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The Policy Framework for the Promotion of Hydrogen and Fuel Cells in Europe: a Critical Assessment*

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BEEP briefing n° 19

September 2008

* The research for this BEEP was partly funded by the EU as part of the Integrated Project "Roads2HyCom"; see for further information www.roads2hy.com.
This publication does not necessarily represent the views of the European Commission.
Valuable comments were received from, inter alia, Per Dannemand, Anne Nygaard, Marcel Weeda, Robert Steinberger, Nick Owen.

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Abstract

This paper reviews the current EU policy framework in view of its impact on hydrogen and fuel cell development. It screens EU energy policies, EU regulatory policies and EU spending policies. Key questions addressed are as follows: To what extent is the current policy framework conducive to hydrogen and fuel cell development? What barriers and inconsistencies can be identified? How can policies potentially promote hydrogen and fuel cells in Europe, taking into account the complex evolution of such a disruptive technology? How should the EU policy framework be reformed in view of a strengthened and more coherent approach?

The paper concludes that the current EU policy framework does not hinder hydrogen development. Yet it does not constitute a strong push factor either. EU energy policies have the strongest impact on hydrogen and fuel cell development even though their potential is still underexploited. Regulatory policies have a weak but positive impact on hydrogen. EU spending policies show some inconsistencies. However, the large scale market development of hydrogen and fuel cells will require a new policy approach which comprises technology specific support as well as a supportive policy framework with a special regional dimension.

Keywords: energy policy, innovation, hydrogen

JEL codes: Q42, Q2, Q55, L51

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1. Introduction

The introduction of hydrogen in Europe's energy system - as envisaged by the Hydrogen Deployment Strategy and the Implementation Plan (Hydrogen and Fuel Cell Technology Platform, 2007) - will constitute a major change based upon a disruptive technological innovation. As hydrogen can be a carbon neutral means to substitute fossil fuels, the European Commission – in line with governments worldwide - regards its further development and market introduction as desirable (EC, 2007a). However, hydrogen cannot compete yet with incumbent technologies and is still in its early stage of market introduction.

The following paper takes on the well-established argument that in early phases of business development and market introduction innovations need a technology specific support scheme. Without such a specific support scheme, lock-in effects of prevailing technologies (Arthur, 1989; David, 1985) provide incentives to incremental innovation only, along existing trajectories and, thus disruptive technologies such as hydrogen cannot emerge. The dominance of prevailing technologies, path dependencies, the risks of being entrapped in a large technological system (Walker, 2000), potential diseconomies of scale (Isoard/Soria, 2001), and the necessity to reach at least a critical mass of production legitimise tailor-made support schemes for hydrogen.

It is important to acknowledge however that due to its distinct characteristics hydrogen needs a more complex support scheme than renewables (Ros et al., 2007; Roads2HyCom, 2008). At least three elements constitute the disruptive character of hydrogen and fuel cells from a policy-related point of view:

1. As hydrogen is an energy carrier (and not an energy source such as wind) it not only needs infrastructure for its production but also for its distribution.
2. Unlike biofuels that can be blended into conventional gasoline or diesel fuels or renewable energy which can be fed into the electricity grid, hydrogen needs to be made compatible with the existing energy infrastructure.
3. The overall performance of hydrogen and fuel cells relies on some weak links such as storage technology where technological progress is crucial.

For those reasons it is unlikely that support and incentive systems that have proven to be successful for renewable energies will be sufficient for the deployment of hydrogen and fuel cells.

We argue that hydrogen requires a comprehensive support scheme which bridges the gap between the three dimensions of (a) market requirements, (b) sustainability/ climate requirements and (c) hydrogen technology development. Such a comprehensive support scheme will have to balance strategic deployment on the one hand and openness and flexibility on the other – a balance which has been discussed with regard to governance and economic policy by Bleischwitz (2007) and Metcalfe (2003). Our paper undertakes a screening of the existing EU policy framework with the aim of an impact analysis towards the development and market introduction of hydrogen and fuel cells. It seeks to identify barriers as well as inconsistencies and side effects that hinder the envisaged uptake of a hydrogen economy in Europe. This is important because in European Member States the policy framework depends to a large part upon the EU level with increasing importance of EU regulation (Pelkmans, 2006).

The EU sets targets for its Member States with regard to energy efficiency or the share of renewable energy in electricity production; it regulates the emission trading system (ETS) and partly also the European markets for gas and electricity.

It sets minimum levels for energy taxation and subsidises energy technologies through its regional funds and research projects. Shedding light on the impact of current EU policies thus is important for future hydrogen and fuel cell development in Europe as well as in other regions. Our approach thus complements research on how policies shape technological change towards sustainable energy, which has been done as ex-post evaluation of US experiences (Norberg-Bohm, 2000), of renewable energy sources in Germany, Sweden and the Netherlands (Jacobsson/ Bergek, 2004) and of energy-efficiency technologies (Grubb/Ulph, 2002).

The paper is organised as follows. Section 2 analyses EU *energy* policies for they have a direct impact on hydrogen and fuel cells as well as on competing technologies (ETS, energy efficiency, renewables). Section 3 deals with *regulatory* policies; those are not directly related to hydrogen and fuel cells but have the potential to hinder or promote the development of these technologies (energy taxation, liberalisation of the internal market for gas and electricity). Section 4 analyzes EU *spending* policies asking whether they might constitute a push factor for hydrogen and fuel cell development. Finally, section 5 draws *conclusions* and gives recommendations for an enhanced policy framework.

2. EU energy policies

Since its early beginning in post-war Europe energy has always played a prominent role in the European integration process. Two of the three founding treaties established organisations which dealt with energy supply: the European Coal and Steel Community (1951) and the European Atomic Energy Community (1957). In recent years, new policies have emerged as a response to climate change (Lechtenböhmer et al., 2005; Pelkmans, 2006). The EU now has substantive power in several fields which are of direct relevance for hydrogen and fuel cell development.

2.1. Energy efficiency policies

Energy efficiency (EE) regulations are normally designed to decrease the energy intensity of an economy, i.e. to minimise "the amount of energy used per unit GDP" (IEA,1987). As fuel cells when used with hydrogen are relatively energy efficient (compared with traditional gasoline powered internal combustion engines), legislation on EE may indirectly favour the development and market introduction of fuel cells.

Since 2000, the Community has adopted several measures in the field of EE. Many legal instruments concern specific sectors such as buildings and the labelling of precisely defined products such as household appliances or electric ovens. Two relatively recent directives are already rather encompassing in their scope and set a framework for nearly all sectors:

- The directive on energy end-use efficiency and energy services of 2005 sets the target that every member state must on average improve by 1% its EE every year. These targets are indicative. The Member States are relatively free to choose the instruments by which they want to reach these goals (EC, 2006a).
- In 2005, the EU also adopted a directive on the ecodesign of energy-using products. This directive applies in principle to any energy using product and aims to improve EE in the whole life cycle of the product. The text provides for EE standards and requirements for every stage of the production beginning with the early design phase. The text itself does not set any binding targets (EC, 2005a).

Some legal texts refer explicitly to fuel cells. For instance, the EU directive on combined heat and power mentions them as a cogeneration technology (EC, 2004). However, even when fuel cells are not directly mentioned in EU directives, the latter can still have great impact on their market introduction. The before mentioned eco-design directive sets a framework for *all* energy-using products (except for vehicles for transport) which therefore also concerns fuel cells. In fact, progress in fuel cell technology in some specific areas like small appliances has the potential to further the development of fuel cells in other areas too, such as transport.

One should note, however, that standards need to be set with a mid term perspective in order to go beyond incremental improvements and to attract financing for the fuel cell business which is SME based (Jacob et al., 2005).

In the coming years the EU is very likely to adopt more ambitious legislation in the field of EE. At its summit of March 2007, the EU has agreed on the target to save “20% of its energy consumption compared to projections for 2020” (EC, 2007b).

According to EU estimates already half of this energy savings target could be reached if the existing legislation was well implemented and the promotional and dissemination activities reached out to a high number of energy consumers. However, to reach the remaining 10%, the Community will need to adopt and implement new legislation (EC 2005b) – which may facilitate the market introduction of fuel cells assuming that a long term perspective beyond 2020 is taken into account.

With regard to further EE legislation it is interesting to see that energy consumption has grown between 1990 and 2004 mainly in two sectors and is expected to continue to grow in future: electricity consumption (households and services demand more electricity) and transport (freight and passenger transport). In the latter, there have so far been relatively little EE improvements (IEA, 2007).

Consequently, the European Commission has proposed relatively ambitious targets for the reduction of future *transport emissions*. Its proposal stipulates that by 2012 the average emissions of new cars sold in the EU shall not exceed 120g CO_2/km (EC, 2007c). Given that in 2004 the average emissions of new sold cars amounted to 163g CO_2/km, the proposal in its current form would force car producers to make drastic cuts in emissions and consequently substantial improvements in EE. However, this proposal is still to be discussed in the Council and the European Parliament. Its content may thus be altered.

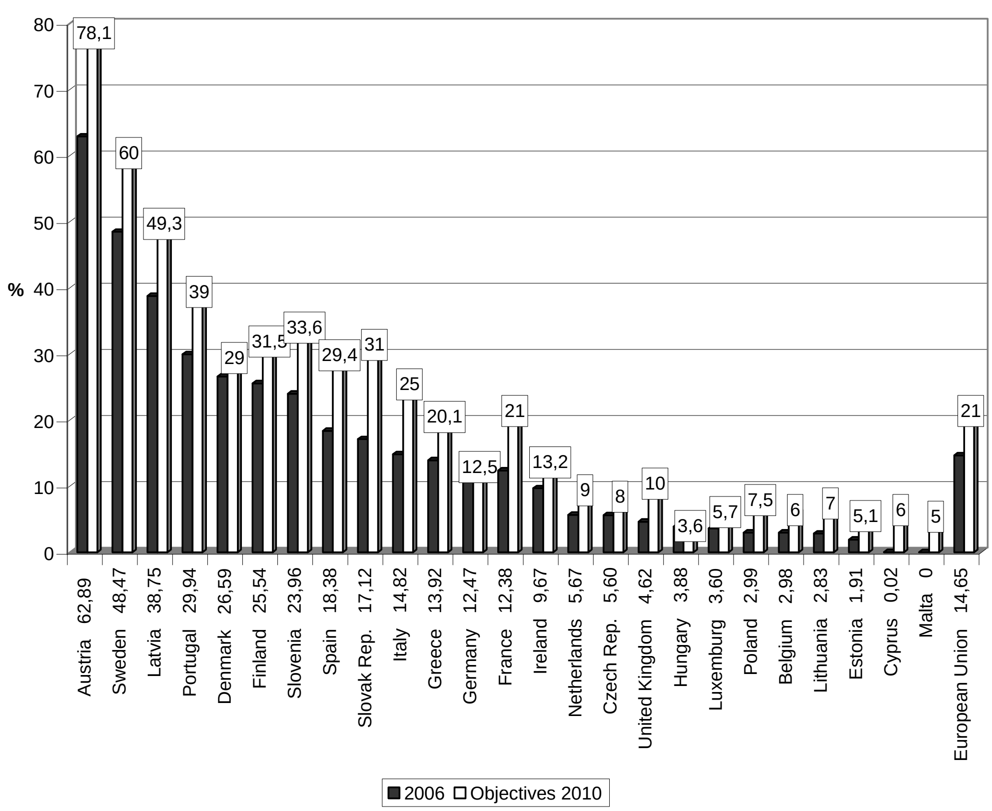
To conclude, the EU has been relatively active in the field of EE in recent years. Moreover, new legislation will need to be adopted if the union is to reach its 20% goal by 2020 (Lechtenböhmer et al. 2005; Business Europe 2007). This development can benefit hydrogen and fuel cells which can be important means for reaching higher EE standards especially if a perspective beyond 2020 is taken. If any cost benefit analysis would focus on ‘low hanging fruits’ and not take into account possible positive alternatives after the year 2020, hydrogen and fuel cells may not be considered a priority.

It is thus not only uncertain whether the EU rhetoric will be followed by new legislation and effective implementation at the national level but also what impact on hydrogen and fuel cells this may have. Looking ahead one may also conclude that EE policy may become a powerful tool for fostering hydrogen and fuel cells in areas where the potential for market penetration is huge (mobile applications, auxiliary power, see Fri, 2003, p. 70 on that aspect of any disruptive technology) and where the environmental pressure to act facilitates actions (e.g. public busses for urban areas).

2.2. Renewable energy policies

Hydrogen is only as green as its energy source. As long as it is produced via gas reforming or via electrolysis based on carbon intensive electricity, it will not significantly curb carbon emissions (Heiman/ Solomon, 2007). The penetration of renewable energy sources in the European energy system is therefore a precondition for the sustainable use of hydrogen. The EU set in 2001 the target of a 21% renewable energy share of total electricity consumption by 2010 (Directive 2001/77/EC). This follows a target set in 1997: increasing the share of renewable energy sources to 12% of gross energy consumption. The current status of renewable electricity production is shown in Figure 1, demonstrating implementation deficits in some Member States.

Figure 1. Share of renewable energies in gross electricity consumption in EU Member States in 2006.



Source: EurObserv'er, 2007

Based on current predictions, it seems very unlikely that the 12% target of primary energy consumption or the target of a 21% share in electricity consumption can be reached by 2010 (EurObserv'Er 2007, p. 73). However, at the EU Summit in March 2007, the EU leaders set the future threshold even higher agreeing to meet 20% of their overall energy needs by the use of renewable energy by 2020.

This shows that the EU does not lack the ambition to increase the share of renewable energies. It has clearly stated its will to do so. However, it clearly shows deficits in the *implementation* of its goals. Thus, the EU will probably fail with regard to its targets for 2010. One of the essential conditions of 'green' hydrogen production is thus currently unlikely of being fulfilled. Yet, the example of Germany which is four years ahead of its schedule shows that with proper incentives – basically with remuneration fees providing certainty about production costs – the EU targets may be reached.

The conclusions for our paper is that the EU will have to better monitor the implementation of the renewables objectives at Member State level in order to comply with its ambitious targets for 2010 and 2020. This will also require dissemination and harmonisation of those support mechanisms that have proven to be successful (Jansen et. al., 2005). It is difficult to imagine that the EU will be in excess of renewable energies by 2020 that can be utilised to produce hydrogen on a large scale. Overcapacities may emerge in some regions (e.g. electric hydropower, windmills in Denmark, on islands or offshore). This has two implications: Firstly, synergies between renewable energies, electricity systems and hydrogen shall be exploited and, secondly, at least for a transition period other options to produce hydrogen (such as by-production in chemical industry or gas reforming) seem more realistic (Steinberger-Wilckens and Truemper, 2007; Ros et al. 2007).

2.3. The Emission Trading System

Emission trading is one of the so-called Kyoto mechanisms to implement the reduction of GHGs. According to economic theory an ETS reduces the costs of reaching a specific emissions target by taking advantage of different marginal abatement costs of the participating actors. Cost savings are particularly big if mitigation costs differ significantly between sources covered by the scheme. The cost differences create an incentive to trade.

Given that hydrogen production can be done via fossil fuels, the specific mechanisms of the EU ETS are of great importance for its future market price.

The European Emissions Trading Scheme (EU ETS) started on 1st January 2005 based on the Directive 2003/87/EC (Bleischwitz et al., 2007). The scheme specifies two periods, the first from 2005-2007 and the second corresponding to the first commitment period of the Kyoto Protocol from 2008-2012. It is a cap and trade system which was initially only focussed on CO_2. Its implementation will, however, take place in different phases with reviews and possibilities for its extension to additional gases and sectors.

The ETS currently applies to combustion installations with a rated thermal input above 20MW, mineral oil refineries, coke ovens, iron and steel production, cement production and pulp and paper production. Around 12000 installations take part in the system which covers about 45% of total EU CO_2 emissions.

With regard to hydrogen the main question is to what extent the EU ETS encourages a shift of investments towards more sustainable energy supply systems, including disruptive technologies such as hydrogen and fuel cells. Existing analysis reveals that the ETS partly encourages the uptake of climate-friendly technologies by rewarding businesses investing in energy efficiency and some green technologies turning their investments into quick, short term profits. But given the uncertainties about the development of hydrogen and fuel cells as well as other more disruptive sustainable technologies, the ETS can hardly encourage investments into long term solutions. The risk of sunk costs, as well as the coordination costs for many investors is still too high (Mc Kinsey and Ecofys, 2005; Endres and Ohl, 2005). This is aggravated by the limited playing field of the ETS: the automobile industry and oil industry are not covered by the EU ETS. Surrounded by those constraints, the EU ETS in its current form does not yet provide enough incentives to embark on new sustainable technologies such as hydrogen and fuel cells.

Instead of setting incentives for hydrogen development, the ETS might at some point even hinder its development. The ETS may in future apply also to hydrogen production.

In its communication "20 20 by 2020, Europe's climate change opportunity" of January 2008 the Commission proposes a major reform of the ETS (EC 2008a):

- the ETS should apply to all important industrial emitters;
- GHGs other than CO_2 should be included in the ETS;
- from 2013 onwards the whole power sector should be part of the ETS;
- EU wide auctioning of allowances should replace the national allocation plans which are currently in place;
- Member States should use at least 20% of their auctioning gain for investment in energy research, technology development and other greenhouse gas (GHG) reducing measures.

If a reformed ETS applied to all industrial emitters, hydrogen production (e.g. in chemical industry) would then most likely fall under it too. Without specific provisions for the advantages of hydrogen on a life-cycle basis, the ETS would thus hinder (GHG intensive) hydrogen production. In contrast, options to facilitate the market introduction of hydrogen and fuel cells are as follows: Processes for hydrogen production could be exempted from the ETS whereas nearly all other industrial emitters may be included. However, GHG intensive hydrogen production should only be exempted from the ETS for a certain time period needed to develop a market. Once a market for hydrogen and fuel cells exist, hydrogen production should be included in the ETS to promote less GHG intensive production processes.

The allocation mechanism may on the other hand be supportive to the hydrogen economy. A company producing hydrogen at certain standards may be entitled to additional free allowances ('grandfathering'), taking into account the GHG reduction via the application of hydrogen. As a complementary mechanism, the funds from auctioning allowances may also be used for the market introduction of hydrogen and fuel cells. Of course, those proposals suppose that the prices for CO_2 allowances rise, meet expectations to rise further and thus set incentives for long term investment in new energy solutions.

3. EU regulatory policies

The EU level also impacts on some regulatory policies. Given that some of these policies may influence the price of hydrogen they can be seen as an essential part of the EU policy framework for hydrogen promotion. In the following our paper will thus analyze the EU policy in the field of energy taxation and the liberalisation of the gas and electricity market

3.1. Taxation

Green taxation has received much academic attention in recent years. Several studies have shown the effectiveness of environmental taxes and emphasise that there still is potential for better and wider use of these Instruments (Glomm et al., 2008; Görres and Cottrell, 2008; OECD, 2006). Energy taxation in particular can be an effective instrument of influencing demand if well applied and combined with other instruments (Berkhout et al., 2004).

The main EU instrument in the field of fuel taxation is the Council directive 2003/96/EC aiming at "restructuring the Community framework for the taxation of energy products and electricity". Before the entry into force of this directive, EC minimum tax rates applied only to mineral oils. The rationale for this directive thus has been to apply minimum taxation also to electricity, coal and natural gas and to reduce distortions of the internal market due to different tax rates.

The directive sets out minimum levels of taxation for energy products. The tax is paid by whoever purchases the energy product in question and not by the producer. Electricity consumed in the production of electricity, so-called on-site consumption is exempted from the directive (EC, 2003a).

The final shape of the Directive which entered into force on 1 January 2004 is characterised by Hasselknippe and Christiansen (2003) as follows:

- new minimum rates are to be set at the latest by 1 January 2012 for a new period from 2013 (see Tables 1 and 2);
- the minimum rates are set at a relatively low level (see Tables 1 and 2);

- some energy-intensive industries can benefit from exemptions; the tax rates for business and industry are generally lower than those for other economic actors;
- a return of revenue to companies/industries is possible if they enter into energy efficiency agreements (100% return to energy-intensive industries with agreement, 50% return to other industries).

Table 1. Minimum rates applicable to motor fuels according to the EU energy taxation directive.

-	Minimum excise rates before 2004	Minimum excise rates from 1.1.2004	Minimum excise rates from 1.1.2010
Petrol (/1000 l.)	337	421	421
Unleaded petrol (/1000 l.)	287	359	359
Diesel (/1000 l.)	245	302	330
Kerosene (/1000 l.)	245	302	330
LPG (/1000 l.)	100	125	125
Natural gas	100 (/1 000 kg)	2.6 (/gigajoule)	2.6 (/gigajoule)

Source: EC (2007d)

Table 2. Minimum tax rates applicable to heating fuels and electricity.

-	Minimum excise rates before 2004	Minimum excise rates from 1.1.2004 (business use)	Minimum excise rates from 1.1.2004 (non-business use)
Diesel (/1000 l.)	18	21	21
Heavy fuel oil (/1000 kg.)	13	15	15
Kerosene (/1000 l.)	0	0	0
LPG (/1000 kg.)	0	0	0
Natural gas (/gigajoule)	-	0.15	0.3
Coal and coke (/gigajoule)	-	0.15	0.3
Electricity (/MWh)	-	0.5	1.0

Source: EC (2007d)

Thus, in absence of any European minimum taxation level, Member States have the freedom to opt for the tax rate which they deem most appropriate at national level.

According to a study led by Bocconi University (Chernyavs'ka et al., 2007), hydrogen is not taxed in a specific way in 13 Member States (Belgium, Denmark, Finland, France, Greece, Hungary, Ireland, Italy, Latvia, Luxembourg, Malta, Slovakia, Spain).

Five Member States tax hydrogen when it is used as motor fuel (Austria, Czech Republic, Germany, the Netherlands, United Kingdom). Seven Member States are not included in the study for they did not reply to the research enquiry (Cyprus, Estonia, Finland, Lithuania, Poland, Slovenia, Sweden).

An optimal tax in environmental terms aims at internalising negative externalities. In this respect, it is important to calculate not only the environmental costs of a given fuel at the end use stage but also at the production stage. Currently, hydrogen *production* causes in some cases higher external costs than the production of competing fuels. Hydrogen *use*, on the other hand, produces little or no external costs (GHG emissions) and may substitute other environmentally more harmful fuels and energy carriers. From a systems perspective, there is no overall rationale for taxing hydrogen as long as it contributes to lowering overall environmental pressure of the energy system. However, this assessment depends upon the assumption that hydrogen is produced in a sustainable way, for instance through electrolysis based on renewable energy or gas reforming combined with carbon capture and storage (Chernyavs'ka et al., 2007).

European states which tax hydrogen impose only low rates. Given that currently hydrogen is produced in a conventional way using fossil fuels, the tax level for hydrogen is estimated to lie below a level which would be needed to internalise its total external costs (Chernyavs'ka et al., 2007). The current European tax systems thus put hydrogen in a favourable position. In view of the promotion of hydrogen in Europe, this situation is definitely positive and should be maintained in the coming years. Member States currently taxing hydrogen may also reflect and withdraw from their taxation of hydrogen.

Looking ahead to the envisaged deployment, however, the question of hydrogen taxation must be addressed. When hydrogen applications pass the threshold from early markets to mass markets, a comprehensive framework which promotes sustainable hydrogen production will be needed. It is likely that there will be a trade off between cost-effective production of hydrogen at a large scale via gas reforming processes on the one hand and GHG reduction and the aim to promote clean energies on the other hand.

Assuming that this situation occurs after 2010, the EU will be faced with the dilemma of having to implement its radical GHG commitments (20 % by the year 2020 based upon 1990 levels, more if other nations follow) and large scale production of hydrogen for which gas reforming is the most cost effective option (Ros et al., 2007). Taxation thus needs to be put into the context of long term GHG reduction after 2020 as well as other energy-related goals such as competitiveness and energy security.

3.2. The liberalisation of the internal market for gas and electricity

The liberalisation of the European market for electricity and gas is supposed to strengthen the competitiveness of European firms and improve the efficiency of the energy market (Pelkmans, 2006; Delgado et al., 2007). Consumers should have greater choice of energy suppliers and all energy suppliers should have access to the market, irrespective their market power and the energy source. Thus, also small producers of sustainable energy technologies could better promote their products provided that the price mechanisms reflect the external costs too; such liberalisation policy has e.g. be proven to be effective in the promotion of cogeneration in the UK (Tichy, 2008, p. 27).

However, in its conclusions of 9 March 2007 the Presidency of the Council of the European Union stated that “a truly competitive, interconnected and single Europe-wide internal energy market […] has not yet been achieved” (EC, 2007b). In view of reaching this goal, the Council sees the need to firstly fully implement existing directives. Secondly, further measures that go beyond existing legislation are to be discussed and implemented.

The implementation of existing legislation refers mainly to two 2003 directives, one on the internal market for natural gas, the other on the internal market for electricity:

- the directives stipulate that for non-household customers the markets for electricity and gas must be liberalised by 1 July 2004;
- the respective markets for the remaining customers, above all private households, must be liberalised by 1 July 2007 (EC, 2007e; EC 2007f).

Notwithstanding these already elapsed deadlines, the internal markets for electricity and gas have not yet been fully liberalised and actors still complain about the persistence of entry barriers to the market. Thus, the Commission stated in a sector inquiry of early 2007 that several problems need to be addressed and respective policy responses to be implemented if the liberalisation is to advance (EC, 2007g).

Among the proposed policy responses, unbundling, i.e. “the effective separation of supply and production activities from network operations” has caused particularly heated debate. The Commission furthermore proposes to establish a European “Agency for the Cooperation of Energy Regulators” which would set the framework in which national regulators operate, oversee the cooperation between transmission operators, take decisions concerning cross-border issues and advise the Commission (EC, 2007h). Currently (July 2008) European politicians are debating these proposals of the Commission. Several alternatives to the proposed agency and unbundling are under discussion.

From today’s perspective, it is difficult to see which option may eventually be retained. However, the reform models under discussion are likely to increase competition on European markets for electricity and gas supply and thus lead on the medium term to lower prices - not in absolute terms but relative to a situation without policy change. The liberalisation of the gas and electricity markets may thus have a certain even though not significant influence on the level of the price curve.

The overall price level will also depend on other factors such as impacts from climate policy and international markets for energy fuels. In addition, any active competition policy favouring market entry is also likely to have positive impacts on hydrogen and fuel cell companies (for business development and financing of hydrogen and fuel cell companies see Mönter and Doran, 2007).

At the current price level, hydrogen is not competitive with most energy sources and energy carriers. One might therefore be tempted to conclude that rising energy prices favour hydrogen development as long as only prices of competing energy vectors and sources increase and not that of hydrogen.

However, electricity and gas are two major inputs for hydrogen production. If gas and electricity prices rise, the price for hydrogen rises too. The price for hydrogen is thus dependent upon the gas and electricity price.

In absolute terms, hydrogen will always be more expensive than gas and electricity as long as it is mainly produced via electrolysis and gas reforming.

Yet, the price for gas and electricity may affect the hydrogen production processes. High prices for gas and electricity can be an incentive for further research of alternative ways of hydrogen production, such as biological production.

Analysis is confronted with a different picture if one blanks out hydrogen for stationary use and looks at hydrogen for transport applications only. From an end user perspective hydrogen for transport applications competes mainly with oil. Thus, the price of hydrogen must be compared with the crude oil price. In a scenario where the medium term increase in crude oil prices is higher than the increase in prices for electricity and gas, hydrogen will become more competitive with regard to oil as a transport fuel (Martinot et al., 2007). Any development with a conducive policy framework that renders electricity and gas relatively cheaper with regard to crude oil can therefore be seen as an incentive benefitting the use of hydrogen in transport. Worth to note: competition for the market for clean cars and sustainable mobility will need to be aligned with those policies.

4. EU spending policies

A glance at the EU budget may suffice to highlight the relative importance of spending policies. Out of the 129 billion € which the EU planned to spend in 2008, around 100 billion € were foreseen for the two biggest items on the budget sheet alone: Cohesion and Natural Resources (the latter referring mainly to the Common Agricultural Policy, see Table 3).

In the following EU spending policies will be screened with regard to their possible positive or negative effects on hydrogen and fuel cells.

Table 3. Expenditure estimates for EU policies.

Expenditure estimates for EU policies (in billion €)	Budget 2008	Change from 2007
Sustainable growth	58	5,7%
Competitiveness, including	11,1	18,4%
Education and training	1,0	9,3%
Research	6,1	11,0%
Competitiveness and Innovation	0,4	6,8%
Energy and transport networks	1,9	92,5%
Social policy agenda	0,2	8,0%
Cohesion, including	46,9	3,1%
Convergence	37,0	5,2%
Regional competitiveness and employment	8,6	-5,1%
Territorial cooperation	1,2	2,6%
Natural resources, including	55,0	-1,5%
Environment	0,3	12,0%
Agricultural expenditure and direct aid	40,9	-3,4%
Rural development	12,9	4,5%
Fisheries	0,9	2,2%
Freedom, security and justice	0,7	16,7%
Citizenship	0,6	14,7%
EU as a global player	7,3	7,3%
Administration	7,3	4,4%
Total	129,1	2,2%

Source: EC, 2008b

4.1. Regional policy

The treaty stipulates that the Community should aim for economic and social cohesion. The main policy destined to respond to this challenge is the Community's regional policy. Enshrined in the EC treaty in Maastricht (articles 158-162) it mainly aims to lessen regional disparities. The latter have drastically increased in recent years. The process of European integration and market liberalisation, however, cannot be blamed for social disparity as Pelkmans points out (Pelkmans, 2007). The gap in wealth between poorest and richest regions has mainly increased due to the enlargement of the Union which opened in 2004 its doors to new Member States whose regions sometimes represent only 50% of the average EU wealth (expressed in GDP per capita in PPP). The importance to lessen regional disparities is reflected by the EU budget: the share of regional spending will increase to 36% of total EU spending by 2013 and represent the amount of 308 billion € over the period 2007-2013.

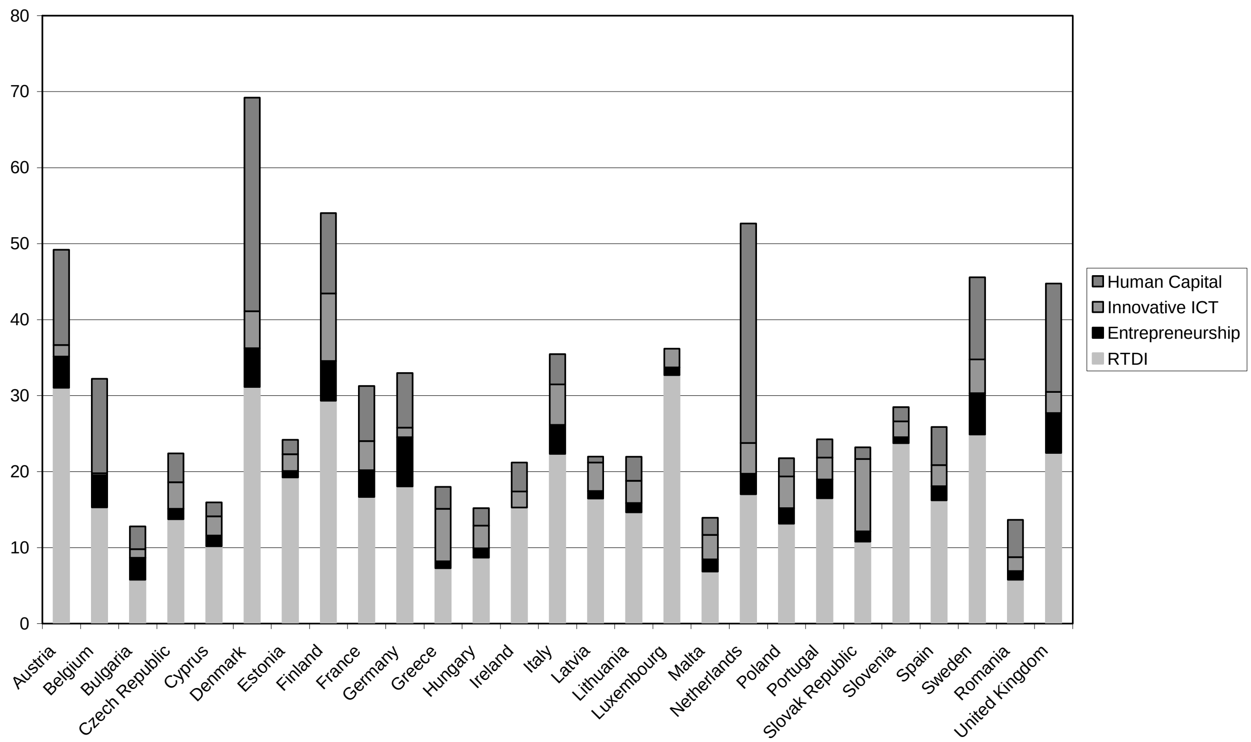
The major part of this amount goes to the poorest regions since only those regions that have a GDP per capita below 75% of the EU average are eligible for all of the three main objectives of regional funding (EC, 2007i). The ensuing spending policy will be of importance for infrastructure investments of the hydrogen and fuel cell economy in Europe (e.g. production and distribution).

In its aim to re-launch the Lisbon strategy and to mobilise all available resources, the Commission has announced to promote growth and employment also through regional policy instruments. Thus, EU regional funding should be concentrated on innovation, research, knowledge and entrepreneurship (EC 2007j) to be sure this enforces a shift from a merely socially oriented policy towards a more forward-looking approach. This shift can potentially benefit to hydrogen and fuel cell development in particular in regions with existing hydrogen by-production and other capacities (see Dannemand/ Nygaard Madsen in this issue).

In the period 2000-2006, 11% of the cohesion spending was dedicated to innovation. For 2007-2013, 25% (85 billion €) of the envelope is planned to be channelled towards innovation. Given that national and private co-financing and additional investment are not yet included, the actual sum will be far greater (EC, 2007j). The role of innovation in the cohesion spending has thus clearly increased in the 2007-2013 financial framework compared with the previous one.

With regard to the three objectives of regional funding, the Convergence objective is allocated by far the greatest financial resources: 282,8 billion € will be available under this heading for the period 2007-2013. Around 61 billion € out of these 282,8 billion € are planned to be spent for innovation which represents nearly 22% of the total allocation. However, only those regions which have a GDP below 75% of the EU average are eligible for Cohesion funding. The most prosperous regions which are in many cases also the most innovative regions are consequently not eligible. Currently 84 regions representing 154 million inhabitants can apply for Cohesion funding.

Figure. 2. Planned investment in innovation 2007-2013 by country (all objectives).



Source: EC, 2007j

The regional level of economic and political governance plays a crucial role in innovation processes (Rodriguez-Pose/ Crescenzi, 2007). It is difficult to assess the effects that the investments in innovation will have on the development of hydrogen and fuel cells. However, innovative regions generally facilitate the adoption of a new, potentially disruptive, technology (Huber, 2004). The Commission defines spending in innovation as spending that falls in one of the following four categories: research and technological development, entrepreneurship, innovative ICT and human capital. The spending for research and technological development (such as the promotion of "environmental-friendly products and processes") is "referred to as innovation in the narrow sense" (2007j). The investment in entrepreneurship (e.g. support for firms and start-ups), innovative ICT and human capital should establish an environment conducive for growth and help to reap the fruits of research activities.

The increased spending for innovative measures can be seen as very positive with regard to hydrogen development. However, it is questionable whether the money is spent in the most effective way. In fact, hydrogen and fuel cells have so far been deployed in relatively innovative regions that dispose of the necessary capital, the political will and technical know-how (see the article of Dannemand and Nygaard Madsen in this issue). Yet, the Commission states itself that “Cohesion policy concentrates its financial support on the poorer regions that are usually included in the group of regions with lower levels of innovation” (2007j). Regions that have already gained some experience with hydrogen and fuel cells and are well placed to pursue their development are often not eligible for the major part of the spending – with a few notable exceptions (e.g. in Spain, Southern Italy or Wales). Regional policy as it has been pursued in the past might be an effective tool to bridge the social gap in Europe. In future, more efforts need to be undertaken to align regional policy with the deployment of hydrogen and fuel cells. The scoping exercice of projects such as Roads2HyCom provide tentative evidence on regions as well as tools that can be used for more in-depth research.

4.2. Biofuels policy

Biofuels are also part of EU energy policies. The reason why they are dealt with in the context of spending policies is the fact that the EU not only sets common targets but also sets financial incentives for biofuels production via the Common Agricultural Policy (CAP) and its regional policy.

In 2003, the EU set the indicative target to increase the share of biofuels in transport to at least 5,75% by 2010. The rationale underlying this target is the assumption that CO_2 emissions in the transport sector might decrease if biofuels partly substitute petrol and diesel (EC, 2003b). According to the Green Paper “Towards a European strategy for the security of energy supply”, the Commission aims on the longer run to increase the share of alternative fuels in transport to 20% by 2020 (EC, 2000). The term “alternative fuels” also includes gas and hydrogen but biofuels will have the main role to play if the Community is to reach this goal. At the EU summit of March 2007, the Council set the target even higher and proclaimed that it aims to reach a 10% share of biofuels in transport by 2020.

In late 2007, the Community was still far away from reaching this objective and it seemed unlikely that the goal of increasing the share of biofuels to 5,75% by 2010 could be reached. A progress report of 2007 shows that for 2010 a share of 4,2% seems more likely. In fact, the EU 25 reached a biofuels share of only 1% in 2005. Yet, other studies, notably the EurOberserv'ER Barometer 2007, estimate that the EU Member States may come close to their targets (EC, 2007k; EurOberserv'ER, 2007).

The 2003 Directive on energy taxation allows Member States to apply reduced excise duty rates to biofuels when those are used in transport or for heating. Many Member States resort to this option to promote biofuels (Bringezu et al., 2007). In addition to the promotion of biofuels by the means of common targets and tax exemptions the EU also supports its production through the CAP. The 1992 reform of the CAP introduced the obligation for farmers to set aside a certain surface of their farm-land. Normally, this land must not be cultivated. Yet, if a farmer produces crops for non-food use he is allowed to resort to the set-aside area. Already in 2005, 0,85 million hectares of set-aside land served for growing oilseeds for biofuel production. Since 2005, also sugar beet for biofuel can be planted on set-aside land (EC, 2006b).

Since 2004 farmers can furthermore benefit from a specific EU premium for energy crops of up to 45 Euros per hectare. This incentive has worked so well that the area where energy crops eligible for this funding were grown increased from 0,31 million hectares in 2004 to 2,84 million hectares in 2007. The funding per hectare has since then been decreased because the budget ceiling for this instrument (90 million Euros per year) was reached (EC, 2007l).The EU furthermore supports investment and training in biofuels via its Regional Development Fund and its Rural Development policy (EC, 2006b).

With regard to its effect on hydrogen and fuel cells the promotion of biofuels may facilitate the shift away from oil. Biofuels are a relatively rapid answer to the growing concern about security of supply, can be blended up to a certain degree with traditional fossil fuels, are easily to introduce (no special infrastructure needed) and might compensate for relative shortages of oil.

Exactly because of these advantages, biofuels can become a rival for hydrogen, at least in the mid term until 2020. However, it is questionable whether biofuels can be a sustainable response to the global energy challenges. First, they will not be able to fully substitute for fossil fuels since the global production capacities are limited by the land available and by shortages in other production factors. Second, it is questionable whether biofuels have such a good environmental footprint as its supporters claim – there is increasing evidence of negative environmental impacts (Bringezu et al. 2007; Patzek, 2007; House of Commons, 2008). In this respect hydrogen performs clearly better, at least hydrogen produced from renewable energy sources. Aligning biofuels policy with concerns about sustainable energy, the deployment of hydrogen and fuel cells and attempts to promote rural development thus will become a major challenge for the next years.

5. Conclusions and proposals for further policy research

The analysis of EU policy impacts on the development of hydrogen and fuel cells has yielded different results.

1) EU energy policies have developed strong push factors towards more sustainable technologies. The ETS, energy efficiency or renewables promotion – all these policy instruments also have some positive impact on hydrogen and fuel cells since they constitute a framework for sustainable energy production and use. However, these push factors are too weak to lead to the deployment of hydrogen and fuel cells because of, firstly, lacking incentives towards long term investments in sustainable technologies and, secondly, inconsistencies and negative side-effects within existing instruments that lead to distortions in hydrogen and fuel cell markets across Europe.

2) Current regulatory policies tend to have a weak but positive impact on hydrogen. In most EU Member States hydrogen is exempted from any taxation or taxed at relatively low rates. Thus taxation currently favours hydrogen over competing technologies.

Yet, the EU cannot be credited with this situation since hydrogen is not explicitly mentioned in the directive on minimum taxation nor has the EU strong competence in the field of taxation. The effects of the liberalisation of the market for gas and electricity seem to be relatively weak. Nonetheless, they are positive and may in general favour the market entry of hydrogen and fuel cells and in particular the use of hydrogen in transport.

3) EU spending policies are a potentially powerful policy instrument for the regional promotion of sustainable technologies and infrastructure since they can channel funds towards them. However, this potential is currently not fully exploited. The analysis of regional policy yields a mixed result. On the one hand more regional funding has recently been directed towards innovation, a field closely related to hydrogen and fuel cells. On the other hand, cohesion funding normally does not apply to those regions which are the most innovative and the most advanced in the field of hydrogen and fuel cells. The CAP as the second big EU spending policy does not favour hydrogen or fuel cells. On the contrary it promotes biofuels which may on the long term compete with hydrogen and thus indirectly hinder its development.

Looking ahead the current policy framework at EU level does not set clear long term signals and lacks incentives that are strong enough to facilitate high investment in and deployment of sustainable energy technologies. The likely overall effect thus seems to be too weak to enable the EU hydrogen and fuel cell deployment strategy. According to our analysis an enhanced EU policy framework pushing for sustainability in general and the development of hydrogen and fuel cells in particular should meet the following key requirements:

1) A strong EU energy policy with credible long term targets: The European governments have given their commitments for a strong reduction in GHG. However, the implementation must be improved and requires additional action. This implies for example higher carbon prices that set clear investment signals, higher energy efficiency requirements and a more ambitious implementation of renewable energy targets at national level.

In additon, targets for the years 2030-2040-2050 need to be formulated and aligned with the hydrogen and fuel cell deployment strategy (see also Jacobssen/Bergek, 2004, p. 840 on the importance of long time scales to transform the energy sector).

2) Better coordination of EU policies: Europe needs a common understanding of key taxation concepts (green taxation, internalisation of externalities) and a common approach for the market introduction of new energy technologies. This requires more harmonisation of tax systems, codes and standards. Hydrogen could for a certain period be exempted from any taxation to promote its development. In the mid to long run when mass markets for hydrogen are forming, it will however become rational to include hydrogen in any minimum taxation Directive or to reform this system taking into account the total external costs of the life cycle of respective energy products. However, policy consistency is of great importance in this respect. If hydrogen utilisation is exempted from any taxation then its production should be part of the ETS. Liberalisation of the gas and electricity markets should be pursued in order to relatively decrease prices and guarantee market access also to small producers of renewable energy sources. Entrepreneurs and SMEs in hydrogen and fuel cell sector should get better access to financing, for example through a European trust fund. The sustainability impact of spending policies furthermore needs to be increased: Setting up a distribution infrastructure for hydrogen and fuel cells will be facilitated if active regions in the field of hydrogen and fuel cells become eligible for the main regional funds.

3) Regions that dispose of strong clusters in hydrogen and fuel cell related areas can further advance the market introduction and establish a first hydrogen infrastructure. Later on the first emerging hydrogen communities could be interconnected to create a wider hydrogen infrastructure in Europe. The EU can support these efforts and play a coordinating role (for the regional perspective see Dannemand and Nygaard Madsen in this issue).

Long term policies need to be adaptive and open to technological change. Alternative developments e.g. battery technology are crucial for the patterns of a hydrogen inclusive economy (Larsen and Höjer, 2007; Macario, 2007). In the short and medium term other technologies may well be more promising than hydrogen and fuel cells. Plug-in hybrid cars are for instance already commercialised in Europe and North America and are expected to highly increase their market share in the coming decade (Wyman, 2008) – it is far from being clear how hydrogen and fuel cells will perform in comparison to these technologies. In the end, this clearly points out the need for a more in depth-research on a comprehensive long term policy framework that induces and enables sustainable energy systems and other eco-innovations.

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