Raimund Bleischwitz / Nikolas Bader, January 30, 08

Pathways towards Hydrogen Communities

Introduction

System innovations take place at different institutional levels. Our contribution assesses the ability of the European level to promote system innovation by encouraging R&D activities, demonstration projects, networks etc as well as its economic policies that might facilitate those efforts. Empirical evidence is gained from the emerging hydrogen economy (www.roads2hy.com)[1] since hydrogen certainly can be regarded a potential system innovation. Furthermore, many research and demonstration projects on hydrogen and fuel cells will run out in the coming years. Thus, the time now seems right for an assessment of what might happen after first demonstration projects have been carried out.

The following study takes on the issue of political and socio-economic conditions for the hydrogen economy as part of a future low carbon society in Europe. It follows the well-established argument that in early phases of business development and market introduction innovative products need a technology specific support scheme. Without such specific support scheme, lock-in effects of prevailing technologies (Arthur 1989) will lead to incremental innovation only and have an advantage over disruptive technologies such as hydrogen. Path dependencies, the risk of being entrapped in a large technological system, lock-in effects of prevailing technologies (Walker 2000), and the necessity to reach at least a critical mass of production legitimize tailor-made support schemes for hydrogen.

It is our hypothesis that traditional support schemes for renewable energies (i.e. technology specific support schemes and beneficial framework conditions) will not be sufficient to pave the way towards a hydrogen inclusive economy. Hydrogen will need a specific support scheme which will be referred to as a "third approach". Our study explains why a third approach is needed for hydrogen and indicates some of its fundamental pillars. However, detailed policy recommendations for a third approach will not be given as this would be beyond the scope of this study.

[1] The authors of this paper are both involved in the FP6 research project www.roads2hy.com; the findings presented here are to a large part based on the research done by their colleagues and themselves in this project. The authors work at the College of Europe in Bruges.

Our study is based on the concept of "Hydrogen Communities". In fact, a policy framework which aims at promoting hydrogen in Europe must respond to the needs and possible development paths of Communities as early adopters. Thus, the study of the Community dimension will lead to the European dimension and the respective policy framework. Conclusions for transition management will be drawn and the main elements of a third approach will be sketched.

The Community Dimension

Communities are defined as a group of stakeholders in a local setting having developed (or in the process of developing) a series of coordinated projects in the hydrogen and fuel cell areas, with a view to deploying hydrogen and fuel cell technologies while practically meeting end-user needs.

In practice such Communities could be regions, cities, remote locations (such as islands) or self-contained entities (airports, seaports, industrial complexes, etc). In a hydrogen community, hydrogen plays a significant role as an energy vector. Communities usually have their own set of institutions and network of actors at the micro level (both formal and informal), but they are also linked to the meso level (regional activities, industrial sectors, value chains) as well as to the macro level (national systems, EU or supranational level).

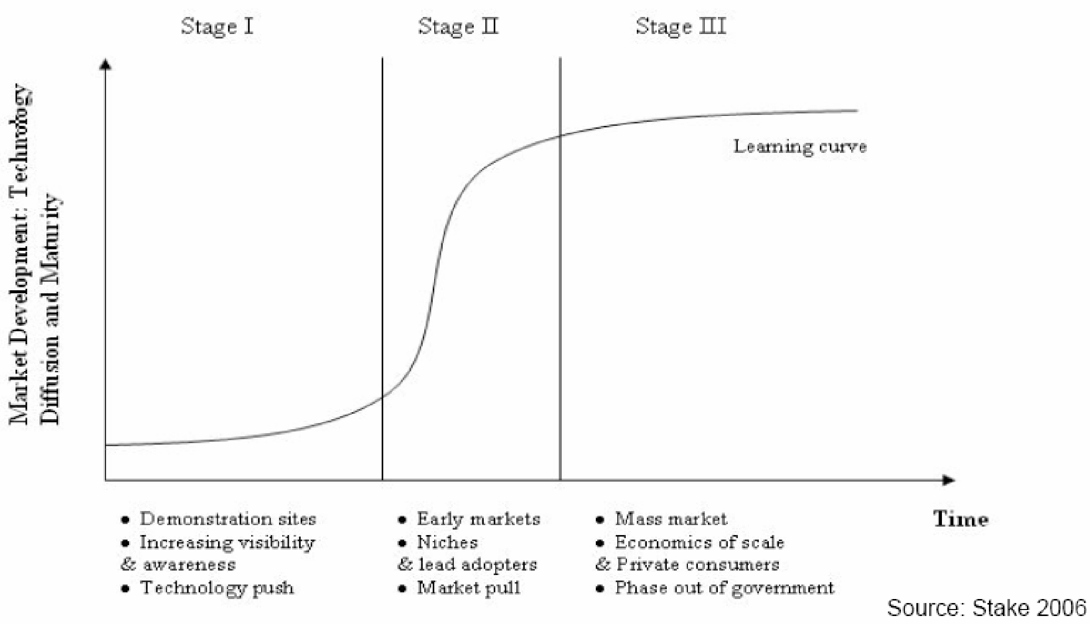
A community might be part of a regional innovation system, but is likely to be smaller and not yet fully connected to other activities in regions. Thus, the question of how communities take off and connect to regional innovation systems will be crucial for success or failure. To some extent, a community can be considered a 'not yet regional innovation system'. The notion stems from innovation research on demonstration projects where often those projects run well, but cannot be continued and extended as intended before.

For several reasons communities are of great importance for the development of a possible hydrogen economy:

- Demonstration projects usually start at community level
- Clusters and networks often start off at community level. There is good evidence from growth theories that communities (incl. regions) act as engines of economic development (Porter 2003)

- Some successful communities might develop as a first larger lead market for other communities to follow
- Hydrogen distribution can be done economically if communities become larger and interconnected. Identifying suitable regions throughout Europe will lower the set-up costs for hydrogen infrastructure (as for other energy carriers).
- Hydrogen lighthouses will need to have a community relation – at least for a considerable number of lighthouses.
- Hydrogen/environmental technology communities seem to be mostly embedded in regions that are in general regarded as innovative

Technology diffusion and learning is reflected by a curve which can be subdivided in three stages (see graph below). Hydrogen communities matter most in stage two of this curve. In fact, after learning through demonstration projects has yielded a first technological push (stage one), early markets are forming which might eventually lead to a market pull (stage two). These early and niche markets will have a community dimension. Infrastructure investments and early adoption of hydrogen is indeed so costly that a full countrywide deployment of hydrogen technologies in a short time period seems impossible. Thus, communities will constitute the first markets and testing sites for hydrogen deployment.



Variety and Selection of Hydrogen Communities

Variety refers to the variety of communities throughout Europe which necessarily arise because of different types of demonstration projects and different conditions within communities. In late 2007, 96 potential hydrogen community projects were to be counted in Europe. A majority of these projects are oriented towards multiple applications (such as transport/stationary/mobile applications) and end-use sectors (Mazzuccheli/Shaw 2007). Communities thus can be seen as a laboratory necessary to test the feasibility of sustainability technologies towards system innovation.

Later on however a *selection* needs to be made and communities will have to adapt. The question is how these selection processes work given that competition still is in a very premature stage when system innovation starts and that other criteria (positive externalities, sustainability potential) might be needed too.

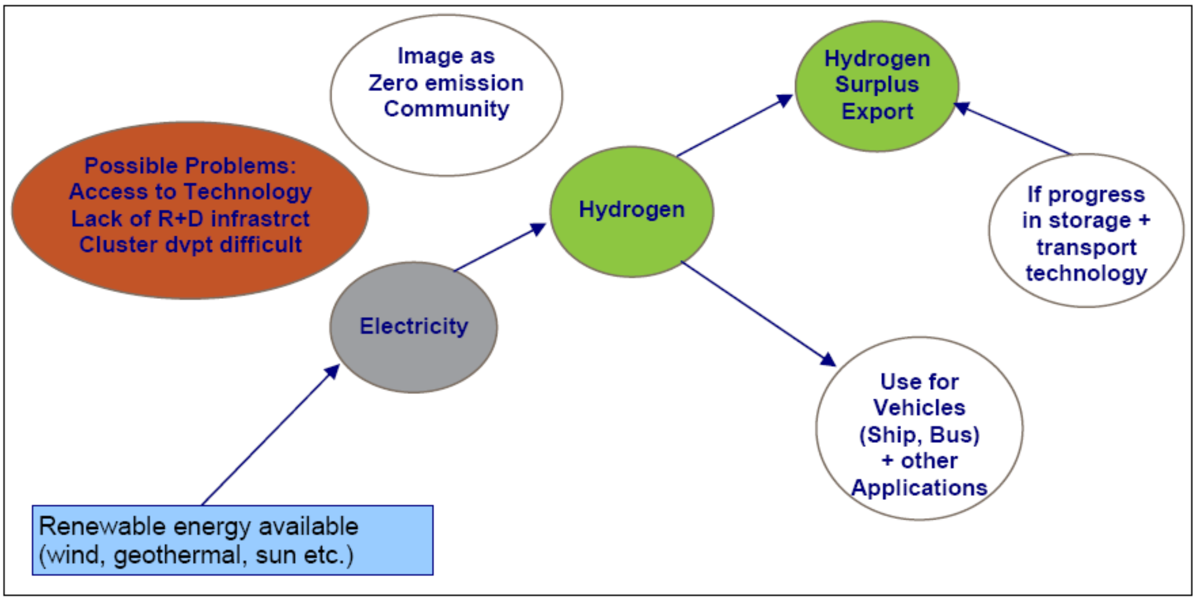
In this context assessment criteria are needed. “Assessment” means a tool for an external assessment (e.g. for further funding) taking into account the different abilities of communities to perform well. These assessment criteria will be used in the selection process when policy makers, public administrations and financial markets are involved.

Potential development paths with regard to community type have insofar to be taken into account for assessment as hydrogen communities are located in very different geographic areas (cities, islands or industrial area). A Hydrogen community on an island faces different problems and has different assets than a hydrogen city. Community successes therefore need to be analyzed against the background of their specific development paths and the respective regional innovation system.

A rural community or an island community may for example have the advantage of being exposed to wind or heat. Moreover, these communities normally have enough space to deploy renewable energy technologies such as wind power plants, geothermal or solar technologies. These renewable energy sources constitute a big asset for Hydrogen development. In fact, hydrogen is today very often produced through gas reforming which is a carbon emitting process. Yet, hydrogen should be produced, at least on the long run, in a less carbon intensive and preferably carbon free way. The electricity produced by renewable energy sources on islands and in rural areas can serve as a means to produce hydrogen via electrolysis which would be almost carbon free. The community could thus not only benefit from the image as a zero emission community. It may furthermore become independent upon the supply of fossil fuels if it disposes of abundant renewable energy sources. Iceland for instance has launched hydrogen and fuel cell projects in view of becoming independent of fossil fuel imports and to power its ships and vehicles with a new energy carrier.

Islands and rural areas have the advantage of sustainable hydrogen production. Yet, they often lack expertise in the field of research. Access to technology can be difficult and very costly due to their remote geographical location. Thus, cluster development may be more difficult than in a city or a region with strong industry and research facilities.

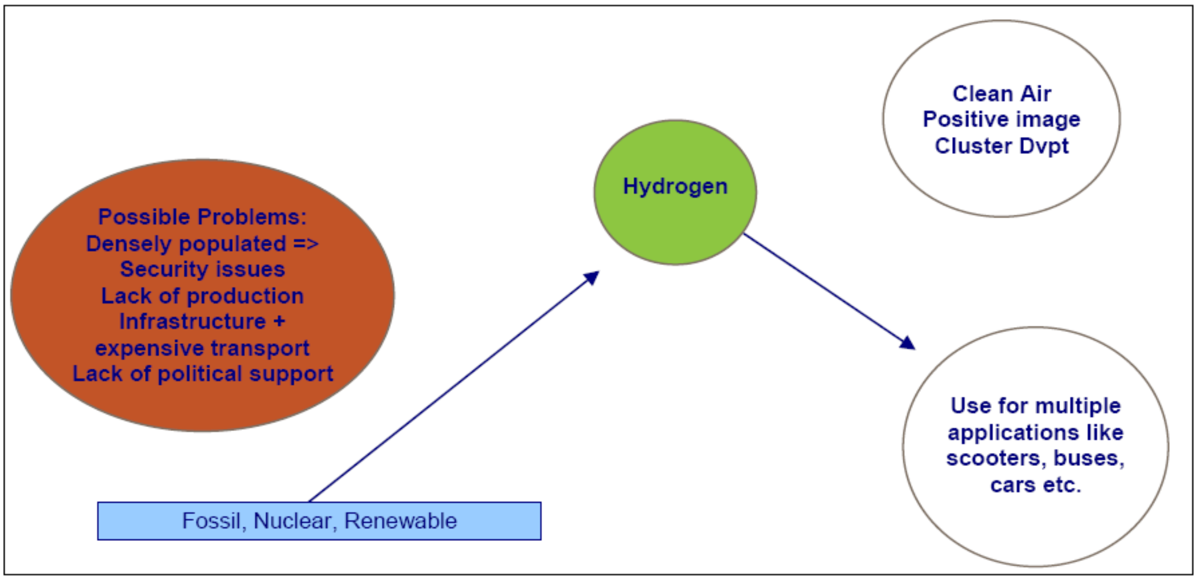
Simplified sketch of a possible development path for community type *island and rural areas*



If we consider the possible development path of a city, we will come to different results. Cities normally do not have the potential of developing abundant renewable energy sources. In most cases, cities will rely on an energy mix which includes also carbon intensive energy sources such as coal or gas. Thus, it will be difficult for cities to produce hydrogen in a carbon free way. However, cities have the possibility to introduce hydrogen bit by bit in their energy system. Hydrogen for transport applications typically takes off on sites where vehicles are used only in a restricted area. In fact, hydrogen transport necessitates a completely new infrastructure with refuelling stations all around the country. The construction of such an infrastructure is not only very costly but also time consuming. The first applications for hydrogen in transport will therefore be found where vehicles drive from a point A to a point B and only one or two refuelling stations (at point A or B) are needed. This is typically the case for bus lines. Cities can thus introduce hydrogen relatively easily in their public transport system. By increasing the hydrogen fuelled bus fleet and the number of fuelling stations, the city may pave the way for further applications such as the first hydrogen fuelled taxis or hydrogen in stationary use.

Cities have the advantage of being able to incrementally introduce hydrogen. Furthermore, if they dispose of good research infrastructure and a competitive industry in hydrogen or fuel cell related fields they may develop new industrial clusters. However, cities will most likely produce hydrogen in a non sustainable way through reforming, at least on the short term.

Simplified sketch of a possible development path for community type *city*



This short sketch of differences between cities and islands/remote areas and the resulting different development paths is by no means an exhaustive analysis of this matter. However, the comparison highlights that the potential development paths of different community types must be taken into account when it comes to assessing projects and investments in the field of hydrogen.

The European Dimension

Any assessment and selection process in Europe will take place in a context of *multilevel governance.* Multilevel governance refers to the ability of different levels to set up governance structures which help to enable demonstration projects to become a community and part of a larger innovation system.

At least three levels can be distinguished in the context of hydrogen promotion in Europe: Firstly, the local level which is the level of decisions and actions taken by stakeholders of the respective region, city or island; secondly, the national level; thirdly, the supranational level, i.e. the European Union.

In the following we will focus on the European level because decisions taken at EU level will set to a large part the socioeconomic framework for hydrogen development in its 27 Member States. Furthermore, hydrogen can only be introduced into the market when industry has the prospect of a great European (mass) market with European standards and harmonized rules. Finally, the EU level matters because it has recently become more and more active in the field of energy policy, whether through ambitious targets (EC 2007) whether through the launch of measures which aim to coordinate European research and deployment in the field of hydrogen (see below).

European cooperation in the field of innovation policy, however, has not yielded many policy successes so far. This can be explained by the fact that the classical Community Method (which confers the power to adopt EU wide binding laws to the supranational level) does not apply to innovation policy. Typically, the Member States therefore try to coordinate their policies in this field through the Open Method of Coordination. Yet, for several reasons this method has not worked well in innovation policy so far (Kaiser 2004):

- *Multilevel character of innovation policies*: In the field of innovation policies at least two levels, the local and national level, play a very important role. In some Member States such as Germany where the German "Länder" also have their say, even three levels actively pursue innovation policy. If the EU is added, up to four levels are involved. This multilevel character of innovation policies and the diversity of actors make vertical coordination difficult and increases transaction costs.
- *Tension between political and market co-ordination*: Innovation policy is not only a field where different political and administrative *levels* are involved in but also different *types* of actors are pursuing their goals. Thus, tensions may arise since market and political actors may follow different rationales.
- *Diversity of national innovation policies and institutions*: The 27 Member States of the European Union have their own institutions and policies to strengthen innovation. Thus, policy learning is very difficult. The success of an

innovation effort in for example Denmark may be caused by its specific innovation system and policies. Other Member States may not be able to copy the Danish innovation policy because of these differences and vice versa.

The Commission has in recent year tried to overcome these barriers through enhanced cooperation at EU level. In the field of hydrogen, these efforts have already yielded first results in terms of closer cooperation. The hydrogen and fuel cell platform, launched in 2002, was the first EU led technology platform (https://www.hfpeurope.org/). Through the creation of technology platforms the Commission attempts to advance European research cooperation in fields of great interest for the society. These platforms are designed as public private partnerships which are supposed to enhance cooperation between a multitude of different actors such as industry, research institutes, public authorities, financial actors, civil society, users and consumers (EC 2007b).

The Commission is currently planning to transform the Hydrogen and Fuel Cell Technology Platform in a “Joint Technology Initiative”. The latter is foreseen by the Commission for a small number of Technology Platforms which develop ambitious plans and scope and therefore need a new structure. According to the Commission a Joint Technology Initiative can only be launched if it meets “the following criteria:

- strategic importance of the topic and presence of a clear deliverable;
- existence of market failure;
- concrete evidence of European Community value added;
- evidence of substantial, long-term industry commitment;
- inadequacy of existing Community instruments.” (EC 2007c)

The creation of a Joint Technology Initiative not only valorizes hydrogen and fuel cells as technological solutions the Commission expects much from. It also shows how significant the role of the European level might become in the field of hydrogen and fuel cells. In fact, the Joint Technology Initiative is deemed to pave the way for market introduction by 2015, “with a view to large-scale mass market roll-out by 2020” (Hydrogen and Fuel Cell Technology Platform 2005). It is supposed to be more binding than a Technology Platform; furthermore, it should concentrate available funds of industry and public authorities on a limited number of projects that seem most promising.

As seen before, the creation of early markets and niche markets depends largely upon communities and their efforts to promote hydrogen and fuel cell technology. However, the Joint Technology Initiative lacks a clear contact point which could represent the regional/community dimension of hydrogen deployment. European regions and municipalities have therefore launched a "Partnership on Hydrogen and Fuel Cells" called HyRAMP (European Hydrogen and Fuel Cell Technology Platform 2007) which is likely to bring the community dimension closer to the EU and industry dimension of innovation policy.

The multiple levels of European innovation policy are thus likely to be better coordinated than before. The outcome of this coordination effort is not foreseeable yet and one could question whether the ambitious goal of a "mass market roll-out by 2020" is reachable at all. However, the Commission has shown serious attempts to overcome the barriers to cooperation in innovation policy and has thus done a first important step towards the creation of hydrogen communities.

The Policy Framework at EU Level

The socioeconomic framework is a further factor which heavily impacts on the chances of hydrogen technologies to be commercialized. Along with increasing maturity and cost-effectiveness of hydrogen technology over time, regulatory emphasis need to shift towards more competitive incentive systems (such as competitive dialogues and bidding processes, general taxation, market based instruments and so on). The Joint Technology initiative and improved multi-level governance alone will not pave the way towards a hydrogen inclusive economy unless it is complemented by a socioeconomic framework which favors hydrogen over other, more carbon intensive technologies.

The assessment of hydrogen technology suggests that hydrogen needs a more complex support scheme compared to e.g. renewable energies. This becomes evident because hydrogen has characteristics of a new energy carrier or an energy vector that not only needs to be produced but also requires a distribution system, preferably at a European and international scale (Bleischwitz/Fuhrmann 2006). This is different to e.g. biofuels that can use upgraded gasoline as well as the existing infrastructure of gasoline stations. It is also different to heat or electricity produced by solar energy and other renewables that can use the existing pipelines and the electric grid. For those reasons, it is unlikely that support systems which have proven to be successful for renewable energy can straightforward be applied to hydrogen. The conditions that enable industry to commercialise hydrogen fuel cell vehicles and other applications are not yet in place. They require regulatory reforms and incentive systems for production, distribution, and end-use application of hydrogen.

There is a need for a comprehensive policy support for hydrogen because:

- Production of hydrogen is only sustainable if it comes from low carbon (ideally: carbon free) sources with low risks and at affordable costs;
- There are requirements for distribution systems, which gives hydrogen a spatial and public good dimension comparable to the establishment of electricity grids in the late 19th / early 20th Century;
- Incumbent technologies hinder the deployment of hydrogen;
- Existing varieties in demo projects and quite different regional features throughout Europe call for local strategies along with coordinated deployment and implementation;
- The upfront set up costs not only are enormous, they might also differ throughout the member states (with larger member states having a higher burden, some member states being in a central distribution position while others are more remote);
- A disruptive technology such as hydrogen has many possible applications which need to be addressed;
- New applications are only attractive for customers if they offer significant additional functionality to justify the cost difference towards a reference technology (Godfroij/ Jenninga/ Ros/ 2007).

We call it a „third approach" because it includes and goes beyond the two traditional approaches to technology support: Alternatively, either the specific support mechanism for a new technology is maintained for quite a long time, or the overall framework conditions are adapted so that they can guide processes better than regulation usually attempts.

This pledge for comprehensiveness and coherence is in line with the hydrogen implementation strategy (European Hydrogen and Fuel Cell Platform 2007) calling upon business and policy makers to prepare for mass market development beyond forerunners and early markets.

A screening of some existing policies on energy and climate already reveals that the policy framework currently in place may at some point hinder hydrogen development. The reason behind such analysis is that even like-minded policies may have unwanted side effects on the deployment of hydrogen that needs to be considered. This can be highlighted at the example of energy taxation or the ETS.

In a directive of 2003, the European Union sets out minimum levels of taxation for energy products. Hydrogen is not mentioned in this directive. 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, 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). Six Member States tax hydrogen when it is used as motor fuel (Austria, Czech Republic, Germany, the Netherlands, United Kingdom). The remaining Member States are not included in the study for they did not reply to the research enquiry (Chernyavs′ka/ Gulli/Lanfranconi 2006).

Even though the current situation with no or only low taxes on hydrogen does not hamper hydrogen development in Europe, it nevertheless bears the risk that one day hydrogen might be taxed in very different ways in the 27 Member States. The internalisation of externalities should be a guiding principle for European tax policies. Energy taxation could thus be regarded as generally positive in environmental terms. However, hydrogen should be exempted from taxation so long as needed for its market introduction. Current EU taxation policy thus neither hinders hydrogen development, nor does it promote it.

A similar conclusion can be made with regard to the EU Emission Trading Scheme (ETS). In its current form it mainly applies to mineral oil refineries, coke ovens, iron and steel production, cement production and pulp and paper production. Hydrogen production is not concerned. However, in its communication on “Europe’s climate change opportunity” of January 2008 the Commission proposes to enlarge the scope of the system to “all major industrial emitters” (EC 2008b, p. 6). Such a reformed ETS, on the one hand, may lead to more long term investment security and thus push towards low greenhouse gas emitting technologies like hydrogen. On the other hand, it would also hinder hydrogen deployment given that it may well apply to hydrogen production which is, at least on the short term, carbon intensive. A socioeconomic framework conducive to the deployment of hydrogen should rely on a reformed ETS which does not apply to hydrogen production but to most other greenhouse gas emitting sectors pushing thus towards more investment in ‘green’ technologies.

Conclusions for innovation policies and transition management

Given the specific features of hydrogen and the high hurdles for its deployment, a new and very comprehensive approach is needed if a hydrogen inclusive economy is to become reality. The following elements must be part of such an approach:

1) More direct support for and coordination of hydrogen initiatives

The recent efforts of the Commission to better coordinate European research and development activities in the field of hydrogen and fuel cells are a good step in this direction. However, even the promising Joint Technology Initiative will certainly be insufficient to lead to system innovation. The initiative will very likely advance big firms but not reach all the small and medium sized enterprises that might be able to innovate in this field. In view of reaching also smaller enterprises, new networks and funding instruments are needed. The aspect of financial instruments and business development assistance for small and medium sized companies is still lacking in the EU strategy (Doran/Monter 2007).

2) A strong focus on community development

Some regions, islands and cities in Europe are already very active in the field of hydrogen technologies. They have the expertise and motivation to go further and to go fast. However, they lack the financial resources to do so. The European Union should therefore concentrate its funding on these promising hydrogen communities. The promotion of local hydrogen economies and their interconnection should also be part of EU regional policy and not only of EU research and energy spending. If these early adopting communities became interconnected and cooperated very closely, Europe could drastically lower the set-up costs of a hydrogen inclusive economy. Examples for potential early adopters are London, Hamburg, North-Rhine Westphalia, South Scandinavia or Lombardy.

3) A policy framework conducive to hydrogen deployment

The EU energy and climate policy aims to internalize negative externalities. In general, these policies benefit to hydrogen since they set incentives for business to invest in low greenhouse gas emitting technologies. However, on the short term, hydrogen will be produced via green-house gas emitting processes such as gas reforming. These production processes are normally less expensive than low carbon emitting production methods. On the long term, hydrogen has to be produced in a ‘green’ way. Yet, hydrogen technologies must first be introduced into the market which is only possible if they are cost competitive. Hydrogen production will therefore rely in the coming years mainly on carbon intensive processes. Policies relevant to hydrogen deployment such as the ETS or tax policies should not ‘penalize’ hydrogen production or utilization even though this might seem rational in the light of the internalization of externalities.

Traditional support schemes for new technologies such as specific technology promotion via subsidies or tax exemptions are needed for hydrogen too. Yet, hydrogen needs much more than that because it impacts on the whole energy system and requires a completely new infrastructure and very high investments. Moreover, it even requires the exemption of polluting production processes from the ETS and taxation. However, on the long run this policy may well prove to be climate and environmentally friendly.

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