Project no. 503190
Project acronym: Zero Regio
Project title:

Lombardia & Rhein-Main towards Zero Emission:
Development and Demonstration of Infrastructure Systems for Hydrogen as an Alternative Motor Fuel

Instrument	Integrated Project
Thematic Priority	Sustainable Energy Systems

Major Milestone MM16:
Socio-economic assessments presented

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Dissemination Level		
PU	Public	x
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Executive summary

Major Milestone 16 (MM16) is a check-point for verifying the completion and full presentation of the socio-economic assessments in the Zero Regio project.

The socio-economic assessments were completed and presented in three formats:

(1) As a set of deliverables containing in-depth scientific reporting of research results. A list of deliverables presenting final results is found on page 4.
(2) Through the Final Summary Report of the project.
(3) Through oral presentations at the Zero Regio final conference.

The present document for milestone verification briefly outlines the socio-economic results, as they have already been presented, mainly to provide an administrative overview. For scientific purposes, the reader is referred to the deliverables, which are the primary reference publications.

Contents

Preface

The Zero Regio project was a demonstration of hydrogen infrastructures and a small number of hydrogen-fuelled cars in Mantova (Italy) and Frankfurt am Main (Germany). It is part of a larger effort by the EU to demonstrate hydrogen technology, for reasons of energy security and environmental protection. Detailed information concerning the Zero Regio project can be found at http://www.ZeroRegio.com, while more general information concerning EU hydrogen policies and activities is found at the web sites of the European Commission[1] and the FCH JU[2]. Funding for the Zero Regio project came from the European Commission and project partners. The Zero Regio project was coordinated by Infraserv Höchst.

The present document presents an overview of results from Work Package 7 (WP7), which was the "container" for the socio-economic assessments accompanying the technology development and demonstration activities that constituted the core of the Zero Regio project. More in-depth reports of results are found in the individual deliverables listed on next page.

Within WP7 the tasks were divided between partners from Denmark (Roskilde University and Saviko Consultants), Italy (IEFE, Bocconi University) and Sweden (Lund University). The contributions of individual researchers and other co-workers, as well as contributions and assistance received from outside the WP7 group are acknowledged in the individual deliverables.

2010-07-15

Peter Helby,
Lund University

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1 http://ec.europa.eu/research/energy/nn/nn_rt/nn_rt_hy/article_1142_en.htm

2 The Fuel Cells and Hydrogen Joint Undertaking, http://ec.europa.eu/research/fch/index_en.cfm

Further reading

All materials mentioned below are available for download on the project web site http://www.ZeroRegio.com

For a complete overview of the Zero Regio project, including the technological aspects and the project organisation, please consult the Final Summary Report published in May 2010.

An alternative means of overview is to access the presentations that were delivered 18 May 2010 at the Zero Regio final conference, which was organised as a session within the World Hydrogen Energy Conference 2010 (WHEC 2010) in Essen, Germany.

For the socio-economic assessments covered in the present document, final results are covered in-depth in the following deliverables:

D7.12 Final report on business development
D7.16 Technological trajectories in H2 cycle
D7.17 Final report on acceptance
D7.18 Economic impact of technical standards
D7.19 Hydrogen supply cost estimates
D7.20 Effect of policies in Europe

Hydrogen competitiveness and hydrogen policies

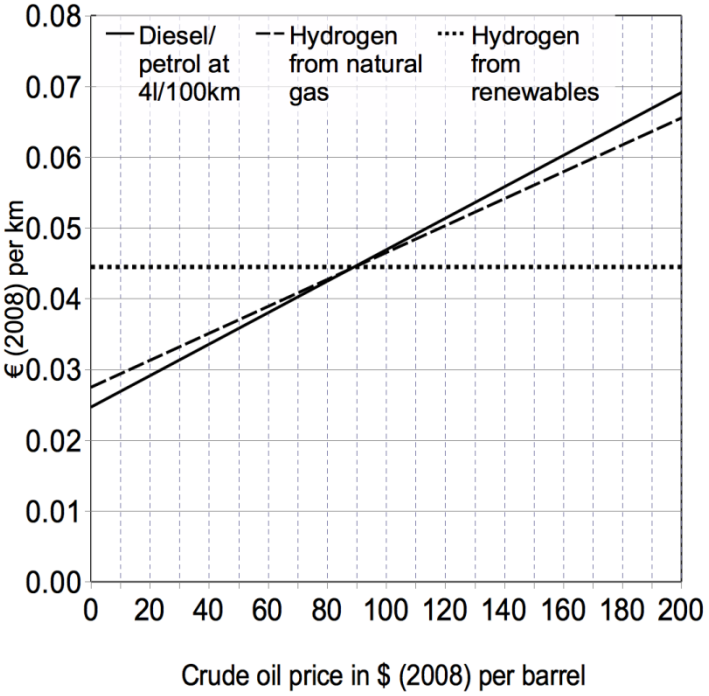
By: Anders Christian Hansen, Roskilde University.

This part of the socioeconomic studies addressed questions concerning the future competitiveness of hydrogen as a transport fuel, the potential contributions of hydrogen to European energy and environmental policy goals and the potential effects of European policies relevant to hydrogen.

The analysis of the future competitiveness of hydrogen studied the potential costs per kilometre for conventional fuels, hydrogen made from natural gas and hydrogen made by electrolysis. It was found that at low oil prices conventional fuels are the most cost-effective, natural gas based hydrogen the second most cost-effective and electrolysis based hydrogen the least cost-effective. At higher oil prices, however, this competitiveness order is reversed. In a simple form, this contingency is shown in *chart 1*.

- This is important because the oil price at which the competitiveness order is reversed could be in a region around $100 per barrel.
- The competitiveness order reversal takes place in a range of oil prices that is lower, the higher the fuel taxes. This is because higher fuel taxes make the more fuel efficient solutions more competitive.
- This result holds even if hydrogen and conventional fuels are taxed at exactly the same rate (€/GJ). Thus, hydrogen can become competitive without favourable tax treatment. This could happen earlier in Europe than elsewhere due to the high fuel taxes in European countries.

Chart 1: **Competitiveness order reversal. How fuel cost per km depends on the oil price. Tax rates €10/GJ and €44/tCO2.**



- If the future costs of hydrogen production are higher than expected - compared to the costs of petrol and diesel - it is possible to compensate for this by raising the fuel tax for all fuels.

- Differentiating the fuel tax in an energy tax (€/GJ) and a CO_2-tax (€/tCO_2) further improves the competitiveness of non-fossil hydrogen, even if the total tax level is not changed.

- These results depend critically on the achievements of the highest conversion efficiencies – that is, the lowest energy waste – in all links along the energy chain leading to hydrogen. Thus, it is important that all fuels involved are subject to the same carbon price, either as a EUA price or as a CO_2-tax.

The role of hydrogen in a wider socio-economic context was studied by analysing whether it is consistent with the European goals of a sustainable energy production and consumption to use hydrogen as a transport fuel. The contribution of hydrogen to meet the requirements of a sustainable energy production and energy use in Europe depends on the supply chain it results from. The study reviews a range of European policies relevant to hydrogen as a transport fuel.

- Hydrogen as a transport fuel will, when it is based on renewables, contribute to the European policy objectives concerning the environment, cost and security of supply. When based on fossil fuels with CCS, GHG-emissions per km can potentially be reduced corresponding to the sustainability criterion for bio fuels, but at a cost of high energy losses.

- For bio fuels it has proven necessary to define rather stringent criteria for environmental sustainability. Sustainability criteria for hydrogen are also suggested, but improvements of energy taxation and Emission Trading System (ETS) rules are suggested as more important.

Development of a European hydrogen market

By: Susanna Dorigoni, IEFE, Bocconi University.

Within the Zero Regio project IEFE was involved in the analysis of socio-economic aspects crucial to the development of a European hydrogen market (Work Package 7). Among the latter the attention has been focused on hydrogen environmental performance, the role of regulation with a special attention to taxation and subsidies, hydrogen technological trajectories and standards.

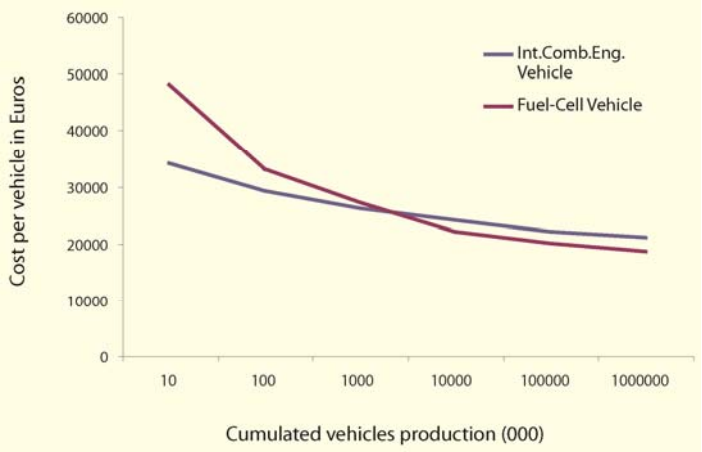
With regard to the environmental performance, hydrogen shows significant advantages in terms of external costs due to local and regional pollutant emissions. Concerning global impacts (namely the external costs of greenhouse gases emissions), hydrogen presents great advantages only when it is produced by means of “CO2-free” energy sources (as renewable or nuclear power) or when carbon capture and storage are feasible. Looking at total external costs, the impact of the natural gas based hydrogen cycle is significantly lower than those of the gasoline and gas oil fuel cycles.

According to the results of the environmental analysis it seems to be clear that a process of tax harmonisation in Europe based on environmental taxes (Pigouvian taxation) would incentive the development and the use of hydrogen as an energy carrier.

Leaving aside taxes, also national and local policies should play a key role by involving the stakeholders of all levels of the industry and government. They should have long term perspective and foresee a constant support covering the whole territory both for vehicles and refuelling stations. Clear and simple rules for the construction of refuelling stations and economic incentives for their operation are needed. Incentives both at local and national level have to be stable and continuous in time.

The role of regulation is of paramount importance for the hydrogen technology take-off provided that sensible improvements could be obtained on (private) costs of producing and using hydrogen as a motor fuel. For this reason the potential for cost reduction in the hydrogen chain has been evaluated starting from a selection of technological pathways. An example of such evaluations is shown in *chart 2,* which show results concerning cost reductions for vehicles.

***Chart 2:* Learning estimations for H_2 vehicles.**



For the time being the only hydrogen technology that seems to be well developed and, therefore, almost competitive, is represented by Steam Reforming. While the scale effect seems to have a significant influence on cost reduction, the analysis of the learning effect potential was almost discouraging.

While natural gas reforming and electrolysis are expected to undergo a discrete investment costs reduction, showing significant progress ratios, experience curves show just negligible learning potential with reference to hydrogen production no matter the technology considered. On the contrary as for fuel cells, considerable cost reductions are expected with reference to different fuel cells types with progress ratios ranging up to 30%. Also a fast decrease in production cost for key hydrogen vehicles components is forecasted, facilitating entrance to first niche markets.

However H2 production from renewable and nuclear energy, being dramatically competitive under an environmental point of view could offset the difference in production costs compared to traditional fuels.

Also more work on harmonisation of codes and standards is yet to be done. Standards and technical regulations are key drivers, together with technological improvements, learning effects and costs reductions, in the develop-

ment of a broad market for hydrogen. Nevertheless they are often considered as a barrier insofar as they imply costs and compliance difficulties for industries. As a matter of fact RCS can be seen as a part of the sustainable market development process that could influence the positive attitude of consumers towards the new energy source provided they are introduced under a set of conditions.

First of all it is necessary to establish a strong link between standards setting and R&D activities in order to acquire the necessary data that are necessary to develop and adjust standards over time. The second condition is in fact represented by the fair revision of codes and standards according to the evolution and improvement of technologies that need to be supported on the one hand, and certified on the other hand, by universally recognized rules and parameters.

Nevertheless a proliferation of RCS should be avoided in order not to place an excessive burden on industries that need time and technical capabilities to adequate to evolving rules. Otherwise the introduction of standards would cause superfluous regulatory costs that could offset the benefits of hydrogen introduction.

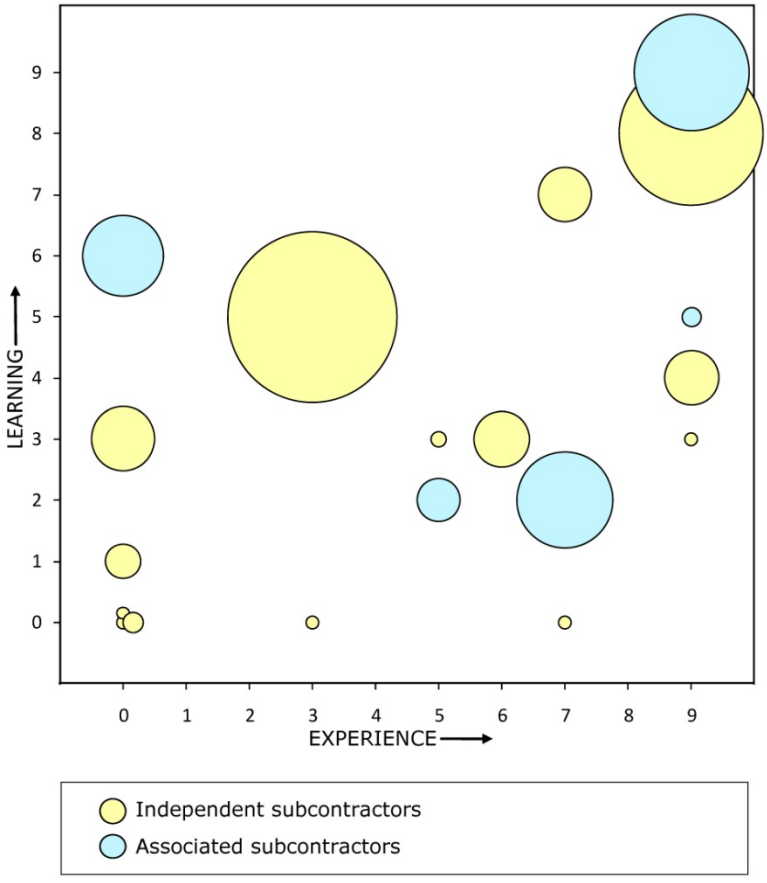
There are many socio-economic variables that should be taken into account in the development of a European hydrogen market. They should be carefully evaluated and properly designed in order to make the new technology take off the ground.

Business development

By: Peter Helby, Lund University[3]

Business development studies have focused on Zero Regio experience regarding stimulation of limited scale entrepreneurial companies, including SMEs. The results show that even though such companies are not represented among the manufacturing partners of the Zero Regio project, there is a powerful demand-pull effect from the project, stimulating activities in smaller, technologically sophisticated companies that provide inputs to the project.

***Chart 3:* Characteristics of subcontractors.**



As shown in *chart 3*, some of this demand-pull (blue colour) remains within the sphere of influence of the very large companies that are the main industrial partners in the Zero Regio project. However, significant parts of the demand-pull (yellow colour) leaks out of these boundaries, and stimulate a broader undergrowth of hydrogen technology suppliers. Each circle in chart 3 represents a subcontractor, while the area of each circle represents the monetary value of the subcontracted task(s). In the chart, subcontractors are distributed on the axes according to estimated hydrogen experience and expected learning effects from the subcontract. As can be seen, subcontracts are spread widely over these dimensions, with no clear clustering. The tasks that leak to smaller companies include some with rather low learning potential, but also a significant

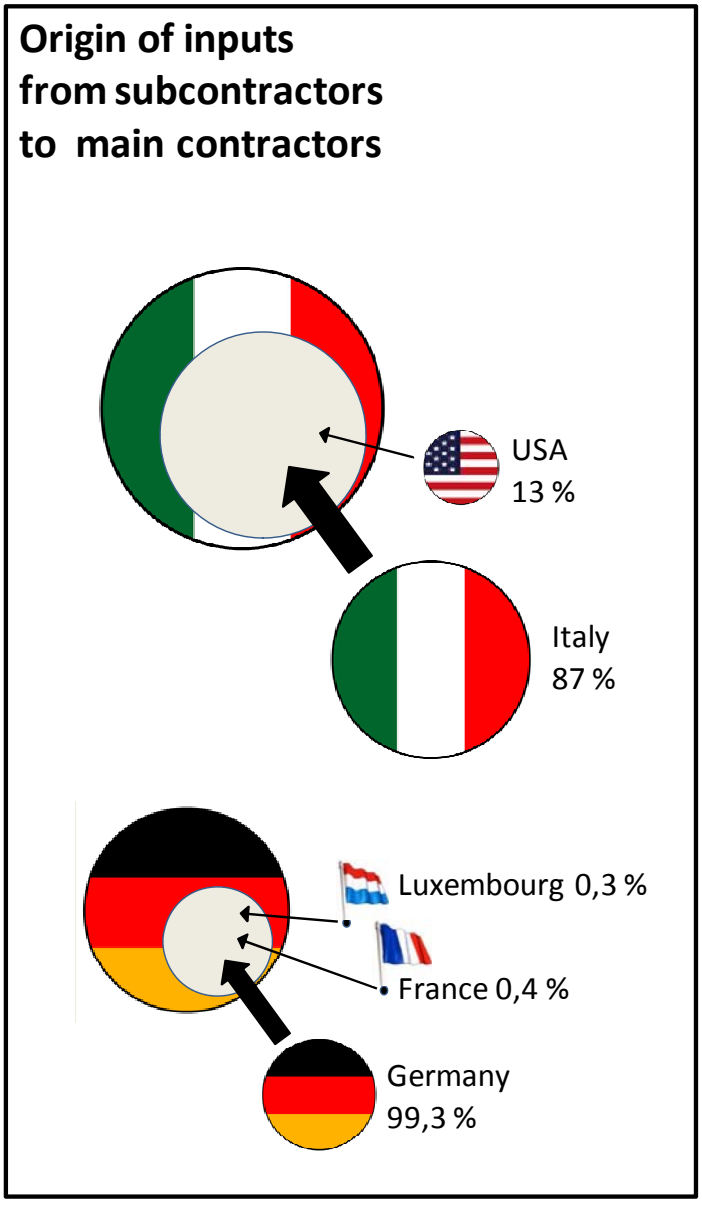
[3] Based partly on work done by Saviko Consultants.

amount of work with high learning potential. It might be expected, that tasks with high learning potential were given predominantly to subcontractors within the sphere of influence of the main contractors, but the blue/yellow colour distribution in chart 2 does not show any such tendency. Evidently, it is not only monetary resources that leak out of the project, towards smaller companies, but also significant parts of the learning that is being stimulated by the project.

The studies include a discussion of the value of such a demand-pull stimulation compared to direct project participation. It finds that there are both positive and negative aspects to this indirect stimulation. The positive aspects are about a leveraging effect, a reduction of risk, and an enhanced market conformity (less bureaucratic involvement). The negative aspects are about reduced autonomy, excessive dependency on larger companies, difficulties in defending intellectual property, and reduced options for networking.

The report also includes observations concerning the formation of technological clusters. In the Zero Regio project, such clusters seem to be developing mainly on the national level, but also in the form of trans-Atlantic integration, whereas no significant European integration is observed. This is illustrated in *chart 4*, where the large Italian and German circles show the value of the main contractor's tasks, and the smaller circles show the input from subcontractors.

Chart 4



From a policy perspective, an important observation from the business development study is an apparent imbalance between technology push and market pull. While the pipeline of technologies for a hydrogen based transportation system is being effectively supplied at one end by strong R&D policies, i.e. a technology push, there is a lack of balancing policies to take technologies out of the pipeline, i.e. to ascertain a corresponding market-pull. This is observed as a problem particularly for enterprises of limited scale and financial means, ending up with promising technologies for which there is insufficient or unreliable demand.

When insights from the business development study are combined with observations from the acceptance study and reports from work packages, it is also evident that there is a need for urgent attention to the problems of infrastructure development, i.e. the deployment of a refuelling system that truly match the progress made by vehicle maufacturers. From an end-user perspective, the most critical bottleneck in the development of a hydrogen based transportation system appears to be the present shortcomings of the refuelling infrastructure and the great uncertainties about its future development. Public regulation has been observed to be hindering, rather than promoting the development of the refuelling infrastructure. Private actors appear to have difficulty seeing any business case for large scale infrastructure investments while public initiatives or incentives are too weak to change this situation. Infrastructure shortcomings in terms of accessibility, reliability and consumer experience constitute the most significant source of negative end-user reactions found in the Zero Regio acceptance study. These shortcomings have the potential to spoil the business case for investments in other areas of hydrogen technology development.

Public acceptance

By: Peter Helby, Lund University[4]

People react to new technologies. Sometimes with pleasure or even enthusiasm (e.g. mobile phones). Sometimes with scepticism or outright opposition (e.g. genetically modified food).

So the question is: How will people react to hydrogen cars? Will they be welcomed because they make cities nicer to live in? Or will they be frowned upon because of the gas they use or the complexity of technology? Or will people find other reasons to hate these cars, or to love them?

This is the acceptance question that the Zero Regio project has explored along with the technical demonstration.

Basically, we have asked 41 drivers and 700 teenagers about their reactions and observations. The drivers are mostly ordinary people who have used the cars in their work or everyday life in Italy or Germany. They had plenty of time to get familiar with the technology and develop a personal opinion. They would also notice reactions among their passengers, colleagues, family and friends.

***Chart 5:* School demonstrations**

The teenagers are from Italian schools, where the cars were demonstrated and a short lesson given. So they know something about hydrogen. They are the generation that matures together along with hydrogen technology. So their reactions are important.

[4] Based mainly on work done by Saviko Consultants.

What do these people tell us: They are certainly not afraid of hydrogen. Negative reactions to the use of hydrogen gas are very few. But drivers want a good car, and are not happy to compromise on driving qualities or range. Driving qualities already seem to have reached a satisfactory level, but driving range remains an important challenge for the car producers.

Even more clearly, there is a challenge for those who provide the fuel. Drivers do not expect a hydrogen station at every street corner, but are fairly tolerant of the need to build the network gradually. They are not tolerant, however, about delivery failures at the refuelling stations. Complaints about refuelling have been much more common than complaints about the cars. Drivers see refuelling as nearly OK when it works. But far too often, in their view, it hasn't worked as it should.

Hydrogen can quickly get a bad name, if the reliability of delivery is not improved dramatically. This problem needs even more urgent attention, because the experts and the public don't seem to agree. The technicians think they have mostly done a good job. Consumers complain that they receive a lousy service. Such lack of mutual understanding can destroy acceptance.

Both teenagers and drivers worry about hydrogen sources, as seen in *chart 6*. Among the teenagers 39% will take a more negative view of hydrogen if it comes from coal. In case it is produced by nuclear power, 47% will take a more negative view. The answers from drivers point in the same direction. This contingency would need careful consideration in any strategy for development of the hydrogen economy. While hydrogen gas in itself does not seem to cause much worry among the public, acceptance might be spoiled by such associations.

***Chart 6:* Reactions to hydrogen sources**

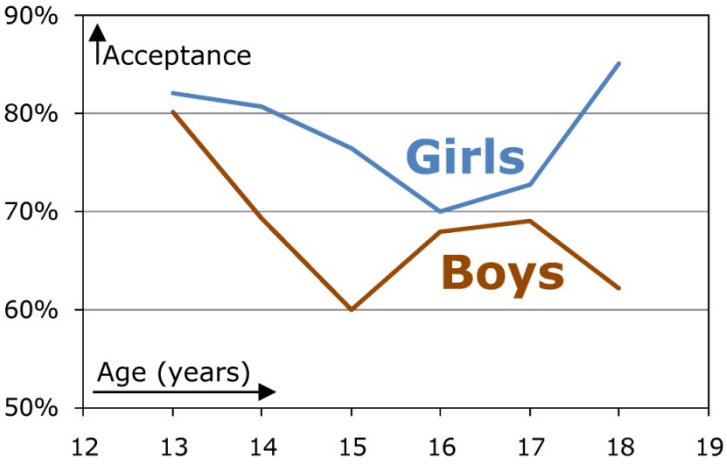
In the future, hydrogen might come from coal or nuclear power. Would that influence your view on hydrogen vehicles?		
Percentage of respondents that would become more negative		
	Drivers	Students
Coal	84%	39%
Nuclear	65%	47%

On an abstract level, teenage reactions to hydrogen technology are remarkably positive, as evident from *chart 7*. This chart is based on responses 1-2 months after demonstration event. This is particularly true for girls, as shown in *chart 8*.

***Chart 7:* General reactions to hydrogen technology**

Students: Percentage that agrees with each of the following statements	
75%	H_2 cars give me more confidence in the future.
20%	H_2 cars increase my desire to have a car.
22%	H_2 cars make me think we are too occupied with technology.

***Chart 8:* Gender differences in reactions to hydrogen technology**



On a more down-to-earth level, when asking about their own scooter, motorbike or car, 30% would prefer hydrogen, against 29% for petrol, 13% for electric batteries, 13% for natural gas and 7% for bio fuels. These results are no doubt influenced by the demonstrations done at schools, but the questions were asked 1-2 months afterwards, so the teenagers had time to think about their views.

In summary, there is no indication that the use of hydrogen as vehicle fuel would cause any significant worries to citizens that are brought into contact with hydrogen technology. Quite opposite, it seems to be met with a certain fascination. However, a future association of hydrogen with controversial energy sources, such as coal or nuclear, could cause a significant loss of acceptance. What does worry people at present, regardless of their acceptance of hydrogen in principle, is the practical performance and costs of the technology. Of course, this is very much the same questions that are occupying industry and policy makers.

POLICY RECOMMENDATIONS

Policy recommendations are emphasised in all studies within Work Package 7 (WP7), and are summarised on the following two pages. Please remember that the observations and recommendations below originate from the socio-economic studies, and thus represent a societal rather than a technological perspective. It is quite possible to make significant technological progress without immediate results in terms of e.g. cost reduction or consumer satisfaction. A consumer can be frustrated by a single bad experience at a facility with high availability and performance. Thus, for an all-round understanding and appreciation of the results of the Zero Regio project, the reader should refer also to the outputs from other work packages that include assessments of technical, environmental and energetic performance of the hydrogen vehicles and infrastructure demonstrated in this project.

Observations	*Recommendations*
Hydrogen shows significant advantages in terms of reduced external costs due to local and regional pollutant emissions. Concerning global impacts (greenhouse gases emissions), hydrogen presents major advantages only when it is produced by means of "CO2-free" energy sources (as renewable or nuclear power) or when carbon capture and storage are feasible. Looking at total external costs, the impact of the natural gas based hydrogen cycle is significantly lower than those of the gasoline and gas oil fuel cycles.	Continue to promote development of a hydrogen based transportation system. Accept natural gas as the dominant short and medium term source of hydrogen, while promoting a long-term shift toward technologies without CO2 emissions.
From an end-user perspective, the most critical bottleneck in the development of a hydrogen based transportation system appears to be the present shortcomings of the refuelling infrastructure and the great uncertainties about its future development. Public regulation has been observed to be hindering, rather than promoting the development of the refuelling infrastructure. Private actors appear to have difficulty seeing any business case for large scale infrastructure investments while public initiatives or incentives are too weak to change this situation. Infrastructure shortcomings in terms of accessibility, reliability and consumer experience constitute the most significant source of negative end-user reactions found in the Zero Regio acceptance study. These shortcomings have the potential to spoil the business case for investments in other areas of hydrogen technology development.	Focus attention urgently on development of infrastructure and the need for effective public policies in this regard.
While the pipeline of technologies for a hydrogen based transportation system is being effectively supplied at one end by strong R&D policies, i.e. a technology push, there is a lack of policies to take technologies out of the pipeline, i.e. to ascertain a corresponding market-pull. This is a source of problems particularly for enterprises of limited scale and financial means that end up with promising technologies for which there is insufficient or unreliable demand.	Strengthen policies to secure a reliable and growing market for hydrogen based transportation solutions.

Observations	*Recommendations*
Somewhat against expectations, the public does not appear to harbour any fears about hydrogen technology, but are easily persuaded by the potential benefits and rather willing to embrace the technology as a solution to environmental problems. However, this high acceptance in principle does not automatically translate to acceptance of the details of hydrogen implementation. Acceptance seems to be strongly contingent on the choice of sustainable sources for hydrogen production. It is also contingent on the ability of industry to provide a satisfying consumer experience, for which the vehicle manufacturers seem quite successful, while the fuel suppliers are observed to be failing.	Urgently address the chasm that is emerging between good vehicles and frustrating refuelling infrastructure. Avoid complacency about the present sourcing of hydrogen, but make sure that there is an early and evident momentum in the progression towards sustainable sourcing of hydrogen.
The high level of automotive fuel taxes in Europe has the effect of making hydrogen more competitive in the European transportation sector than in regions with lower taxes. Thus, from an economic view point, present policies are giving Europe a competitive advantage as a space for the development of automotive hydrogen technologies. European policy makers should be careful to ascertain that this competitive advantage is not spoiled by other barriers, such as excessive regulation or insufficient development of refuelling infrastructure. Results from the Zero Regio project indicate that these non-economic barriers are significant.	Do not give any favourable tax treatment to hydrogen fuel, but focus promotion on reduction of vehicle costs and non-economic barriers.
A favourable tax regime for hydrogen fuel is not necessary to support the transition to hydrogen. Higher general fuel taxes will have the same effect, and may be more acceptable from a fiscal view point and more consistent with general policies to promote energy efficiency. The present fiscal problems in many European countries have the potential to result in an enhancement of the competitiveness of hydrogen, on condition that the drive for additional tax revenue is directed towards automotive fuels.	Use the present fiscal crises as an opportunity to raise automotive fuel taxes.
The Zero Regio survey results indicate that a non-fossil origin of hydrogen is important for the acceptance of hydrogen as automotive fuel. The economic study shows that a competitive twist in favour of non-fossil hydrogen can be achieved without additional taxation, if fuel taxes were split into separate energy tax (€/GJ) and CO2-tax (€/tCO2).	Review the details of automotive fuel taxation to ensure that the embodied incentives work effectively in favour of energy efficiency and carbon reduction.