Dijk, 2003).

Both support of supply or demand will have an effect on the overall competitiveness of the end-use application (such as a hydrogen vehicle). Theoretically, a cost comparison between the reference option (ICE-vehicle) and the hydrogen vehicle should be made on costs per km (€ct/km), taking into account that the overall costs include fuel prices as well as investments (and depreciation). However, the purchase decision of the end-user (consumer) is in practice not always equal to the most economic decision that assumes perfect knowledge and rationality. If a hydrogen vehicle has an additional investment of € 5.000 but costs per kilometre driven are lower than for the reference vehicle, leading to an overall identical cost per kilometre driven, the consumer might still prefer the reference vehicle due to various reasons. First of all, the additional investments may have an acceptable pay back time, but if funds are not available, a serious hurdle has to be overcome. Secondly, studies have shown that consumers often use a very high discount rate, which is way higher than makes sense from an economic point of view, when making their decisions on what option to buy.

Obligations (regulation) can either target on quantity (minimum share of biofuels or renewable electricity) or act as standards (emission standards such as maximum CO_2 emission per km driven). However, in both cases there is a risk that neither the demand (in case of on obligation of supply) nor the supply (in case of an obligation of demand) will exist if serious market failure occurs.

Table 4.3 gives an overview of the policy support mechanisms according to if they are supply or demand orientated. Figure 4.3 shows the policy support mechanisms distinction, but in time.

Table 4.3 *Supply or demand oriented policy support mechanisms*

	Price driven	Quantity driven
Supply orientated	Investment subsidy (Low interest) loan (guarantee) Production subsidies Accelerated depreciation	Environmental standards Obligations on producer (possibly with certificates)
Demand orientated	Ecotax exemptions Fuel duty exemptions Customer rebate	Obligations on supplier & customer Public procurement Voluntary agreements on production/consumption clean energy Emission trading system
Other		Voluntary agreements on environmental standards

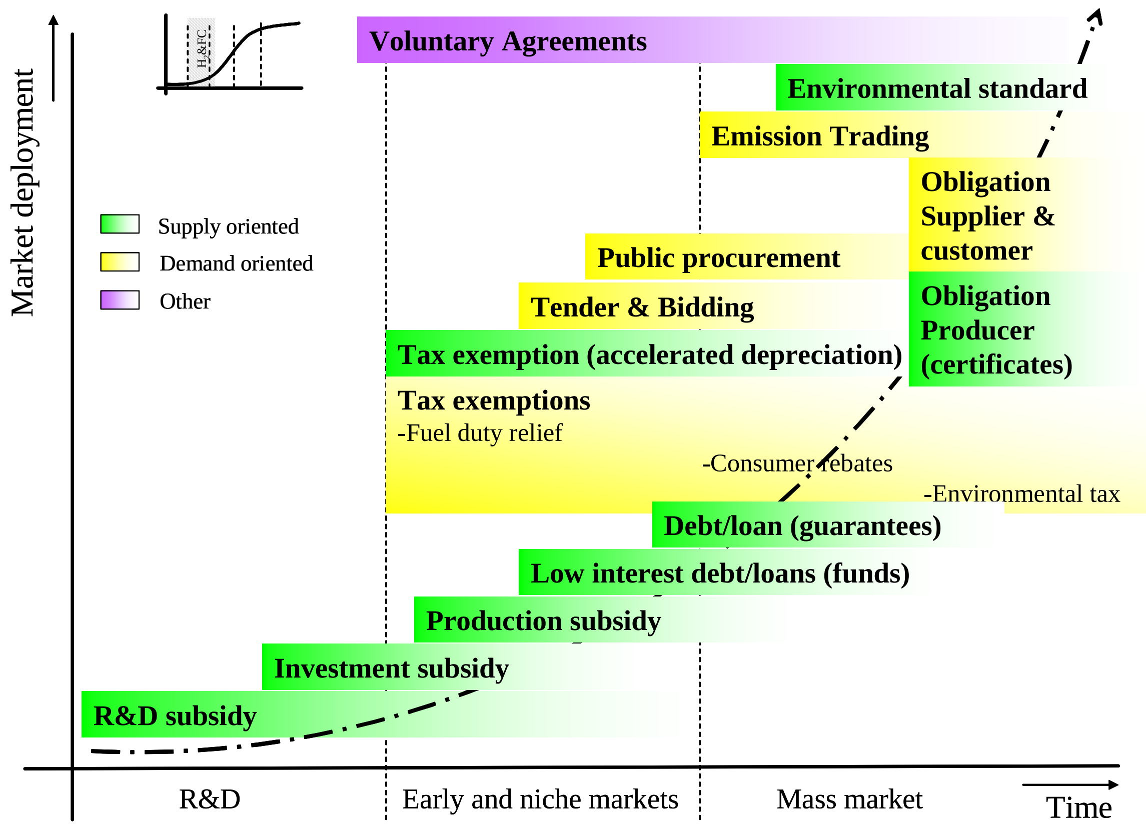

Figure 4.3 *Overview of policy support mechanisms in time divided by supply or demand orientation*

4.5 Direct versus indirect

By increasing the competitiveness of a technology the next phase in the technology development can be reached. The competitiveness is determined by both the costs of the option as well as the technical performance (and also end-user preferences). A policy support framework can contribute to this in a direct as well as indirect way.

A direct impact on the competitiveness is obtained through changing by the price level of the reference technology (e.g. by taxation) or decreasing the price level of the innovation (i.e. by subsidising). 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.[6] A reduction in costs through R&D will lower the total cumulative investments needed to reach the break even point. In comparison to the direct support mechanisms, the (desired) effect of the indirect instruments can not be guaranteed; technology improvement on the level of individual technologies is not a linear process and technological break troughs can neither be predicted nor guaranteed.

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. How to find the optimal balance between direct and indirect support schemes is a priority field in academic research. With given knowledge, no straightforward general statements can be made with respect to the optimal balance between R&D and deployment for hydrogen in transport. However, both mechanisms play an important role and need to be included in the policy support framework.

4.6 Summary

This chapter gives an overview of the different focus, drivers and impacts of the financing mechanisms. Together with information from the previous chapter an overview is given of the different financing mechanisms, by providing a short description. The description for every policy support mechanism will outline the drive, targeted stage (as described in 2.1), focus, technology specific or generic and supply or demand characterisation.
Figure 4.4 shows on a more abstract level the policy support mechanisms.

Financing mechanism: R&D subsidy

- *Description:* Funds and grants made available by governments to support research and development of new technologies.
- *Price of quantity driven:* Research and development programs, if targeted in a specific way, can reduce the price of new technologies.
- *Targeted technology development stage:* R&D
- *Focus:* On labour and investment cost of research and development activities.
- *Technology specific of generic:* A R&D program can be designed to target specific technology components, or at least target explicitly on a technology field, like hydrogen.
- *Supply or demand (technology push or pull):* R&D subsidies can reduce the price of new technologies and therefore stimulate the supply of these technologies on the market.
- *Government level:* Federal and/or state/regional

[6] In an early stage of technology development, public R&D schemes can initiate/facilitate the development of an innovation. When market prospects improve, private R&D is aligned and a multiplier effect is obtained, increasing the effectiveness of the public R&D.

Financing mechanism: Investment subsidy

- *Description:* Grants made available by governments to support investments in new technologies. The subsidy is dependent on the size of the installation (MW installed)
- *Price of quantity driven:* Investment subsidies reduce the price per installed MW.
- *Targeted technology development stage:* R&D and Early market commercialisation phases
- *Focus:* Investment cost of newly installed production capacity (dependent on the amount of MW installed)
- *Technology specific of generic:* The investment subsidy can be targeted on specific technologies and can be diversified by time, size, technology and location.
- *Supply or demand (technology push or pull):* Investment subsidy reduces the investment cost and therefore is supply orientated.
- *Government level:* Federal

Financing mechanism: Production subsidy

- *Description:* Grants made available by governments to support exploitation and operation of not yet commercial technologies with (not economical) benefits, hereby reducing the competitiveness gap.
- *Price of quantity driven:* Production subsidies reduce the price per produced unit.
- *Targeted technology development stage:* Early market commercialisation
- *Focus:* Operation and exploitation cost of production
- *Technology specific of generic:* The production subsidy can be targeted on specific technologies and can be diversified by time, size, technology and location.
- *Supply or demand (technology push or pull):* Production subsidy reduces the operation and exploitation cost and therefore is supply orientated.
- *Government level:* Federal

Financing mechanism: Zero and low interest loan

- *Description:* Based on government funds commercial banks can provide zero or low interest loans. Investment funds can provide attractive interest loans to stakeholders and does not need government participation, while guarantee funds with government involvement provide a guarantee to the bank for stakeholders to loan money.
- *Price of quantity driven:* Loans can reduce the cost of capital and thus price
- *Targeted technology development stage:* Early market commercialisation
- *Focus:* Loans reduce the cost of capital needed for investment in (pre-) commercial application of a technology, so investment focussed.
- *Technology specific of generic:* Depending on the conditions set by the bank and/or government (for the guarantees).
- *Supply or demand (technology push or pull):* Loans increase the capital cost and increases the supply of a technology
- *Government level:* Federal

Financing mechanism: Tendering and bidding

- *Description:* Tendering and bidding procedures are a mechanism to select beneficiaries for investment, production support, or limited rights.
- *Price of quantity driven:* Tendering and bidding stimulate the quantity by which a technology is deployed.
- *Targeted technology development stage:* Early market commercialisation
- *Focus:* Depending on the criteria used to evaluate a proposal or bidding procedure this mechanism is production focussed, but in a later stadium may become environmental performance focussed.
- *Technology specific of generic:* Depending on the layout.

- *Supply or demand (technology push or pull):* Tendering and bidding give the technology a push by reducing the cost, increasing the supply of the technology.
- *Government level:* Federal and/or EU

Financing mechanism: Fiscal systems/tax exemptions
- *Description:* Tax exemptions or credits, mostly for a proportion of the eligible cost, are awarded for investment or use of specific technologies.
- *Price of quantity driven:* Tax credits have an ongoing and direct price reducing effect
- *Targeted technology development stage:* Early and mass market
- *Focus:* Taxes have a production focus while it stimulates the use of new technologies by offering exemptions and/or credits
- *Technology specific of generic:* Taxes can be technology specific
- *Supply or demand (technology push or pull):* Attractive tax exemptions generate market demand
- *Government level:* Federal and in some cases EU

Financing mechanism: Quota obligations
- *Description:* Quota obligations mandate a minimum share of an activity, e.g. production, sales, etc. Compliance can be sometimes (partially) be by buying credits.
- *Price of quantity driven:* Quota obligations mostly focus on the production and sales and thus have a quantity driven effect.
- *Targeted technology development stage:* Early and mass market
- *Focus:* Obligations mostly are production focussed
- *Technology specific of generic:* Obligations are technology specific
- *Supply or demand (technology push or pull):* An obligation can be supply or demand oriented, depending on for whom the obligation applies (consumer, manufacturer, sales)
- *Government level:* Federal and/or EU

Financing mechanism: Emission trading
- *Description:* Emission trading sets a price per tonne emission (like CO_2) by setting a cap or maximum on emissions emitted. Each user has an allowance and can trade the certificates so the total emissions remain below the specified cap.
- *Price of quantity driven:* Emission pricing has an effect on the price.
- *Targeted technology development stage:* Mass market
- *Focus:* Emission trading (and pricing) reward cleaner fuels and technologies, therefore it is environmental performance focussed.
- *Technology specific of generic:* Because emission can occur everywhere it is a technology generic instrument, although agreements can be made on which sector is subjected to the emission trading.
- *Supply or demand (technology push or pull):* The price of emissions will affect the sales price and will create or further stimulate the demand for the cleaner technologies and/or fuels.
- *Government level:* EU/International

Financing mechanism: Environmental standards/regulation
- *Description:* Environmental standards can enforce technological requirements for a technology, or an information requirement to the potential users by for instance labels so they can make more informed investment decisions.
- *Price of quantity driven:* Environmental standards have a quantitative effect.
- *Targeted technology development stage:* Mass market
- *Focus:* Environmental standards have an focus on environmental performance of a technology

- *Technology specific of generic:* Standards are set for generic technologies, e.g. cars. Labels have to be technology generic for an accurate and comprehensive comparison by the potential investor.
- *Supply or demand (technology push or pull):* The demand for technologies complying to the standard or with the most positive characteristics for the user (on the labels) will increase.
- *Government level:* Federal and EU

Policy option: Voluntary agreements

- *Description:* Voluntary agreements can be made between a government and industry on technology performance for instance.
- *Price of quantity driven:* none
- *Targeted technology development stage*: any, but mostly mass market
- *Focus:* Can be on production or performance
- *Technology specific of generic:* Technology specific
- *Supply or demand (technology push or pull):* Any
- *Government level:* EU/Federal/local

Policy option: Public procurement and co-operative private procurement

- *Description:* Procurement policies secure support for a technology in the form of guaranteed purchases of these technologies. Mostly, government entities will buy the technology for their own use, increasing the commercialisation of new technologies that can result in a decline in price over time, but also companies can set up such a scheme.
- *Price of quantity driven:* By generating market demand, public procurement is quantity driven.
- *Targeted technology development stage:* Early market commercialisation.
- *Focus:* By raising the demand the focus is on increasing the production.
- *Technology specific of generic:* Public procurement is usually set up by using a set of criteria which the technology has to meet in order to be bought, so public procurement is a technology generic instrument.
- *Supply or demand (technology push or pull):* Public procurement increases the market demand for a new technology.
- *Government level:* All, including government agencies

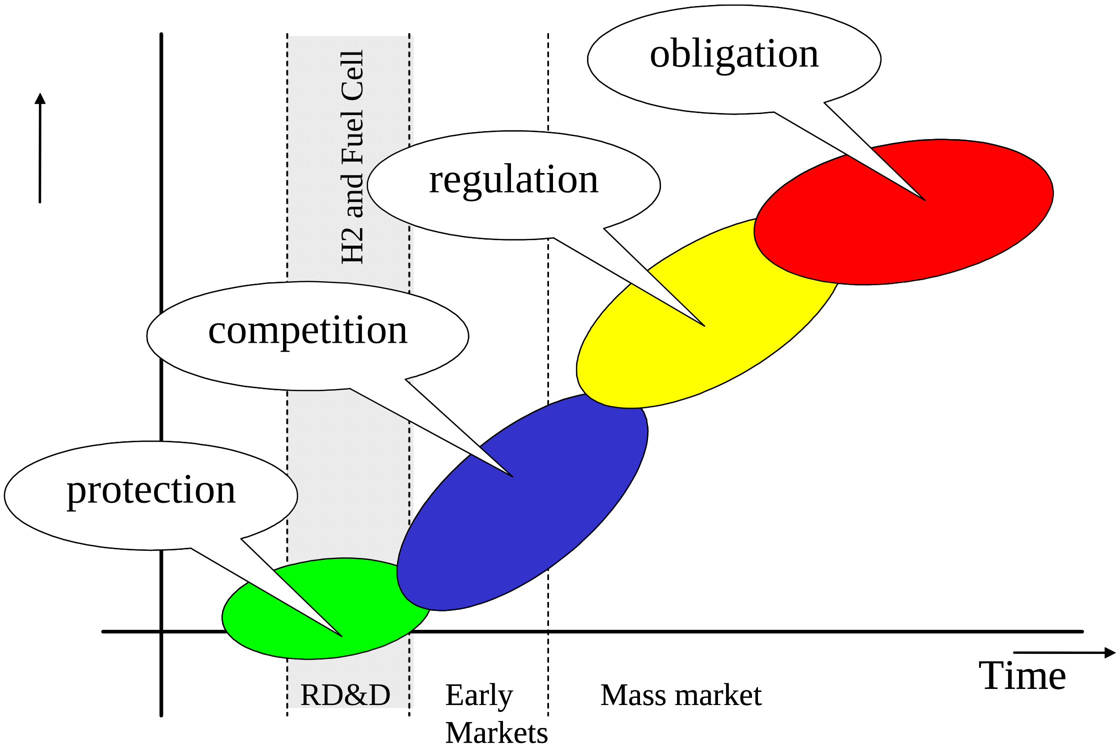

Figure 4.4 *Overview of policy support focus for the different technology development stages in time*

5. H_2 support compared to support mechanisms for RES-e

What can we learn from the support mechanisms for renewable energy? In what way can these be translated to the case of hydrogen? After outlining the policy support mechanisms and applying how and when they can provide support during the technology development cycle this chapter provides a comparison between renewable electricity production and the hydrogen energy chain. This will result in insight into the impact of supporting a technology part of a chain. This is done by comparing the renewable energy chain for electricity (RES-e) with the hydrogen chain taking into account the various stages of technology development.

5.1 Renewable energy chain for electricity

With respect to energy chains, as for RES-e and hydrogen, a distinction can be made between production, distribution and end-use. The production of RES-e can be with wind, biomass or PV. For RES-e the main distribution network already exists and only needs maintenance and some further exploitation with new districts. Moreover, the end-use in household depends on the need of electricity for household applications, but does not depend on the origin of the electricity. Increasing the share of RES-e will have no impact on the end-use applications (no barriers) and has limited effect on the (high voltage) distribution grid. When production capacity (MW_e) of renewables increases significant, reinforcement of the grid may be needed. This however also holds for the case of adding additional conventional power plants. The major barriers for RES-e lie therefore in building the capacity rather than in building up infrastructure or end-use applications[7].

From a financial point of view the RES-e price is higher than conventional produced electricity. It will not be financial feasible for companies to invest in RES-e such as windmills, hydro, PV or biomass if there is no need (environmental legislation), drive (policy support from the government), or demand. The government can stimulate the production of RES-e by providing a production subsidy (€/GJ_e), investment subsidy (€/MW) or performance (€/tonne CO_2 avoided). These support mechanisms in most cases still allows the government to differentiate between the various production methods, depending on the way they are implemented. Some can actually be used to stimulate specific renewable energy sources (e.g. technology specific investment subsidy) while others simply promote renewable energy (e.g. performance based subsidies based on avoided CO_2 emissions).

Instead of supporting production of RES-e also or alternatively the demand of renewable electricity can be stimulated. This can be done by e.g. tax exemptions on RES-e. This will affect the demand of households for RES-e because the price of RES-e can be the same (or even lower) as common produced electricity. However, by implementing tax exemptions at the end-user level the government cannot control the technology used to produce RES-e. It is left to producers to decide if they want meet the demand by installing windmills, hydro, PV or a biomass installation.

Summarizing, the technological barriers in the RES-e chain primarily on the production site. The financial barriers, since production of RES-e is more expensive than electricity from conventional resources, can be tackled by government intervention in the production part, or at the end use part of the chain (see Figure 5.1).

[7] At very high shares of intermittent renewable resources like wind and pv, changes to the power sector may be needed (i.e. storage or back up power) in order to compensate for the intermittent character.

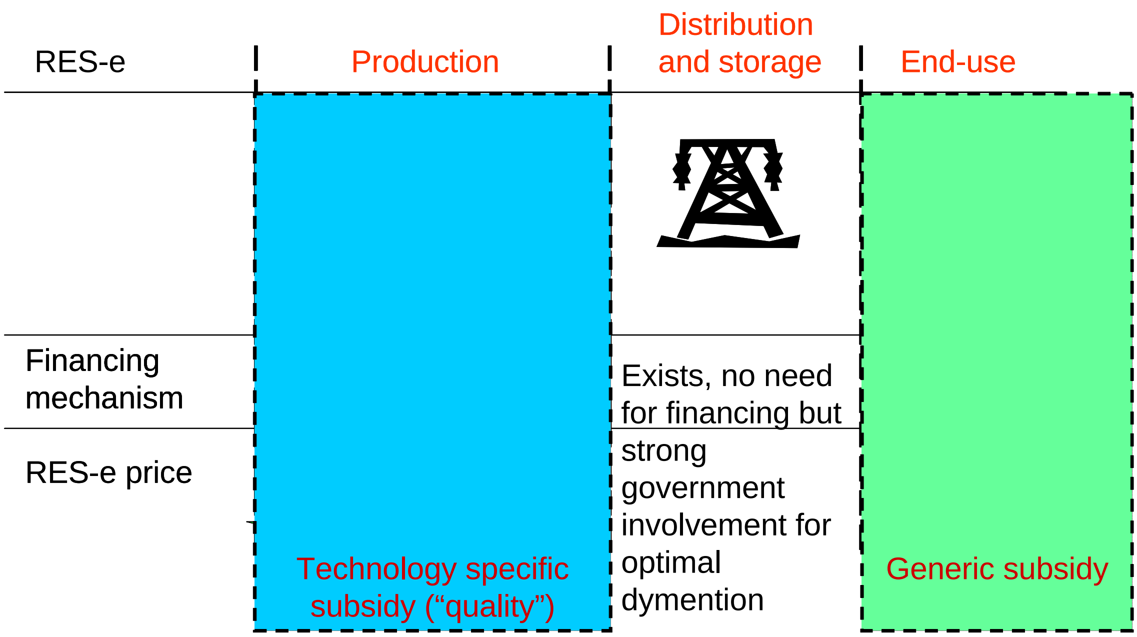

Figure 5.1 *Overview of the effects of policy support mechanisms in the renewable electricity chain*

5.2 The hydrogen energy chain

The hydrogen energy chain for transport consists of production, distribution, storage, refuelling and end-use. The end-use application (the hydrogen vehicle) can not be introduced into the current infrastructure. On all levels of the energy chain (from production to end-use) changes have to be made. Each of these changes have their specific barriers that have to be overcome. To facilitate the introduction of hydrogen various policy support mechanisms can be used, all having different effects on specific parts of the hydrogen energy chain.

Hydrogen production can be stimulated with an investment (€/MW) or production subsidy (€/GJ or €/kg). By applying these policy support mechanisms in this part of the chain, technology specific incentives can be given to hydrogen production options. The subsidy for instance can only apply to sustainable or renewable produced hydrogen (from fossil fuels with CCS or wind, biomass, or PV) and not to hydrogen produced from fossil fuels. Also tax exemptions (instead of subsidies) on fuels can give hydrogen production advantages and can be differentiated based on the way the hydrogen is produced (based on primary energy source or production pathway) in order to promote sustainable production systems (HFP, 2005). Subsidising or tax exemptions will lead to a debit on the governmental budget. Taxation of conventional fuels will have a comparable effect but lead to a return on the governmental budget. A combination of subsidies and tax exemptions for hydrogen and taxation of fossil fuels can make the total monetary flows budget neutral.

The absence of a hydrogen infrastructure imposes a barrier for the introduction. Infrastructure funding has no value of its own, since nobody buys a hydrogen vehicle just because of a refuelling station nearby, but without a filling station that provide hydrogen no one will by a hydrogen vehicle. Therefore the infrastructure support needs to be orientated at the production and end-use development and cannot be seen as autonomous parameter.

Different kinds of infrastructure can be distinguished. There can be a flexible and sometimes temporary infrastructure which can be easily expended (liquid hydrogen trucks and storage tanks at the refuelling station). There can also be 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. The same holds, though to a lesser extent, for a hydrogen production unit. In case long term (expected) demand is taken into account in the design of hydrogen production capacity and/or pipe line infrastructure, severe underutilisation will occur for a significant period of time. This underutilisation likely leads to temporary negative cash flows, despite the fact that when considering the technical life time the capacity of the production unit is designed well. Both a temporary underutilisation as well as the uncertainty of development the future hydrogen demand represent major barriers in the build up of the hydrogen production infrastructure.

A possible way to overcome these barriers is by providing an investment subsidy (€/km or €/filling station) in which the additional cost of a hydrogen infrastructure compared to a for instance gas infrastructure are supported/covered. In the past, build up of infrastructure was often coordinated by a public body. Infrastructure build up involves usually high investments and the lifetime and payback time of the infrastructure is long. The optimal infrastructure over the total lifetime may differ significantly from the most cost effective solution based on demand development within e.g. the next decade. Under utilisation may play a significant role in the first couple of years. However, in time, the building of an infrastructure that can also meet future demand may be more cost-effective from a societal point of view. Therefore the policy support should be focused on risk reduction of investments.

Given current market conditions, it is unlikely that a public body will be in charge to build up any new infrastructure themselves. However, by means of applying the right policy incentives, the development of infrastructure can be influenced and long term requirements can be taken into account explicitly. Due to the long payback time and investment horizon related to investments in infrastructure, the choices made for demonstration projects can already affect the infrastructure buildup for the early market phase (HFP, 2005).

Important for the deployment of hydrogen are the total cost for the end-user. The total costs are determined by the costs of the end-use application as well as the operational costs (fuel costs, maintenance costs, depreciation of the vehicle etc.). Purchase of the hydrogen vehicle can be stimulated by putting an investment subsidy (€/vehicle), or by putting tax exemptions (or subsidies) on the hydrogen fuel price (€/GJ). The investment subsidy influences the cost for a customer when buying a hydrogen car. The tax exemption influences the hydrogen fuel cost, or operational cost, of a hydrogen vehicle.

An important difference in comparison to stimulating hydrogen production is that in this case, as well as in the renewable energy chain for electricity, by applying support mechanisms at the end-use side of the chain the government has no control on how the hydrogen is produced (‘quality’ of the hydrogen).

Summarizing, the case of supporting hydrogen energy technologies is more complicated than the case of renewable energy systems for electricity (RES-e). While hydrogen technology is a disruptive technology, a whole new energy chain has to be built and barriers have to be overcome in production, distribution and end-use. For RES-e, only the production has to be stimulated. This can be done either at the end-use side (general non-technological incentives) or by specifically supporting certain production options (see Figure 5.2). How to balance the various potential support mechanisms over the hydrogen chain is the key question for further research.

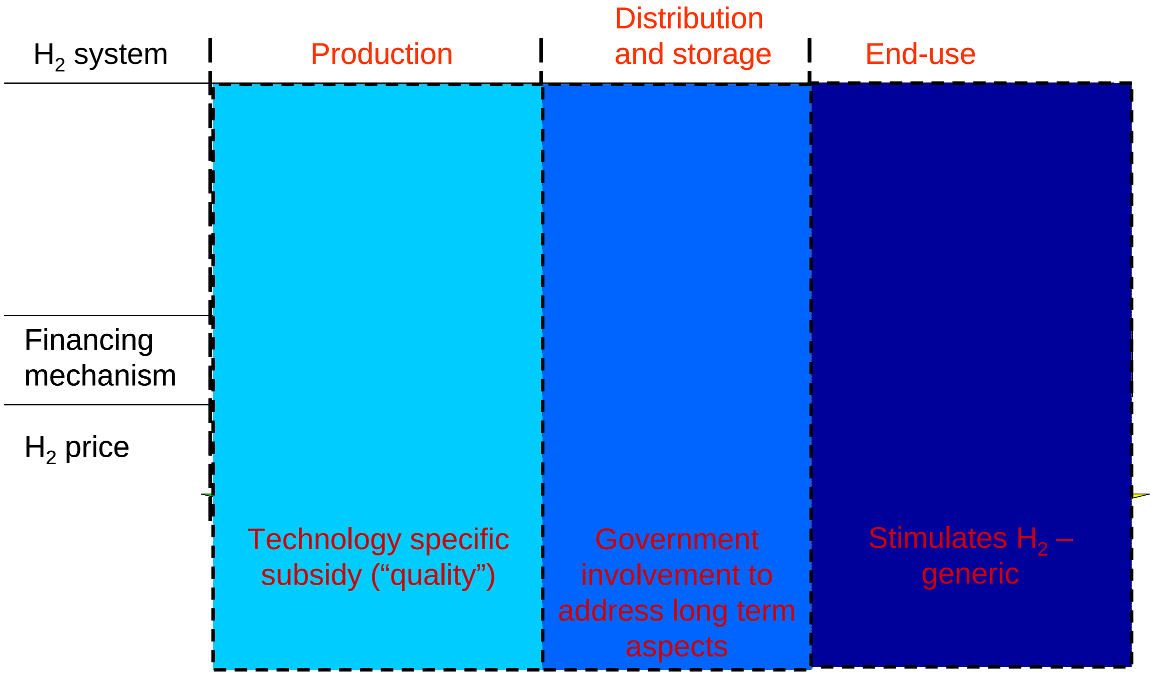

Figure 5.2 *Overview of the effects of policy support mechanisms in the hydrogen chain*

6. Current policy support mechanisms for hydrogen and fuel cells in transport

Hydrogen and fuel cell technologies are being researched for decades and a number of demonstration projects have been carried out for hydrogen in transport. Within these past and ongoing demonstration projects, policy support mechanisms are already in place. This chapter provides an overview of the current policy support in the EU. In addition, a comparison is made to the support mechanisms in place in the US (States and National). The analysis is limited to hydrogen in transport. Vehicles are sold on a world wide market and the (potential lack of a) level playing field between the EU, US and Japan may influence technology development in Europe. Although it is likely Japan has policy support mechanisms in place, no English document could be found and therefore are not included in this report.

6.1 Hydrogen support schemes in Europe

For Europe the analysis of hydrogen related policy support mechanisms is only done for the EC-level and not yet for the different Member States. On EU level there where no policy incentives found except from the Framework programmes (FP) supporting R&D and demonstrations. Looking at the 6th, and current FP, demonstration activities are subsidised for 35%, training is supported for 100% and 50% of R&D activities is supported (EC decision 1513/2002/EC) (see Figure 6.1).

Maximum reimbursement rates of eligible costs	Research and technological development or innovation activities	Demonstration activities	Training activities	Management of the consortium activities	Other specific activities (*)
Network of excellence				100% (up to 7% of the contribution) (AC : eligible direct costs)	100%
Integrated project	FC/FCF : 50% AC : 100%	FC/FCF : 35% AC : 100%	100%	100% (up to 7% of the contribution) (AC : eligible direct costs)	
Specific targeted research or innovation project	FC/FCF : 50% AC : 100%	FC/FCF : 35% AC : 100%		100% (up to 7% of the contribution) (AC : eligible direct costs)	
Specific research project for SMEs	FC/FCF : 50% AC : 100%		100% (for collective research only)	100% (up to 7% of the contribution) (AC : eligible direct costs)	
Integrated infrastructures initiative	FC/FCF : 50% AC : 100%	FC/FCF : 35% AC : 100%		100% (up to 7% of the contribution) (AC : eligible direct costs)	100%
Coordination action			100% (FC indirect costs : flat rate(**))	100% (up to 7% of the contribution) (AC : eligible direct costs) (FC indirect costs : flat rate(**))	100% (FC indirect costs : flat rate(**))
Specific support action				100% (up to 7% of the contribution) (AC : eligible direct costs) (FC indirect costs : flat rate(**))	100% (FC indirect costs : flat rate(**))

Figure 6.1 *Financial guidelines of the EC, overview of reimbursement rates of eligible cost*
Source: Guide to Financial Issues related to Indirect Actions of the Sixth Framework Programmes, 2005.

It is expected that for the FP7 framework, the guidelines will be close to the guidelines in FP6. Hydrogen and fuel cells may become technologies to be covered by means of a Joint Technology Initiative. It is not clear yet what the conditions for support of hydrogen and fuel cells will be in case such a JTI becomes operative. A number of stakeholders plead for increasing the investment subsidy to 50% of the total costs. This support level is comparable to the support level in the US (see next paragraphs). Others argue that the investments subsidy should not exceed the maximum as given in the FP6 framework (35% investment subsidy for demonstration activities).

Within the current support framework, no distinction is made between the different parts of the hydrogen energy chain. Also, the framework is hardly technology specific. Hydrogen applications are receiving the same support level as other innovations in the demonstration phase.

Another policy support mechanism in Europe is the directive on the promotion of the use of biofuels or other alternative fuels for transport (EC directive 2003/30/EC) giving EU member states the possibility to comply with the targets by using renewable hydrogen in stead of mixing biofuels to gasoline and/or diesel. However this is not an obligation specifically focussing on hydrogen, but leaving open and only outlining other options.

6.2 Hydrogen support schemes in the US

Within the US, national as well as state initiatives play a role with respect to policy incentives for hydrogen. On a national level, the US government agreed on a new Energy Policy Act in 2005 (EPAct). This policy act provides policy incentives for hydrogen as well as all other energy sectors (oil, gas, coal, biomass, nuclear, etc.) The EPAct is briefly discussed in Paragraph 6.2.2. More details can be found in Appendix A. A summary of state initiatives and policy support is given in Paragraph 6.2.3 with a detailed overview in Appendix B. Special attention is paid to the California Zero Emission Vehicle Regulation and this is therefore described separately in Paragraph 6.2.4 (Appendix C and Appendix D give a more extensive overview). Started is with a short outline of a fiscal advantage in the US.

6.2.1 Fiscal rules in the US

A general support mechanism in the US is the tax incentive in the form of accelerated depreciation. The US uses the Modified Accelerated Cost Recovery System (MACRS). Under MACRS, certain assets are divided into classes which dictate the number of years over which an asset's cost will be recovered. Solar, wind and geothermal property where already able to use the MACRS, but with the passage of the EPAct, fuel cells, micro turbines, and solar hybrid lighting technologies are now classified as 5-year property as well. This means MACRS allows capital to be depreciated on an accelerated schedule (a 200% double-declining balance schedule), allowing the owner to take more tax deductions earlier in the depreciation period, thus lowering the net present value of the cost of the plant (compared to when straight-line depreciation is used).

The MACRS model is comparable to some models used in a number of European countries in order to stimulate investments in energy efficiency. The MACS model does not specifically target a specific part of the hydrogen energy chain but supports in a general way investments in hydrogen.

6.2.2 Energy Act of 2005

The information provided in this paragraph summarizes the impact of the US Energy Policy Act 2005 for hydrogen for transport options. In many cases, the provisions require further rulemaking by the appropriate agencies. Keep in mind that although EPAct 2005 ‘authorizes’ funding for activities, in some instances, the funds must still be assigned through a separate federal budgeting process. The authorized funding listed indicates maximum budgets that federal agencies may request for the defined activities.

The EPAct 2005 distinguishes the following policy support mechanisms (see for more detail Appendix A):

- R&D grants (subsidies), for all parts of the hydrogen chain with a budget of $160 million in 2005 rising to $250 million in 2010.
- Demonstration grants (subsidies) for:
  - Vehicle demonstration at 30 geographically dispersed locations with project subsidy limited to $15 million (total budget $200 million), but with 50% cost share for five years.
  - 25 fuel cell transit buses in five geographically dispersed locations with $10 million per fiscal year (2006-2010).
  - Fuel cell school bus demonstration with a non-federal share of 20% of infrastructure and 50% of vehicles (total budget $25 million through 2006-2009).
- Public procurement regulations (obligation), requiring federal fleets to begin leasing or purchasing fuel cell vehicles no later than 2010, with budgets of $15 million in 2008 rising to $65 million in 2010 (with such sums necessary until 2015).
- Tax credits (tax exemption) can be received:
  - By the taxpayer for a fuel cell motor vehicle placed in service from 2009 (amount depends on weight of the vehicle, but is between $8,000 and $40,000).
  - By organisations building an alternative refuelling property and equal to 30% of the cost up to $30,000 for business property and $1,000 for residential refuelling equipment.

Also some large scale demonstration projects are (going to be) set up with a hydrogen component, these are:

1. *FreedomCar* (budget $700 million) aiming at the development of emission and petroleum-free cars and light trucks and the infrastructure to support them. The Partnership focuses on the high-risk research needed to develop the necessary technologies, such as fuel cells and advanced hybrid propulsion systems
2. *FutureGen* (budget $1 billion) is an initiative to build the world's first integrated sequestration and hydrogen production research power plant
3. *Next Generation Nuclear Power Plants* (budget $1.25 billion) is a new project to be established (according to the EPAct 2005) consisting of research, development, design, construction, and operation of a prototype Generation IV Nuclear Energy System plant, including a nuclear reactor that shall be used (A) to generate electricity; (B) to produce hydrogen; or (C) both to generate electricity and to produce hydrogen

Some interesting observations can be made based on US federal policy support. Firstly, there are larger budges for R&D compared to demonstration budgets, but the funding level is the same 50%.

Secondly, the large scale demonstrations focus on different parts of the hydrogen chain. The ‘FutureGen’ and ‘Next Generation Nuclear Power Plants’ focus on the production of hydrogen, while the ‘FreedomCar’ initiative concentrates on end-use. However, these large scale demonstrations do not merely focus on hydrogen, but also on other energy technologies. Taking the other support mechanisms into account the whole technology chain is covered. All production methods will be researched and demonstrated (sometimes just as a laboratory prototype), although all the different options are not mentioned in the list above (see for more detail Appendix A).

Thirdly, market demand will be created by 2010 when federal fleets are required to lease or purchase fuel cell vehicles. Also taxpayers are stimulated by tax credits they receive when they buy a fuel cell vehicle.

6.2.3 State activities that promote fuel cells and hydrogen infrastructure development

Also the states have several policy support mechanisms in place to stimulate hydrogen use in transport. Besides budgets for R&D and demonstration, public procurement, sales and purchase obligations and tax incentives (like income tax deductions) the states also provide policy incentives focussing on parking fee exemptions, high occupancy vehicle lanes (HOV lanes) and fuel duty relief. A more detailed overview of state activities for hydrogen is given in Appendix B.

A recently implemented scheme is a tax exemption for early adopters who want to convert their vehicle for alternative fuels. Whether this is a feasible incentive for hydrogen vehicles remains to be seen. Theoretically, the scheme supports the conversion of conventional ICE vehicles into hydrogen ICEs. Also, a conversion to fuel cell vehicles is covered by the scheme. This is however hardly realistic given the major differences between the ICE an FC vehicle.

It is interesting to see all states together almost cover all policy support mechanisms thinkable. However, reviewing states separately some states specifically focus on stimulating one part of the hydrogen chain, for instance Indiana has a subsidy for purchasing, conversion and/or installation of refuelling facilities, but no stimulations for other parts of the hydrogen chain.

Another difference between State support and National US government support are the availability for specific transport related support mechanisms, like fuel duty relief and free parking. Also the purchase obligation for cars and busses are different between state and national level. On state level the obligations mostly apply to alternative fuelled vehicles (including hydrogen) but not hydrogen fuelled vehicles specifically, while the national obligation is specifically on fuel cell vehicles.

6.2.4 The California Low-Emission Vehicle Regulations

This section will give an outline[8] of the California Low-Emission Vehicle Regulations and specifically the parts related to hydrogen and zero-emission passenger vehicles. A summary of the regulations concerning the GHG emissions standard is given, followed by the zero-emission vehicle (ZEV) standards. More detailed overviews are given in Appendix C and Appendix D.

GHG emissions standard

In September 2004, the California Air Resources Board (CARB) approved regulations to control greenhouse gas emissions (GHG) for new vehicles beginning with the 2009 model year. The regulation sets a declining fleet average standard (see Appendix C), with separate standards for the lighter and heavier vehicle fleets and depending on the average annual California sales. Tradable certificates are part of the regulation, so compliance to the regulation includes credit generation, averaging, banking and trading of these credits within and among manufacturers. The values of the certificates earned earlier then the regulation applies keep part of their value through time.

If a car manufacturer does not or cannot comply with the regulation Health and Safety Code 43211[9] becomes effective. This means for the number of vehicles not meeting the regulation a fine of $5,000 has to be paid. It is unclear if this is a one time fine, a daily fine or a yearly fine. If non compliance continues the CARB may prohibit the car manufacturer to sell any cars in California.

---

8 Because the outline in this report is short and focuses on the impact on hydrogen for transport some of the details may be overseen, therefore this report cannot be used for any legal purposes.

9 The Health and Safety Code 43211 states: "No new motor vehicles shall be sold in California that does not meet the emission standards adopted by State Board and any manufacturer who sells, attempts to sell, or causes to be offered to sell a new motor vehicle that fails to meet the applicable emission standards shall be subject to a civil penalty of $5,000 for each such action.

For hydrogen fuelled vehicles this regulation may be a chance. Hydrogen fuelled vehicles reduce the average GHG emission and contribute to meeting the GHG regulation for the fleet average. However, the CO_2 equivalent of hydrogen fuelled vehicles is not zero, because upstream emission factors have to be taken into account (Appendix C). Vehicle manufacturers may also prefer to put up for sale other alternative fuelled cars (natural gas, E85, LPG, bi- or flex-fuel, hybrid, etc.) in stead of hydrogen fuelled vehicles. So, the GHG emission standard is a policy mechanism specifically focussed on the end-use, but this not necessarily means hydrogen fuelled vehicles are going to be sold. Also initiatives for the refuelling infrastructure for hydrogen are missing (although California has a target) which may hamper the sales of any hydrogen fuelled vehicle.

Zero-Emission Vehicle standards

On top of the GHG emission standards and more important for hydrogen FC-vehicles, regulation has been introduced for a minimum sales share for zero emission vehicles. As for the GHG emission standards, also a distinction is made between large, medium and small volume manufacturers. The minimum zero emission vehicles (ZEVs) required for each manufacturer as the percentage of the passenger cars and light-duty trucks is:

Model years	Minimum ZEV Requirement [%]
2005 through 2008	10
2009 through 2011	11
2012 through 2014	12
2015 through 2017	14
2018 through subsequent	16

The minimal requirement is based on the average sale of the prior fourth, fifth and sixth year. Car manufacturers can also choose individually how they want to phase in light-duty trucks (see Appendix D).

The ZEV passenger cars and light-duty trucks generate credits which can be traded. The ‘value’ of the credits depends on the classification of the car[10], decreases in time and there has to be at least a certain amount of fuel cell or (full) electric vehicles. Credits generated by fuel cell vehicles in one state that adopted the regulation may be counted in all the other states as well. Vehicles that are demonstrated in California (under a California advanced technology demonstration program) may earn credits even if it is not delivered for sale. The manufacturer must show that the vehicle will be used in California for more then 50% in the first year.

If a car manufacturer does not or cannot comply with the regulation Health and Safety Code 43211[11] becomes effective. This means for the number of vehicles not meeting the regulation a fine of $5,000 has to be paid. It is unclear if this is a one time fine, a daily fine or a yearly fine. If non compliance continues the CARB can prohibit the car manufacturer to sell any cars in the States[12] who adopted the ZEV by retracting the certification of all vehicles of the manufacturer.

---

[10] The different types are: zero emission vehicle (ZEV, e.g. fuel cell vehicles), advanced technology partial zero emission vehicle (AT-PZEV, e.g. hybrids) and partial zero emission vehicle (PZEV, e.g. super-ultra-low-emission-vehicle).

[11] The Health and Safety Code 43211 states: “No new motor vehicles shall be sold in California that does not meet the emission standards adopted by State Board and any manufacturer who sells, attempts to sell, or causes to be offered to sell a new motor vehicle that fails to meet the applicable emission standards shall be subject to a civil penalty of $5,000 for each such action.

[12] Other states that also administer to the ZEV requirement are Massachusetts (2007), New York (2007), Vermont (2007), Rhode Island (2008), Connecticut (2008), New Jersey (2009) and Main (2010). Between brackets is the introduction date of the ZEV regulation.

So, this regulation means car manufacturers are obligated to put a minimum share of fuel cell vehicles up for sale, depending on their size. This regulation hereby increases the supply of FCV to the market and hopes customer demand will increase/follow. For car manufacturers the penalty is severe, especially after not being able to comply for a few years because they are then no longer allowed to sell any vehicle. For the other stakeholders of the hydrogen chain this regulation has no impact on their activities. By applying this regulation and thus increasing the supply of FCV California hopes the infrastructure buildup will follow. An advantage for the producers and suppliers of hydrogen is however that they can foresee the demand for hydrogen, although where the demand in California is going to be is uncertain.

6.3 Different support strategies for US and EU

Comparing the policies in place by the EU (only on EC level) and US (national and on State level) there are differences in how they aim to bring the hydrogen vehicles to the market. First of all the difference in amount of policy mechanism in the US compared to the EU is striking. The EU has R&D and demonstration subsidy under the Framework Programmes and gives the possibility to comply with the Directive promoting biofuels by supplying renewable hydrogen. While the US has sales obligations, public procurement (obligation) and tax incentives are on top of the RD&D subsidies. The US thus not only supports R&D and demonstration, but also stimulates the market by obligating sales (ZEV obligation, see 6.2.4) and procurement. In the EU the focus now is on large scale demonstration project, after which it is expected the hydrogen vehicles will come to the market but no policy incentives on EU level are in place yet.

Taking a closer look at the similar policies, R&D and demonstration subsidy another difference is the height of the financial support. The US funds R&D and demonstration 50%, while the EU funds R&D 50% but demonstrations by 35%.

So, the comparison of the support schemes for the US and the EU (see Figure 6.2) at the various stages of the innovation cycle shows that the incentives for introduction of hydrogen, more specifically fuel cell vehicles, exceed the incentives within Europe. These different (innovation) strategies may disturb the level playing field. For car manufacturers operating world wide, demonstrating the vehicles in the US may be more attractive and can, in the case of California, even be obliged to a certain level. In the early stages of the innovation cycle, a large number of FC vehicles have to be put up for sale in the US to meet the obligation. The learning effects of the automotive industry might be sufficient for further improvement of the next generation of vehicles, making additional deployment in Europe potentially superfluous. If present trends are not challenged, the US will build on its financial, regulatory and market advantage and is likely to attract most of the investments in fuel cell research and deployment. Manufacturing capacity and human capital will certainly follow up the financial capital (HFP, 2005). This may result in a deceleration in the introduction of hydrogen fuelled vehicles to the EU market. This however does not mean that the incentives that are currently in place in the US should be copied. Setting obligations on the deployment of a new technology that is in the 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.

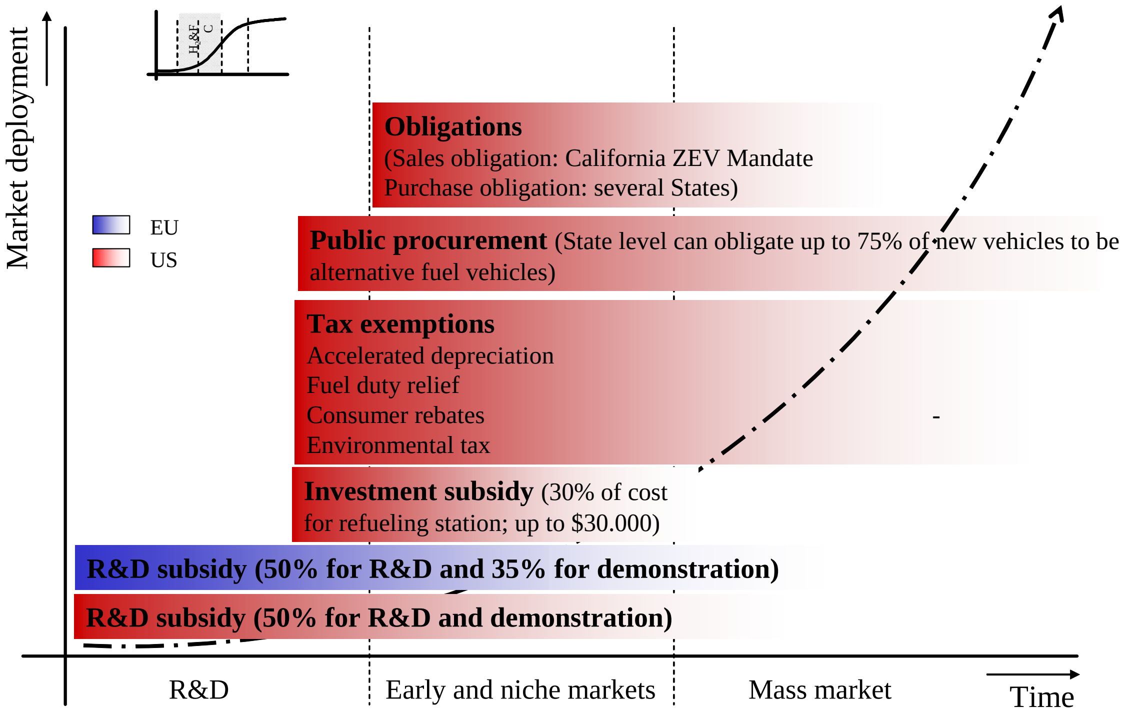

Figure 6.2 *Comparison of policy support mechanisms in the US and EU*

7. Synthesis

In the previous chapters, the capability of policy instruments to stimulate technology deployment in a specific technology development phase is described as well as the necessity and ability to specifically support certain parts of the (hydrogen) energy chain. In addition, a comparison is made between the hydrogen support scheme in Europe and the US. This chapter suggest possibilities of different applications of policy support mechanisms to stimulate hydrogen in transport. It will take into account the different parts of the hydrogen energy chain, so a division between support mechanisms between production, distribution and end-use will is also made.

It should be noted that this study is the first and more general study conducted in order to derive recommendations for a support framework for large scale demonstration projects for hydrogen in transport. This report serves as background report, the executive summary of results of phase I can be found in (Jeeninga, 2006) In the second phase of the project, the study will solely focus on support schemes (financing issues) for large scaled demonstration projects for hydrogen by building upon the results from the study carried out in the first phase of the project.

7.1 Possible policy support mechanisms for hydrogen in transport

There are different policy support mechanisms to support technology development (as described in Chapter 3). These are:

1. R&D and demonstration subsidies (or investment subsidies)
2. Low interest loans and loan guarantees
3. Production subsidies (like feed-in tariffs and fixed premium systems)
4. Tax exemptions
5. Quota obligations
6. Emission trading
7. Tendering and bidding
8. Environmental standards or regulation
9. Voluntary agreements
10. Public procurement

Different designs of the policy support mechanism can be applied to stimulate hydrogen in transport (see Table 7.1). The choice, design and target of the policy support mechanisms however have effects on:

- Other parts of the hydrogen energy chain (see Chapter 5), mostly how hydrogen is produced.
- Competition between technology options (see Paragraph 4.3), namely the conventional technology and/or other technologies contributing to sustainable transport.
- supply or demand of hydrogen for transport (see Paragraph 4.4).

So, careful thought has to be put into the design and choice of a policy support mechanism. The effectiveness of a policy support mechanism greatly depends on the ability to adapt to the developments of the technology and the changing requirements which come with technological progress. In time different policy support mechanisms have to be applied.

For demonstration projects there is currently the tendency to apply subsidies in Europe, while the United States applies a variety of policy support mechanisms. The United States hereby not only support the demonstration phase but also starts to prepare early market demand (by for instance requiring public procurement and sales obligations). In order to re-establish the level playing field, Europe may need to reconsider its approach and start to apply not only R&D subsidies, but also a combination of production subsidies, investment subsidies, tax exemptions and public procurement in order to successfully start large scale demonstration projects and increase the chance of early market demand.

Table 7.1 *Overview of policy support mechanisms for the production distribution and end-use of hydrogen in transport*

Policy support	Production	Distribution	End-use
RD&D and investment subsidy	% subsidy for R&D % of (additional) investment cost	% subsidy for R&D % of (additional) investment cost for pipeline infrastructure	% subsidy for R&D % of (additional) investment cost
Production subsidy	€/produced kg H_2	Subsidy per distributed kg H_2 per km (€/kg H_2/km)	€/produced H_2 vehicle €/driven km
Zero and low interest loan	Zero or low interest loans for investment in (renewable) H_2 production facilities	Zero or low interest loans for investment in (renewable) H_2 pipeline network	Zero or low interest purchase loan for consumer
Tendering and bidding	For sites for renewable hydrogen production	For refuelling sites at existing or high potential locations	Tendering of demonstration projects based on locations, etc.
Fiscal systems/tax exemptions	Accelerated depreciation	Accelerated depreciation No excise cost on H_2	No excise cost on H_2 Lower purchase tax on vehicle Lower road tax No VAT Free parking
Quota obligations	Minimum number of kg H_2 produced (and delivered)	Minimum number of refuelling stations	Minimum number of H_2 fuelled cars produced and/or sold GHG fleet average
Emission trading	Renewable hydrogen can be part of the carbon credits trading system (ETS)	(Renewable) hydrogen can be part of the carbon credits system (ETS), the credits are handed to the fuel distributors	
Environmental standards			CO_2 emission maximum per vehicle
Voluntary agreements	Agreement on the amount of (renewable) hydrogen production	Agreement on the deployment of the hydrogen infrastructure in the region	Agreement on the introduction date and number of sales of hydrogen fuelled vehicles
Public procurement			Purchase of H_2 vehicle

7.2 Next steps

In order to further contribute to the HyLights project the next step based on this study will be to look more specifically at demonstration projects. The analysis in this report of policy support mechanisms in time already gives some first insights into possible policy support mechanisms, but further research is needed. By looking into current policy support of demonstration programmes and addressing stakeholders involved in these demonstrations and the hydrogen field more insight will be gathered in:

(i) their experiences with current policy support mechanisms and
(ii) their view on future policy support mechanisms

Not only will their preference for policy support mechanism be interesting to review but their thoughts of height and effectiveness of support as well. The distinction between the different parts of the hydrogen chain will be taken into account. Additionally, further study of current policy support of Member States in Europe will be conducted and will also looking at the current pricing (taxation) of hydrogen if it is sold as a transportation fuel.

Based on these insights recommendations can be made for policy support mechanisms (and their height) for future large scale demonstration programmes.

References

California Air Resources Board (2000): The California Low-Emission Vehicle Regulations.

Dijk, A.L. van, et al. (2003): Renewable Energy Policies and Market Developments. ECN-C--03-029, ECN.

European Commission (2001): Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal market.

European Commission (2002): Decision No 1513/2002/EC concerning the sixth framework programme of the European Community for research, technological development and demonstration activities, contribution to the creation of the European Research Area and to innovation (2002 to 2006).

European Commission (2003): Directive 2003/30/EC on the promotion of the use of biofuels or other renewable fuels for transport.

European Commission (2004): Directive 2004/17/EC coordinating the procurement procedures of entities operating in water, energy, transport and postal service sectors.

European Commission (2004): Directive 2004/18/EC on the coordination of procedures for the award of public works contracts and public supply contracts and public service contracts.

European Commission (2005): Guide to financial issues relating to indirect actions of the sixth framework programmes.

European Hydrogen and Fuel Cell Platform (2005): Deployment Strategy.

Grübler, A. et al. (1999): Dynamics of energy technologies and global change. Energy Policy, Vol. 27, Issue 5, pp. 247-280

Haas, R., N. Wohlgemuth and C. Huber (2001): Financial incentives to promote renewable energy systems in European electricity markets: a survey. Int. J. Global Energy Issues, Vol. 15, Nos. ½, pp.5-24

Jeeninga, H. et al. (2006): Policy support for large scale demonstration projects for transport: Summary report HyLights phase I. ECN-E--06-065, ECN.

Kellen (2006): Initial comparison of different legal forms and management structures of demonstration projects under preparation or in proposal phase throughout Europe. Deliverables W5.1 and W5.2 for the HyLights project

Kemp, R. and D. Loorbach (2005): Dutch Policies to Manage the Transition to Sustainable Energy. Forthcomming in Innovationen und Transformation. Band 4. pp. 123-150

OECD (2003): Technology, Innovation, Development and Diffusion. COM/ENV/EPOC/IEA/SLT(2003)4, OECD and IEA information paper.

Pembina Institute and Canadian Energy Research Institute (2004): Case study on the role of fiscal policy in hydrogen development: Economic Analysis. For the National Round Table on the Environment and Economy (NRTEE).

Sagar, A.D. and B. van der Zwaan (2006): Technological innovation in the energy sector: R&D, development and learning-by-doing. Energy Policy, Vol. 34, Issue 17, pp. 2601-2608

Sawin (2004): National policy instruments: Policy lessons for the advancement and diffusion of renewable energy technologies around the world. Thematic Background Paper, Ineternational Conference for Renewables. Bonn

United States of America Senate and House of Representatives (2005): Energy Policy Act of 2005.

Appendix A Energy Policy Act of 2005

Table A.1 *Overview of US Energy Policy Act on hydrogen for the transport sector*

Section(s) and title	Short overview
634 Demonstration hydrogen production at existing nuclear power plants	Establishes two projects in geographic areas that are regionally and climatically diverse to demonstrate the commercial production of hydrogen at existing nuclear power plants. Prior to making an award determined will be whether the use of existing nuclear power plants is a cost-effective means of producing hydrogen. EPAct 2005 authorizes $100,000,000 for the purposes of carrying out this section.
Section C 641 - 645 Next generation nuclear power plant	Establishes a project to be known as the 'Next Generation Nuclear Plant Project.' The Project shall consist of the research, development, design, construction, and operation of a prototype plant, including a nuclear reactor that is based on research and development activities supported by the Generation IV Nuclear Energy Systems Initiative and shall be used A. to generate electricity; B. to produce hydrogen; or C. both to generate electricity and to produce hydrogen. By September 2021 the construction should be complete and begin operations of the prototype nuclear reactor and associated energy or hydrogen facilities is started. EPAct 2005 authorizes $1,250,000,000 for the period of fiscal years 2006 through 2015, and such sums as are necessary for each of fiscal years 2016 through 2021.
721 - 723 Advanced vehicles demonstration and pilot program	Establishes a competitive grant program, administered by Clean Cities, to fund up to 30 geographically dispersed advanced vehicle demonstration projects. EPAct 2005 authorized $200 million (until expended) for this program. Grant recipients will be limited to state and local government agencies and metropolitan transport authorities. Applications must include a registered participant in the Clean Cities initiative. Participants can be public to private entities. Projects are limited to $15 million with 50% cost share for five years. Grant funds can pay for: - AFCs (including neighbourhood electric vehicles)

Section(s) and title	Short overview
	- Fuel cell vehicles - Ultra low sulphur diesel vehicles - Acquisition and installation of fuelling infrastructure - Operation and maintenance of vehicles, infrastructure and equipment
731 Fuel cell transit bus demonstration	Establishes a transit bus demonstration program to make competitive, merit-based awards for 5-year projects to demonstrate not more than 25 fuel cell transit buses (and necessary infrastructure) in 5 geographically dispersed localities. EPAct authorizes $10 million for each of fiscal years 2006 through 2010.
741 Clean School bus program	Establish a program for awarding grants on a competitive basis to eligible recipients for the replacement, or retrofit (including re-powering, aftertreatment, and remanufactured engines) of, certain existing school buses. The grant may support 100 percent of the retrofit technologies and installation costs. For the replacement of school buses in the amount of up to one-half of the acquisition costs (including fueling infrastructure) depending on emission and model year in which the engine is manufactured. EPAct authorizes $55 million for each of fiscal years 2006 and 2007 and such sums as are necessary for each of fiscal years 2008, 2009, and 2010.
743 Fuel cell school buses	Establishes a DOE demonstration program involving fuel cell school bus manufacturers and at least two units of local government currently using natural gas school buses. The non-federal cost share will be at least 20% of infrastructure and 50% of vehicles. EPAct 2005 authorizes $25 million for fiscal years 2006 through 2009.
782 Federal and state procurement of FC vehicles and hydrogen energy systems	Requires federal fleets to begin leasing or purchasing fuel cell vehicles and hydrogen energy system no later than January 1, 2010. DOE shall provide incremental cost funding and may provide exemptions if the vehicles are not available or appropriate for fleet needs. EPAct 2005 authorizes $15 million in 2008, $25 million in 2009, $65 million in 2010, and such sums as are necessary each year in 2011 - 2015.
805 Programs	A research and development program shall be established, focusing on technologies relating to the production, purification, distribution, storage, and use of hydrogen energy, fuel cells, and related infrastructure. Activities under this section may be carried out by funding nationally recognized university-based or Federal laboratory research centres. EPAct 2005 authorises $160 million (FY 2006), $200 million (FY 2007), $220 million (FY 2008), $230 million (FY 2009), $250 million (FY 2010) to carry out projects and activities relating to hydrogen production, storage, distribution and dispensing, transport,

Section(s) and title	Short overview
	Education and coordination, and technology transfer. Projects and activities relating to fuel cell technologies are authorized to $150 million (FY 2006), $160 million (FY 2007), $170 million (FY 2008), $180 million (FY 2009), $200 million (FY 2010).
808 Demonstration	Grants shall be provided, on a cost share basis as appropriate, for use in: - devising system design concepts that provide for the use of advanced composite vehicles in programs under section 782 - designing a local distributed energy system that incorporates renewable hydrogen production, off-grid electricity production, and fleet applications in industrial or commercial service; EPAct 2005 authorises $185 million for fiscal year 2006, $200 million for 2007, $250 million for 2008, $300for 2009, and $375for 2010.
809 Codes and standards	Grants are provided to such professional organizations, public service organizations, and government agencies to support timely and extensive development of safety codes and standards relating to fuel cell vehicles, hydrogen energy systems, and stationary, portable, and micro fuel cells. Together with educational efforts by organizations and agencies $4 million in 2006, $7 million in 2007, $8 million in 2008, $10 million in 2009 and $9 million in 2010 will be available for these activities.
812 Solar and wind technologies	Establishes 5 projects in geographic areas that are regionally and climatically diverse to demonstrate the production of hydrogen at solar energy facilities, including one demonstration project at a National Laboratory or institution of higher education. The EPAct establishes a program: A. to develop methods that use electricity from photovoltaic devices for the onsite production of hydrogen, such that no intermediate transmission or distribution infrastructure is required or used and future demand growth may be accommodated B. to evaluate the economics of small-scale electrolysis for hydrogen production C. to study the potential of modular photovoltaic devices for the development of a hydrogen infrastructure, the security implications of a hydrogen infrastructure, and the benefits potentially derived from a hydrogen infrastructure. Establishes 5 projects in geographic areas that are regionally and climatically diverse to demonstrate the production of hydrogen at existing wind energy facilities, including one demonstration project at a National Laboratory or institution of higher education. EPAct 2005 authorizes such sums as are necessary for carrying out the activities under this section for each of fiscal years 2006 through 2020.
933 Low-cost renewable hydrogen	Establishes a RD&D program to determine the feasibility of using hydrogen propulsion in light-weight vehicles and the integration of the associated hydrogen production infrastructure using off-the-shelf components.

Section(s) and title	Short overview
and infrastructure for vehicle proportion	
934 Solar power research program	A program of RD&D shall be conducted to evaluate the potential for concentrating solar power for hydrogen production, including cogeneration approaches for both hydrogen and electricity.
1341 Alternative motor vehicle credit *	*Fuel Cell Motor Vehicle Credit* Allows a tax credit for new qualified fuel cell motor vehicle credit with respect to a new qualified fuel cell motor vehicle placed in service by the taxpayer during a taxable year. The tax credit is: - $8,000 ($4,000 in the case of a vehicle placed in service after December 31, 2009), if the vehicle has a gross vehicle weight rating of < 8,500 pounds - $10,000, if such vehicle has a gross vehicle weight rating between 8,500 and 14,000 pounds - $20,000, if such vehicle has a gross vehicle weight rating between 14,000 and 26,000 pounds - $40,000, if such vehicle has a gross vehicle weight rating of more than 26,000 pounds The amount of vehicles lighter then 8,500 pounds shall be increased if the city fuel economy is better compared to the 2002 model year city fuel economy. The increase ranges from $1,000, if the vehicle achieves at least 150% to 175% of the 2002 model year city fuel economy, to $4,000 if the vehicle achieves at least 300% of the 2002 model year city fuel economy (with steps of $500 with every 25%). *Alternative Fuel Motor Vehicle Credit* The new qualified alternative fuel motor vehicle credit is 50% of the incremental cost of any new qualified alternative fuel motor vehicle placed in service by the taxpayer during the taxable year. An additional 30% can be received if the vehicle meets or exceeds the most stringent standard available for certification under the Clean Air Act for that make model year vehicle (other than a zero emission standard) or meets or exceeds the most stringent standard available for certification under the State laws for that make and model year vehicle (other than a zero emission standard). Incremental cost of any new qualified alternative fuel motor vehicle is equal to the amount of the excess of the manufacturer's suggested retail price for such vehicle over such price for a gasoline or diesel fuel motor vehicle of the same model and may not exceed - $5,000 if the vehicle has a gross vehicle weight rating of < 8,500 pounds, - $10,000, if such vehicle has a gross vehicle weight rating between 8,500 and 14,000 pounds, - $25,000, if such vehicle has a gross vehicle weight rating between 14,000 and 26,000 pounds, - $40,000, if such vehicle has a gross vehicle weight rating of more than 26,000 pounds.

Section(s) and title	Short overview
1342 Credit for installation of alternative fuelling stations **	It expires December 31, 2009 (hydrogen purchases expire in 2014). Allows a tax credit equal to 30% of the cost of any alternative refuelling property, up to $30,000 for business property. Buyers of residential refuelling equipment can receive a tax credit for $1,000. For non-tax-paying entities, the credit can be passed back to the equipment seller. The credit is effective on purchases put into service after December 31, 2005. It expires December 31, 2009 (hydrogen purchases expire in 2014). This legislation replaces the Tax Deduction Timeline for the refuelling property tax deduction extended by Work Families Tax Relief Act of 2004.

Source: Energy Policy Act of 2005, public law 109-58-aug. 8 2005).
* Alternative fuel means compressed natural gas, liquefied natural gas, liquefied petroleum gas, hydrogen, and any liquid at least 85 percent of the volume of which consists of methanol.
** Qualifying alternative fuels are natural gas, propane, hydrogen, E85, or biodiesel blends of B20 or more.

Appendix B State activities

Table B.1 *US state activities for promoting alternative fuels and related technologies*

Scheme	Scheme (detailed)	Activity	State	Note
Subsidy and Loan (R&D & demo)	R&D subsidy	New Energy Technology Grant program	Connecticut	Grants up to $10.000 for individuals or SME for FC technology that are in the prototype or pre-commercial stage of development
		Alternative fuel vehicle research grants	Iowa	A grant for the purpose of conducting research connected with vehicle, not for the purchase of the vehicle itself
	Demonstration subsidy	Hydrogen energy Technologies Act	Florida	For demonstration projects, infrastructure and vehicle development and demonstration and public procurement
		Alternative fuel vehicle grant program	Indiana	$1.1 million available for purchasing, conversion, installation of refuelling facilities, use or a combination of these purposes. Grants range from $2000 to $50000
			Minnesota	$600.000 in matching funds for three multi-fuel hydrogen stations and fleet vehicle demonstrations in Moorhead, Alexandria and the Twin Cities
		Ohio fuel cell Initiative	Ohio	Also for demonstration projects including hydrogen infrastructure
		Emissions reduction incentive grants	Texas	On-road heavy-duty vehicles (8500 lbs+) are eligible for grants under this program; fuel cells qualify for the category ‘demonstration of new technology’
	Loan (guarantees and low interest) & Funds	Carl Moyer Air Quality Attainment Program	California	Fund for purchasing cleaner then required engines and equipment (e.g. heavy-duty FC vehicles)
		Clean Transportation Funding	California	Mission is to fund projects that reduce air pollution of motor vehicles within the South Coast Air District
		Connecticut Clean energy fund	Connecticut	$37.5 million was committed to the Fuel Cell initiative over a 5-year period ending in 2005

Scheme	Scheme (detailed)	Activity	State	Note
		Fund	Massachusetts	$10 million fund to assist municipalities and regional transit authorities in building alternative fuel station
		Clean-Fueled Bus program	New York	Provides funds to state and local transit agencies, municipalities and schools for up to 100% of the incremental cost of new alternative buses (with a seating capacity of 15 or more passengers)
		New York State Clean Cities Challenge	New York	Members of the NY Clean City organizations can apply for funds (on competitive bases) to cost share up to 75% for acquiring an alternative fuel vehicle and/or refuelling infrastructure
		Energy Loan Program	Oregon	Promote energy conservation and renewable energy (including use of alternative fuels)
Tax exemptions	Accelerated depreciation			
	Fuel tax relief		Connecticut	Prior to 2008 petroleum products sold for use as fuel in fuel cells are exempt from petroleum gross earnings tax
			Illinois	Alternative rebate program (start 1998) provides a choice to get: fuel rebate (see also purchasing tax), purchased from an Illinois company.
			Idaho	Refund on taxes on the purchase of 50 gallons or more for use for a non-taxable purpose. Not available for recreational vehicles
			North Dakota	Sales and use tax exemption for hydrogen and equipment used in production, storage and transportation at the production facility
	Consumer rebates (e.g. on purchasing, emission testing, registration tax)	Emission testing of vehicle	Arizona	Exemption for vehicles registered in or used to commute into metro Phoenix or metro Tucson
			Missouri	Exception from emission inspection exemption
			Nevada	Exception from emission inspection exemption
		Registration tax	Arizona	Reduced registration tax rate

Scheme	Scheme (detailed)	Activity	State	Note
		Purchasing (sales) tax and conversion of vehicle	Arizona	Applies only if the vehicle was diesel fuel and is converted
			California	Small Alternative Fuel Vehicle (weighing no more then 10.000 lbs) purchase Incentive ranging from $1000 to $5000 per vehicle
			Colorado	Income tax credit for increment cost of Alternative Fuel vehicle or conversion of a vehicle (in 2009, ranging from 25 - 95%(for ZEV))
			Connecticut	Prior to 1 July 2008 hydrogen vehicles are exempt from state sales tax
			Illinois	Alternative rebate program (start 1998) provides a choice to get: (1) vehicle rebate (up to 300 vehicles); (2) conversion rebate (see also fuel rebate for third option), purchased from an Illinois company.
			Georgia	Income tax credit up to 20% or $5000 (whichever is less)
			Massachusetts	For 2006-2010 $2000 income tax deduction
			Montana	Income tax credit up to 50% of the equipment and labor costs for converting vehicles ($500 for vehicles with weight of max 10.000 pounds and $1000 for vehicles over 10.000 pounds)
			New Jersey	Local government entities are entitled to rebates up to $12.000 if they either purchase or convert to alternative fuel vehicles
			New Jersey	ZEV sold, rented or leased are exempt from state sales and use tas.
			Oregon	$750 tax credit for purchasing a hydrogen vehicle and 25% of the conversion cost (up to $750)
			Pennsylvania	Incremental cost (up to $500) of purchasing a alternative fuel vehicle as funds are available (first come first serve basis)
			Virginia	Any corporation, individual or public service corporation is allowed to deduct 10% against income or grow receipts tax for purchasing of clean fuel vehicle

Scheme	Scheme (detailed)	Activity	State	Note
			Washington	Beginning in 2009, till 20011, sales tax does not apply to sales of new passenger cars, light duty trucks and medium duty passenger vehicles which are powered by clean alternative fuel
		License tax fee	Arizona	Reduction
			California	Exemption from (incremental cost of) light-duty motor vehicle license fee
		Refueling facility	Colorado	Tax credit for actual costs for (re)constructing or acquiring and alternative fuel facility (till 2006 50%; till 2009 35%; till 2011 20%). For alternative fuel derived from renewable energy the percentage is multiplied by 1.25
			New Jersey	Local governments, state colleges and universities, school districts, and government authorities get 50% of the cost of purchasing and installing refueling infrastructure for alternative fuel (up to $50.000)
			New York	Tax credits are available for 50% of installation cost of clean fuel refueling property
			Virginia	Any corporation, individual or public service corporation is allowed to deduct 10% against income or grow receipts tax for refueling property placed in service
	Environmental tax			
	Other tax	Business tax credit	Oregon	Of 35% of eligible project costs; applicable for whom investing in less-polluting transportation fuels and pay taxes in Oregon or partner with an Oregon business or resident who has an Oregon tax liability
Production subsidy, tender & bidding				
Public procurement		Energy Efficiency Vehicle Group Purchase Program	California	Encourage purchasing of energy efficient vehicles (passenger cars or light-duty trucks) in vehicle procurement contract of local and state agencies. Requirement may be up to 75% of fleet
Obligation	Purchase obligation	Purchase requirement of cars	Massachusetts	5% of all new state agency fleet vehicles be hybrids or run on alternative fuel, with 50% of the state fleet reliant on alternative fuels by 2010

Scheme	Scheme (detailed)	Activity	State	Note
			Minnesota	State agencies are required (as of 2004) to use clean fuels in motor vehicles owned or leased and when purchasing a vehicle must purchase a vehicle that is capable of being powered by clean fuels if the clean fuels and vehicle are reasonably available at similar costs and capable of carrying out the purpose of the purchase
			New Mexico	75% of vehicles acquired by the agencies and departments of state government and educational institutions must be capable of operating on alternative fuel or are hybrid vehicles.
			North Carolina	At least 75% of the new or replacement light duty cars and trucks purchased by the state must be alternative-fuel vehicles or low emission vehicles
		Purchase requirement of busses	California	Requirement of retrofitting or replacing older diesel busses; (15%) begin in model year 2008 or 2010, depending on fuel path*
			New Jersey	Beginning in 2007, all buss purchased must have improved pollution control or be powered by alternative fuels
	Sales obligation	ZEV Sales mandate	California	For car manufacturers
			Maine	Each manufacturer’s sales fleet of passenger car and light-duty trucks produced and delivered for sale must contain the same percentage of ZEV as of 2009
			New York	In model year 2007, one percent of a manufacturer's sales must be ZEV, partial ZEV or some combination thereof. In model year 2008, one percent of a manufacturer's sales in NY must be ZEV
	Information obligation	Alternative fuel vehicle notification requirement	Arizona	Increase public awareness by providing information
Other		High Occupancy Vehicle (HOV) lane access for single-occupant	Arizona	

Scheme	Scheme (detailed)	Activity	State	Note
			California	When meeting the requirements of AB2628
			Massachusetts	Right to travel in HOV lane for 3 years when alternative fuel vehicle is purchased.
		Park exemption	Arizona	H_2 vehicles park for free in designated carpool operators parking area's
			California (LA)	H_2 vehicles may park for free after purchasing a California Clean Air Vehicle Decal
			Massachusetts	Discount or free parking in municipalities choosing to participate
		Fast Lane	Massachusetts	A waiver for initial $27.50 application fee for the fast lane transponder when purchasing an alternative fuel vehicle
		Vehicle plates	Virginia	Clean Special Fuel license plates are available for clean fuel vehicles

Source: State Activities that Promote Fuel Cells and Hydrogen Infrastructure Development, 2006)

* See http://www.arb.ca.gov/regact/bus04/bus04htm

Note The promotion activities are not hydrogen specific, but alternative fuel orientated, this includes hydrogen besides natural gas, propane, electricity and ethanol. Technology startup business support is left out of the table.

Appendix C California GHG emissions standard

In September 2004, the California Air Resources Board (ARB) approved regulations to control greenhouse gas emissions (GHG) for new vehicles beginning with the 2009 model year. The regulation sets a declining fleet average standard, with separate standards for the lighter and heavier vehicle fleets. For independent low volume and intermediate size manufacturers[13] the regulations are delayed. Compliance methods include credit generation, averaging, banking and trading of these credits within and among manufacturers.

If car manufacturers do not or cannot comply with the LEV regulation (within 5 years) Health and Safety Code 43211 becomes effective. This code states: “No new motor vehicles shall be sold in California that does not meet the emission standards adopted by State Board and any manufacturer who sells, attempts to sell, or causes to be offered to sell a new motor vehicle that fails to meet the applicable emission standards shall be subject to a civil penalty of $5,000 for each such action. Any penalty recovered pursuant to this section shall be deposited into the General fund.” If non compliance continues the CARB may prohibit the car manufacturer to sell any cars in California.

Reviewing the regulations in more detail for passenger cars for *large volume manufacturers*[14] shows the *fleet average* for passenger cars, light-duty trucks (0-3750 lbs.), Light weight vehicle (LWV) and medium-duty passenger cars is:

Table C.1 *Fleet average GHG emissions*

	Passenger cars [grams per mile CO_2 equivalent]	Light-duty vehicles [grams per mile CO_2-equivalent]
2009	323	439
2010	301	420
2011	267	390
2012	233	361
2013	227	355
2014	222	350
2015	213	341
2016+	205	332

The calculation method to determine the average GHG emission value is outlined in the regulations and will not be reviewed in this report. It is important to note that for the calculation of the CO_2-equivalent emissions of H_2ICE and H_2 FC ZEVs an upstream emission factor is accounted to the vehicle. Unless the manufacturer can show the produced H_2 emits less CO_2 by using renewable energy sources the following numbers apply:

13 Small volume manufacturers have an average annual California sale below 4,500 units based on the average number of vehicles sold for the three previous consecutive model years. Intermediate volume manufacturers have an average annual California sale between 4,500 - 60,000 units based on the average number of vehicles sold for the three previous consecutive (model) years. Independent low vehicle manufacturers have an average annual California sale below 10,000 units based on average numbers of vehicles sold for the three previous consecutive model years.

14 Large volume manufacturers have an average annual California sale exceeding 60,000 units based on the average number of vehicles sold for the three previous consecutive (model) years.

Vehicle Type	Upstream emissions factor [CO_2 equivalent g/mi]
H_2ICE vehicle	290
H_2 FCV	210

Intermediate volume manufacturers[15] do not have to apply to these regulations before the 2016 model year. In 2016 intermediate volume manufacturers shall either:

a. have a fleet average GHG emissions value of 233 g/mi, or
b. not exceed a fleet average GHG emissions value of 0.75 times the baseline fleet average GHG emissions value .

Small volume manufacturers and independent low volume manufacturers[16] do not have to apply to these regulations before the 2016 model year. In model year 2013 these manufacturers shall calculate the GHG emissions of their fleets by comparing these to large volume manufacturers vehicles based on horsepower and horsepower to weight ratio. In 2016 intermediate volume manufacturers shall either:

a. not exceed the fleet average GHG emissions value calculated in 2013, or
b. have a fleet average GHG emissions value of 233 g/mi, or
c. by demonstrating a vehicle model using an engine, transmission, and emission control system that is identical to a configuration of that of a large volume manufacturer.

Compliance to the regulations can be done based on *credit generation*. From 2000 through 2008 credits are received by achieving fleet average GHG emissions value applicable to the required 2012 model year. Credits are calculated in units of g/mi by:

((fleet average GHG requirement for 2012 model year)-(manufacturer's fleet average GHG value))*(total number of vehicles produced and delivered for sale in California (including ZEVs)).

In 2009 and beyond credits are received through the same method and equation, except the required model year is the value of the subsequent model year (e.g. credits in 2009 are earned when the fleet average is lower then the requirement for the 2010 model year).

It is also possible to earn credits for low emission vehicles that have been sold before 2009. Credits earned by vehicles of 2000 to 2008 model years shall be treated as if they were earned in the 2011 model year and shall retain full value through the 2012 model year. If these credits are not used to equal debits in the 2009 to 2012 model years the value of these credits will be discounted by 50% of its original value in 2013, 25% by 2014, and will have no value in 2015.

Credits earned in the 2009 and beyond model years shall retain full value through the fifth model year after they are earned. If these credits are not used to equal debits in the sixth model years the value of these credits will be discounted by 50% of its original value, 25% in the seventh model year, and will have no value in eighth model year.

With 2009 and subsequent model years *debits* (also in units of g/mi) can be received if the fleet average is higher then the required fleet average for the corresponding model year. For the 2009 and subsequent model years the total credits or debits earned for the fleet shall be summed together. A manufacturer shall equalize debits within five model years after they are earned otherwise the Health and Security Code section 43211 penalty shall apply for the number of vehi-

15 Intermediate volume manufacturers have an average annual California sale between 4,500 - 60,000 units based on the average number of vehicles sold for the three previous consecutive (model) years.

16 Small volume manufacturers have an average annual California sale below 4,500 units based on the average number of vehicles sold for the three previous consecutive (model) years. Independent low volume manufacturers have an average annual California sale below 10,000 units based on the average number of vehicles sold for the three previous consecutive (model) years.

cles that do not meet the emission standard for the model year in which the debits were first incurred[17].

[17] The number of cars not meeting the standard is determined by dividing the total amount of g/mi GHG emission debits for the model year by the g/mi GHG fleet average requirement.

Appendix D California Zero-Emission Vehicle standards

The Zero-Emission vehicle standard requires manufactures to put up for sale a minimum of zero emission vehicles (ZEVs). The percentage of the passenger cars and light-duty trucks is:

Model years	Minimum ZEV Requirement [%]
2005 through 2008	10
2009 through 2011	11
2012 through 2014	12
2015 through 2017	14
2018 and subsequent	16

The requirement will be calculated:

1. Based on an average volume of *passenger cars and light-duty trucks* produced and delivered for sale in California. For model year 2005 the average of 1997, 1998 and 1999 will be calculated to determine the volume of ZEVs required. For subsequent three-year periods following model year 2005 the manufacturers volume will be based on a three year average of the prior fourth, fifth and sixth year (e.g. 2006 to 2008 ZEV requirements will be based on the average of 2000 to 2002 model years).[18]
2. As an alternative, a manufacturer may (during 2005 or the first year of a three year period) chose to base its ZEV requirement volume upon the phase in of *light-duty trucks*[19]. The light-duty trucks shall be included in the calculation for the ZEV requirement as shown in the table below.[20]

2007	2008	2009	2010	2011	2012+
17%	34%	51%	68%	85%	100%

In this calculation the ZEVs produced by the manufacturer (or by a subsidiary in which the manufacturer has a greater then 50% ownership interest) and delivered for sale in California are excluded.

It is also possible to earn credits by introducing vehicles at a more early point in time than required. Also the credits can partially be obtained by so called PZEVs[21].

The alternative path percentage of large volume manufacturers electing to use the alternative path percentage is calculated as the target number of credits for each time period divided by the

[18] By choosing this calculation method large volume manufacturers must meet at least 20% of the ZEV requirement with ZEVs, advanced technology PZEVs or ZEV credits generated by such vehicles for model years 2005 to 2008. Another 20% has to be met by ZEVs, advanced technology PZEVs, or credits generated by such vehicles. The remainder may be met using PZEVs or credits generated by such vehicles. As the ZEV requirement increases in time the maximum proportion of PZEVs or credits generated by such vehicles is limited to 6%. Advanced technology PZEVs or credits generated by such vehicles may be used to meet up to 50% of the manufacturer's remaining ZEV requirement. For intermediate volume manufacturers in model year 2005 and subsequent model years the ZEV requirement may be met with up to 100% PZEVs or credits generated by such vehicles.

[19] Light-duty truck means a 'LEV II' light-duty truck with a loaded vehicle weight of 3751 pounds to a gross vehicle weight of 8500 pounds, or a 'LEV I' light-duty truck with a loaded vehicle weight of 3751-5750 pounds.

[20] By choosing this calculation method large volume manufacturers must meet at least 40% of the ZEV requirement with ZEVs or advanced technology PZEVs, or credits generated by such vehicles. The remainder may be met using PZEVs or credits generated by such vehicles. As the ZEV requirement increases in time the maximum proportion of PZEVs or credits generated by such vehicles is limited to 6%.

[21] PZEV means any vehicle that is delivered for sale in California and that qualifies for a partial ZEV allowance of at least 0.2.

applicable combined model year ZEV obligation of *all* large volume manufacturers for that same time period, where:

Model years	Target number of alternative path Type III vehicles	Credits per vehicle	Target number of credits	Combined model year ZEV obligation	Alternative path percentage
2005 - 2008	250	40			
2009 - 2011	2,500	4	10,000	A	(10,000/A)* 100
2012 - 2014	25,000	3	75,000	B	(75,000/B)* 100
2015 - 2017	50,000	3	150,000	C	(150,000/C) *100

A = the combined total obligation percentage based on the general ZEV requirement and the phase-in of light-duty trucks for model year 2010.
B = the combined total obligation percentage based on the general ZEV requirement and the phase-in of light-duty trucks for model year 2013.
C = the combined total obligation percentage based on the general ZEV requirement and the phase-in of light-duty trucks for model year 2016.

Production requirement
If a large volume manufacturer elects to subject to the alternative compliance requirement there are some requirements for the number of Type III ZEVs[22] placed in service in California. These requirements are:

Model years	Share of Type III ZEVs, or equivalent number of credits generated by such vehicles to meet the alternative path percentage	Maximum share of Type I* and Type II** ZEVs which may be used
2005-2008	Cumulative percentage of 1.09 percent of the manufacturers annual California sales (as calculated) over the five year period from model years 1997 through 2001	• 50% of the requirement, where 20 Type I or 10 Type II ZEVs equal one Type III ZEV • 1997 - 2003 model year Type I or Type II ZEV still in use also generate credits
2009-2011	Sufficient Type III ZEVs or credits generated to meet the average requirement as calculated for 2010	• 50% of the requirement, where 20 Type I or 10 Type II ZEVs equal one Type III ZEV • 1997 - 2003 model year Type I or Type II ZEV still in use also generate credits
2012-2014	Sufficient Type III ZEVs or credits generated to meet the average requirement as calculated for 2013	• 50% of the requirement, where 10 Type I or 5 Type II ZEVs equal one Type III ZEV
2015-2017	Sufficient Type III ZEVs or credits generated to meet the average requirement as calculated for 2016	• 50% of the requirement, where 10 Type I or 5 Type II ZEVs equal one Type III ZEV

* Type I ZEV is a City Electric Vehicle (range 50 to 100 miles)
** Type II ZEV is a Full Function Electric Vehicle (range 100+ miles)

Credits
The ZEV requirement is linked to a credit system. Each H_2 FC ZEV (Type III ZEVs) produced and delivered for sale will earn an amount of credits as indicated in the table below.

[22] The ZEV regulations refer to a Type III ZEV as a FC electric vehicle

2003	2004	2005	2006	2007	2008	2009	2010	2011	2012+
40	40	40	40	40	40	4	4	4	3

The amount of ZEV and PZEV credits earned by a manufacturer shall be expressed in g/mi NMOG (non-methane organic gas).

A vehicle that is placed in a California advanced technology demonstration program may earn ZEV credits even if it is not 'delivered for sale.' The manufacturer must show that the vehicle will be regularly used in applications appropriate to evaluate issues related to safety, infrastructure, fuel specifications or public education, and for more then 50% of the first year of placement the vehicle will be situated in California.

A manufacturer may meet the ZEV requirement in any model year by submitting the amount of g/mi ZEV credits. Credits may be earned or acquired from another party.

A manufacturer shall equalize debits within the specified time period otherwise the Health and Security Code section 43211 penalty shall apply for the number of vehicles that do not meet the ZEV standard for the model year in which the debits were first incurred.

All the Type III vehicles placed in service in California may be counted towards the percentage ZEV requirements of any state that is administering the California ZEV requirements[23].

[23] States that also administer the California ZEV requirement are Massachusetts, New York, Vermont, Rhode Island, Connecticut, New Jersey, and Maine