Fraunhofer Institute
Systems and
Innovation Research

Final Draft

Deliverable D3.7

Report on the Lead market approach and the input/output analysis of energy systems on all branches of industry

Deliverable of Work Package 3 in the scope of:

The Development and Detailed Evaluation of a Harmonised
„European Hydrogen Energy Roadmap“
under FP6

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1 Executive summary

1.1 Introduction

The two main objectives of the modelling approach are to identify possible sectoral shifts and employment effects due to the application of hydrogen in an energy system. The analysis is mainly carried out with the ISIS model.

To achieve the aims, first of all import/export scenarios have to be developed, among other on a detailed analysis of the Lead market potential of countries in the hydrogen and fuel cell technology field. In addition, to reach an adequate technology translation into the needs of economic modelling, an extended analysis of the hydrogen and energy technologies has been carried out. Finally to get an insight into the sectoral shift and employment effects the scenario assumptions and the technology data are implemented into the input-output model ISIS and several analyses are carried out.

1.2 Economic analysis of hydrogen fuel cell vehicles compared with conventional vehicles

Four major drivers influence the cost-competitiveness of hydrogen cars compared with conventional vehicles: the crude oil price, hydrogen price (infrastructure costs), internalization of CO2-emissions and hydrogen drive system costs.

Figure 1 shows the influence and the range of uncertainty of different drivers on the economy of fuel cell vehicles (FCV).

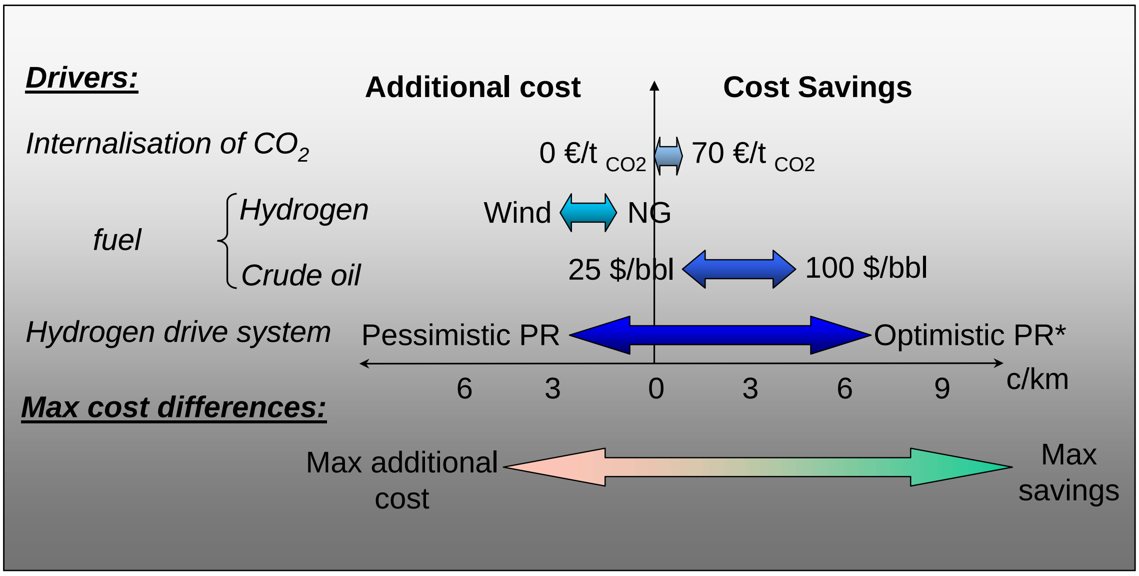

Figure 1: Specific additional cost and savings of a FCV compared with a conventional vehicle (PR* *PR: Progress ratio for fuel cell cars: describes the speed of cost reduction over the cumulative output, for assumed values see Deliverable D3.6)*:

Dominant are the cost assumptions for the hydrogen drive system followed by the variation of crude oil price and hydrogen feedstock and production technology and then the internalization of CO_2 emissions. Whereas the infrastructure costs for a hydrogen economy can be estimated on the basis of today's technologies, it is more difficult to estimate the future development of hydrogen drive system costs. The main challenge to hydrogen use in the transport sector is to reach a price plateau for FCVs near the prices of conventional vehicles (dependent from the other drivers between 0 and 1500 Euro of additional cost compared to conventional vehicles).

It is important to note that up to now, the calculations have been based on the assumption that FCVs are perfect substitutes for conventional cars.

Investments in research and development are necessary in order for FCVs to become cost competitive. Figure 2 shows the cumulative investments required for FCVs to reach a level of cost-competitiveness of FCV for different scenarios. In all analyzed cases, FCVs will reach this cost-competitiveness, although the cumulative cost shows a wide range.

From the economic viewpoint, CO_2 reduction is not a major driver for the introduction of hydrogen. As compared to for example the price of hydrogen production and transport, reasonable carbon prices are relatively low. Only if FCVs are near the cost-competitiveness could they play a relevant role in influencing consumer behaviour. Having said this, if hydrogen fuel cell cars enter the market due to competitiveness reasons, this would lead to a significant CO_2 reduction (up to a factor of 10 for every substituted vehicle). It is a win-win situation for the economy and environment. The benefits are even greater, as not only CO_2 emissions but also other local air emissions and noise will be reduced by the FCVs.

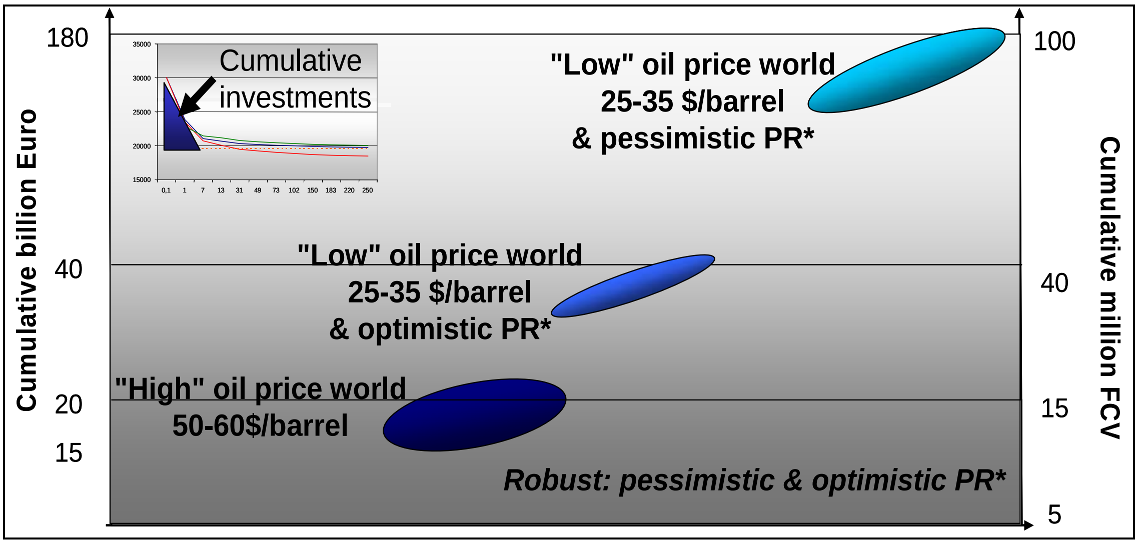

Figure 2: Accumulated car investment and cars until cost-competitiveness of FC car is reached (without externalities and interest rate, from the beginning of mass production, worldwide)

1.3 Lead Market analysis

The lead market concept is used to estimate the competitiveness of a country and forecast the import/export shares of hydrogen technologies. Lead markets are defined as the regional markets to first adopt an innovation design in a technology field which have specific characteristics that enhance the probability that the same innovation design will be adopted broadly in other countries as well.

To identify lead markets, different indicators like patents, R&D-Budget, demonstration projects or density of population are identified which influence the lead market potential of a country (all together 42 indicators are used). It should be mentioned that the quantitative figures for the indicators are based on the available historical data and that very recent developments may not be reflected in this analysis. Based on an analysis of the indicators the lead market potential of the 6 MS is identified.

The results shows that Germany is has the highest figures for nearly all indicators for all European countries. In the field of hydrogen production, especially based on steam reforming, Germany has a good competitive position and Germany is also well placed in the field of stationary applications and mobile applications (system integration). However, when looking beyond Europe to a more global view, Germany loses ground, especially in the field of stack production compared to US, Canada and Japan.

All the absolute indicators show that France is in a relatively well-placed position in Europe, although there is no prominent potential visible in any one category. If relative indicators, which taken into account the country size, were regarded, however, the smaller countries like the Netherlands, Denmark and Norway caught up. In summary, based on its historical activities in the hydrogen and fuel cell field, France is not in a position to become a lead market. However, it does seem to have the potential to be a fast follower or, with additional research efforts, it could close the gap to the leading countries over the next few years.

Italy has the promising potential to become a lead market area in the mobile sector. In addition, there is a lead market potential for hydrogen production technologies, among others due to the export orientation of the manufacturing and equipment sector. However, compared with Germany, but also with the UK and France, Italy lags a little behind the other larger European countries. Overall seen Italy has the potential to be a fast follower.

As mentioned before the Netherlands and Norway are well-placed by relative indicators but also by some absolute indicators. Compared with other research activities, hydrogen and fuel cell research are prominently well-placed in these countries. The Netherlands seems to be in a good competitive position, especially for hydrogen production with a focus on partial oxidation. A lead market potential for the Netherlands can also be identified for stationary and to some extent for mobile applications. Norway's strength lays in the areas of hydrogen production area and the access to feedstocks (gas, cheap electricity).

When regarding the overall picture painted by the selected indicators, Greece does not seem to have the potential to become a lead market in any hydrogen-related area. A relevant indicator for Greece is the large number of populated islands (168) where the construction of a hydrogen infrastructure could have greater advantages (combination of renewables (e.g. wind power) and hydrogen production using electrolysis).

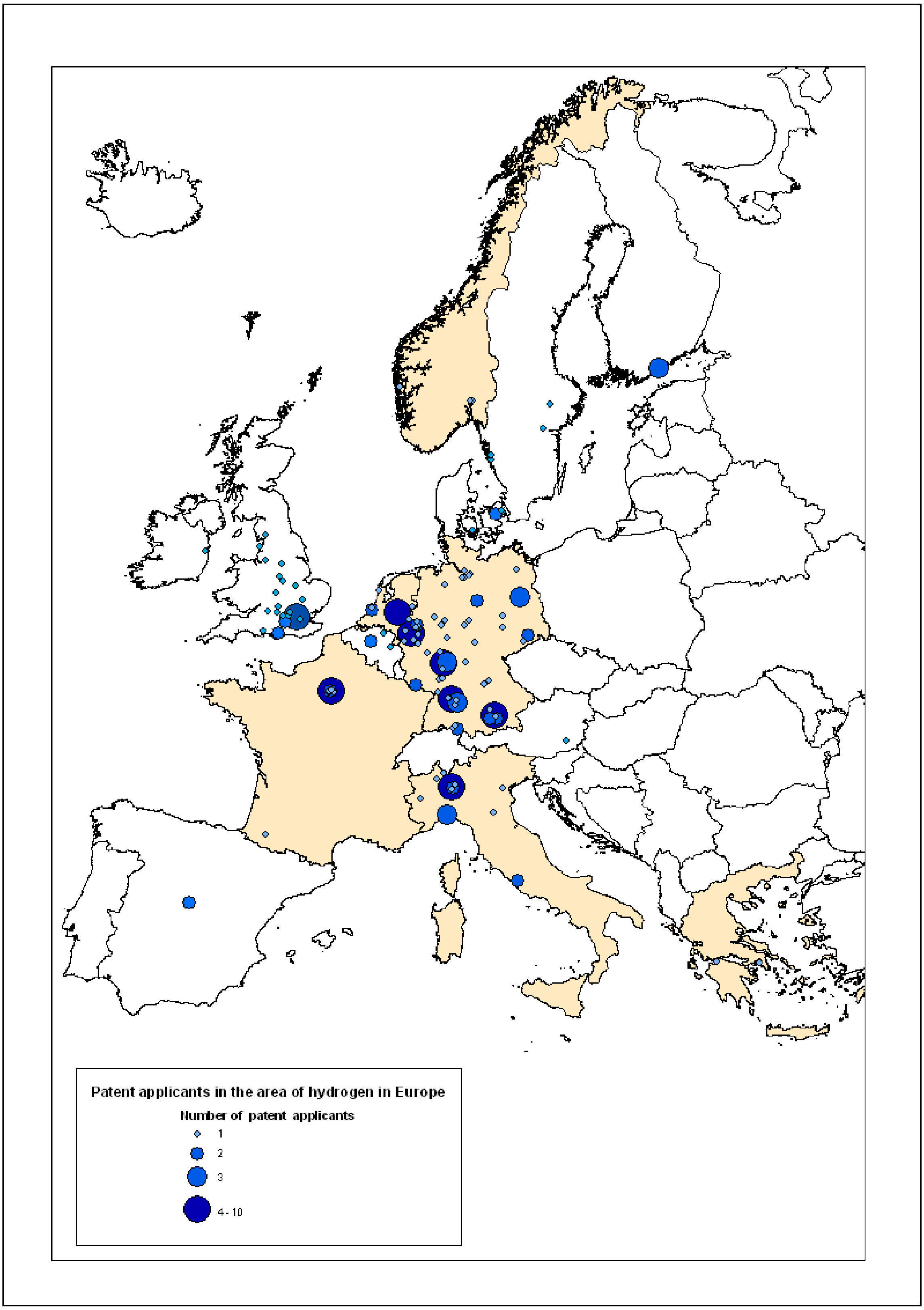

Figure 3: Example of one lead market indicator: Geographical distribution of firms with hydrogen patents

1.4 Impacts of a hydrogen economy on employment

The structure of the investments necessary for a transition to a hydrogen economy is clearly dominated by the expenditures for hydrogen vehicles (see Figure 4.). If a country a hydrogen vehicle is imported, not only the hydrogen drive system will be imported, but very likely the whole vehicle. Therefore the structure of the domestic vehicle industry sector turned out to be one of the key factors for an employment analysis, and further for GDP and welfare development.

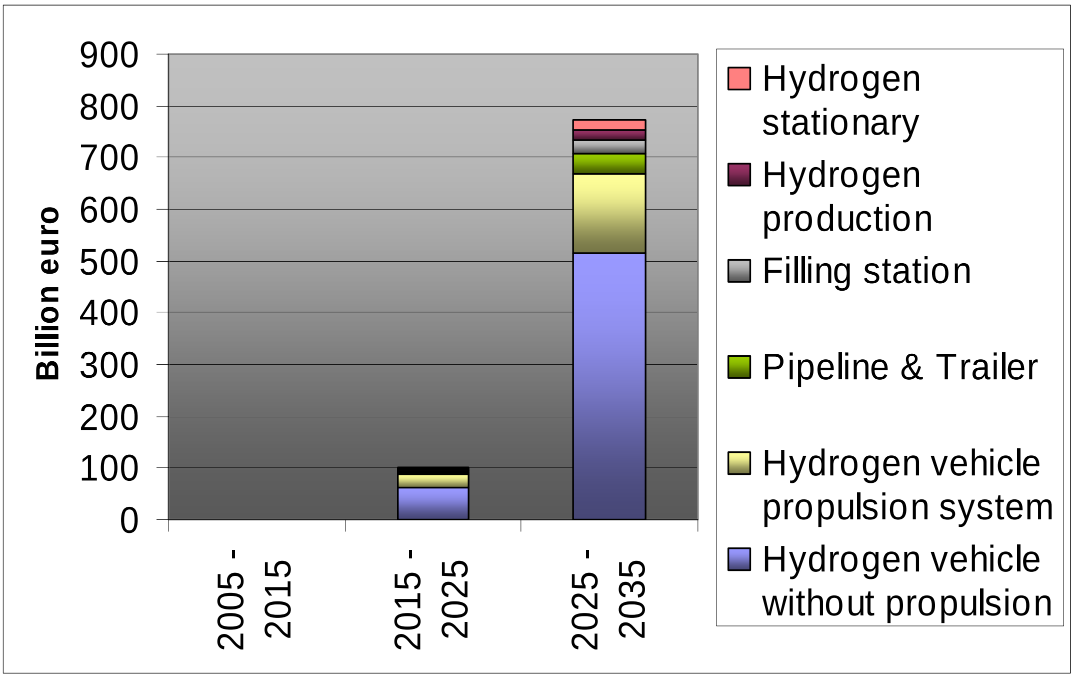

Figure 4: Structure of the investments in a hydrogen economy of the six HyWays countries (cumulative for ten year period, hydrogen high penetration scenario)

Four import/export scenarios have been analysed so far. Every scenario tells a story of a possible future for the competitiveness of the hydrogen technologies produced within the EU. The “Structural identity” scenario is based on today’s technology imports and exports, in which the EU and the six countries have a good market position, seen overall. But as the lead market analysis has shown, other regions of the world, namely USA and Japan, also are in a very strong position to become a lead market for hydrogen, and in the “Today's potential” scenario the EU falls back, compared to the structural assumption scenario. The “Pessimistic” scenario shows what could happen if other regions of the world take over the leading position and Europe has to import hydrogen vehicles. In the “Optimistic” scenario, great efforts will be undertaken which result in an increase of the EU exports in hydrogen vehicle and technologies (see Figure 5). For the single countries the today potential could be different in respect to the structural identity scenario. For The Netherlands the “Today’s potential” seems to be from nowadays view much better in respect to hydrogen technologies than the “Structural identety” scenario.

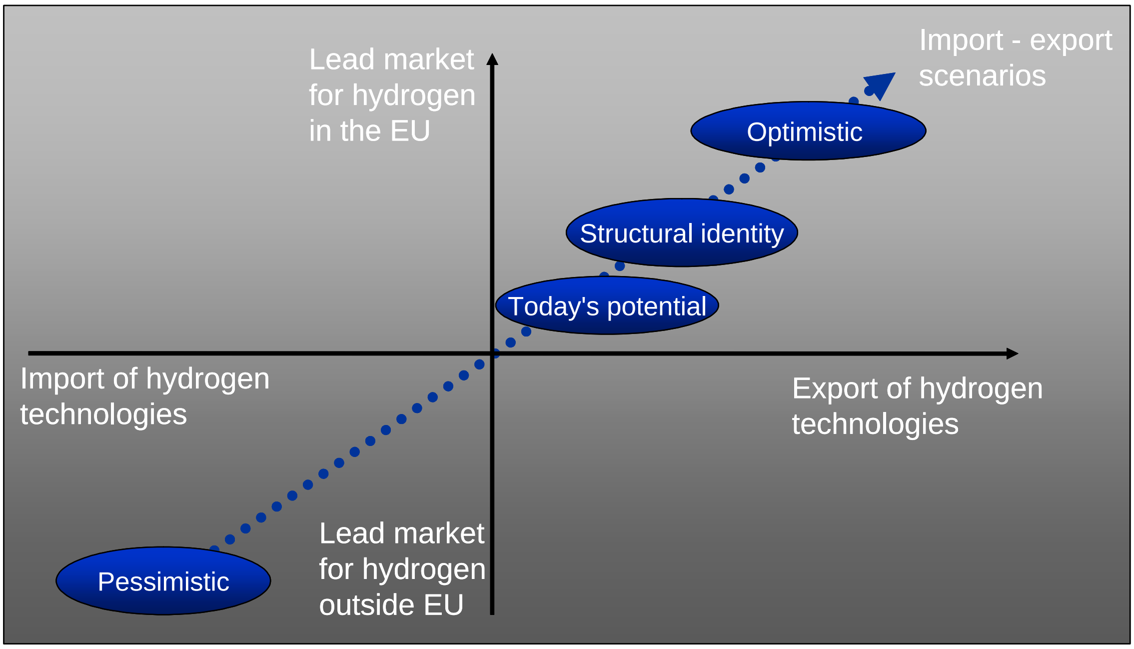

Figure 5: The classification of the four hydrogen import and export scenarios for the economic analysis.

The largest direct effects on employment due to the transition to a hydrogen economy are seen for the automotive industry, and to a lesser extend for the plant and equipment sector. Whether the impact is negative or positive depends strongly on the effort Europe puts into consolidating or improving its current position in the car market (see Figure 7). This holds even stronger for the current car manufacturing countries, which therefore face the dilemma: should they invest in a new technology, losing possibly many billions of R&D and infrastructure build up investments, or not, at the possible expense of even higher losses in GDP and jobs. Especially France, Germany and Itlay could be seen as candidates for the dilemma situation (see Figure 6). The differences between the winnigns and losses of these countries could be traced back to the differences in the structure of the automotive sector. Germany for example has very high export shares in automotive sector, compared to France and Italy. Therefore drastic changes in the share of hydrogen vehicles have also stronger effect on the production for export and not only on the production for domestic use.

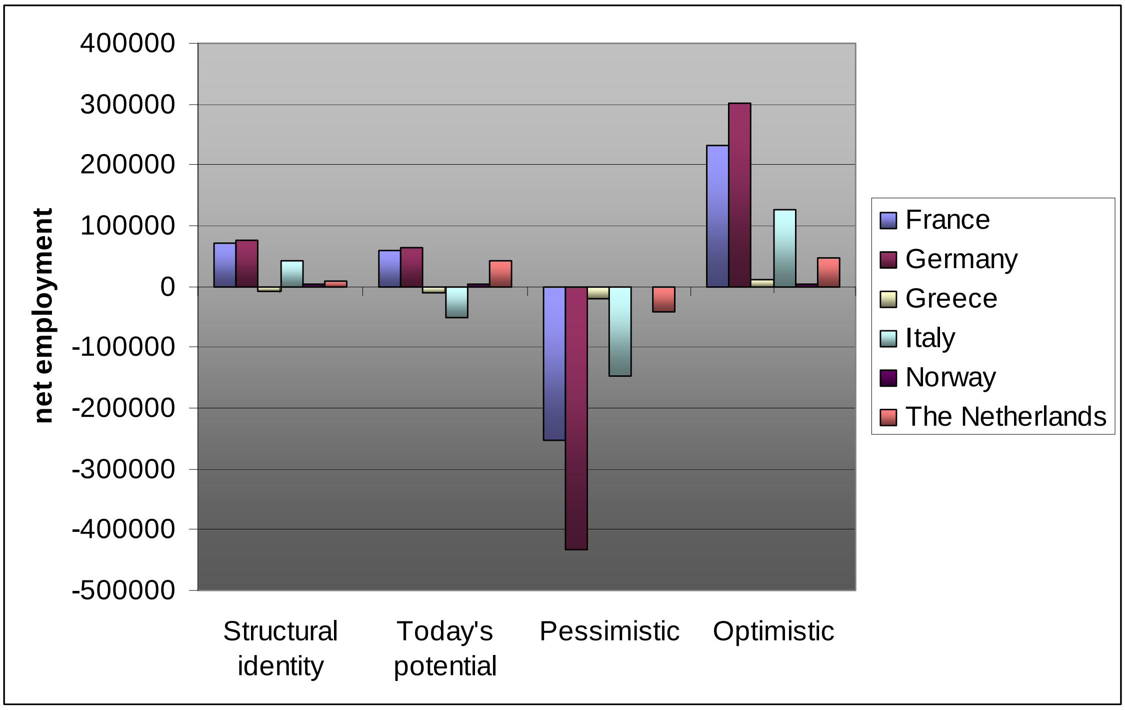

Figure 6: Net employment effects for the hydrogen high penetration (H2H). Shown are the net employment effects for the single HyWays countries in four import and export scenarios.

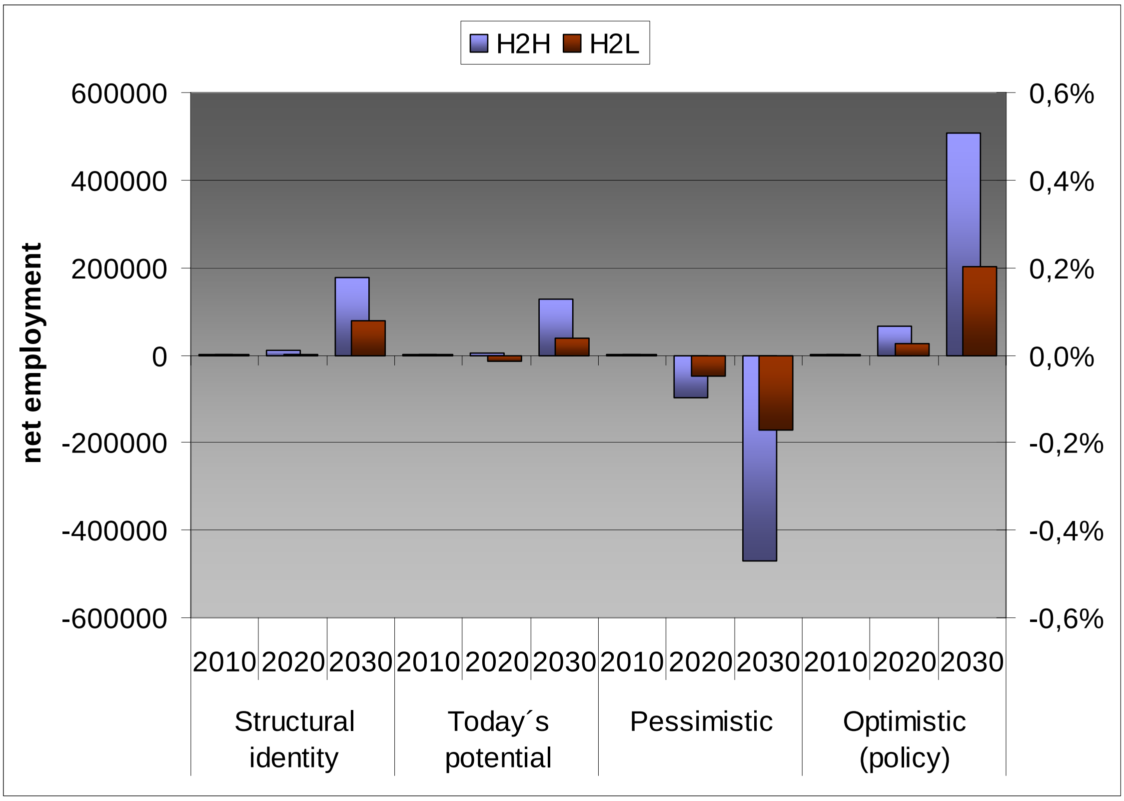

Figure 7: Net employment effects for the hydrogen high penetration (H2H) and low penetration (H2L) scenarios with high learning rates for hydrogen passenger cars for the year 2010 to 2030. Shown are the overall net employment effects for the six Hy-Ways countries in four import and export scenarios.

The replacement of conventional vehicles by FCVs induces sectoral employment shifts away from the traditional car manufacturing (see Figure 8) This shift requires considerable workforce training, and because of the required gradual built-up of manufacturing capacity and hence skilled labour force in, combination with expected mass production by 2015, it necessitates political early action.

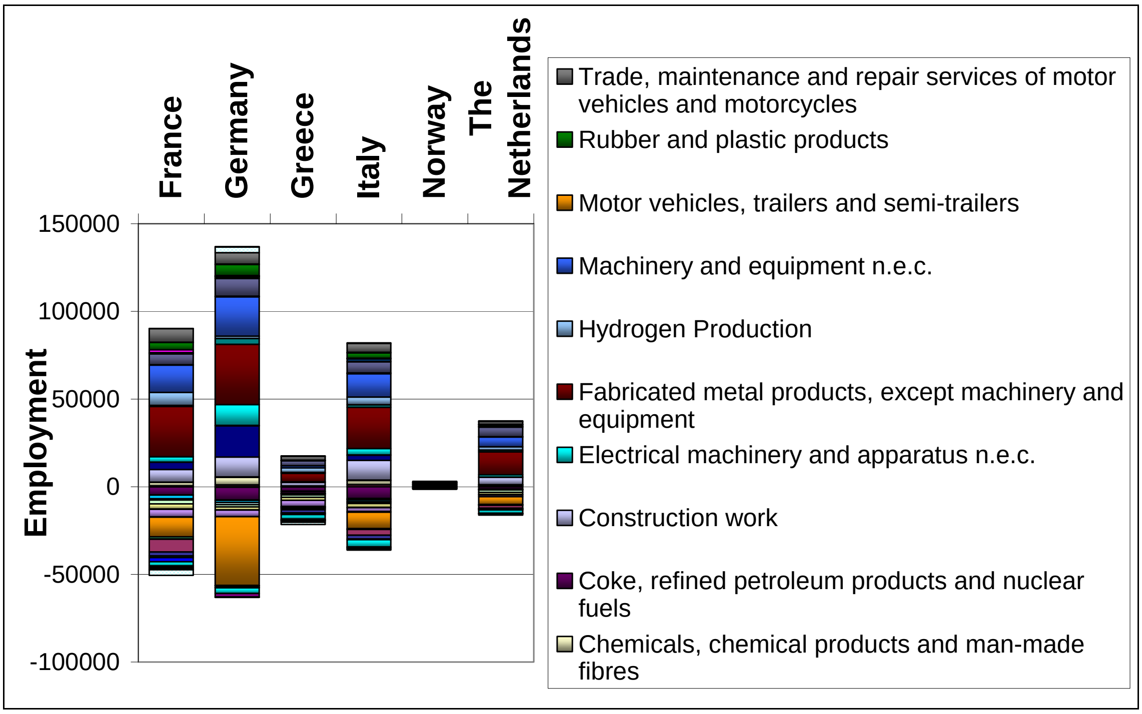

Figure 8: Employment effects for the hydrogen high penetration (H2H) in the structural identity scenario for the different economic sectors of the six HyWays MS countries.

1.5 Conclusions

Following conclusions can be drawn:

- Future development of H_2 drive system costs and crude oil price development pose major uncertainties.
- Price of FCV reaching that of conventional cars is major challenge for H_2.
- FCVs will reach cost advantage in all scenarios analysed, but necessary cumulative investments in FCVs show wide range for different scenarios (20 - 180 billion Euro worldwide). Who will take over this financial burden?
- Automobile industry structure of a country dominates economic and industrial effects: Losing a vehicle to a foreign competitor looses the complete vehicle, not only the hydrogen drive system comprising ~90 % of all investments in H_2 for all calculated scenarios.
- Major employment gains/losses expected from import/export ratio development of automobile sector.

- Significant shifts between economic sectors are identified. Required workforce skills in H_2 must be available for this to happen.
- Small gains in employment can be reached in all countries for similar import/export shares for H_2 technologies as for conventional technologies, which will be substituted by hydrogen technologies. However the same level of competitiveness as for conventional technologies must be reached on world markets first.
- For the large automobile countries (Germany, France and Italy) following dilemma situation is identified:
    - Job losses (up 0.7% in 2030 for pessimistic scenario) could be drastic should the automotive countries in Europe lose market shares due to a late market entry.
    - Uncertainties regarding market success of H_2 cars and potential risk of losing several billion Euro due to investments in premature H_2 infrastructure and H_2 car development.
- From the large automobile countries in Europe Germany has the highest lead market potential in nearly all hydrogen and fuel cell areas, followed by France and then Italy. However, taken into account the international competitiveness – especially for fuel cell – Europe falls back.
- Compared with large automobile countries the economic risks of a hydrogen economy are much smaller for the Netherlands, Norway, and Greece and following the right strategy promise a significant gain in employment. Especially the Netherlands and Norway have a significant lead market potential in selected hydrogen and fuel cell areas.

2 Introduction

2.1 Objectives of the modelling approach

The two main objectives of the modelling approach are to identify possible sectoral shifts and employment effects due to the application of hydrogen in an energy system. The analysis is mainly carried out with the ISIS model.

To achieve the aims, first of all import/export scenarios have to be developed, among other on a detailed analysis of the Lead market potential of countries in the hydrogen and fuel cell technology field. In addition, to reach an adequate technology translation into the needs of economic modelling, an extended analysis of the hydrogen and energy technologies has been carried out. Finally to get an insight into the sectoral shift and employment effects the scenario assumptions and the technology data are implemented into the input-output model ISIS and several analyses are carried out.

2.2 Scenarios

On the basis of exogenous settings (e.g. penetration rates of hydrogen cars) and results of the Markal and infrastructure analysis (e.g. installed capacities and production volumes of hydrogen on the basis of decentral SMR) market penetration curves for the various hydrogen technologies were delivered (see deliverable D 3.6 “Energy system modelling of a hydrogen economy”). These market penetration curves are one important input for the macroeconomic analysis.

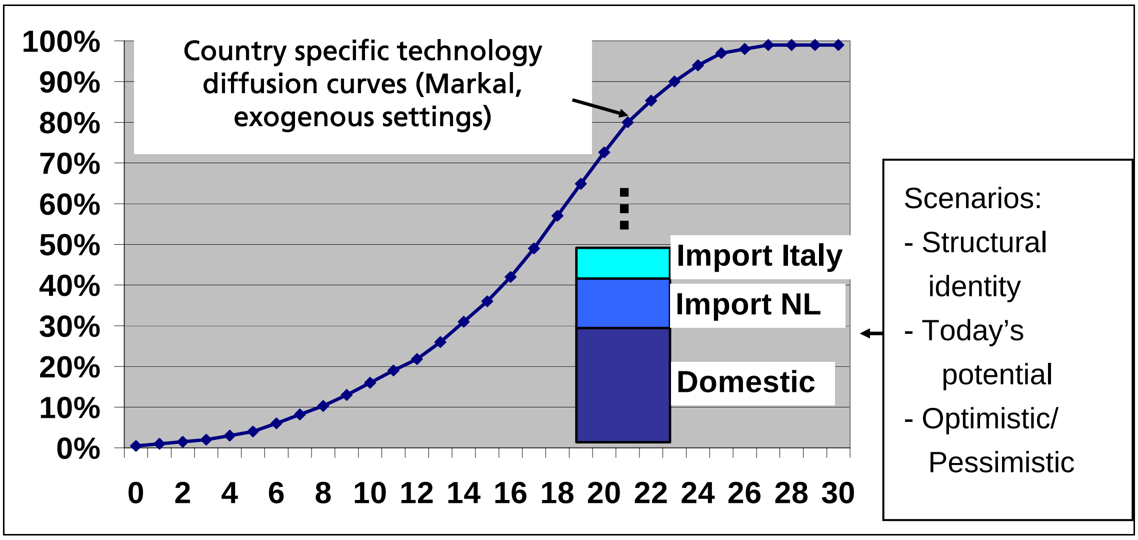

Figure 9: Example of a country specific market penetration curve for a technology and import/export shares

Further, for a macroeconomic analysis it is important if the technology and the components of the technology are produced in the domestic market or imported from foreign countries. To identify the domestic shares as well as the import/export development the following scenarios are defined:

- **Structural identity scenario**: Import/export shares on the basis of the historical market shares for conventional technologies
- Possible alternative scenarios:
  - **Today's potential (Lead market) scenario**: Import/export based on a comprehensive analysis of lead market potential
  - **Pessimistic scenario**
  - **Optimistic scenario**

The so-called Structural identity scenario is based on the assumption, that the international competitiveness of a domestic industry for hydrogen technologies is mainly influenced by today's competitiveness of industrial branches which are producing products of a high similarity to hydrogen technologies. E.g. if a country produces and exports conventional cars this country is likely to export them in the future. Or if a country has today a leading position for the production of gas turbines, this country is likely to produce hydrogen turbines in the future.

This approach can be criticized, because today's domestic industry situation with regards to conventional technologies does not automatically equate to a leading position for hydrogen technologies in the future. For example, if a country today has manufacturing capacity for the construction of conventional internal combustion engines this must not necessarily lead to the situation that this country will also have in the future a relevant industry for stack production due to the technological differences of both technologies (these might include different materials, production processes, and education). To take this into account, three alternative scenarios have been developed.

The first one is the Today’s potential (Lead market) scenario. This is based on a detailed analysis, which is described in the following chapters. It assesses which country has the most promising potential to become a Lead market in hydrogen production or fuel cell application. The results are translated into different import/export shares for each country.

The second and third alternative scenarios are developed to show possible extreme positive and negative developments. For example, as a result of the Lead Market analysis Germany is in a good position to become a lead market for hydrogen production and construction of hydrogen cars. However, if the political support is missing and the firms don't realize their potential some negative effects could occur for the German economy. The aim of the optimistic and pessimistic scenarios is to show the bandwidth of possible future economic and social developments from a positive (optimistic) and a negative (pessimistic) view.

For the different scenarios the two main framework assumptions vary. The technologies could be produced mainly on a domestic basis (the country is a lead market) or could be mainly imported (in this case the hydrogen lead market is outside) (see Figure 7).

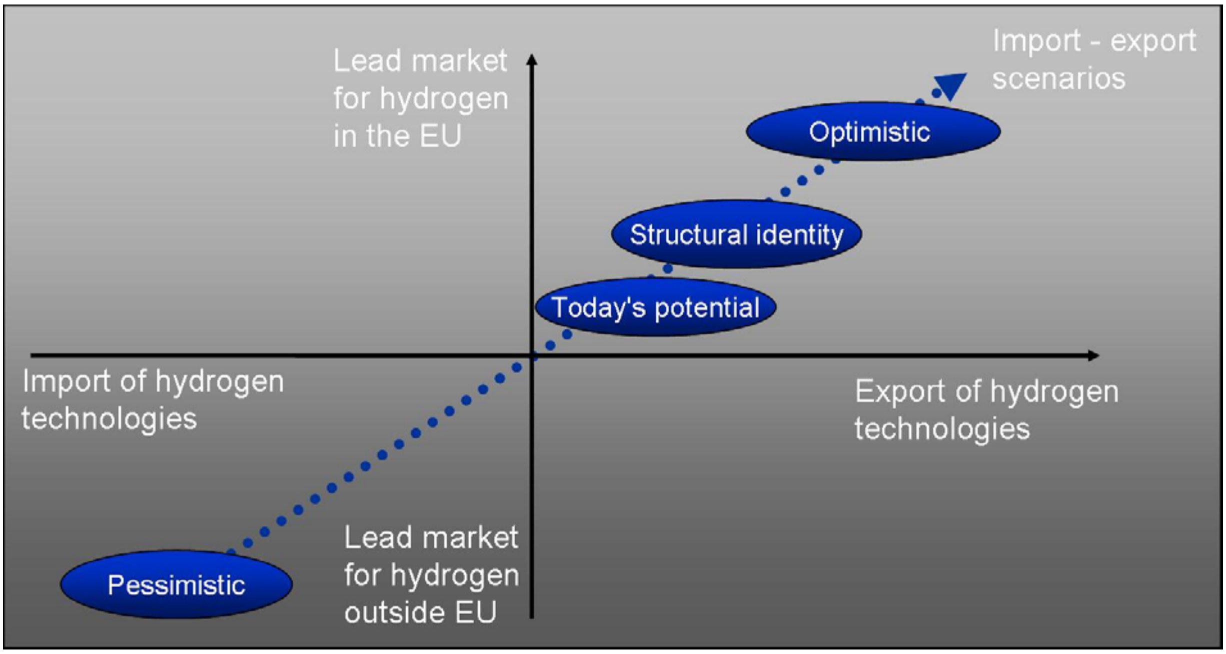

Figure 10: Schematic scenario overview

3 Model Interaction

See deliverable D 3.2 Definition of model data exchange and model interfaces.

4 Lead market approach

4.1 Methodical approach

4.1.1 The lead market concept and the application in HyWays

Lead markets are defined as regional markets (in most cases countries) that first adopt an innovation design in a technology field and that have specific characteristics (so-called lead market factors) that enhance the probability that the same innovation design will be adopted broadly in other countries as well.

The new and innovative approach for analysing lead markets focuses not only on the technological capabilities of firms and institutes (usual approach of conventional innovation concepts) but also on the demand side of a market as well as on the role of policy and regulation for explaining the export capability and the competitiveness of a region in a specific technology field. (see for further information about the theoretical concept [Meyer-Krahmer, 2003], [Beise, 2001], [Suarez, 2003]).

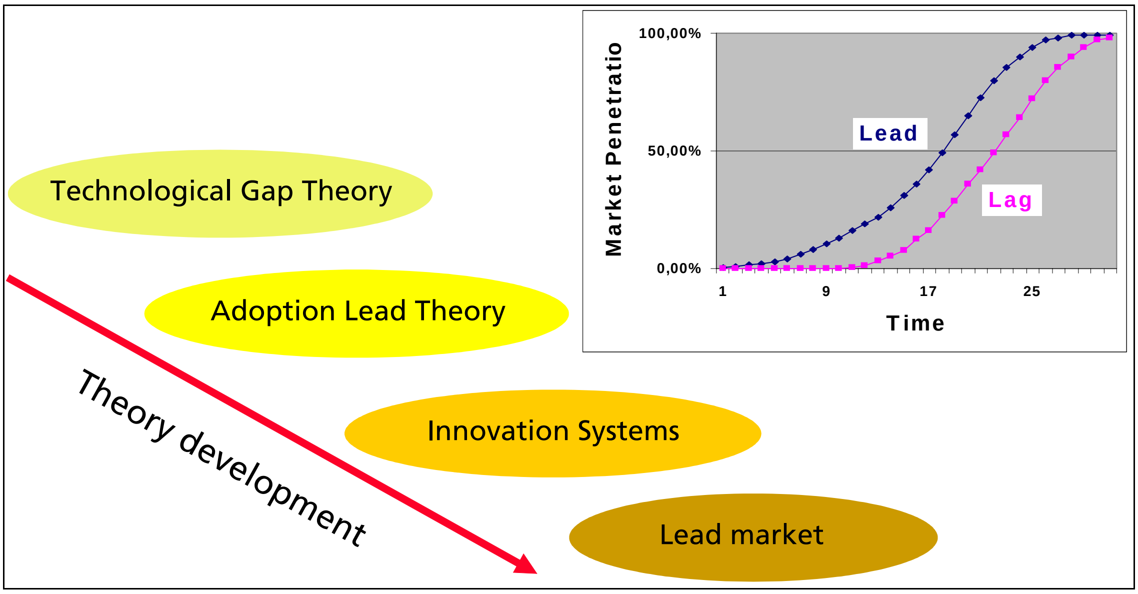

Figure 11: Theories of diffusion processes for innovations

The Lead market concept will be used to identify the relevant indicators for a forecast of export and import shares of hydrogen technologies in the selected member states of HyWays. In theory a country with a high Lead market potential in a certain technology field will produce and export these technologies. The quantification and evaluation of these indicators provides an input for the so-called Lead market scenario of the Hy-Ways project

4.1.2 Lead market factors

Three categories of factors which influence the probability that a country will become a lead market have been identified. The first category covers all kind of market factors such as demand conditions, price conditions, market growth potential or the competitive situation. These are typical factors for Lead markets (see [Beise, 2001]). Firm specific factors which are determined by the technological performance of the firms and their strategic positioning such as export orientation belong to the second category. The factors of this category come over in the technology cap theory (see [Legler et al. 2002] and are often used and well-accepted to explain the market diffusion of new technologies and the export success of regions. The third category covers political and regulation topics and are important among others for infrastructure investments and environmental technolgies.

Market factors are:

- **Market structure advantages:** A high competition between firms leads to an increase of inventions (empirically validated) and development of alternative technology designs, which increase the probability to select the most appropriated technology design.
- **Cost advantages:** Market size, market dynamic and market growth have a relevant impact on cost reduction and international competitive advantages.
- **Transfer advantages:** The transfer (export) to other regions will have advantages, if the risk of technology adoption is minimized due to demonstration effects and similarities between the consumer preferences.
- **Demand advantages:** First demand for innovation occurs in regions with the highest benefit from the innovation. In these regions the technology diffusion process starts normally.

Firm factors are:

- **Technological superiority/Knowledge**
- **Strategic behaviour:** Market introduction strategy of firms
- **Installed basis:** Market introduction advantages due to regular customers. Regime of appropriability, which describes the internal capability of a firm to identify and use the market chances of new developments.
- **Reputation**

Policy and regulation figures are:

- **Support schemes**
- **Standards**
- **Codes**

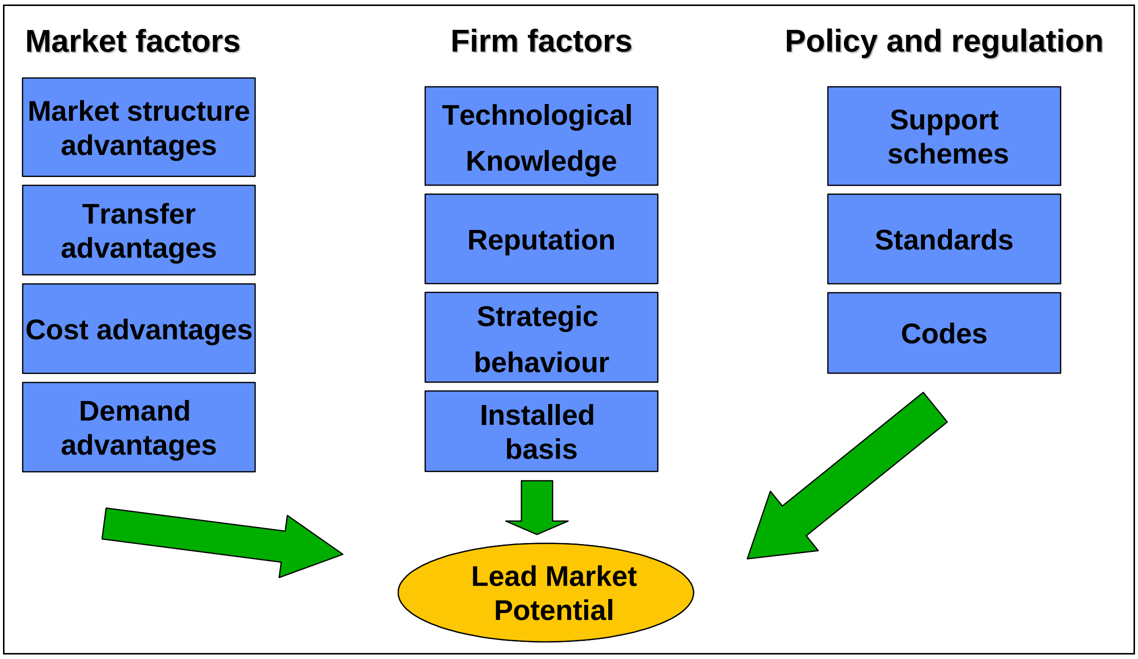

Figure 12: Categorisation of Lead market factors

4.1.3 Indicators and weighting of indicators

To measure the categories quantitative indicators have to be identified. Possible indicators for the above mentioned factors are for example:

- patent shares to indicate the technological performance of a firm,
- number of competitors and their market shares to receive knowledge about the competitive structure of a market or,
- government funding on R&D to indicate the politic involvement in a technology.

To have a clear and transparent overview, only quantitative indicators with a high acceptance are selected and qualitative indicators are neglected.

In the chosen approach the indicators are differentiated into two classes. In the first group all indicators with a direct relation to hydrogen like hydrogen patents, R&D-Budgets for fuel cells or hydrogen demonstration projects are collected. In the second group "indirect" indicators like today's motor vehicle production for conventional cars or energy resources and prices are collected, which doesn't show, that the country is moving towards a hydrogen economy, but which indicates, that a country might have significant potential (a good starting position) to become a Lead market.

To come to a final evaluation about the Lead market potential the indicators have to be weighted and summarized to one value. The direct indicators receive a higher ranking (factor of two) compared to the indirect indicators.

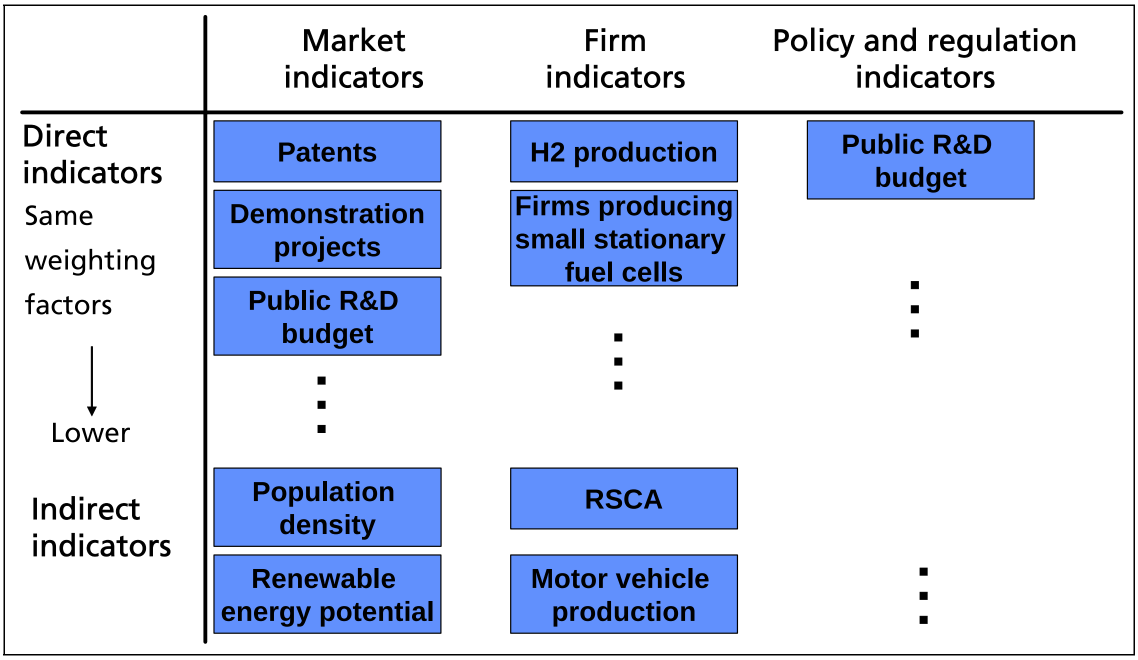

Figure 13: Examples for indicators to measure the Lead market potential and their weighting

4.2 Input data, assumptions and indicator interpretation

4.2.1 Introduction

To fit in the needs of the Input-Output analysis within HyWays the indicators are divided in overall country indicators and in the three specific technology field country indicators: production, stationary and mobile. This should be seen as a first step to identify possible technology specific lead markets on country level.

4.2.2 Overall indicators for Europe

4.2.2.1 Patents

Rationality

- The competitiveness of companies, regions or countries can be measured by patents due to the strong correlations between patents and RTD&D budgets, patents and innovations, patents and employment, patents and export shares as well as patents and economic success (empirically validated).
- Patents (especially the chosen World patents (WO) and European patents (EP)) demonstrate the economic interest of firms to invest in future technologies.
- Patents are well-accepted and often used indicators for such kind of research questions.
- The database is very good

Limitations

- Not all inventions which are patent-relevant ultimately result in a patent registration.
- Time lag between the invention, patent registration and availability of patent data in the various public or commercial available databases.
- Identification of an adequate quality indicator for patents.

Database and methodological aspects

- WO and EP patents (patent database: WPI and PATDPA)
- In the time period 1990-2002 for EP patents and 1997-2002 for WO patents. [Wietschel, 2004]
- All published patents (not only granted ones) to identify current developments.
- Chosen quality indicator: International recognition of WP and EP patents and significant value in their own right (patent application of WO and EP is expensive)

Indicators

- Total amount of hydrogen patents [Wietschel, 2004]
- Total amount of hydrogen patents/per capita [Wietschel, 2004], [Eurostat 2004]

  The second indicator is a relative indicator. The effect of country and population size doesn't play a role (small countries can have a high value).
- Total amount of hydrogen patents/total amount of all patents [Eurostat 2004]

  The third indicator is a relative indicator, too. It shows, if hydrogen plays an over average role in the activities of firms or not.

Results

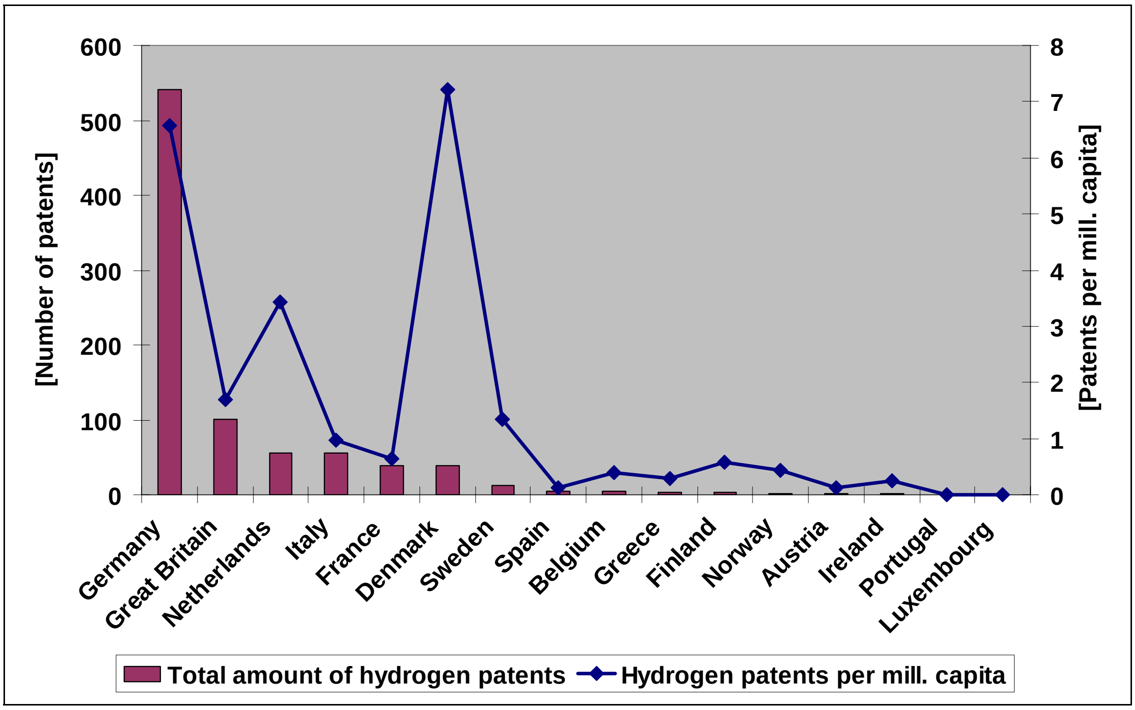

Figure 14: Total amount of hydrogen patents and hydrogen patents per million capita (1990 – 2002)

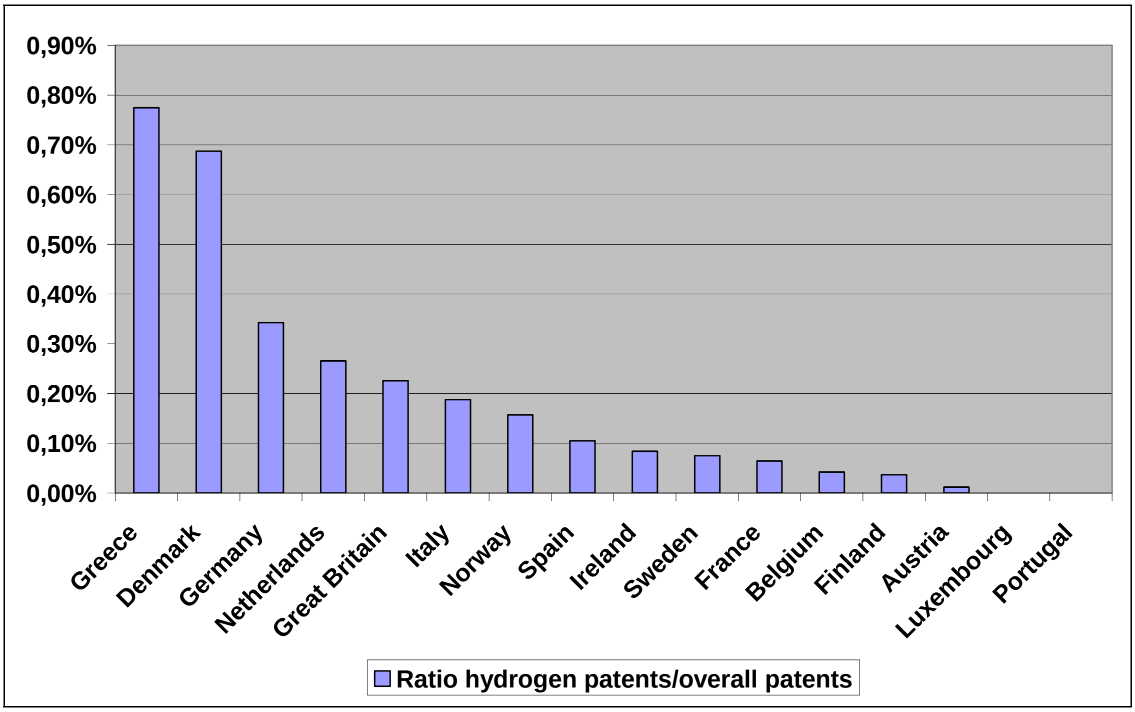

Figure 15: Ratio of hydrogen patents to overall patents

Germany has a leading role in all three patents indicators. The relative indicators show that hydrogen compared to other industrial activities plays an important role in Denmark and also in the Netherlands (compared with other countries). Great Britain is also well-placed. The leading role of Greece in the indicator ratio of hydrogen patents to overall patents can be explained due to the relatively low patent activities in Greece.

The following figure visualizes the geographical distribution of firms with hydrogen patent activities.

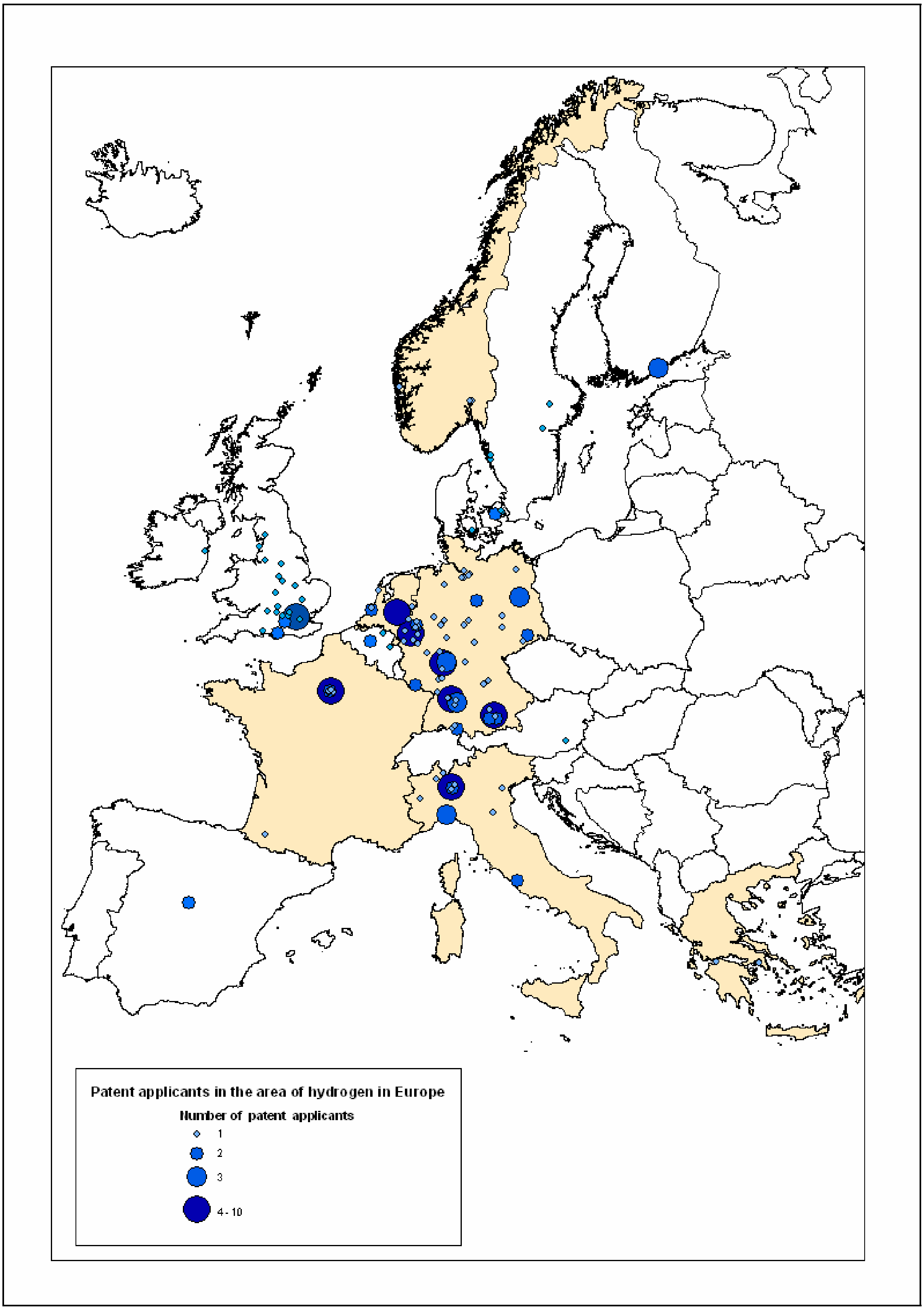

Figure 16: Geographical distribution of firms with hydrogen patents

4.2.2.2 Demonstration projects

Rationality

- Demonstration projects are a good indicator for the transfer advantages of a country
- Further they demonstrate the praxis relevance of the activities and the capability to translate theory into practice
- The experience gained in demonstration projects may lead to the realization of cost advantages
- Demonstration projects increase the reputation of firms

Limitations

- Data base is weak (no comprehensive public or commercial data bases are available), especially a problem in small countries without any central coordinators of hydrogen activities

Database and methodological aspects

- Data research over internet, project databases and journals
- Locations of the demonstration projects are collected (not the firm locations)

Indicators

- Total amount of demonstration projects
- Total amount of demonstration projects/capita

Results

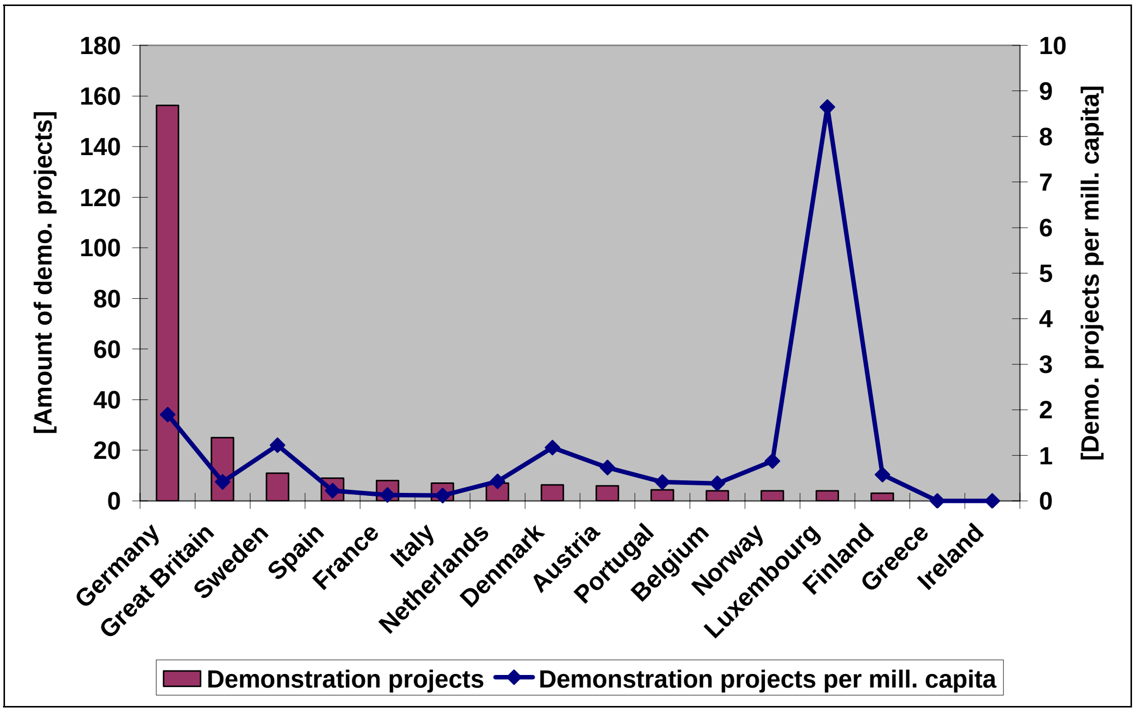

Figure 17: Amount of total demonstration projects and demonstration projects per million capita (realised projects till 2004)

Germany has the highest amount of demonstration projects, followed with a relevant distance by Great Britain. In relation to the number of inhabitants Denmark, Sweden and Norway have high shares of demonstration projects followed by Austria and Finland. However, these shares are lower than the share of Germany, but higher than the share of Great Britain.

4.2.2.3 Public R&D budget

- *Rationality*
- Public R&D budgets indicate the political support of a new technology field
- Further they are often used as an indicator for the general innovation climate of a country
- Further high budgets can lead to cost advantages and transfer advantages, if they are used for demonstration projects

Limitations

- Weak database and problems to identify hydrogen related budgets

Database and methodological aspects

- Next to the specific R&D budget for hydrogen and fuel cells also the total R&D budget are taken into account to extend the research work. The specific R&D figures are a more powerful indicator, however due to the week database also the absolute R&D figures can give some hints to the general innovation friendliness of a country.

- As additional information the R&D-project cost of the EU-MS under the EU Framework programme 5 and 7 are given.
- Data research over research projects (SWOT-analysis), internet and journals, main source [Amorelli, 2004], for EU-projects [SENTER NOVEM 2004]
- The average figure is chosen in case of discrepancies in the data sources

Indicators

- Total amount of public R&D-budget for hydrogen and fuel cells (average about the last four years) [Amorelli, 2004] and internet research
- Total amount of public R&D-budget for hydrogen and fuel cells/Million GDP [Amorelli, 2004] and [Eurostat 2004]
- Total amount of public R&D-budget/Million GDP [Eurostat 2004]
- Absolute and relative project cost of hydrogen and fuel cell projects under the EU Framework programme FP5 and FP6 [SENTER NOVEM 2004]

Comment: Former research activities came to the results that the public R&D budget increase is positive correlated with a GDP (Gross domestic product) or population increase. This leads to the consequence, that in cases of same values of the relative indicator between a small and a large country the small country is in a better competition situation.

Results

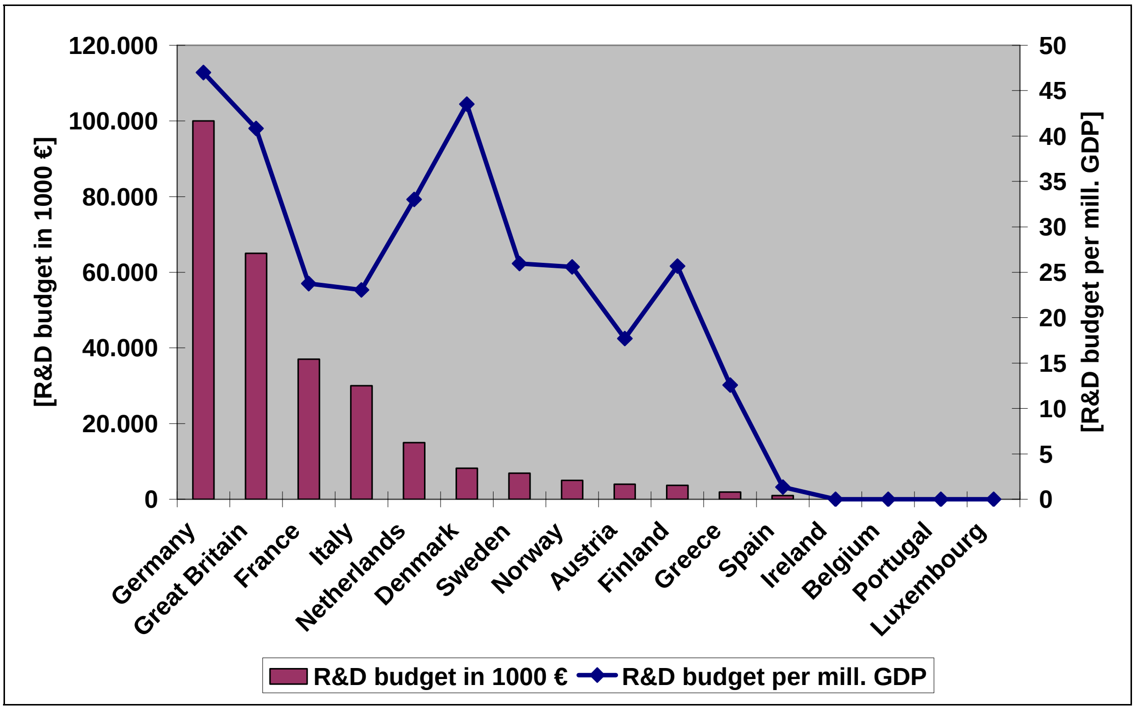

Figure 18: Total amount of public R&D budget and R&D budget per GDP (based on average date 2000 – 2002)

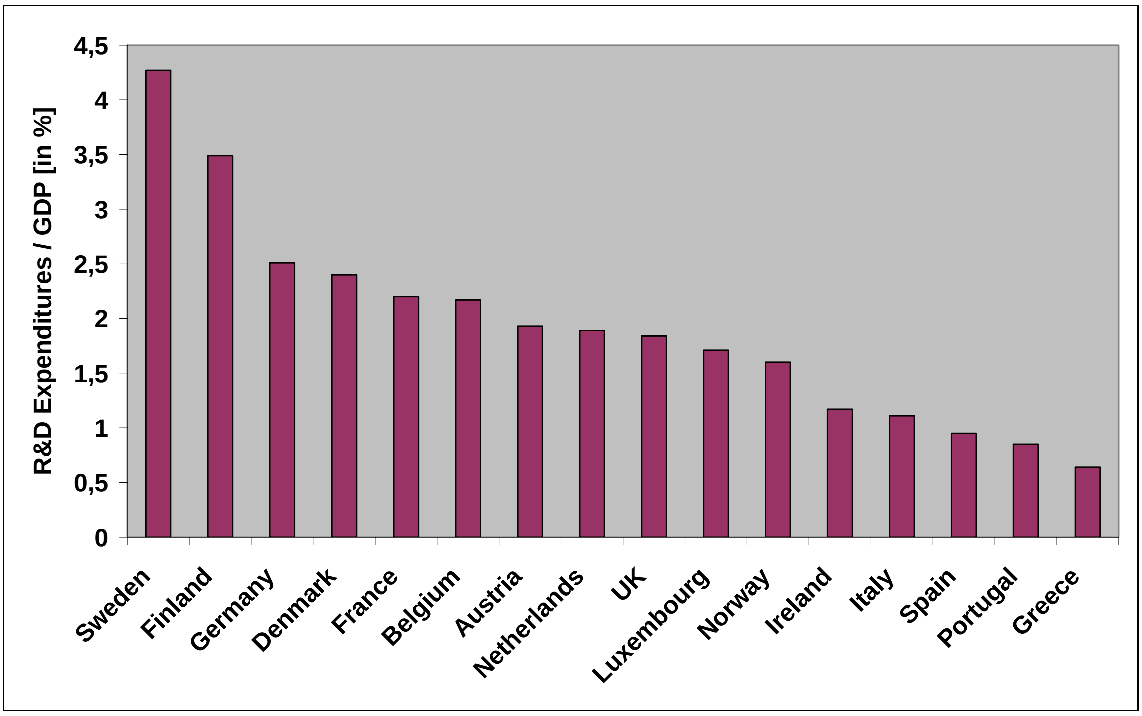

Figure 19: Total amount of overall R&D budget per GDP (for the year 2002)

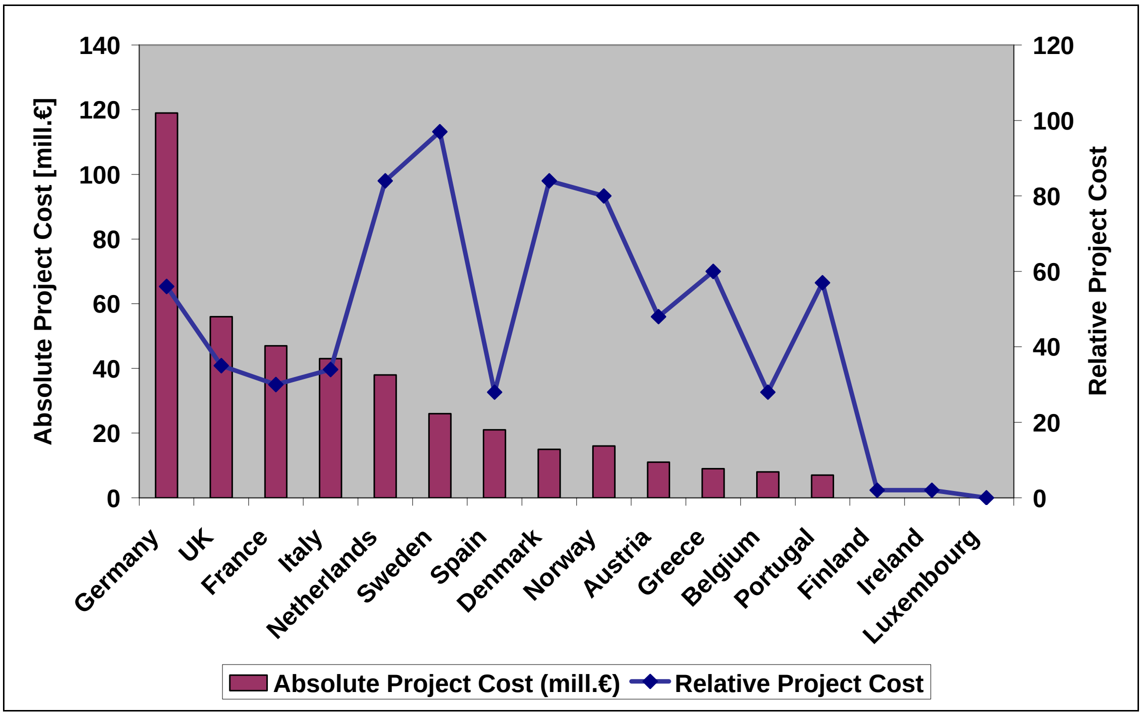

Figure 20: Absolute and relative project cost (per GDP) for EU FP5 and FP6 between 1998 and 2003

Again Germany has a leading role in the selected R&D budget figures for hydrogen and fuel cells. France and Italy have high amounts of total R&D budgets. The relative indicator shows, that in Denmark and also in the Netherlands hydrogen plays a very important role in the national research strategy. Norway, Italy, Sweden, Finland and France have a more or less similar ratio of R&D budget to GDP. Looking on the total R&D figures per GDP Sweden and Finland are in leading role, followed by Germany and Denmark.

In general Sweden and Finland use a high part of their GDP for R&D, which can be interpreted, that these countries are innovation-oriented.

4.2.2.4 Foreign trade in hydrogen relevant industry branches

Rationality

- Foreign trade figures show the economic success of products in the world market

Limitations

- For hydrogen as an energy carrier and the hydrogen technologies no foreign trade figures exist

Database and methodological aspects

- Due to the lack of hydrogen specific foreign trade figures conventional industry branches are selected, which have a very close linkage to hydrogen technologies [EUROSTAT 2004]

Indicators

- Revealed Comparative Advantage:

$$RCA_{ij} = (X_{ij} / {}^{i}\sum X_{ij}) / ({}^{j}\sum X_{ij} / {}^{i}\sum {}^{j}\sum X_{ij})$$

The export share of a sector i in a country j in relation to the total export of the country j are set in relation to the average share of export of this sector i to the total export of all OECD countries. For a better interpretation a standardisation of the indicator is carried out:

- Revealed Symmetric Comparative Advantage RSCA=(RCA-1)/(RCA +1)

This indicator shows the level of export specialization in hydrogen related areas of a country for relevant industry branches. Please keep in mind that due to the construction of proportion the meaningfulness of this indicator is limited for the export orientation of small industry branches of a country.

Results

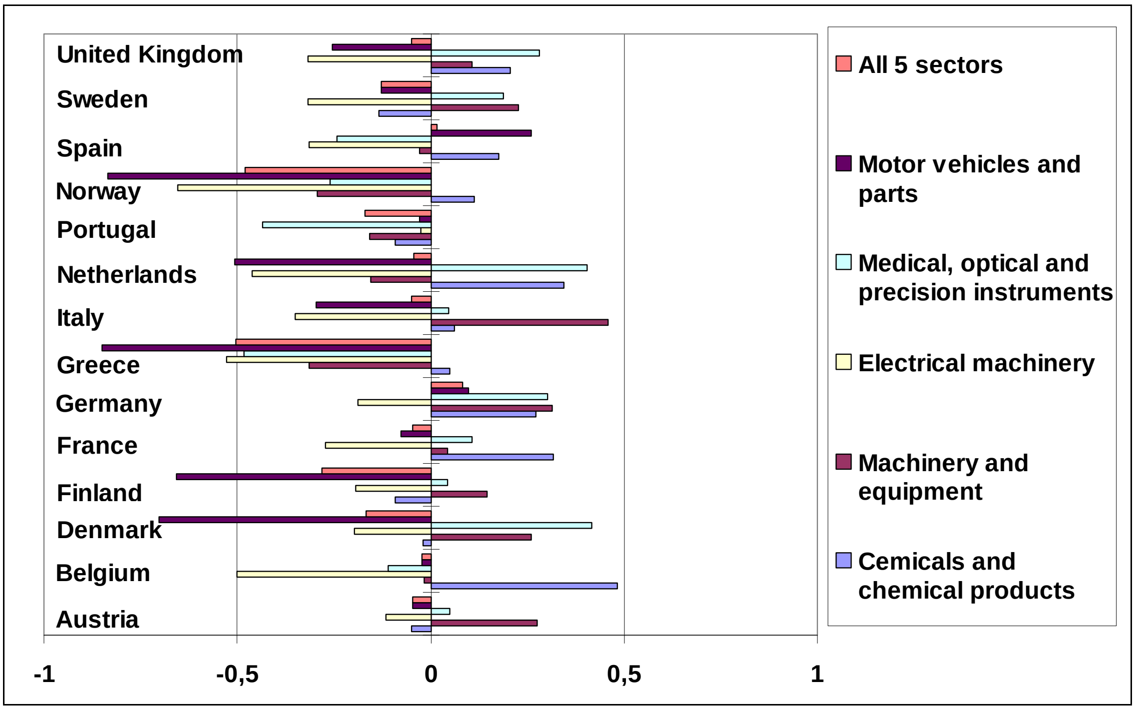

Figure 21: Revealed Symmetric Comparative Advantage of different countries by relevant industry branches

Overall only Germany has in total an over average export orientation for the "hydrogen relevant" industry sectors. Spain, Austria, Belgium, Italy, the Netherlands and France are also more export oriented in these sectors than other countries. However, especially in Norway the selected indicators may not lead to a well balanced picture due to the dominant role of energy carriers in the export/ import balance of Norway.

Looking at single branches, Italy's machinery and equipment sector has a strong specific export orientation and especially the Netherlands and France are export-oriented in chemical products.

4.2.2.5 Indicators for electricity from renewable sources

Rationality

- It is assumed, that renewable energy carriers will play a relevant role for hydrogen production in the future
- Especially a large share of large-scale hydropower allows a cheap electricity production from renewable sources
- Further a high potential of fluctuating renewable energy carriers (wind, sun) may offer a good opportunity for hydrogen as a storage option

Limitations

- No data for Norway available

Database and methodological aspects

- Renewable electricity potentials, Advanced renewable strategy scenario [MITRE 2004]
- Energy statistics (ES) - supply, transformation, consumption (Gross production from hydro power station, capacity >10 MW) [EUROSTAT 2004]

Indicators

- Total renewable electricity potential (separated in large hydro, non fluctuant and fluctuant renewables)
- Renewable electricity potential per capita

Results

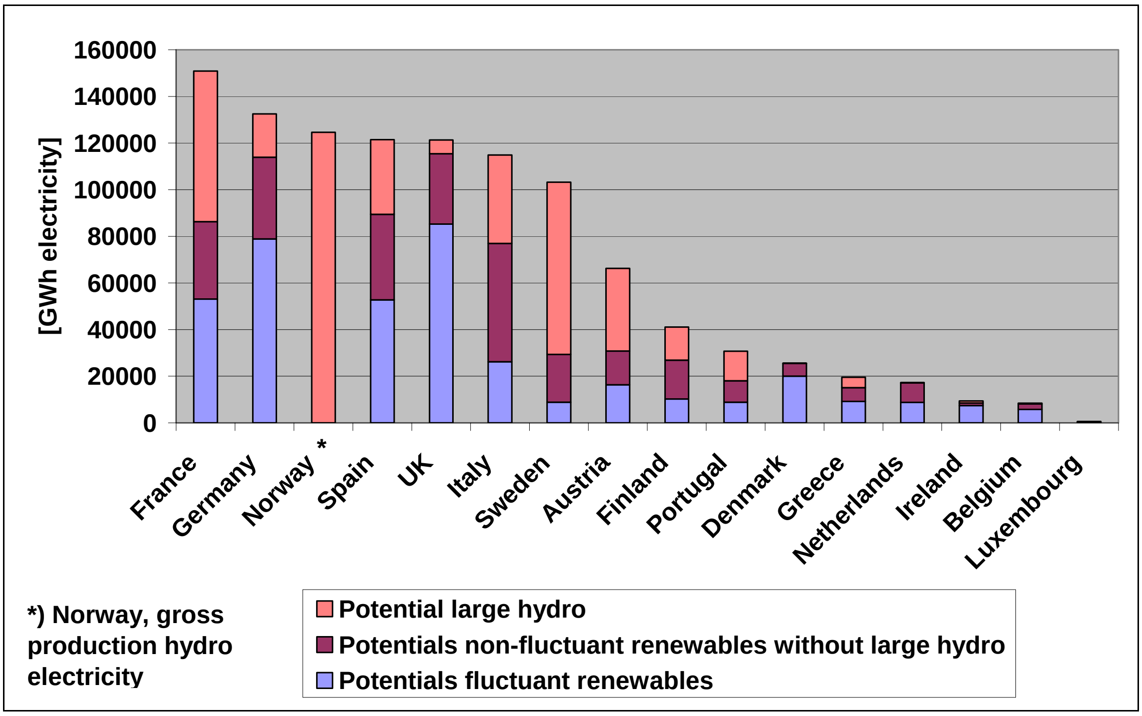

Figure 22: Renewable electricity potentials

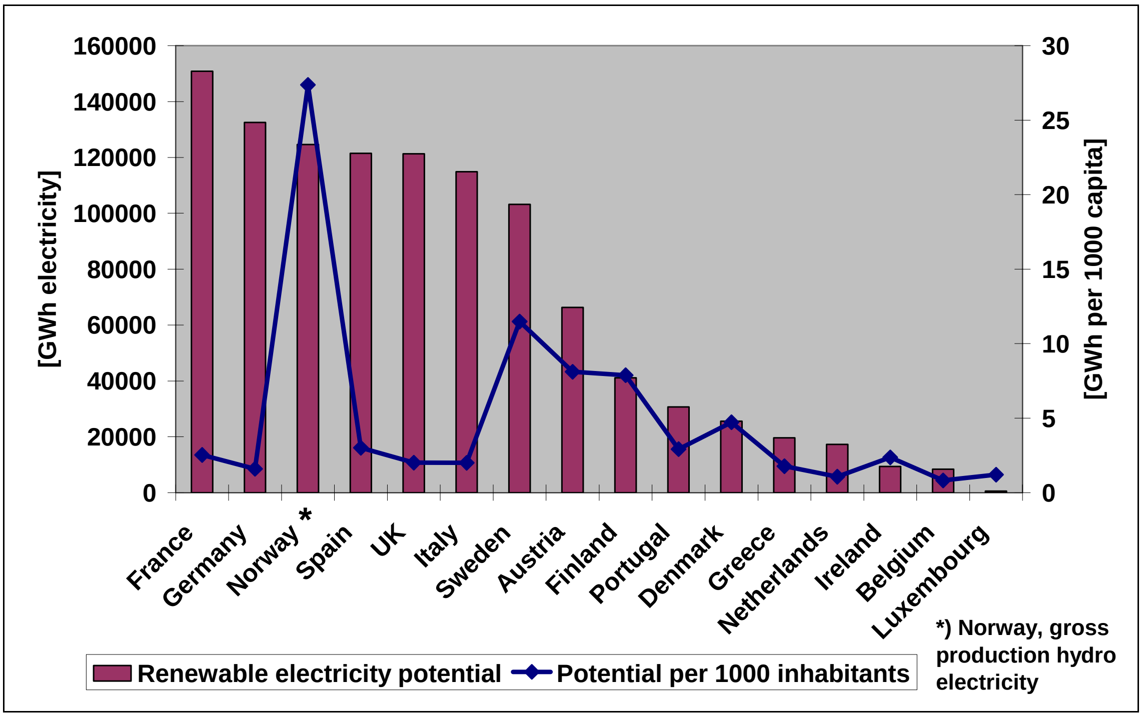

Figure 23: Renewable electricity potentials and relative potentials

France has the highest total renewable electricity potential with a high amount of large hydro potential. Germany, Spain and the United Kingdom follow, due to their large potential in wind energy (fluctuant). No renewable potential data for Norway is available and therefore the hydro electricity production data for Norway from 2002 is taken into account. The high values show the importance of hydro electricity in Norway. In relation to the number of the inhabitants of each country, Norway, Sweden, Austria and Finland have remarkable high values.

4.2.2.6 Indicator industry electricity price

Rationality

- The electricity prices are an indicator for the hydrogen production through electrolysis

Limitations

- Future price developments are not taken into account

Database and methodological aspects

- Electricity prices first half year without taxes (ES - Electricity - industrial consumers - half-yearly prices) [EUROSTAT 2004]

Indicators

- Electricity price for industry

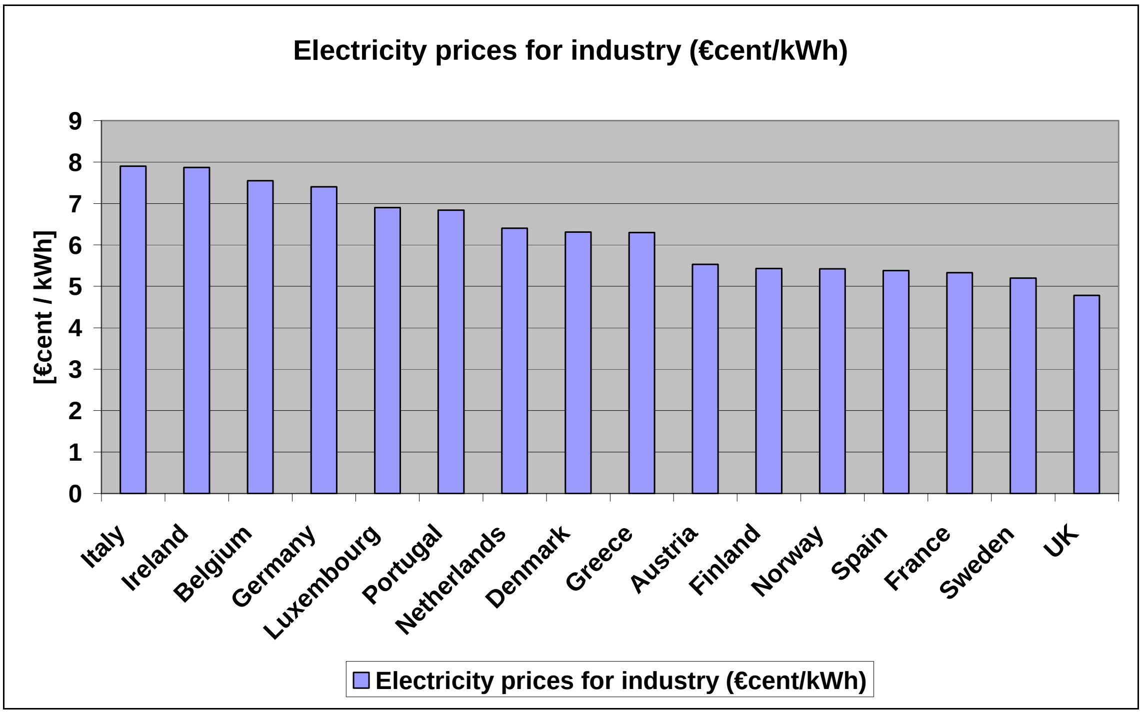

Figure 24: Electricity prices for industry

Italy and Ireland have the highest electricity prices, followed by Belgium and Germany. Due to low electricity prices in the United Kingdom and also in Sweden, France, Spain, Norway, Finland and Austria there are lower cost barriers to produce hydrogen through electrolysis.

4.2.2.7 Venture Capital Investments

Rationality

- Venture Capital Investments indicate the extent of financial resources for entrepreneurial activities and technology transfer in a new technology field

Limitations

- Weak database and problems to identify hydrogen related investments

Database and methodological aspects

- Data research over internet, statistic reports and journals [EVCA 2002]
- The average figure is chosen in case of discrepancies in the data sources

Indicators

- Total amount of Venture Capital Investments (average about 1999-2003)
- Total amount of Venture Capital Investments per GDP

Results

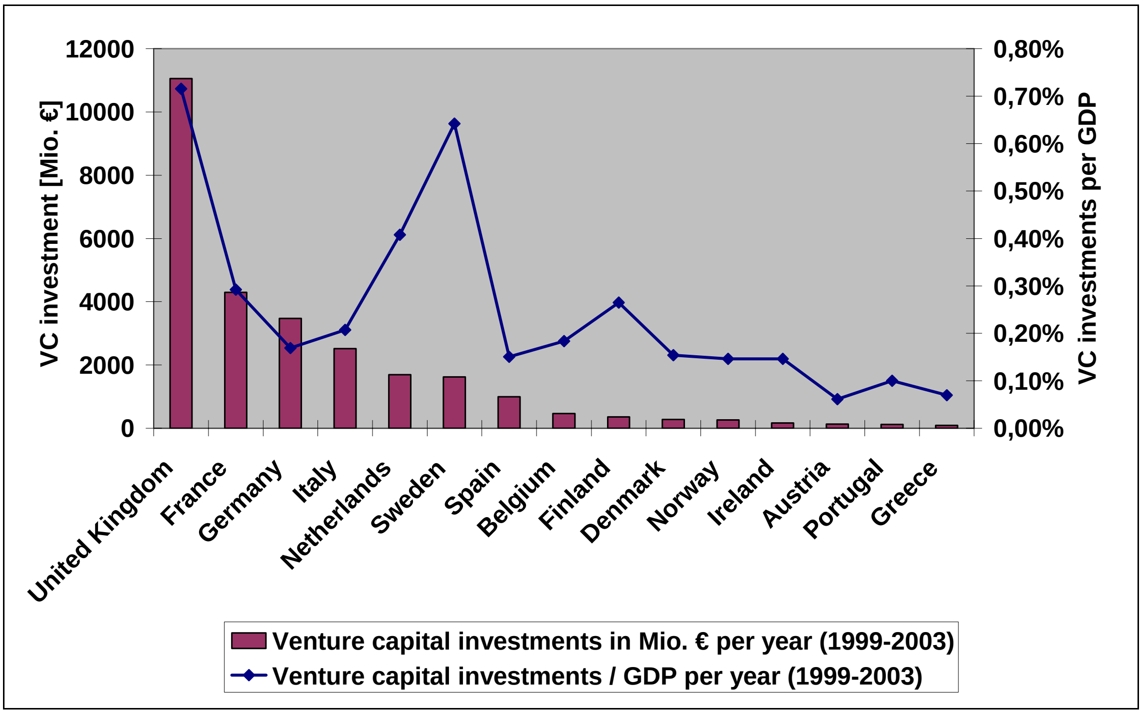

Figure 25: Total amount of Venture Capital (VC) Investments and Venture Capital Investments per GDP (based on average date 1999-2003)

United Kingdom seems to have the best access to venture capital (in absolute and relative values). Germany and France have high absolute venture capital investments. However a lot of smaller countries have relevant higher venture capital investments per GDP.

4.2.3 Indicators for hydrogen production

4.2.3.1 Introduction

Four indicators are used:

- Total number of patents for hydrogen production
- Total number of patents for hydrogen production/capita
- Actual hydrogen production numbers in industry
- Export orientation of machinery and equipment industry

The patents indicators have already been discussed before. Therefore only the discussion of the hydrogen production figures follows.

4.2.3.2 Current production of hydrogen for industry applications

Rationality

- The actual figures about hydrogen production for industrial purposes (like refineries or fertilizer production) are an indication for cost advantages and existing infrastructure

- Further this indicator shows the technical competence in the field of hydrogen production (construction and operation of hydrogen plants)

Limitations

- The database is weak

Database and methodological aspects

- Public information is used
- Annual hydrogen production [LBST, 1999]

Indicators

- Total amount of hydrogen production

4.2.3.3 Results for the selected indicators

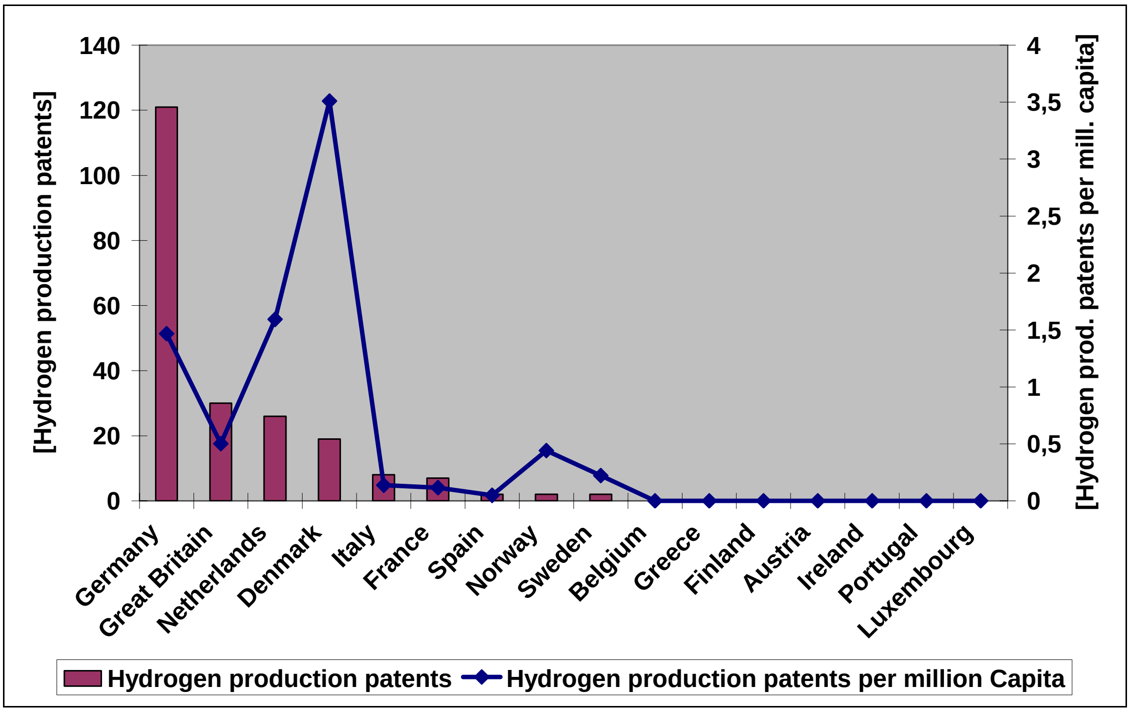

Figure 26: Total amount of patents for hydrogen production and hydrogen production patents per million capita (1990 – 2002)

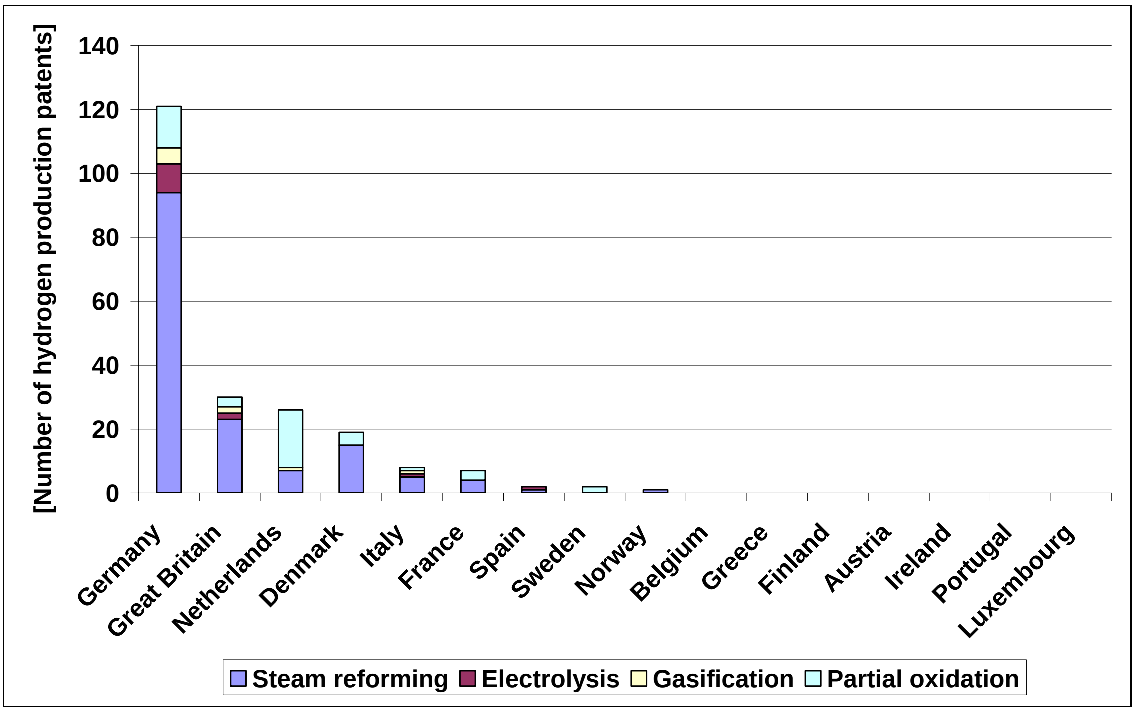

Figure 27: Total amount of patents for different hydrogen production options (1990 – 2002)

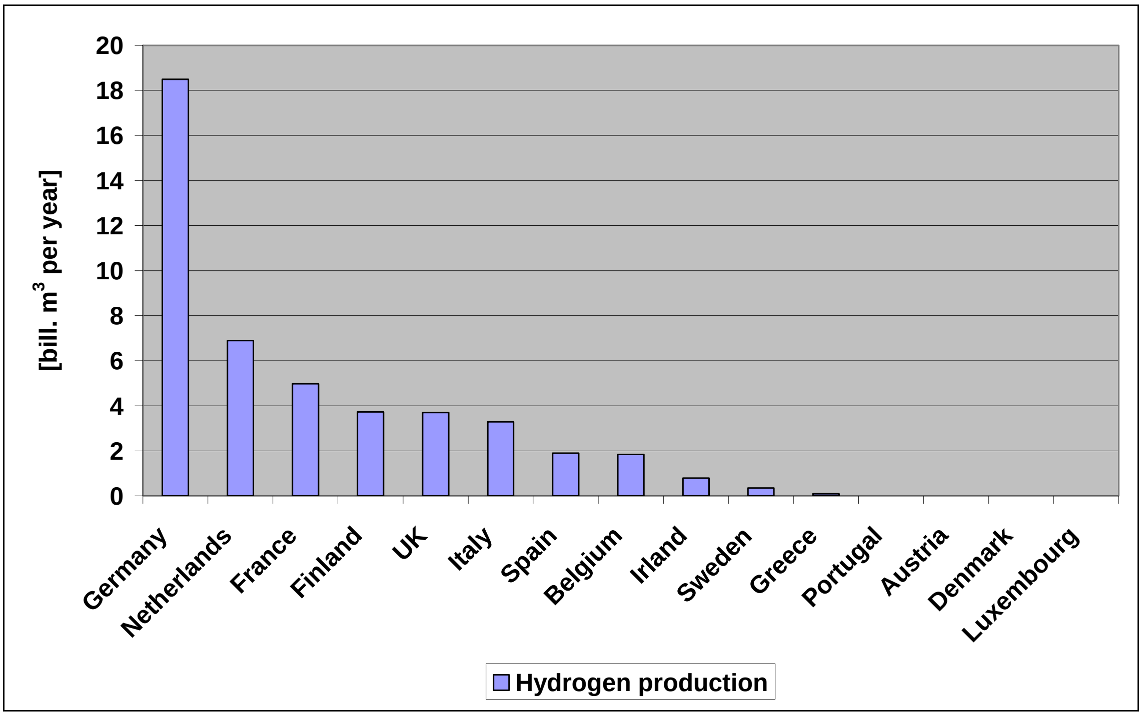

Figure 28: Annual hydrogen production (for Norway no data are available)

In relative figures but also in absolute figures Denmark is well-placed in the hydrogen production area. In Germany the highest amount of hydrogen was produced in the past. Looking on the total numbers of patents for hydrogen production, Germany is the leading country with a focus on steam reforming, electrolysis and gasification. In the Netherlands the patent activities focus on partial oxidation – in total the Netherlands have more patents for partial oxidation than Germany.

4.2.4 Indicators for stationary applications

4.2.4.1 Introduction

Three indicators are used

- Total amount of patents for fuel cell technologies
- Total amount of patents for hydrogen production/capita
- Fuel cell demonstration projects

4.2.4.2 Results for the selected indicators

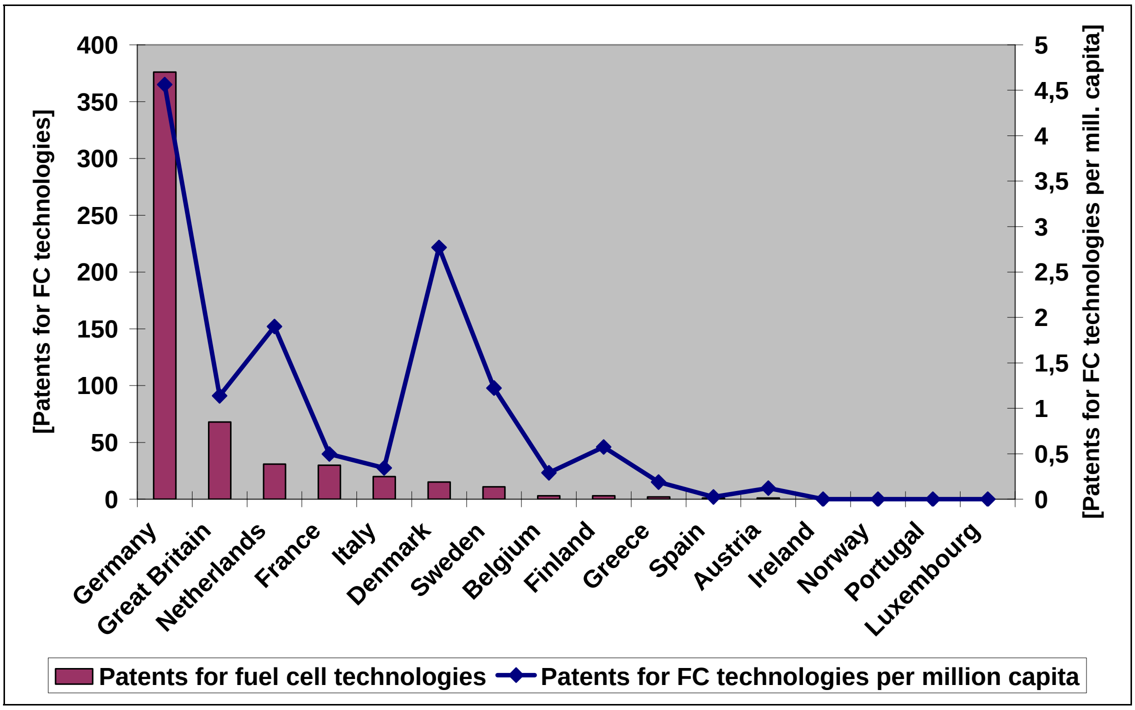

Figure 29: Total amount of patents for fuel cell technologies and patents for fuel cell technologies per million capita (1990 – 2002)

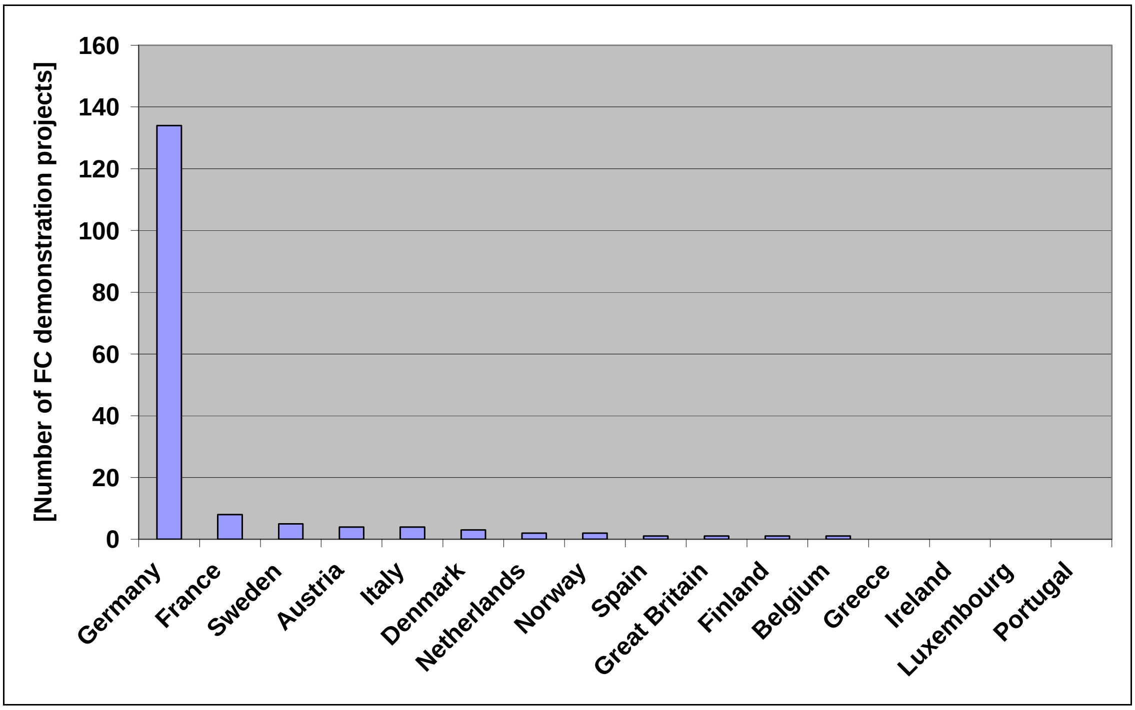

Figure 30: Number of fuel cell demonstration projects

Looking on the total number of fuel cell demonstration projects, the total amount of fuel cell patents as well as the relative indicator total amount of patents per capita Germany has a clear leading role. The firms and institutes of the Netherlands are very active in the patent registration, whereas France has comparable high figures for patent activities as well as for the demonstration projects.

The countries in Europe where small stationary fuel cell manufacturers are already located until now are Germany, Great Britain, Italy and Denmark. These countries are already working or planning to work in this technology sector (see [FCTODAY, 2003]). In the worldwide scope just Germany (11%) and UK (4%) have a relevant amount of fuel cell manufacturing activity and can play a leading role in this sector for Europe (see [WFCIS2004]).

4.2.5 Indicators for mobile applications

4.2.5.1 Introduction

The following indicators are used:

- Total amount of patents for hydrogen internal combustion engines (ICE) and PEM-fuel cell technologies

- Total amount of patents for hydrogen internal combustion engines (ICE) and PEM-fuel cell technologies/capita
- Demonstration projects for mobile applications
- Income per capita and average passenger car age
- Population density
- Average motor vehicle production

The indicators with the exception of *Average motor vehicle production,* the *Income per capita and average passenger car age* and *Population density* were already discussed before.

4.2.5.2 Average motor vehicle production

Rationality

- The average motor vehicle production is an important factor for the lead market approach. It shows the experience and the potential of building vehicles as a mass product. Further this indicator may also reflect the financial power and willingness to invest in a new technology like hydrogen cars.
- A view on the relative motor vehicle production per GDP gives the information of how important the motor vehicle industry in the respective countries is. At high levels of this ratio it could be assumed, that a high policy support exist and that a relevant lobby exist.

Database and methodological aspect

- Public information is used [OICA, 2003]

Indicators

- Total motor vehicle production

4.2.5.3 Income per capita and average passenger car age

Rationality

- In the general discussion about lead market factors the income per capita is mentioned as a very important indicator for the measurement of the potential to invest in new and expensive technologies.
- A more hydrogen specific factor is the average age structure of cars, which can be interpreted as the willingness of people to invest in new and innovative car types.

Database and methodological aspects

- Public information is used [EEA 2002]

Indicators

- Average passenger car age and income per capita (correlation)

4.2.5.4 Regional population density

Rationality

- A high population density can be an important lead market indicator for two reasons. First of all the built up of the infrastructure for mobile applications is much easier in areas with a high population density. Secondly in such areas often problems with the air quality and the increased noise loading of inhabitants occurs which may push the demand for hydrogen applications in the mobile sector.

Database and methodological aspects

- Public information is used. [IIASA, 2004]

Indictor

- Regional population density per capita and square kilometres

4.2.5.5 Results for the selected indicators

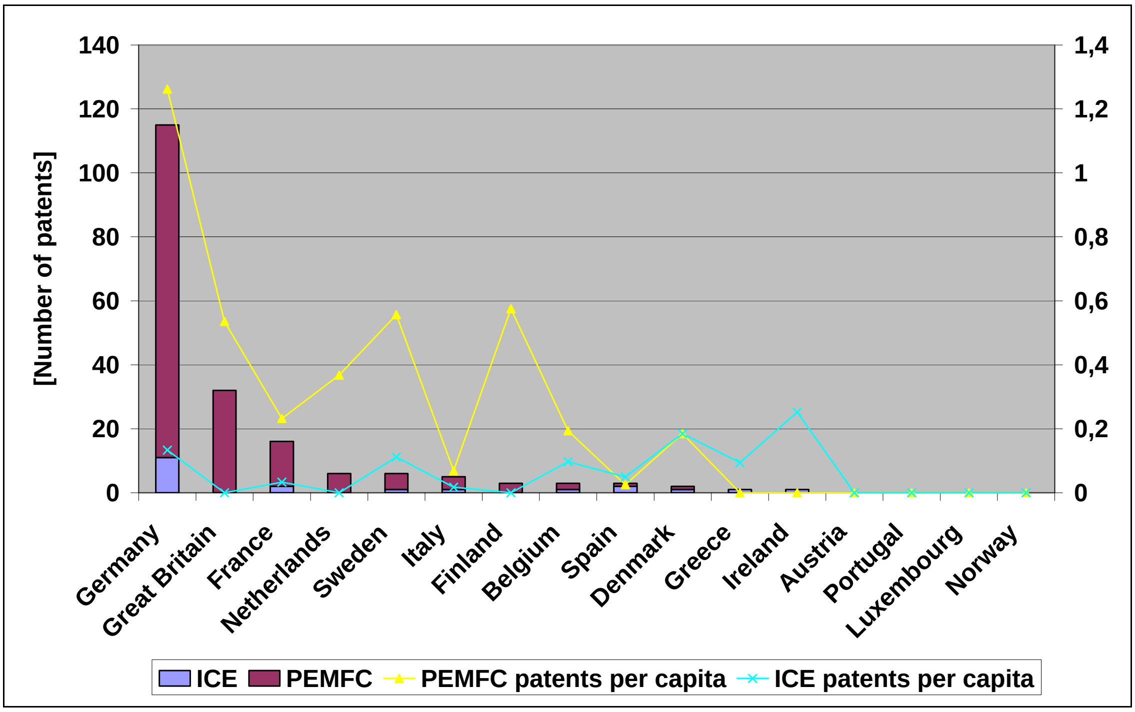

Figure 31: Amount of patents for hydrogen ICE and PEM

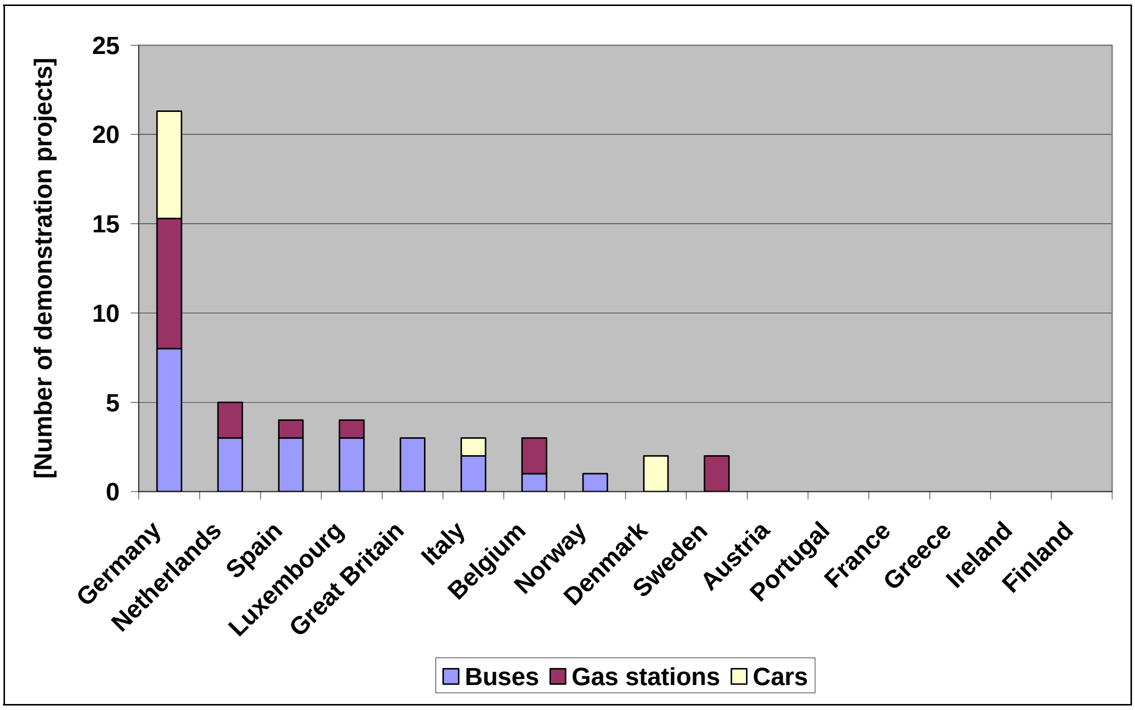

Figure 32: Amount of demonstration projects in the mobile sector (buses, cars, gas stations)

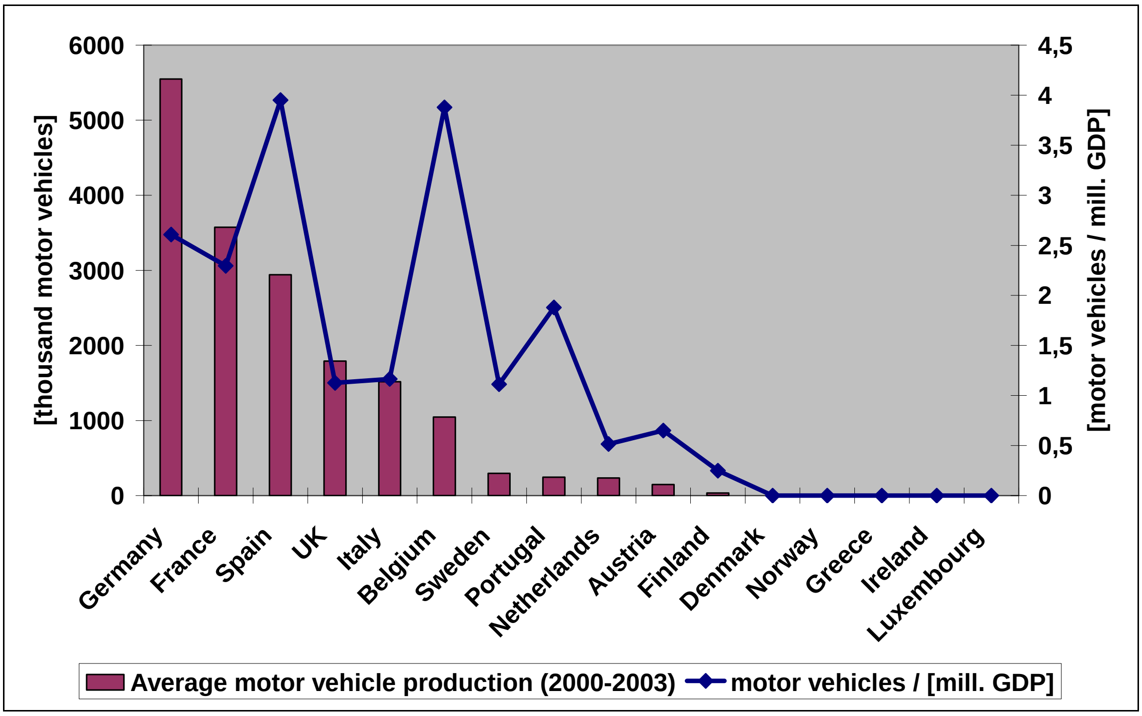

Figure 33: Average motor vehicle production and motor vehicle production per million GDP (average data 2000-2003)

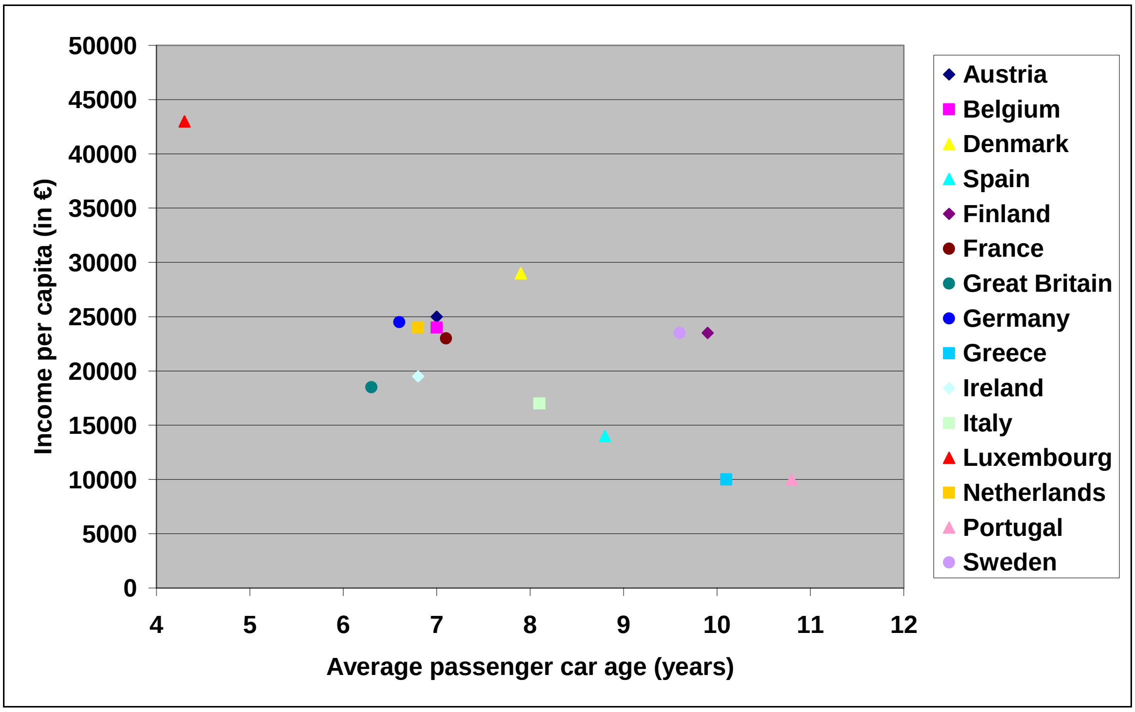

Figure 34: Average passenger car age and income per capita (2002)

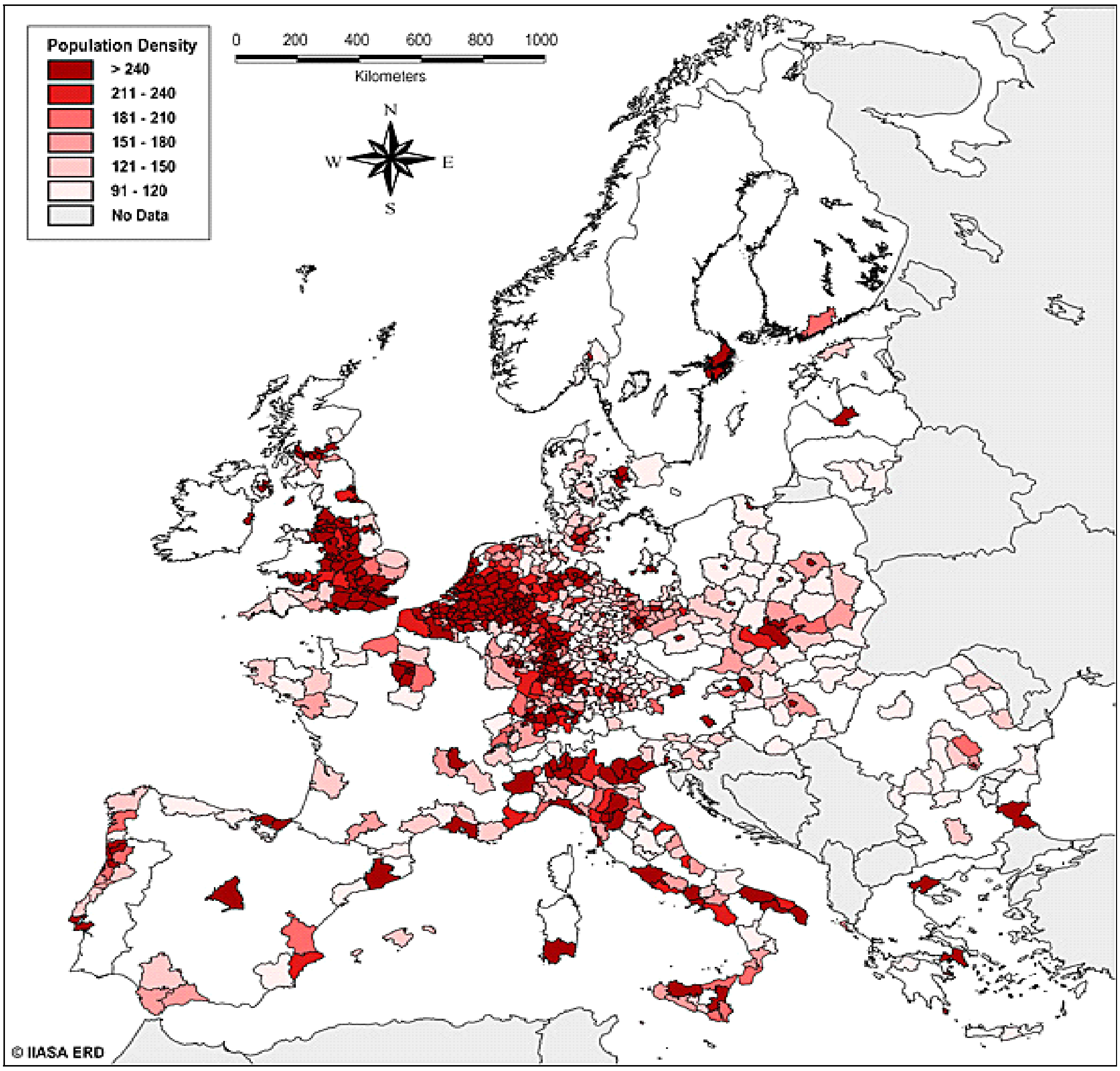

Figure 35: Regional population density in Europe per capita and square kilometers

For the selected mobile indicators Germany has the highest values. The high number of patents and demonstration projects is a result of the important role of the automotive industry within Germany. The two other countries with an economically important automotive sector, France and Italy, seem to have up to now less activities in this research field.

Next to UK France and also the Netherlands have a high relative patent activity for PEM-FC and in the Netherlands also a lot of demonstration projects (buses) are happening. The passenger car age and the income per capita indicators shows that Germany, the Netherlands and France seem to have an economic advantage compared to Italy and Greece.

Looking on the conventional motor vehicle production numbers Germany, France, Spain, UK, Italy and Belgium are the important car manufacture countries in Europe.

If the population density is taken into account the whole of the Netherlands, the north of Italy, parts of Germany as well as the metropolitan area of Paris have strong advantages. However, some Greek islands have also a very high population density.

4.3 Comparison with Japan, USA and Canada

4.3.1 Introduction

In the following section a short overview about the situation with regards to international competition in the field of hydrogen and fuel cells is given. Due to limited capacity this is not completed with the same detail level as the Lead market analysis for European countries. However, for the estimation of import/ export shares in a Lead market approach the international perspective is of relevance. Further the analysis focuses on the main competitors USA, Japan, and Canada.

Next to the evaluation of indicators also the results of so-called SWOT-analyses are taken into account. These SWOT (**S**trength-**W**eakness-**O**pportunities-**T**hreat)-analyses try to work out the country specific competition situation and the market opportunities and risks.

4.3.2 Patent analysis

The geographical distribution of the total number of hydrogen patents shows the USA, Japan and Germany in the leading position producing similar numbers of patents per annum. Germany accounts for the major share of the EU´s patents, although patent activity has decreased recently, followed by Canada and the UK.

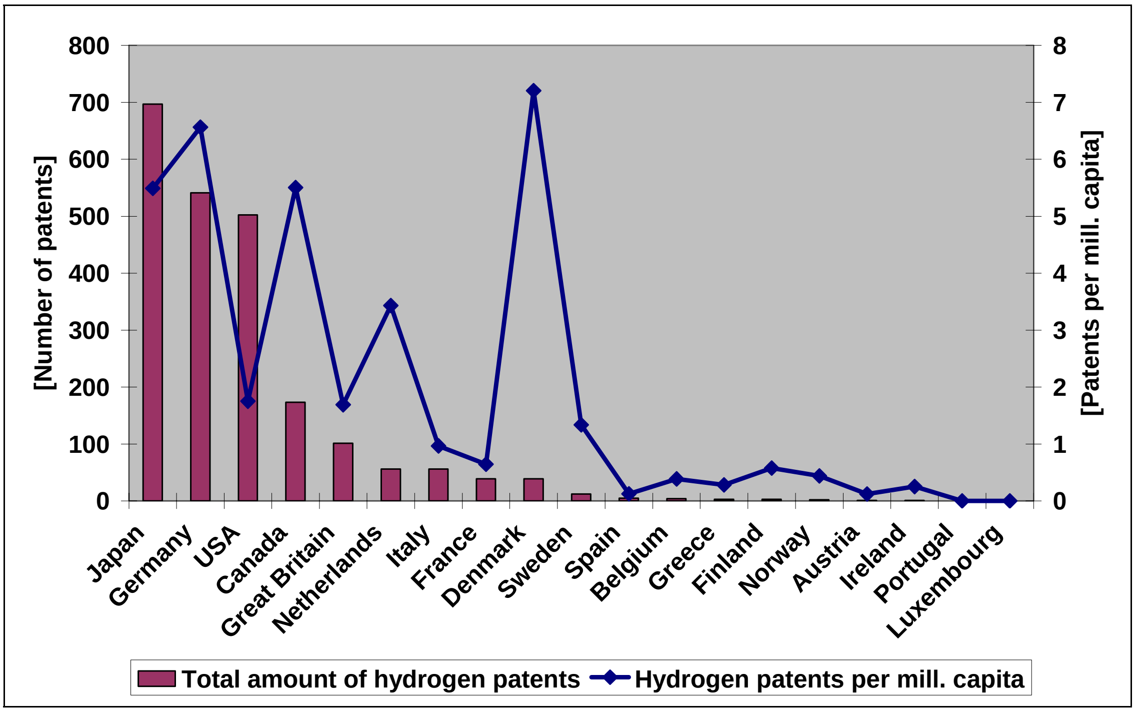

Figure 36: Total amount of hydrogen patents and hydrogen patents per million capita including USA, Japan, Canada (1990 – 2002)

Concerning hydrogen production patents the EU and Japan have the majority and the most significant ones. Most hydrogen production patents are for steam reforming (reforming of natural gas in industrial applications like the ammonia production in the fertilizer production is at present the most commonly used technique). The leading role of the EU in the field of steam reforming is not only based on patent activities in Germany, but also on patent activities in the UK and Denmark. Germany and the USA focus more on the gasification of coal and biomass than Japan. The US is the leading country for partial oxidation patents, but the Netherlands also show remarkable patent activities in this field, while electrolysis plays only a minor role. Indeed, when analysing the public sector promoted projects, electrolysis plays an important role.

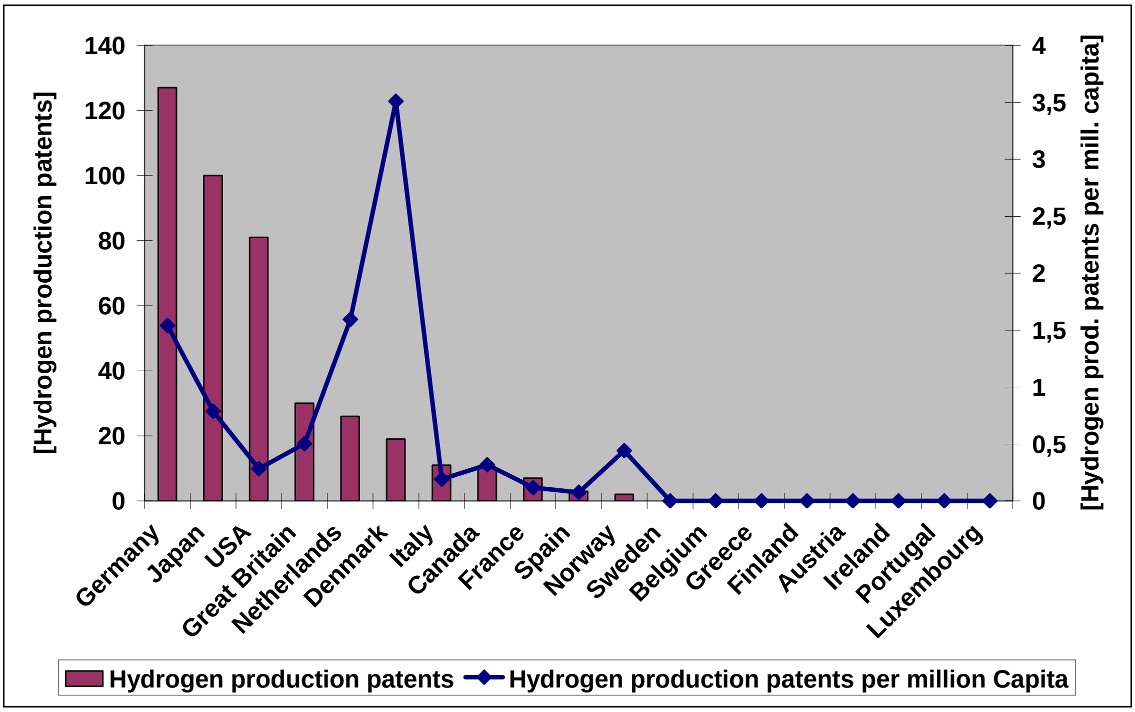

Figure 37: Total amount of patents for hydrogen production and hydrogen production patents per million capita including Japan, USA, Canada (1990 – 2002)

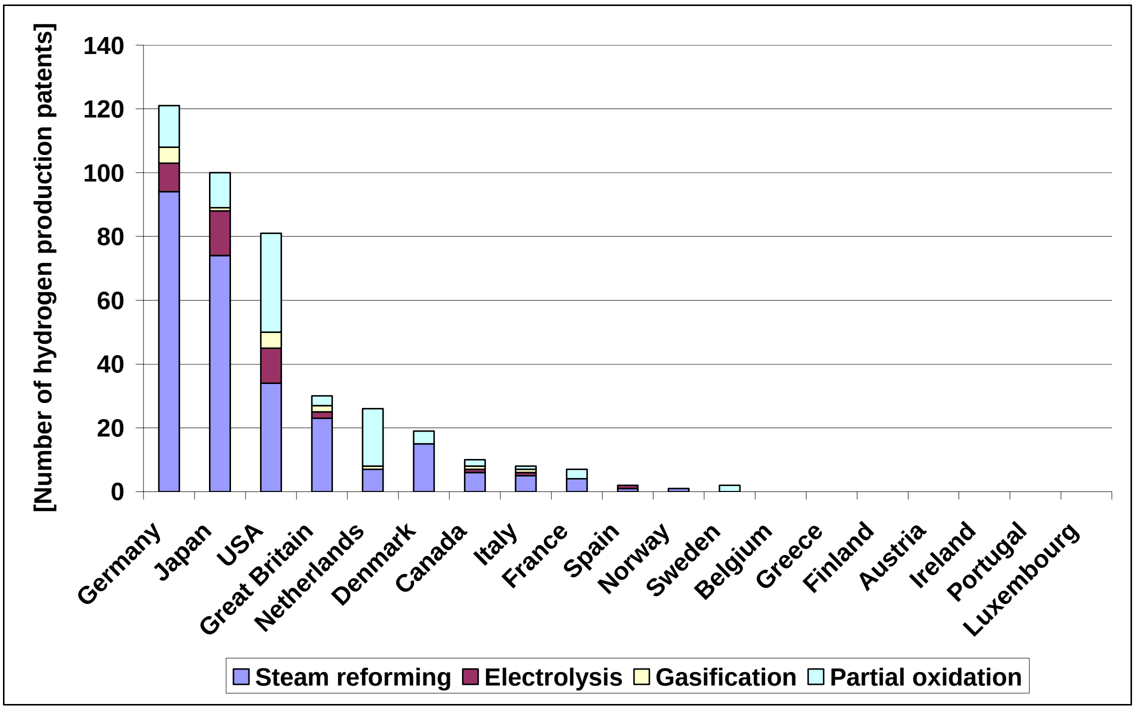

Figure 38: Total amount of patents for different hydrogen production options including Japan, USA, Canada (1990 – 2002)

Considering the fuel cell technologies, the PEMFC is the most important technology worldwide. Especially Japan is focusing more on the PEMFC, whereas the US and the EU have a broader research approach. Patents for ICE (internal combustion engine) are insignificant compared to PEMFC patents. The US and Germany are the leading regions for ICE research. It is hard to determine the right moment to specify on technology. If the PEMFC will lead to a broad diffusion, as is thought likely, than Japan has a big initial advantage.

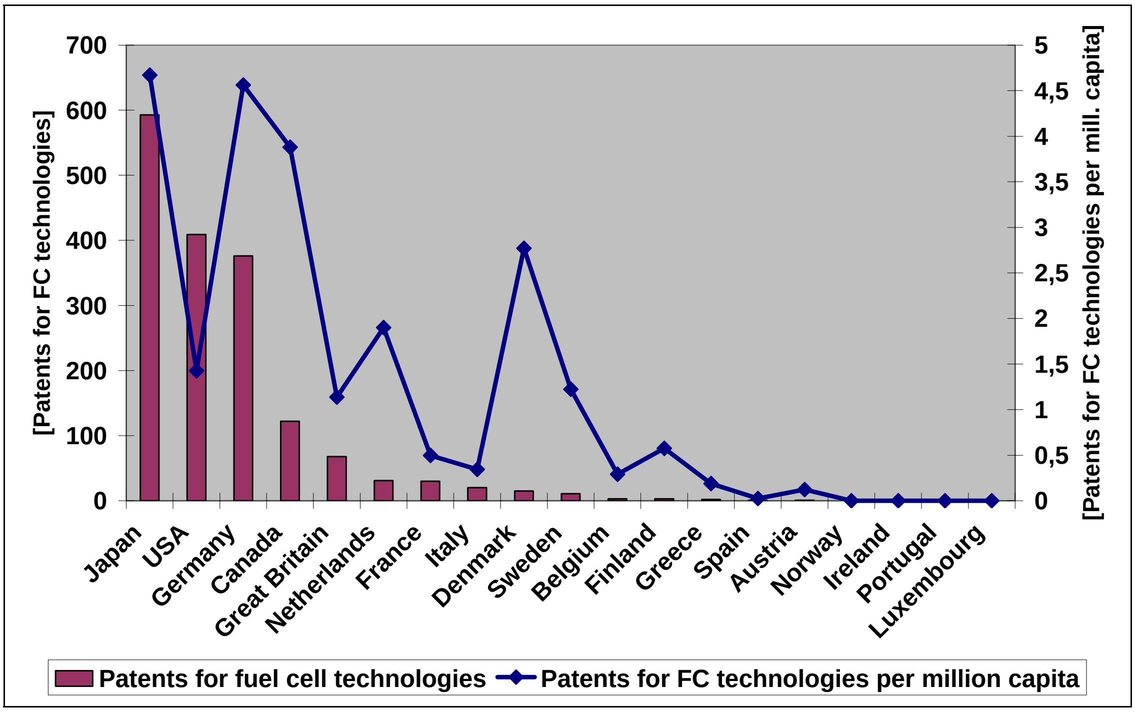

Figure 39: Total amount of patents for fuel cell technologies and patents for fuel cell technologies per million capita including Japan, USA, Canada (1990 – 2002)

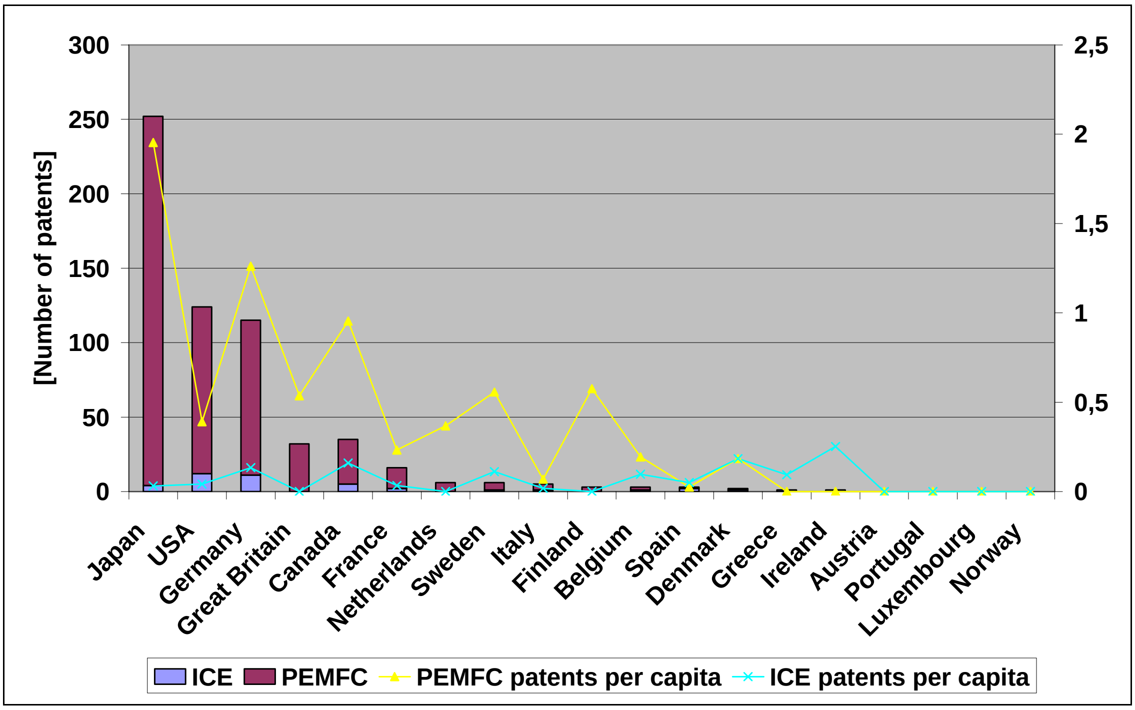

Figure 40: Amount of patents for hydrogen ICE and PEM including Japan, USA, Canada

4.3.3 Other indicators

Next to patents also the access to venture capital, the fuel cell manufacturer and R&D budgets for fuel cells, as well as the foreign trade in hydrogen relevant industry branches are evaluated.

Looking on the access to venture capital the USA, United Kingdom, and Sweden are well-placed. The USA has also a leading role by private and public R&D expenditures for fuel cells. Overall Japan and Germany shows the highest export orientation in hydrogen relevant technology fields.

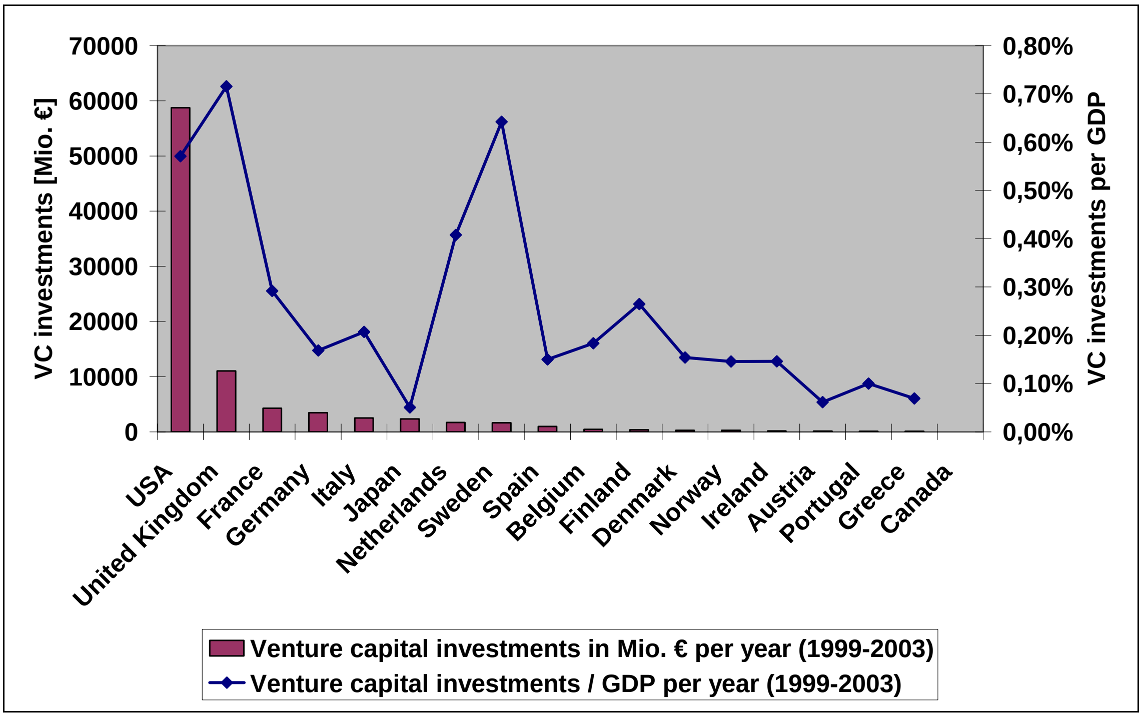

Figure 41: Total amount of Venture Capital Investments and Venture Capital Investments per GDP (based on average date 1999-2003)

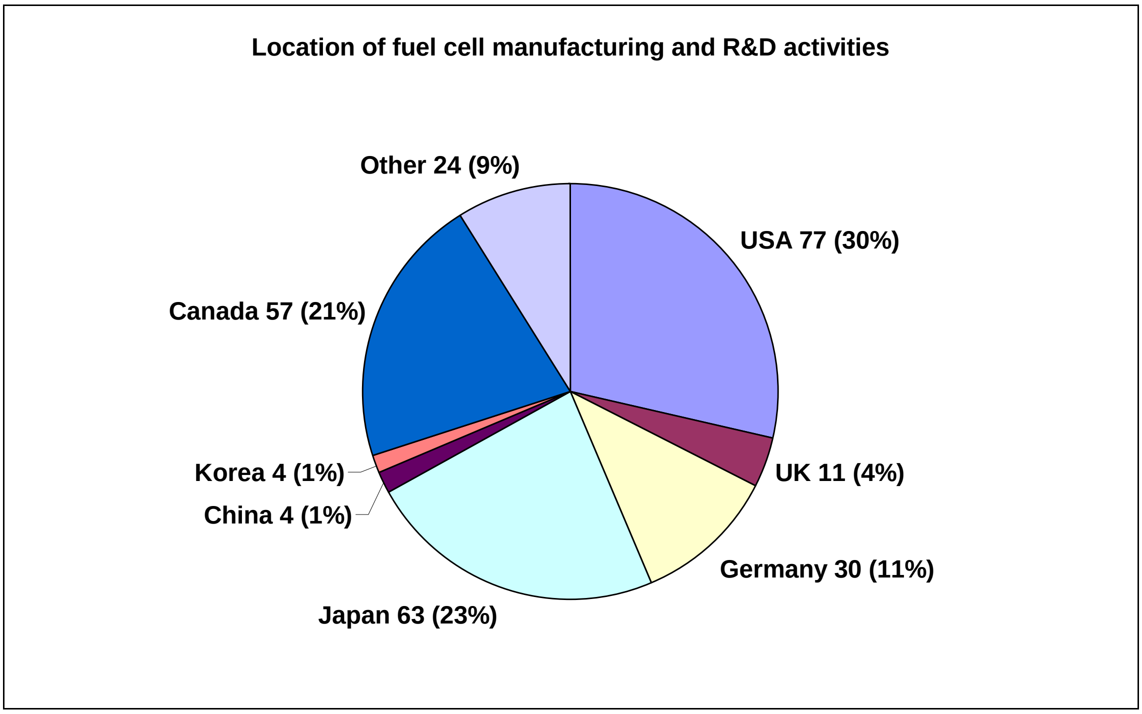

Figure 42: Location of fuel cell manufacturing and R&D activities (source: [WFCIS2004])

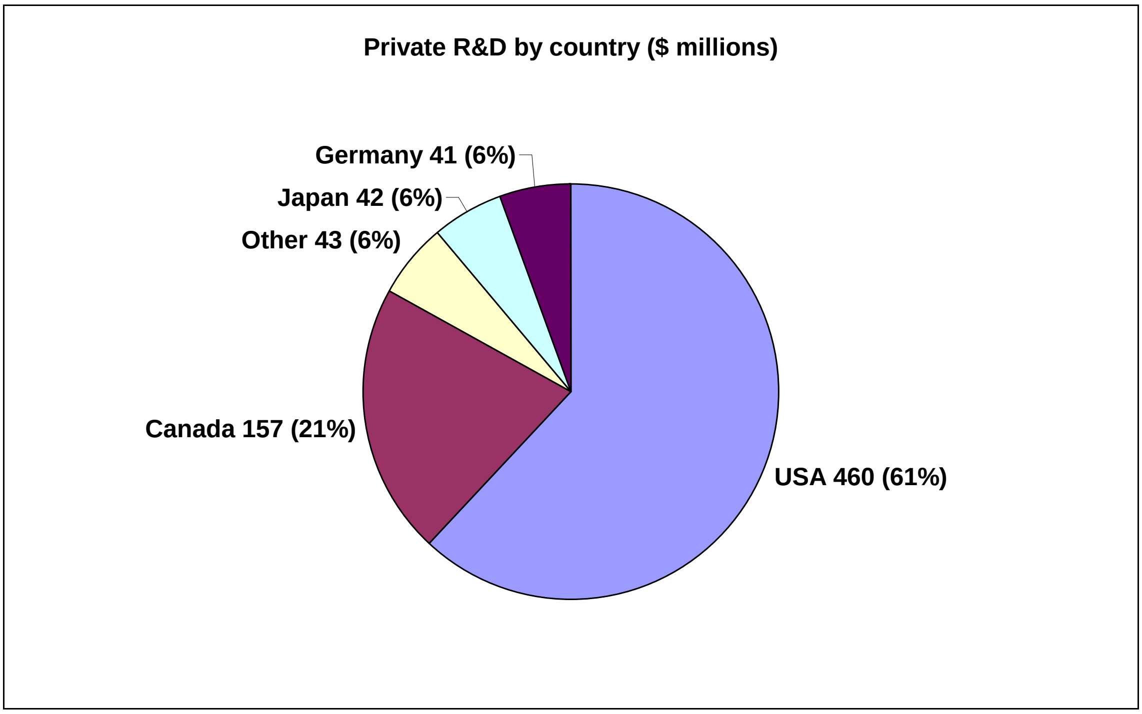

Figure 43: Private fuel cell R&D expenditures by country (source: [WFCIS2004])

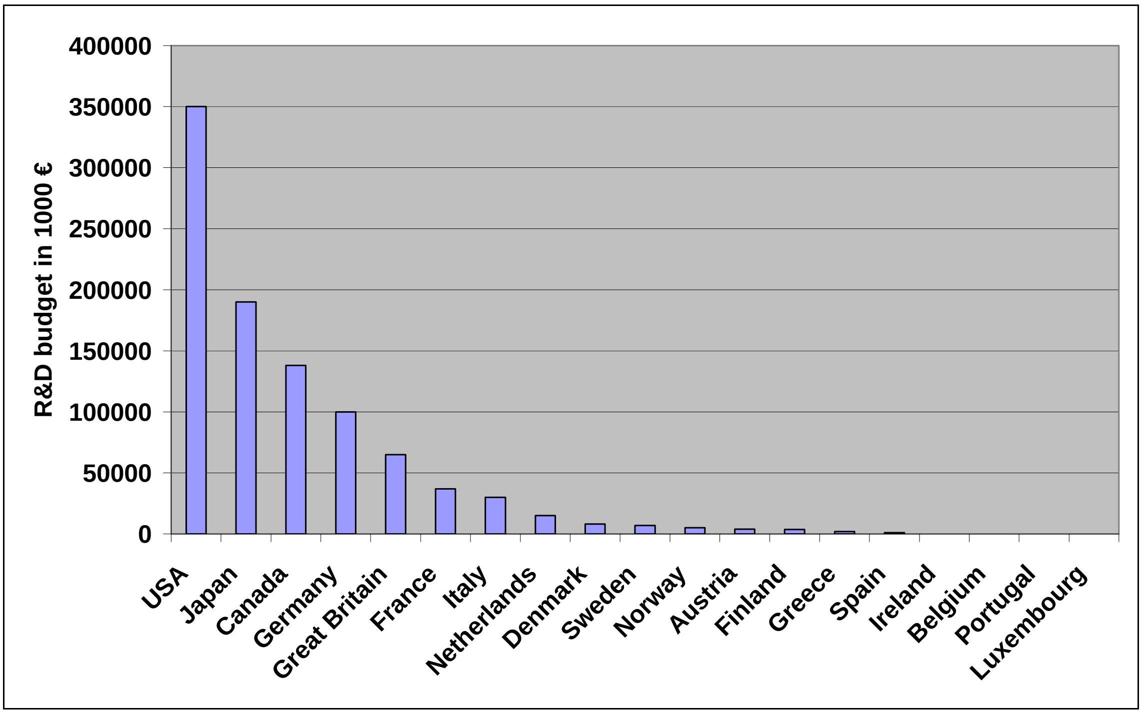

Figure 44: Public R&D budget in fuel cells and hydrogen [AMORELLI 2004]

The US government announced in 2003 its plan to spend USD 1.7 billion over the next five years on fuel cell R&D including hydrogen production, storage and infrastructure [OECD 2005]. Japanese government spending on fuel cell R&D in 2004 was USD 320 million. The European Community announced plans to spend USD 2.1 billion between 2003 and 2006 on renewable energy, mostly on hydrogen fuel cells.

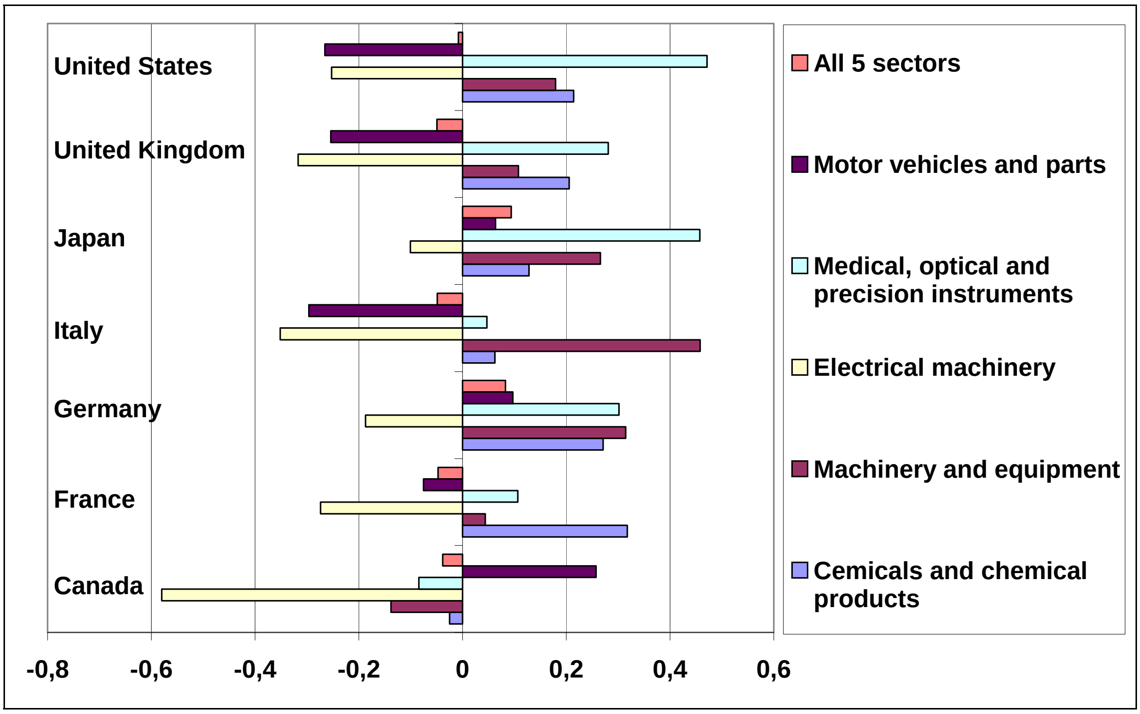

Figure 45 Revealed Symmetric Comparative Advantage of different countries by relevant industry branches

4.3.4 Summary

The main outcomes of the SWOT-analysis[1] and the previous explanations follow:

- European industry is well placed with regards to conventional generation of hydrogen from fossil fuels and via water electrolysis.
- Europe is behind the US and Japan for industrial development and manufacturing of fuel cells.
- In the fuel cell research Europe, and the USA, have a broader approach. At present it cannot be estimated if this is an advantage or a disadvantage especially against Japan, where the focus is on PEMFC.

[1] For roadmaps see: Japan: [Naki 2004], [Morata 2003], [Haug 2004]: US: [DOE 2001], [DOE 2003], [DOE 2004], EU: [HLG 2003], [HyNet 2004] and for SWOT analysis see: [AMORELLI ET AL. 2004], [FHIRST 2004], [HySociety: 2004], [OECD 2005].

- Although Europe is at the forefront in many fields, a lack of coordination as well as well defined targets could make it less suited to commercial and industrial exploitation. But at present there are some efforts to fund and develop a scientifically sound and broadly accepted European Roadmap.
- The ecological targets as, the existing environmental problems and targets as well as the population density offer in Europe good conditions for the implementation of a hydrogen and fuel cell economy.
- The overall competitiveness of the industries in Europe, Japan and the USA can be regarded as equivalent. But the better access to venture capital in the USA, and also in Canada, can give these countries an advantage, especially at developing innovative small and medium-sized companies.
- Concerning law regulations there are efforts in Europe, but the USA, Japan and Canada have the leading position.
- Overall Europe can be regarded as well-positioned, but Europe runs the risk to fall further behind the USA and Japan, that are in the leading position right now and enlarge it through specific improvements.

4.4 Summary and conclusions

The lead market concept is used to estimate the competitiveness of a country and forecast the import/export shares of hydrogen technologies. Lead markets are defined as the regional markets to first adopt an innovation design in a technology field which have specific characteristics that enhance the probability that the same innovation design will be adopted broadly in other countries as well.

Three categories of factors were identified which influence the lead market potential of a country and different indicators were chosen to measure them:

- *Market factors* including cost advantages (e.g. patent activities, public R&D budget), transfer advantages (e.g. demonstration projects), market structure advantages (e.g. strong competition between firms) and demand advantages (e.g. density of population, age of cars, income per capita).
- *Firm-specific factors* such as technological superiority (e.g. patents, demonstration projects), strategic behaviour (e.g. export orientation) and reputation.
- *Policy support* (e.g. public R&D budget).

It should be mentioned that the quantitative figures for the indicators are based on the available historical data and that very recent developments may not be reflected in this analysis. In addition, this analysis focuses mainly on European states. Some work has been done on an international level (including among others the USA, Japan and Canada), but this only provides a first insight and should be extended.

Open methodological questions include, among others, how to rank smaller countries like the Netherlands or Denmark alongside larger countries like Germany and France (do absolute or relative indicators give a more accurate picture?) and how to weigh the different indicators.

In the following section, the lead market potential of the six selected HyWays Member States of Phase I is summarised:

France: All the absolute indicators show that France is in a relatively well-placed position in Europe, although there is no prominent potential visible in any one category. France was often one of the best three or four countries in Europe, if absolute values were considered (e.g. R&D budget for hydrogen and fuel cells, demonstration projects). If relative indicators were regarded, however, the smaller countries like the Netherlands, Denmark and Norway caught up.

There may be some potential for mobile applications due to the high income per capita, the conventional motor vehicle production and the densely populated Greater Paris area. Further, the low industry electricity prices and the high renewable potential offer good opportunities for the production of hydrogen via electrolysis and renewables. Additionally, today, there is also a remarkable amount of hydrogen production for industrial purposes.

If not only European countries but also other major competitors like the USA, Japan and Canada are taken into account then France is not prominently placed as a lead market country.

In summary, based on its historical activities in the hydrogen and fuel cell field, France is not in a position to become a lead market. However, it does seem to have the potential to be a fast follower[2] or, with additional research efforts, it could close the gap to the leading countries in the hydrogen and fuel cell field over the next few years.

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2 The role of France in the fuel cell topic as a fast follower is also seen in the recent research study [OECD 2005].

Germany: Compared with other European countries, Germany has the highest figures for nearly all the selected lead market indicators (absolute figures and relative figures, which take country size into account). These factors indicate that Germany is in a very good position to become a lead market in Europe for hydrogen production and application technologies. The economic opportunities presented by hydrogen fuel cells are a powerful driver for Germany (but also for Japan, the United States and France) as a country with large automobile manufacturing sectors (see also [OECD 2005]).

In the field of hydrogen production, especially based on steam reforming, Germany has a good competitive position due to the high numbers of patents which demonstrate the research activity and technological competence in this field as well as due to the large amount of hydrogen which is already being produced for industrial purposes. Germany is also well placed in the field of stationary applications - measured by the number of patents and demonstration projects. The same can be said about mobile applications when looking at the demonstration projects, the patents for PEM-FC and hydrogen ICE, population density, income per capita, conventional motor vehicle production and age of passenger cars.

One disadvantage Germany has is the limited access to venture capital. In addition, the high electricity prices in Germany could be a problem for the electrolysis of water. On the other hand, due to the high presence of fluctuating energy carriers for electricity production such as wind power, hydrogen could be a storage option for Germany.

However, when looking beyond Europe to a more global view, Germany loses ground, especially in the field of stack production (based among others on patent numbers and other research activities of firms in the field). Furthermore, looking at the historical development in the last decades it is clear that Germany held a much better position in the nineties than it does today. It is still unclear whether Germany can reverse this trend.

Greece: when regarding the overall picture painted by the selected indicators, Greece does not seem to have the potential to become a lead market in any hydrogen-related area. A relevant indicator for Greece is the large number of populated islands (168) where the construction of a hydrogen infrastructure could have greater advantages.

On these islands, the combination of renewables (e.g. wind power) and hydrogen production using electrolysis could prove to be a promising option and may offer export opportunities for Greece in the future.

Italy: Italy has the promising potential to become a lead market area in the mobile sector (high population density in the North and additionally some highly concentrated areas, e.g. around Rome, and the prominence of conventional motor vehicle production). In addition, there is a lead market potential for hydrogen production technologies, among others due to the export orientation of the manufacturing and equipment sector, which plays an important role in Italy.

One barrier to the production based on electrolysis may be the high electricity prices for industry.

Compared with Germany, but also with the UK and France, Italy lags a little behind the other larger European countries. If relative indicators are regarded, the smaller countries (e.g. the Netherlands, Denmark and Norway) also closed the gap. However, from today's viewpoint, Italy has the potential to be a fast follower.

Norway: If relative indicators are regarded which express hydrogen activities relative to country size, then Norway has a good market position. Norwegian firms and research institutes are concentrating a significant share of their research and patent activities on the field of hydrogen.

Looking at the various hydrogen fields involved, Norway seems to have a good market position in the hydrogen production area (high share of hydrogen production patents in relation to capita). There is a significant potential for producing and using hydrogen based on the country's abundant natural gas reserves and the availability of cheap electricity for producing hydrogen at low cost via electrolysis.

However, in the stationary and mobile application areas, evaluating the indicators shows that the probability of Norway becoming a lead market is rather slight. Due to the country's size, the absolute number of many indicators is small. However, the interest in fuel cells is oriented towards stationary applications to provide power to a widely scattered population where access to power grids can be difficult.

The Netherlands: compared with other research activities, hydrogen and fuel cell research is prominently placed in the Netherlands. When looking at the patent activities or the export-orientation of the chemical industry, the Netherlands seems to be in a good competitive position, especially for hydrogen production with a focus on partial oxidation. In addition, a significant amount of hydrogen is already produced for industrial purposes in the Netherlands.

A lead market potential for the Netherlands can also be identified for stationary and to some extent for mobile applications (relevant patent activities and a high number of demonstration projects). This conclusion is supported by the evaluation of the relative figures – which take into account that the Netherlands belongs to the small country group, but also by many of the absolute figures. The market pressure is high (local pollution in areas with a population density). This offers on the other site good infrastructure conditions for mobile hydrogen applications. One additional advantage of the Netherlands is the good access here to venture capital and the high income per capita.

5 ISIS model

5.1 Methodical approach

5.1.1 Model description of Input Output Model ISIS (Integrated Sustainability Assessment System)

When selecting appropriate instruments for modelling economic impacts (impact analysis), the level of analysis chosen has to be taken into account. The discussion of the impacts of strategies using new technological processes in the past focused primarily on the impacts of the additional investment costs or the demand and income flow effects caused by these. Such questions are analysed on an aggregated macroeconomic level typically by using econometric or general equilibrium models.

In contrast to these questions, which have a more macroeconomic nature, the studies conducted with ISIS are **mesoeconomic analyses,** in which macroeconomic impacts such as changes in income flow effects play only a subordinate role. The spotlight here is on impacts triggered by structural shifts. Particular significance is assigned to those impacts on structural change in sectors since these exert a major influence in the other dimensions on indirect effects as well.

These kinds of questions are a classical field of application for an input-output model which fully maps the flow of goods between the economic sectors for an economic domain such as, e.g. the Federal Republic of Germany, on a mesoeconomic aggregation level (Petit 1995; Meyer-Krahmer 1999). By adding various modules to this input-output model, alongside sectoral structural change, quantitative and qualitative employment effects can also be catalogued within a consistent model framework.

Based on the sectoral interrelations which are illustrated in the input-output model and which form the status quo, the impulses triggered by the closed-loop strategies are then able to be modelled. These either effect upstream production (e.g. increased secondary raw materials and a parallel decrease in the use of primary raw materials) or are linked with changes in the final demand for goods (e.g. decrease in the production level of end products due to the introduction of long-life products, but more repair and maintenance work). With the help of the information about the interrelations contained in the input-output model, the effects triggered upstream by these impulses can be determined right up to the raw material suppliers.

The main elements of ISIS are described briefly here, a more detailed description of the model can be found in the technical model description.

At the core of ISIS is a statistical input-output model (IO model) used to examine the structural impacts of the various environmental strategies. Other modules for employment effects, qualification structure and job conditions, regional effects and environmental effects were developed or added to analyse other dimensions of sustainability. The results of the scenario calculations from the IO model, i.e. production changes as a result of the different strategies, serve as inputs for the other modules.

5.1.1.1 Input-Output model

The IO model used for ISIS is based on the most recent input-output tables of the European statistical Office (Eurostat) for the year 2000 and can be assigned to the group of static, open Leontief models. It divides the single economies into 59 manufacturing sectors and 6 sectors of final demand and illustrates both the supplies of goods and services between the manufacturing sectors (intermediate demand) and supplies from these to the final demand sectors. This IO model is used to calculate sectoral differences in production between reference and sustainability scenarios. These results form the basis for further analyses in the additional modules. In these additional analyses, therefore, not only the direct but also the indirect effects from all input relations are taken into account.

5.1.1.2 Employment module

Assuming that a linear approximation can be made for the correlation between the sectoral employment level and the sectoral production level, the quantitative impacts on employment are calculated using job coefficients. On the one hand, it is analysed which employment effects can be listed in the individual sectors. In an *impulse-based approach*, the total employment effects are each assigned to the economic impulses which trigger them. These impulses consist of the demand shifts triggered by the sustainability scenario, e.g. the rise in sorting and processing activities of recycled plastics on the one hand (positive impulse) and the drop in production of new plastics on the other hand (negative impulse). The employment effects assigned to one economic impulse include the workers who are directly or indirectly involved in the production of the goods linked with the impulse. They thus specifically incorporate upstream production. The ratio which relates the change in the number of employed to the impulse triggering it is characterized as the **specific total employment effect**. This can be split into three separately interpretable components:

$$\text{Total effect} = \text{production multiplicator} * (1 - \text{import share}) * \text{employment intensity}$$

- The *production multiplicator* indicates to what extent an impulse contributes to a production increase through the acquisition of necessary inputs. The larger the production multiplicator, the larger the production effects triggered by an impulse. When calculating the production multiplicator, the gross production value of the goods is entered as the numerator which are directly and indirectly required for the supply of the goods linked with the economic impulse. This includes imported goods. The denominator is the gross production value of the impulse.
- The *import share* shows which share of the total production triggered by the impulses is accounted for by imports. The higher the import share, the lower the share applicable to domestic production.
- The average *employment intensity* indicates how many persons are employed per million Euro of domestic production resulting from the impulse.

5.1.1.3 Qualification structure and job conditions module

The results from the IO model are combined with data from the European Labour Force Survey to analyse the impacts of the various environmental strategies on the qualification structure of employees and job conditions. To assess the impacts on qualification structure, changes with regard to qualification requirements and fields of activity are examined. The analysis of job conditions can be done using the parameters *part-time and temporary work contracts, weekend and bank holidays and evening, night and shift work*.

5.1.2 Technical model description of ISIS (Integrated Sustainability Assessment System)

5.1.2.1 Input-Output-Model

An input-output model forms the framework for the simulations conducted for a country. This completely models the flow of goods between the economic sectors. The IO model used by the ISI is based on the most recent Eurostat input-output tables for 2000 and is one of the static, open Leontief models. The structure of such an IO table is shown in Figure 46. In the tables used, the single economies are split into 59 manufacturing and 6 final demand sectors. The lines of the tables contain the supplies of goods and service between the manufacturing sectors (intermediate demand) as well as those from these to the final demand sectors. The columns indicate which preliminary inputs the sectors require from other sectors in order to produce their respective products. It is also possible to recognize the so-called demand for primary inputs which (minus import inputs) correspond to the sectors' gross value added. This is comprised of the consumption of fixed capital, the difference between production taxes and subsidies, income from business activity and assets as well as income from employment. The interrelation matrix forms the core of the input-output table which depicts the interrelation of goods between the production sectors.

Figure 46: Layout of an input-output table with additional emission and employment coefficients

		Manufacturing sector	Final demand sector				Production value
		Sectors 1 – 59	Consumption by households	Consumption by government.	Capital formation	Exports	
Manufacturing sector	Sectors 1 – 59	Interrelation matrix: supplies of goods and services among the sectors (intermediate demand) (million Euro)					
Imports							
Gross value added	Consumption of fixed capital						
	Operating surplus						
	compensation of employees						
Production value							

Employment coefficients	Volume of work per Mio. Euro
Emissions coefficients	Environmental impact per Mio. Euro
Module qualifications/job conditions	Fraction of volume of work

The following abbreviations are used in the input-output model:

$i = 1,..., n;\ j = 1,..., n$	Indices for production sectors, where n = 59
$k = 1,.....,m$	Index for final demand aggregates, where m = 6
x_i	Production value for sector i
$X = (x_i)$	Vector of the sectoral production values
$y_{i,k}$	Demand for good i over final demand aggregate k
$Y = (y_i) = (\sum_{k=1}^{m} y_{i,k})$	Vector of the total final demand for good i

$Z = (z_{i,j})$	Matrix of the intersectoral flow of goods
$A = (a_{i,j}) = Z\hat{X}^{-1}$	Interrelation matrix normed for production values whose elements $a_{i,j}$ indicate how many value units of good i are needed to produce one value unit of good j. $\hat{X}$ represents a diagonal matrix with the sectoral production values as the main diagonal elements.

Since the production value of each sector is made up of the sum of supplies to intermediate and final demand, it is true that:

$X = AX + Y.$

The correlation between final demand and production can then be formulated in this static input-output model as follows:

$X = (I – A)^{-1} * Y.$

$(I – A)^{-1}$ is also referred to as the Leontief-Inverse C and represents the core of the input-output model. Each element $c_{i,j}$ of this matrix mirrors the direct and indirect production which is necessary in sector i (at upstream production levels) in order to produce one unit of good j for final demand. The production effects of any demand for goods can thus be determined using this correlation.

New technologies or economic activities can be incorporated into the IO model in analogy to the other sectors of the IO table by quantifying the goods supply on the input side from other sectors (including imports) and the components of gross value added as well as the supplies to the other sectors on the output side and the final demand.

The standard IO model was extended in ISIS so that an analysis of the impact of various strategies on the level of employment and the qualification structure could be conducted within a consistent model framework.

5.1.2.2 Employment module

If it is assumed that there is an approximate linear correlation between the level of employment in a sector and the level of production in a sector, the employment effects of the different strategies result from:

$L = l * X .$

Where l stands for the diagonal matrix with the sectoral employment coefficients l_i as elements of the main diagonals.

The projection analyses are based on the year 2020/2030. In order to avoid overestimating the employment effects it is therefore necessary to take into account the growth in productivity which will have taken place by then. To do so sector-specific productivity indices are determined which indicate the ratio of specific employment (i.e. employment/gross output value) in the projected year to specific employment in the base year. These indices are based on data in Impact of Technological and Structural Change on Employment [Impact analysis,2020].

5.1.2.3 Qualification structure and job conditions module

The 2002/2003 survey within the scope of the European Labour Force Survey was used to analyse the impacts of the different environmental strategies on the qualification structure of employees and the in-company job conditions. The data used are based on an anonymized random population sample (e.g. in Germany 0.45 per cent random population sample) of the population for households/persons of 2002 of 2003 (state-specific). Alongside basic social-economic information, this data set also contains information on *the qualification requirements, fields of activity, part-time and temporary work contracts, weekend and bank holiday as well as evening, night and shift work* of the persons surveyed.

For employed persons, it is also known in which economic sector they were employed at the time of the survey. The information on qualification structure and job conditions was elaborated for each individual economic sector. The difference in employees between the reference and sustainability scenarios, which was calculated in the IO model for each economic sector, can be used to determine differences in qualification structure.

Care had to be taken when linking the IO model with data from the European Labour Force Survey since the demarcation of economic sectors or branches differs in the IO model and the Labour Force Survey. This is why data used in the Labour Force Survey, which are based on the classification of economic branches of 1995 (WZ 95), were adjusted to the demarcation of the IO tables. Remaining and usually negligible differences in absolute figures mainly result from differences in the classification of the sectors. The demarcation of the sectors for the IO tables is done according to the principle of functional classification, whereas this is performed according to the principle of institutional classification in the European Labour Force Survey. In addition to this there are differences in the concept of “gainfully employed”. In accordance with the internationally valid standard of the labour force concept, “gainfully employed” in the European Labour Force Survey applied to those persons older than 15 who had worked for a minimum of one hour in the reference week.

5.2 Input data and assumptions

5.2.1 Technology analysis

For the different scenarios Markal calculated on the basis of the assumptions a mix of technologies used in the scenarios. The Markal output was then transferred in the needs of the economic input output model ISIS. Therefore a detailed technology analysis has been carried out. The HyWays partners have been interviewed and asked to deliver technology data for each used Markal hydrogen technology on a component basis. Not only the technology components of the investment and so called running costs have been analysed but also the costs of the used energy carriers.

The aim of the process was to achieve for each technology a sectoral split of each technology to introduce new technologies in the model. From the origin of the investments, operation and maintainance cost as well as the cost of the energy carrier which was delivered by the Markal model a component analysis has been carried out. On the basis of the single components a sectoral analysis has been carried out to define possible economic sectors which "produce" this kind of economic commodity by an expert group out of engineers and economists. At the end combining all the sectors of the components again a technology view was created but this time in a sectoral manner. Because of the sensitivity of this data form the different HyWays partners it was agreed with the interview partner to give only an example of the used sectoral split. See as example of a sectoral technology split the central electrolysis technology in Figure 47.

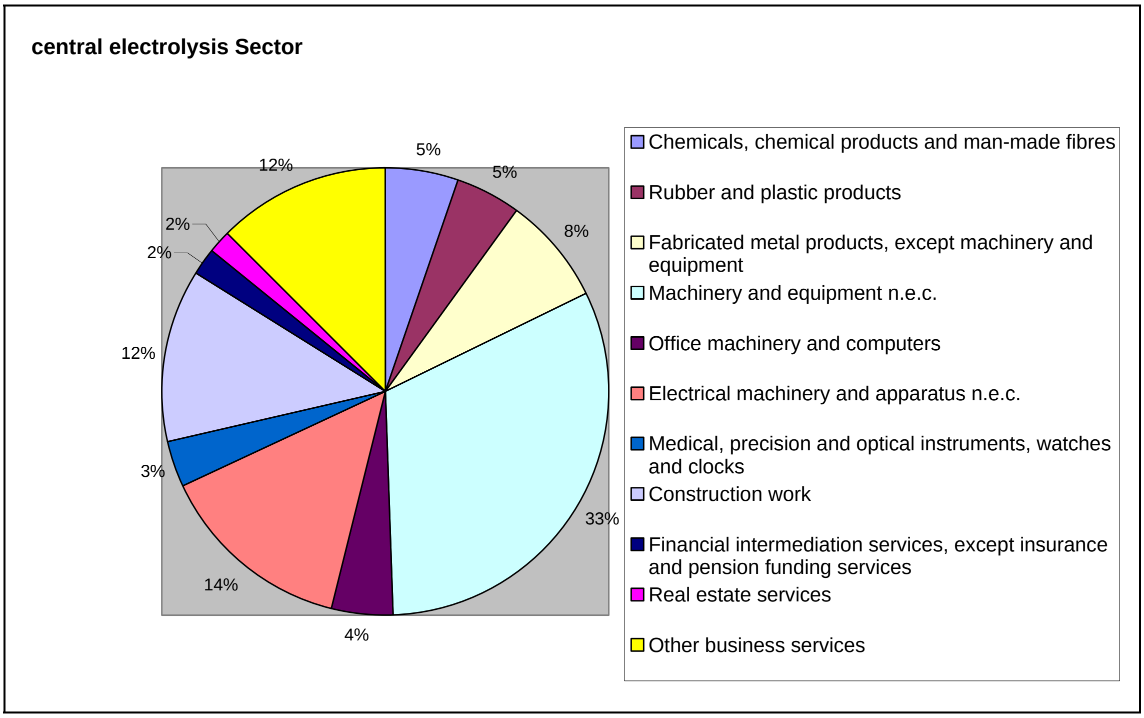

Figure 47: Example for technology analysis, e.g. 5% of rubber and plastic products means that five percentage of the investment in a central electrolyser are produced in economic terms in the sector rubber and plastic products.

5.2.2 Statistical input data

The main statistical data used are the public available input output tables from eurostat.

See also: http://epp.eurostat.cec.eu.int

5.2.2.1 Input Output Tables

Available input output tables from Eurostat for:

- Greece
- Germany
- France
- Italy
- The Netherlands
- Norway

5.2.2.2 Employment

The used employment data is based on the OECD STAN statistics and the eurostat employment statistics to ensure a cross country comparability of the used data. The data was compared and updated with other sources to ensure quality and the specific needs of the model.

5.2.3 Scenarios

For the economic analysis different additional scenarios to the central HyWays scenarios have been developed. The aim of developing different import export scenarios is to allow control over one of the major driver for economy. Which could be not expected the same for hydrogen technologies and conventional technologies.

The aim was to show the bandwidth of possible future economic and social developments for optimistic and pessimistic view. Within this scope one additional scenario has been developed to show a more "realistic" view from today´s viewpoint. The import export shares used are based on the lead market share described above. Compared to the structural identity scenario were historical import / export shares have been used for the new hydrogen technologies (See also 2.1).

An overview of the assumed import/export ratios is shown in Figure 49

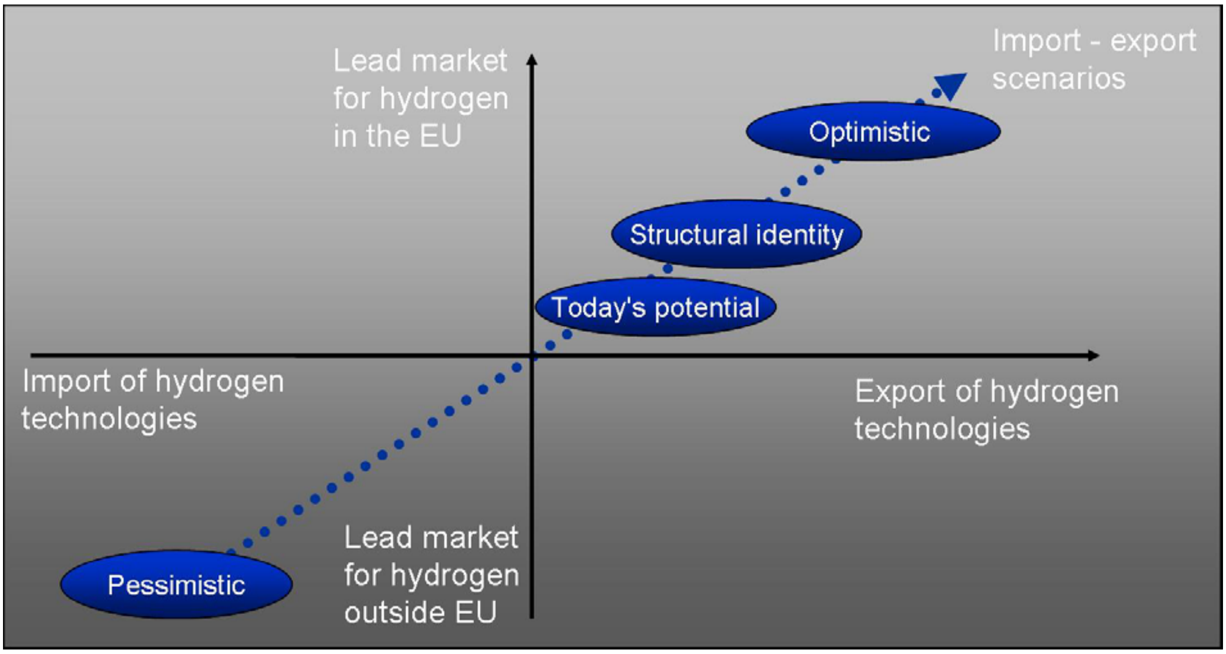

Figure 48: Shematic scenario overview

	Structural identity	Today's potential	Pessimistic	Optimistic
France				
H2 car production (FC, ICE)	1,4	1,4	0,0	2,1
Stack production	1,4	0.8	0,0	2,1
H2 plant production	1,1	1,1	1,1	1,7
Germany				
H2 car production (FC, ICE)	2.0	2.0	0,0	3.0
Stack production	2.0	1.0	0,0	3.0
H2 plant production	2.0	3.0	2.0	3.0
Greece				
H2 car production (FC, ICE)	0.1	0.1	0,0	0.1
Stack production	0.1	0.1	0,0	0.1
H2 plant production	1,3	1,3	1,3	2,2
Italy				
H2 car production (FC, ICE)	0.9	0.5	0,0	1,4
Stack production	0.9	0.3	0,0	1,4
H2 plant production	2.0	1.0	2.0	3.0
Norway				
H2 car production (FC, ICE)	0.2	0.2	0,0	0.3
Stack production	0.2	0.2	0,0	0.3
H2 plant production	0.9	1,4	1,4	2.0
Netherlands				
H2 car production (FC, ICE)	0.8	1,2	0,0	1,2
Stack production	0.8	1,2	0,0	1,2
H2 plant production	1,9	1,9	1,3	2,9

Figure 49: import- export scenario assumptions (***e.g. 1.4 for cars means that for every car sold in the domestic market, the domestic producer exported additional 1.4 cars)

5.3 Results

5.3.1 General economic analysis

Two major drivers influence the competitiveness of hydrogen fuel cell cars: the oil price and the learning curve for the fuel cell power drives. Figure 50 demonstrates the influence of both drivers.

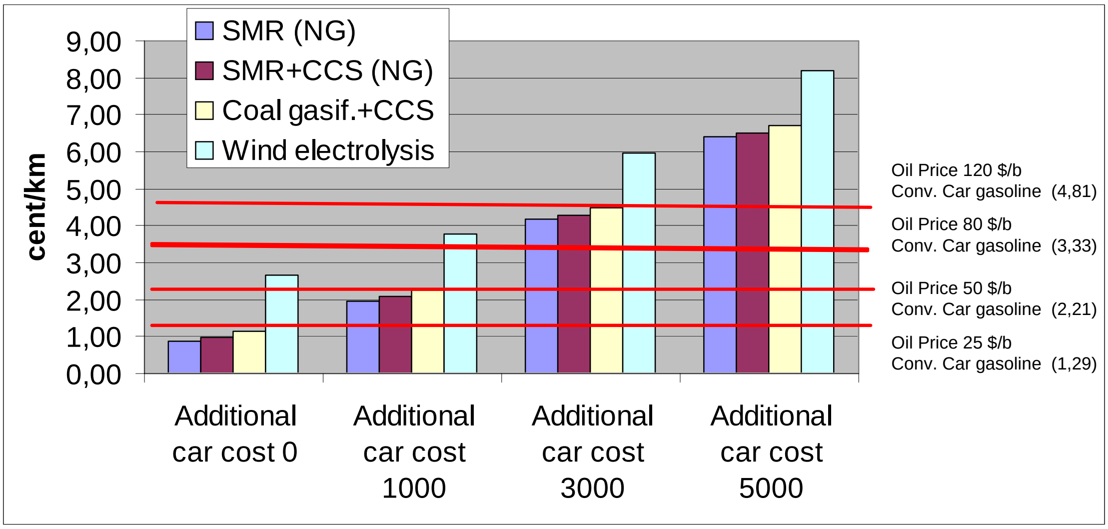

Figure 50: Influence of oil price and additional car cost (hydrogen fuel car - conventional car) on the competitiveness of hydrogen fuel cell cars (*Explanation: Without tax, hydrogen cost based on centralized plants without distribution and filling stations)*

Under current HyWays assumptions the use of hydrogen cars is cost effective from the year 2020 in the best case and 2038 in the worst case (see Figure 54), mainly due to the learning effects of mass production of FC-hydrogen cars (see Figure 50 and Figure 52), although this also depends on the oil price development.

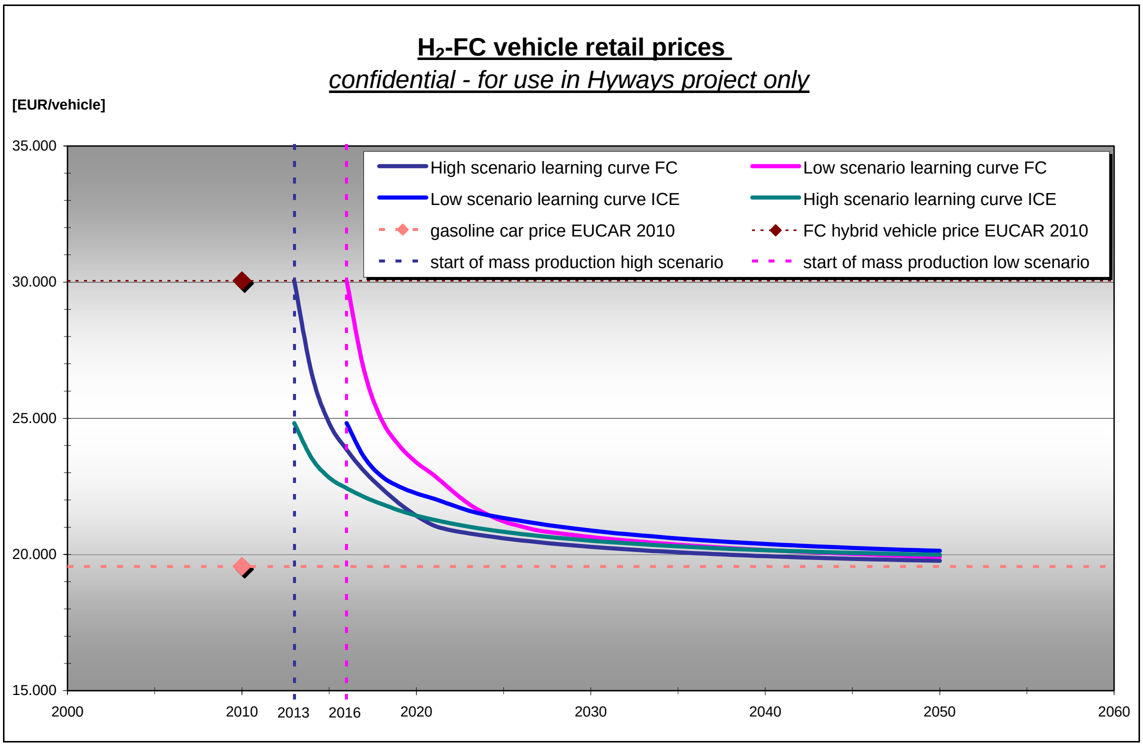

Figure 51: Low learning effects for hydrogen cars (source: Hyways automobile group)

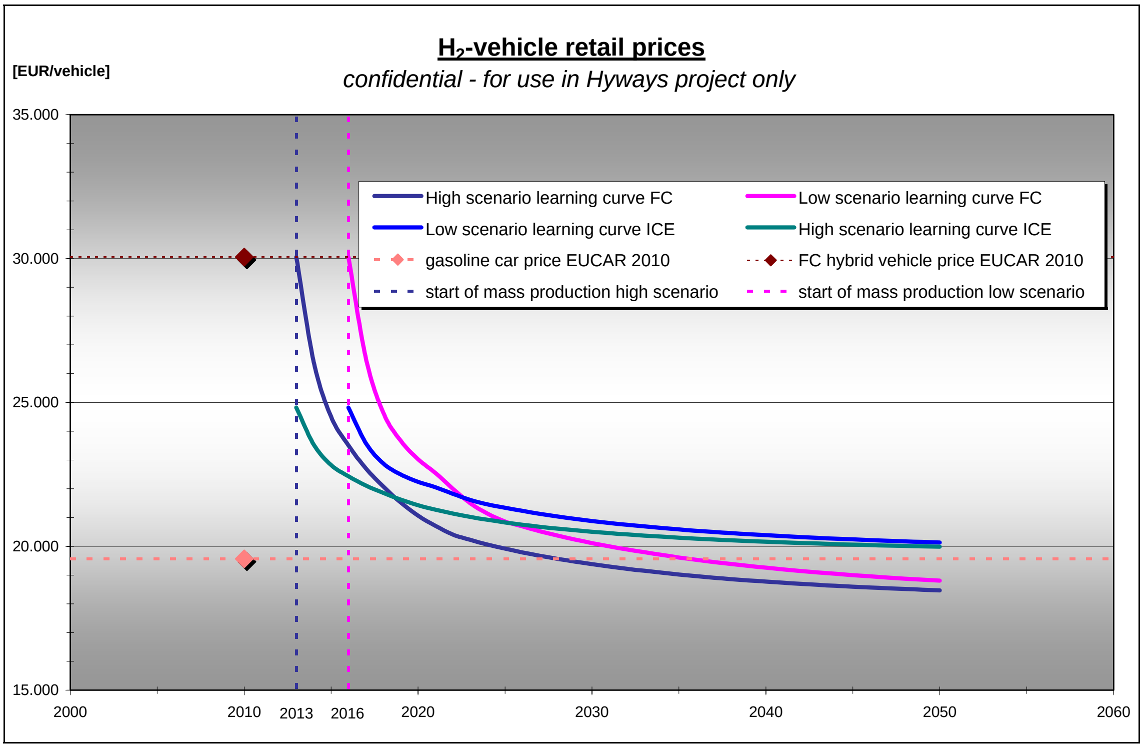

Figure 52: High learning effects for hydrogen cars (source: HyWays automobile group)

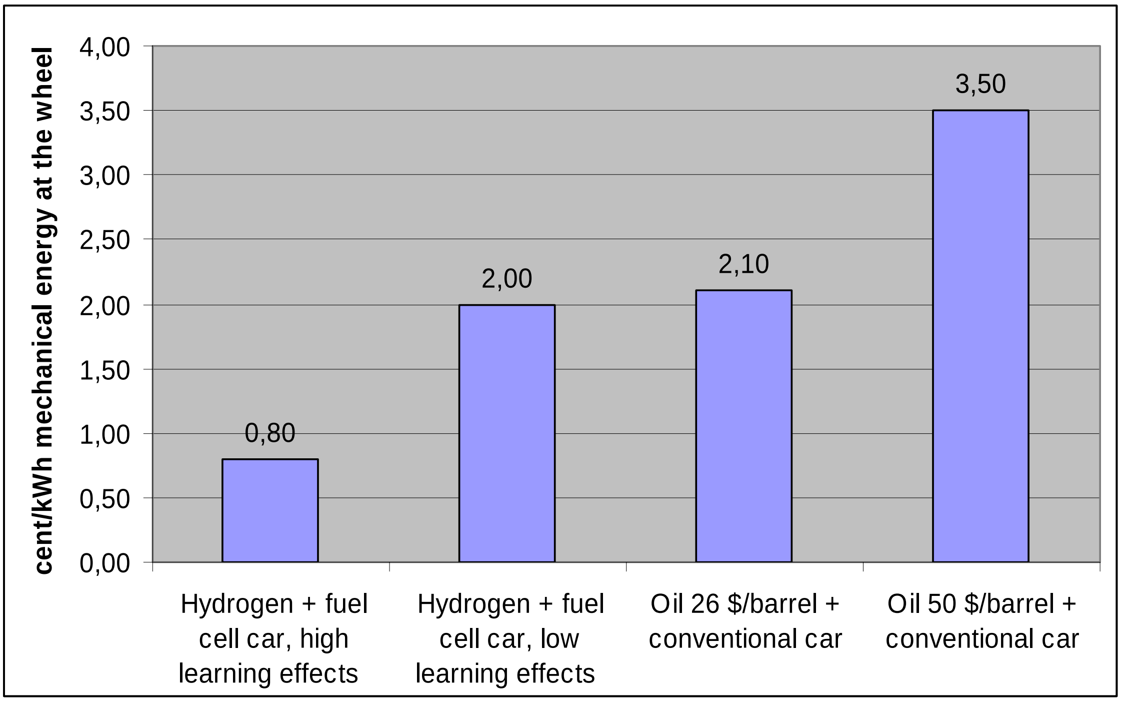

Figure 53: Specific cost of hydrogen fuel cell cars vs. conventional cars in 2030 (*Explanations: Without tax, cost difference between conventional car prices – fuel cell car price: for high learning effects the fuel cell cars are 180 Euro cheaper and for low learning effects the fuel cell cars cost 700 Euro more; cumulated fuel cell car production for*

both, low and high learning effects, in 2030 in Europe: 37 Million, the hydrogen cost at filling station are calculated to 60 $/barrel oil equivalent in 2030, higher efficiency of fuel cell cars: 45 % vs. 22%)

One open questions is, who will overtake the necessary investments to reach the learning effects from around 13 billion Euro in the cheapest case (high learning rates and high oil prices) and 170 billion Euro (low learning rates and low oil prices). See Figure 54. The next question is who will invest in parallel in the build up of the hydrogen infrastructure?

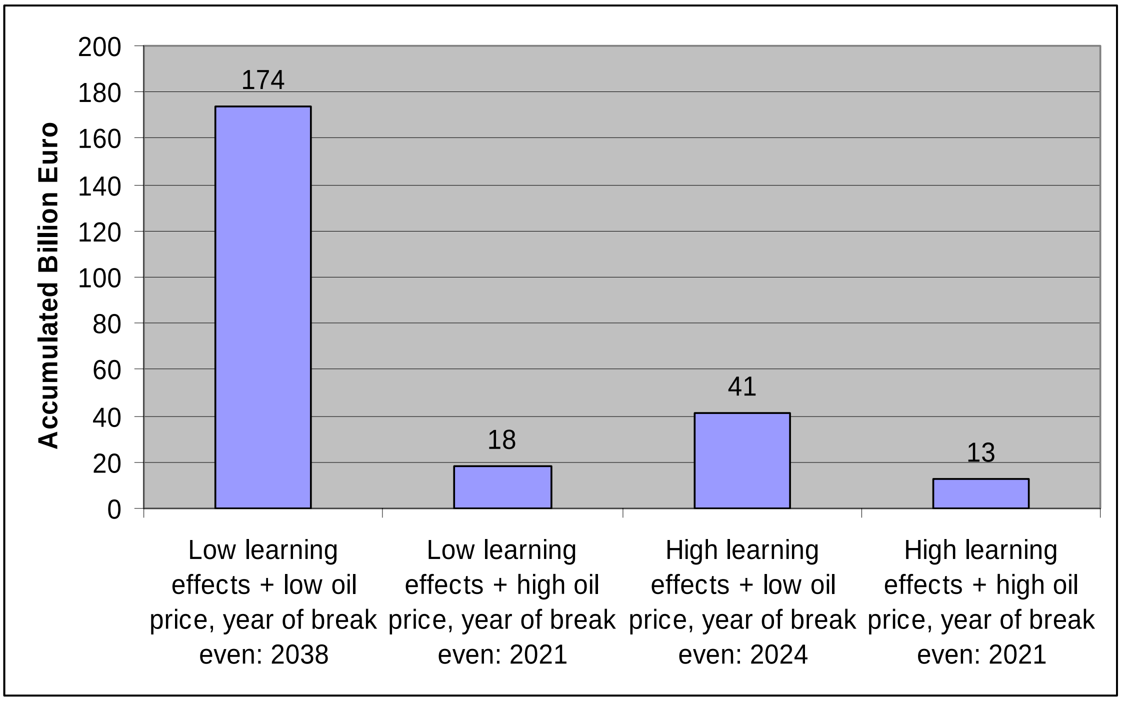

Figure 54: Accumulated expenditures for fuel cell cars (cost difference fuel cell car – conventional car) until the fuel cell cars reach their competitiveness in Europe.) (*Explanations: Without tax, the calculation includes the expenditures for fuels (hydrogen fuel cost per km minus fuel cost for conventional cars, low learning effects for fuel cell cars see* Figure 50*, high learning effects see* Figure 51*, high oil price: 60$/barrel, low oil price: 30$/barrel, 12000 km per year and vehicle)*

The investment in hydrogen vehicles and hydrogen infrastructure is varying between the six HyWays member states. Hydrogen vehicle costs are between five and eleven times higher than the annually needed investment in new infrastructure. The main reason for the differences in total investment is the country size and population. For an operational comparison the Markal data from the hydrogen high scenario with fast learning was analysed with relative indicators. Therefore per capita values are calculated to give the possibility of a direct comparison between the countries. The differences between the vehicle investments per capita indicators could be explained by variation of the vehicle structure between the countries (share of local, regional, inter-regional cars). The variation in the per capita infrastructure investment could be mainly explained by the different choice of hydrogen production pathways.

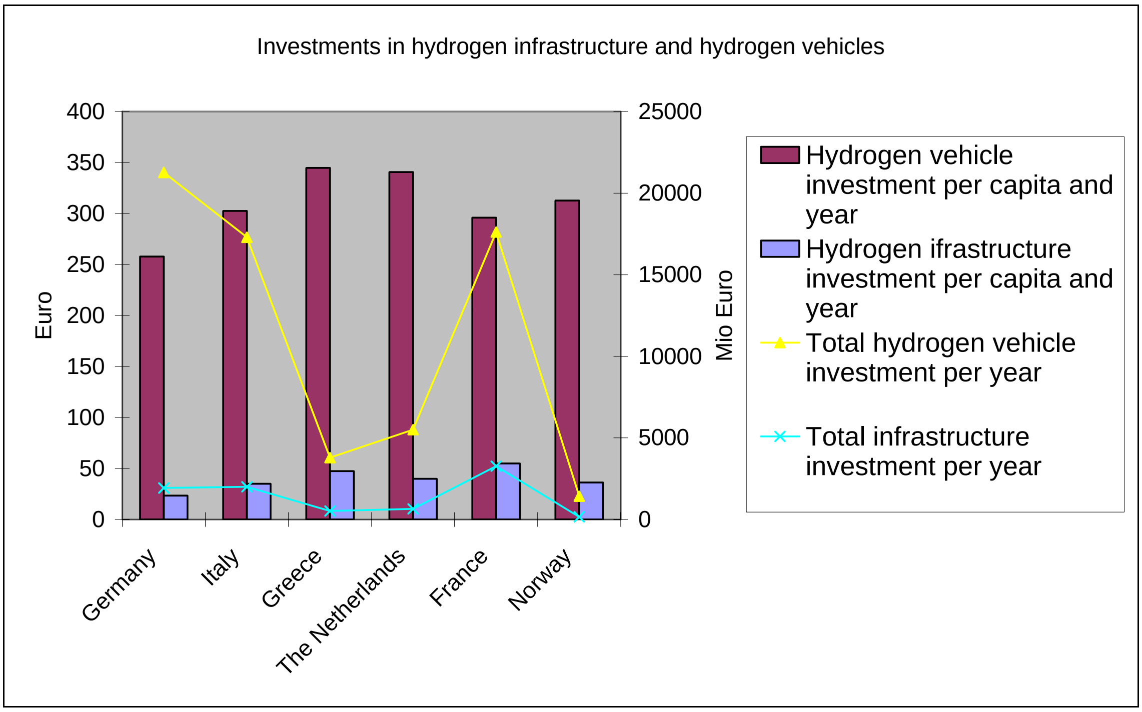

Figure 55: Investments in hydrogen infrastructure and hydrogen vehicles in 2030

5.3.2 MS Results: France

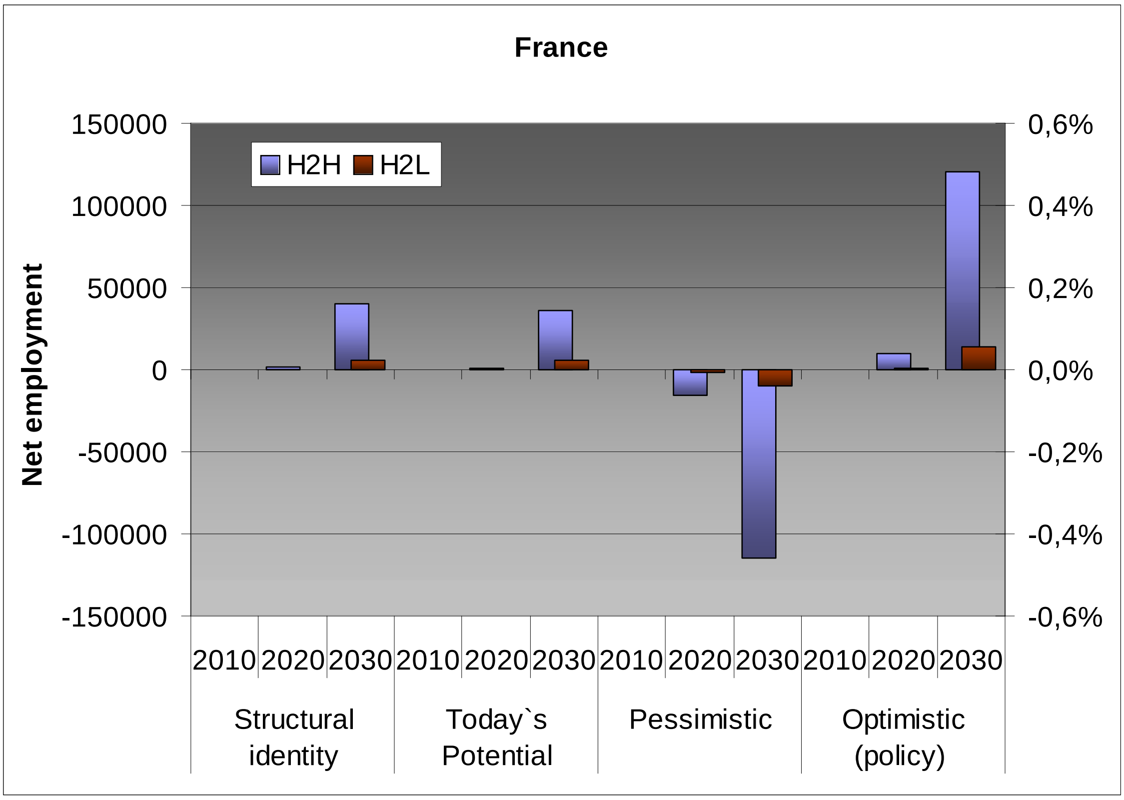

Figure 56: Employment effects for France Optimistic Learning high (H2H) and low (H2L) penetration

5.3.2.1 High learning scenario high penetration rates

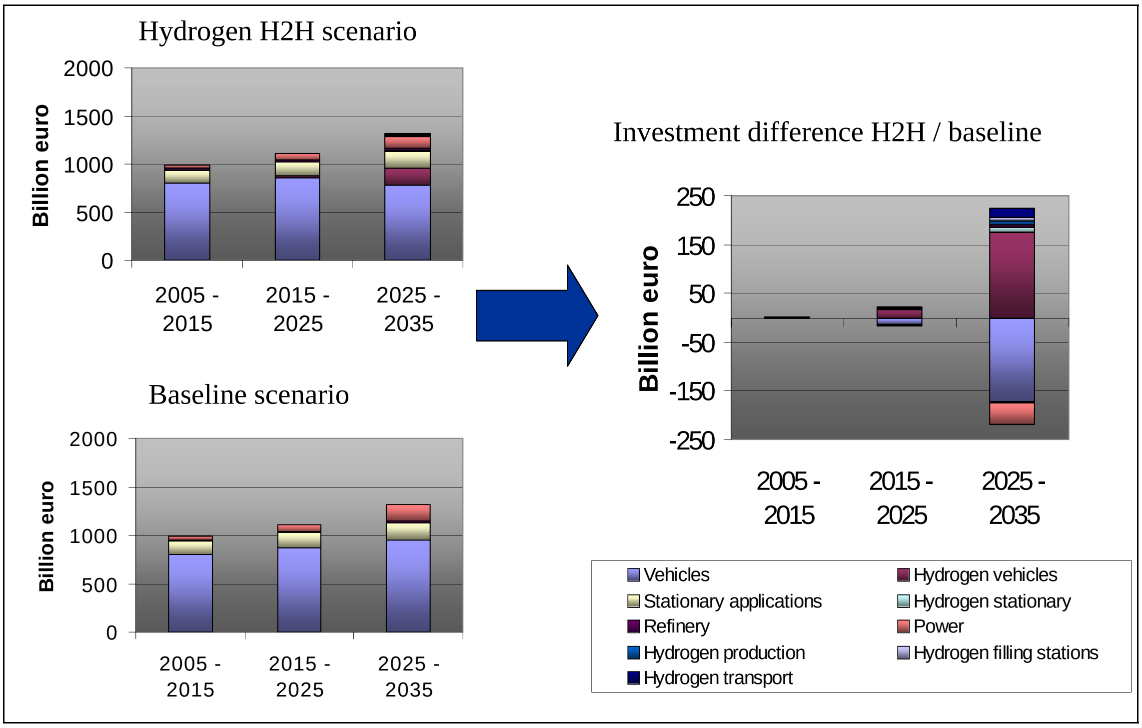

Figure 57: Hydrogen investment structure for France

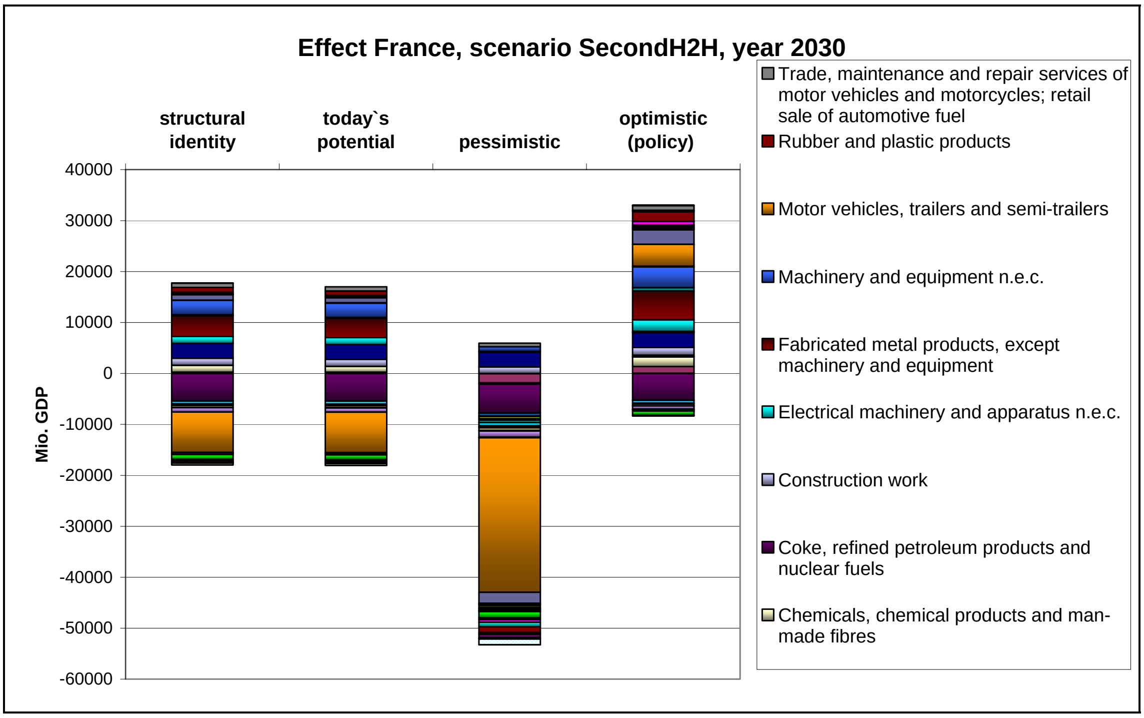

Figure 58: Sectoral economic effects France 2030 optimistic learning high penetration (H2H)

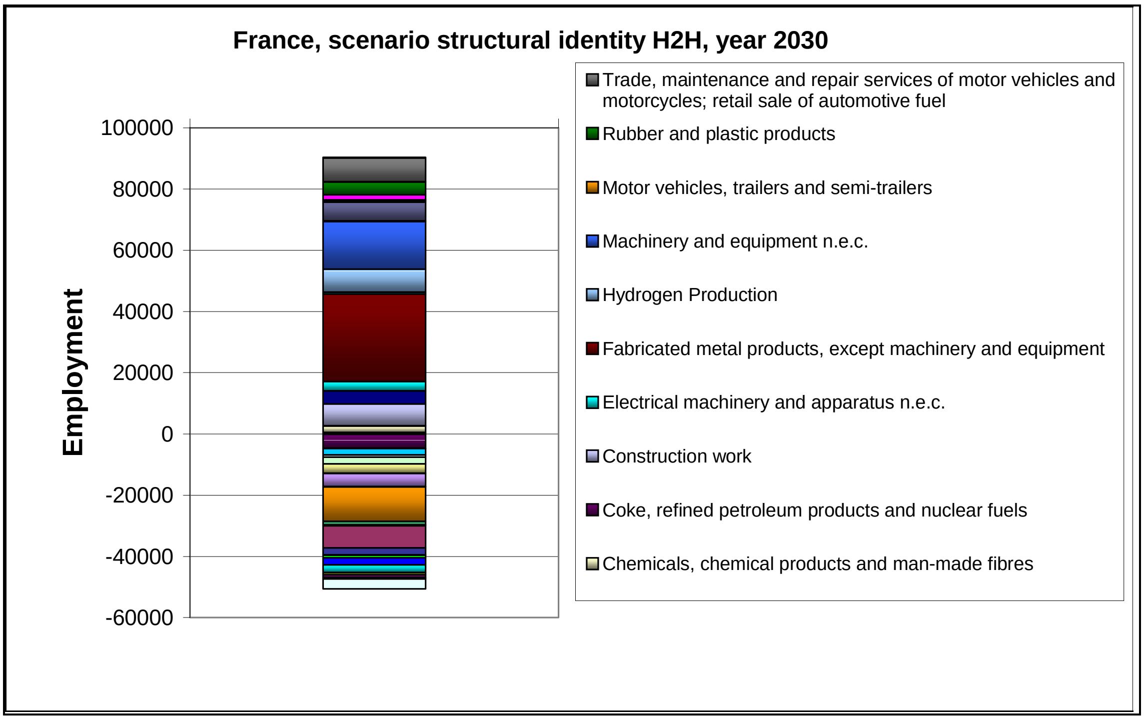

Figure 59: Sectoral employment shifts for France optimistic learning high penetration (H2H)

5.3.2.2 High learning scenario low penetration rates

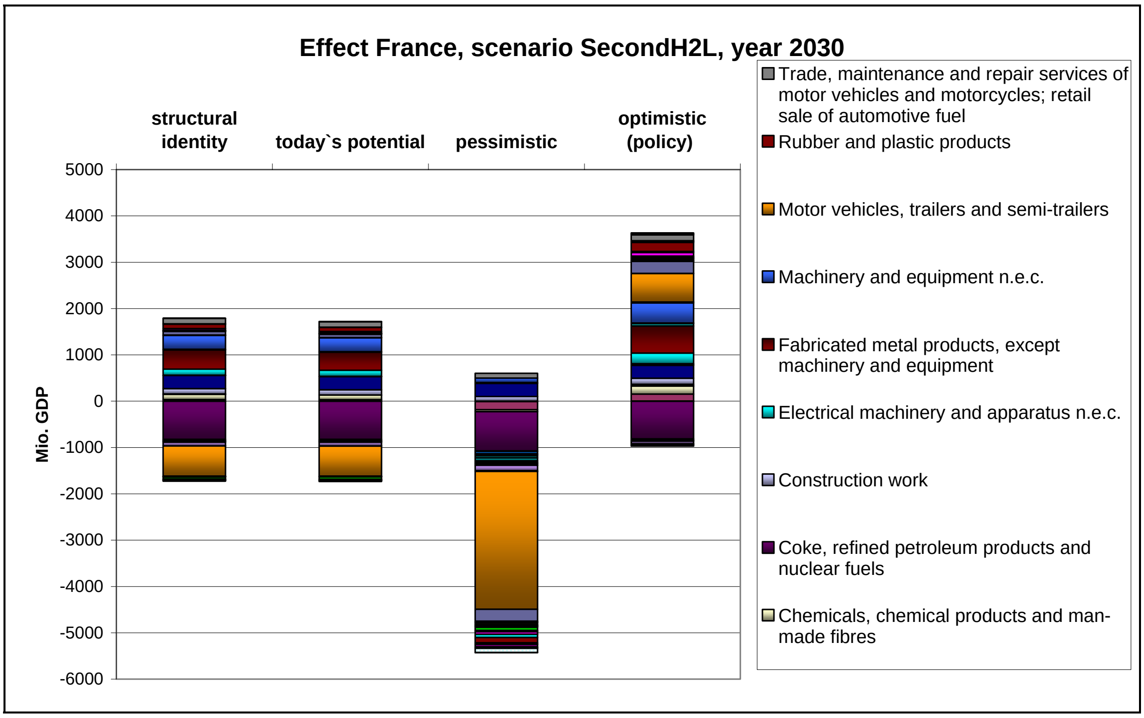

Figure 60: Sectoral economic effects France 2030 optimistic learning low penetration (H2L)

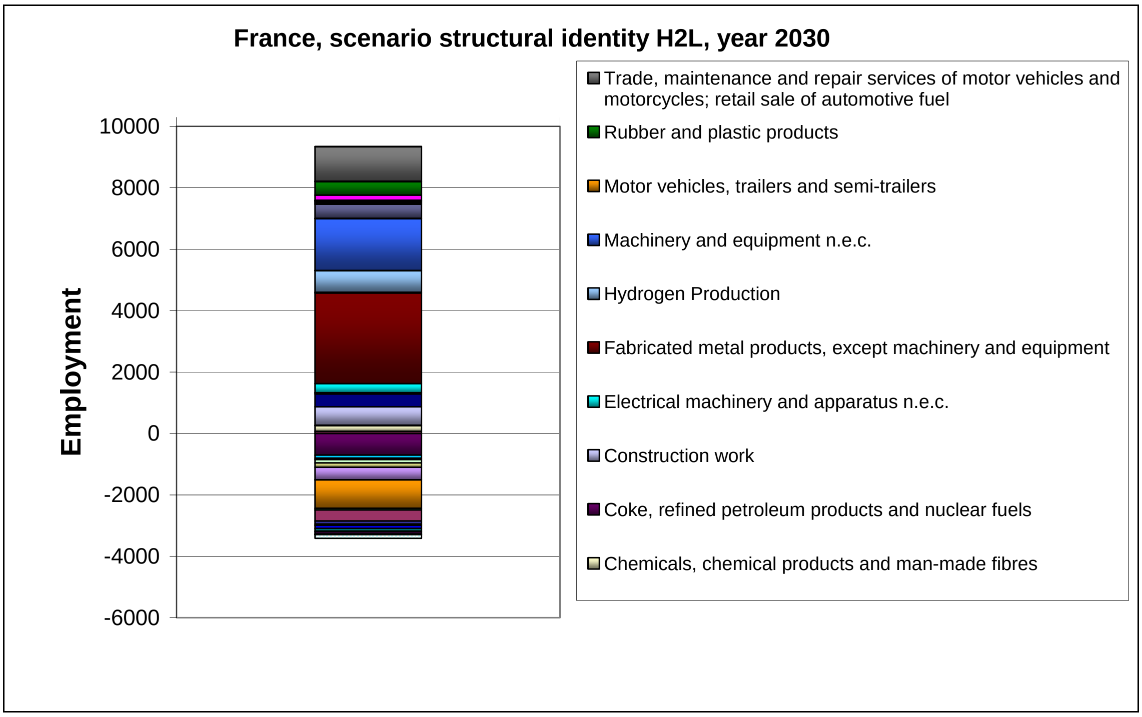

Figure 61: Sectoral employment shifts for France optimistic learning low penetration (H2L)

5.3.2.3 Conclusion

- The scenarios are dominated by the automobile industry structure of the countries.
- Main employment gains or losses due to import and export development of the vehicle sector.
- Significant shifts between the economic sectors could be identified, therefore the necessary workforce skills in hydrogen have to be available already.
- The scenarios showed that the manufacturing of stacks seems to be less important in terms of employment than vehicle production.
- The **dilemma situation**: There are some uncertainties regarding the market success of hydrogen vehicles and there is a risk of losing several billion Euro due to investments in a hydrogen infrastructure and hydrogen car development. However, if France with a large automobile industry lose market shares due to too late market entry, the job losses and GDP losses could be drastic.
- Compared with relevant competitors the lead market potential for stack production in France is limited.

5.3.3 MS Results: Germany

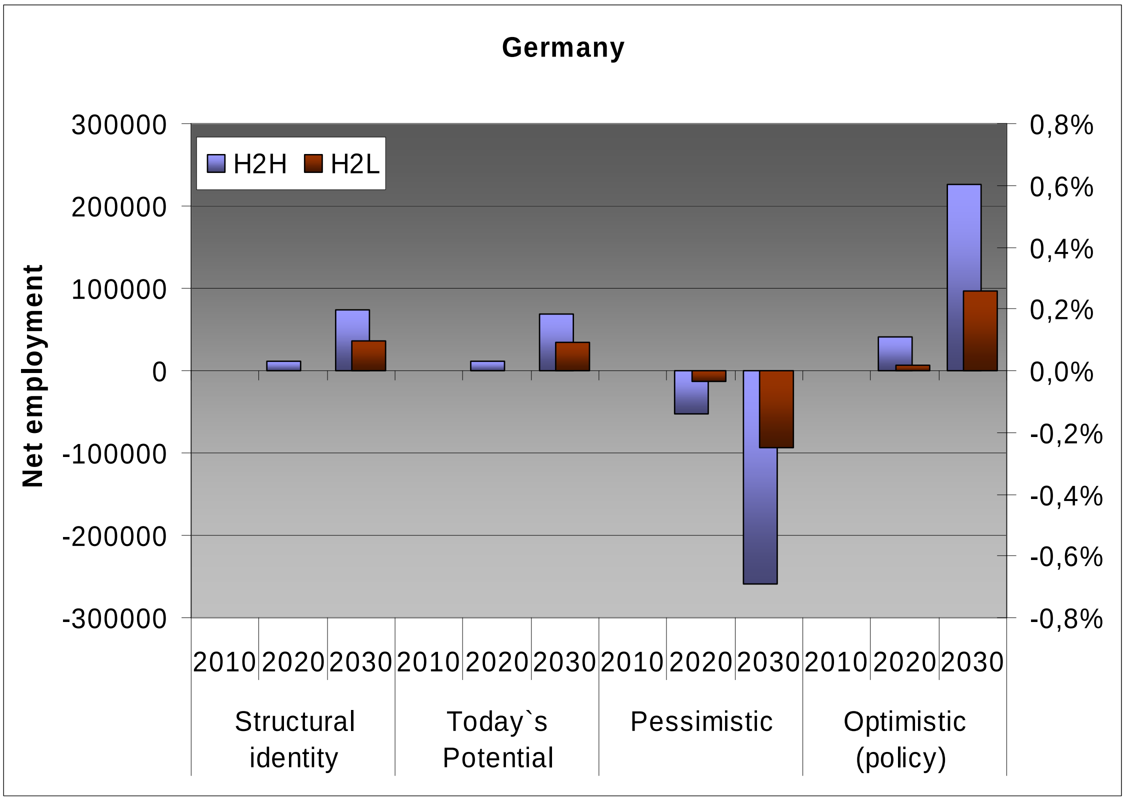

Figure 62: Employment effects for Germany Optimistic Learning high (H2H) and low (H2L) penetration

5.3.3.1 High learning scenario high penetration rates

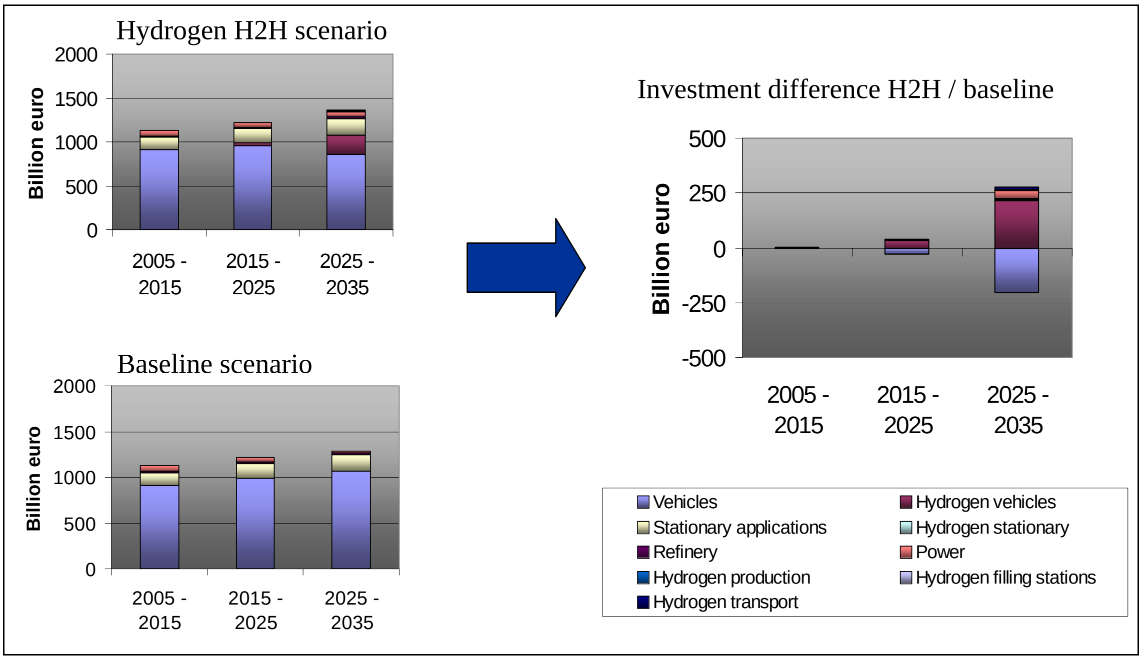

Figure 63: Hydrogen investment structure for Germany

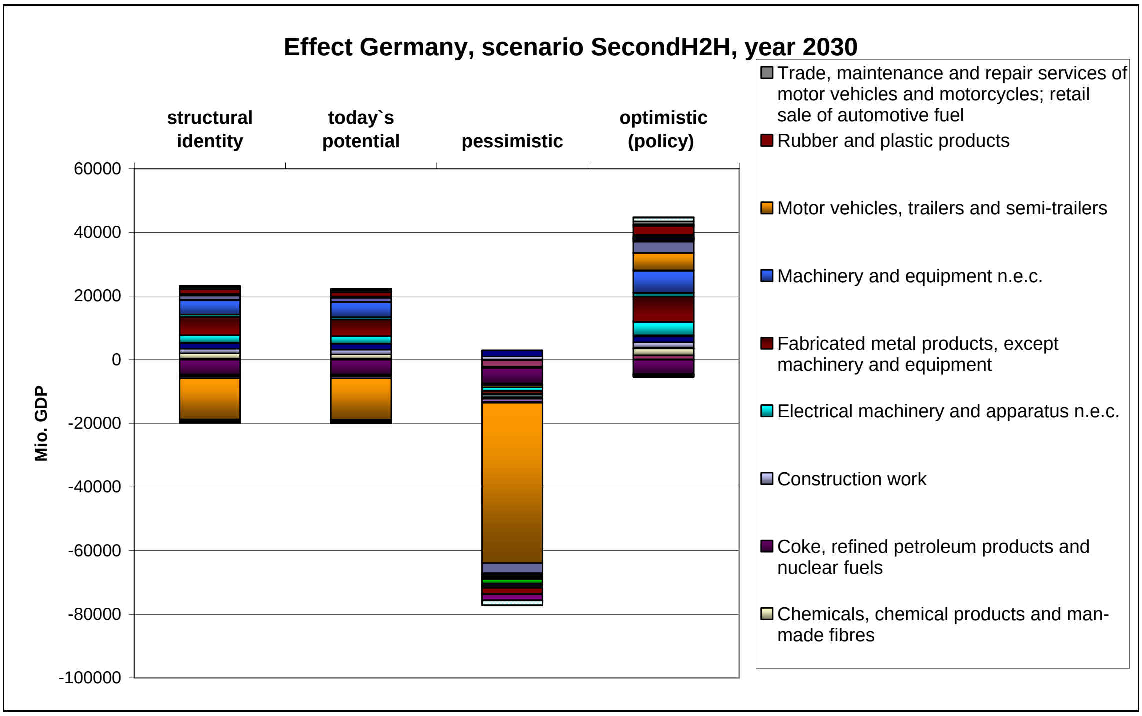

Figure 64: Sectoral economic effects Germany 2030 optimistic learning high penetration (H2H)

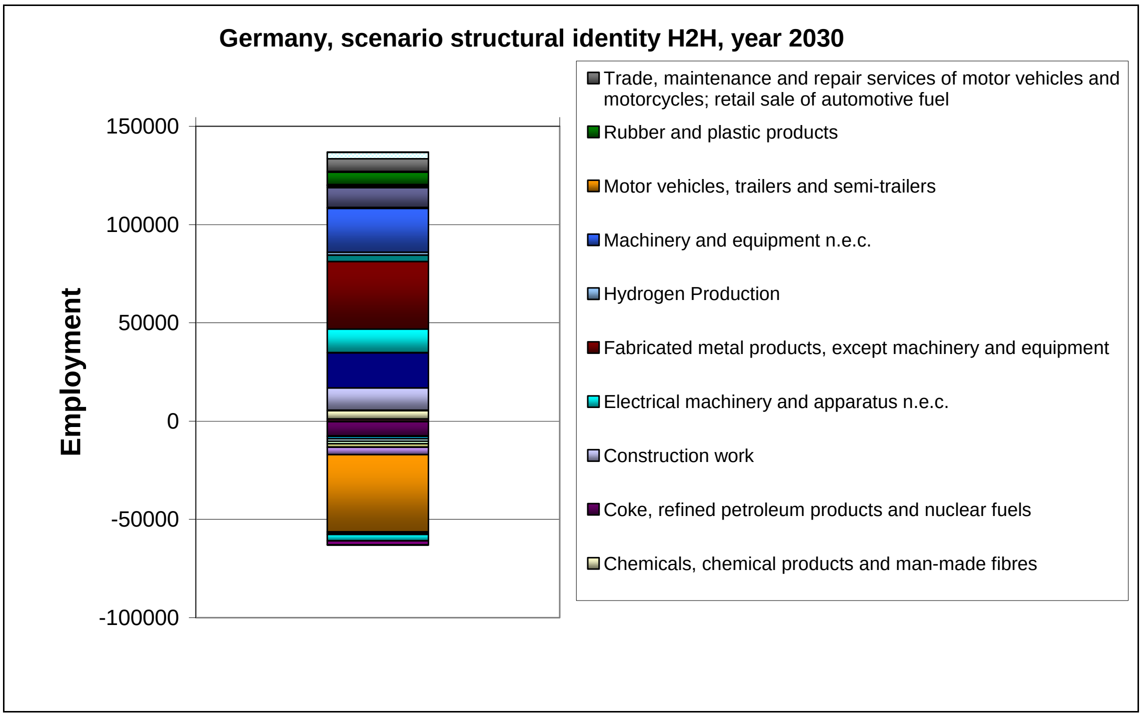

Figure 65: Sectoral employment shifts for Germany optimistic learning high penetration (H2H)

5.3.3.2 High learning scenario low penetration rates

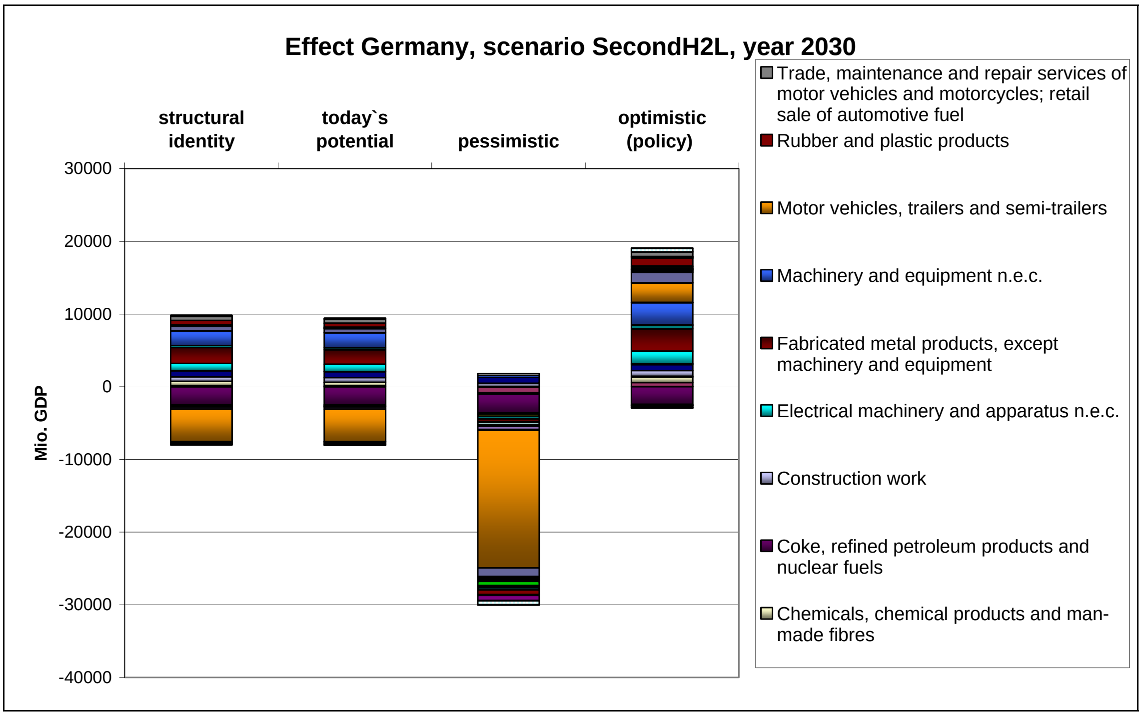

Figure 66: Sectoral economic effects Germany 2030 optimistic learning low penetration (H2L)

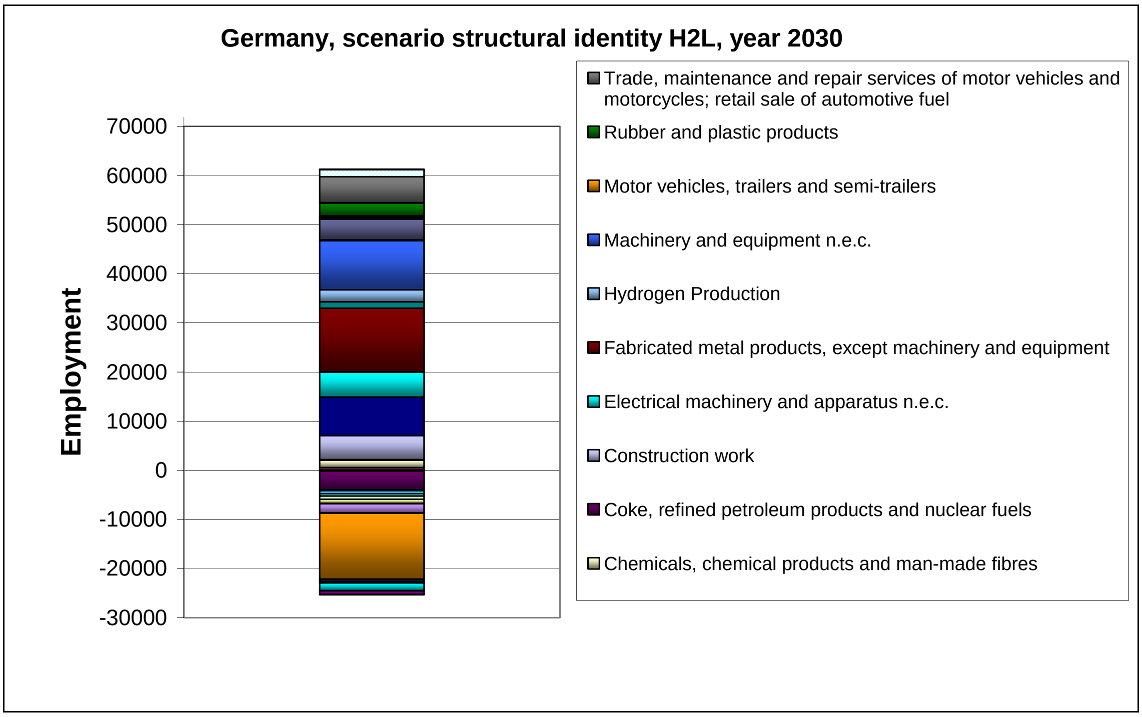

Figure 67 Sectoral employment shifts for Germany optimistic learning low penetration (H2L)

5.3.3.3 Conclusion

- The scenarios are dominated by the automobile industry structure of the countries.
- Main employment gains or losses due to import and export development of the vehicle sector.
- Significant shifts between the economic sectors could be identified, therefore the necessary workforce skills in hydrogen have to be available already.
- The scenarios showed that the manufacturing of stacks seems to be less important in terms of employment than vehicle production.
- The **dilemma situation**: There are some uncertainties regarding the market success of hydrogen vehicles and there is a risk of losing several billion Euro due to investments in a hydrogen infrastructure and hydrogen car development. However, if Germany with the largest automobile industry in Europe lose market shares due to too late market entry, the job losses and GDP losses could be drastic.

- Additional exports could be realized by hydrogen production technologies, where Germany has a high lead market potential

5.3.4 MS Results: Greece

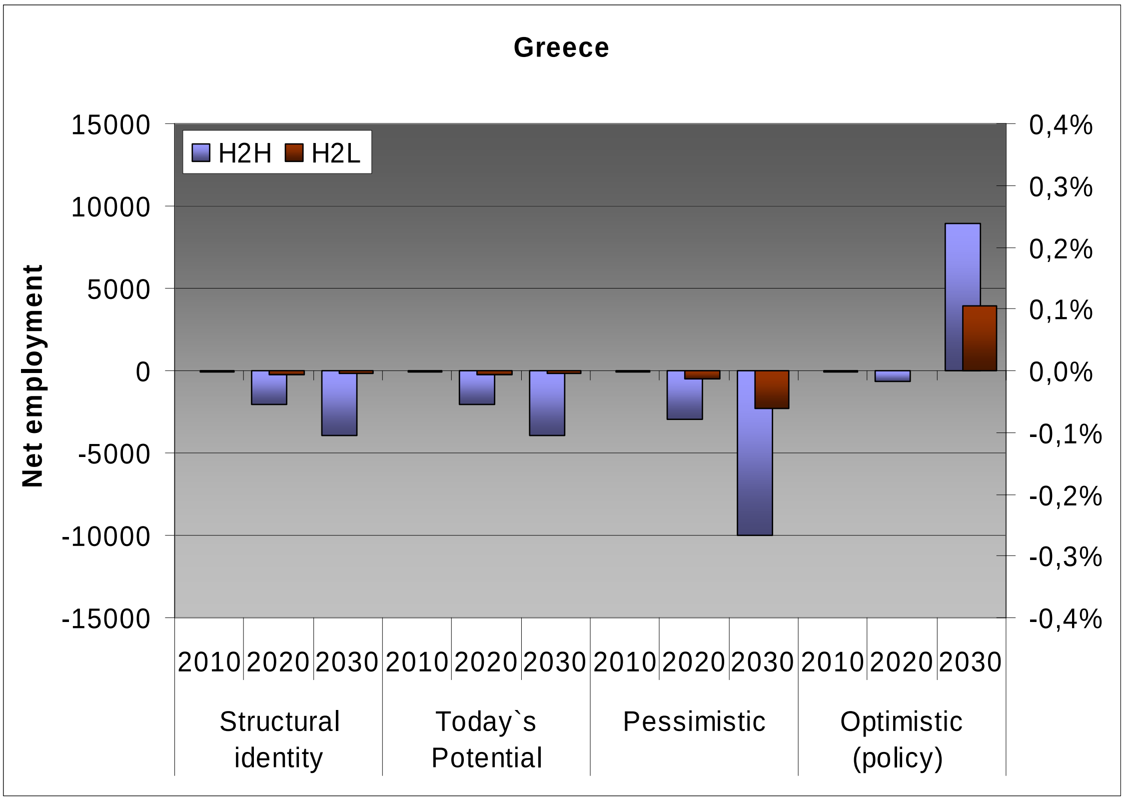

Figure 68: Employment effects for Greece Optimistic Learning high (H2H) and low (H2L) penetration

5.3.4.1 High learning scenario high penetration rates

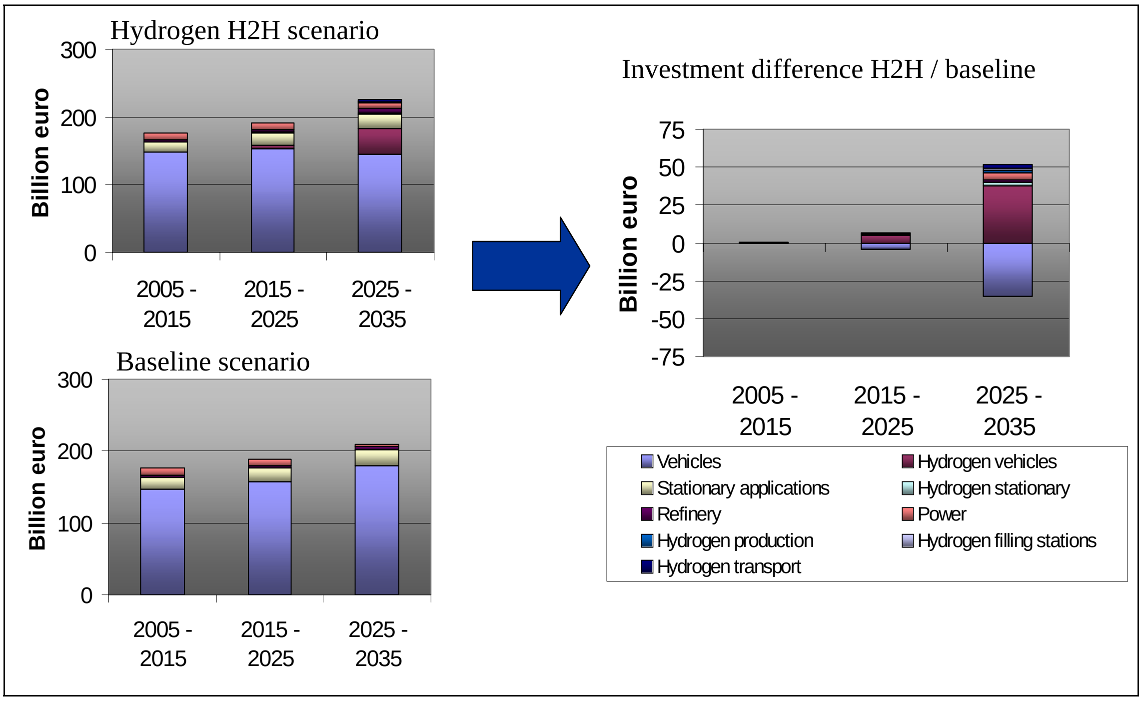

Figure 69: Hydrogen investment structure for Greece

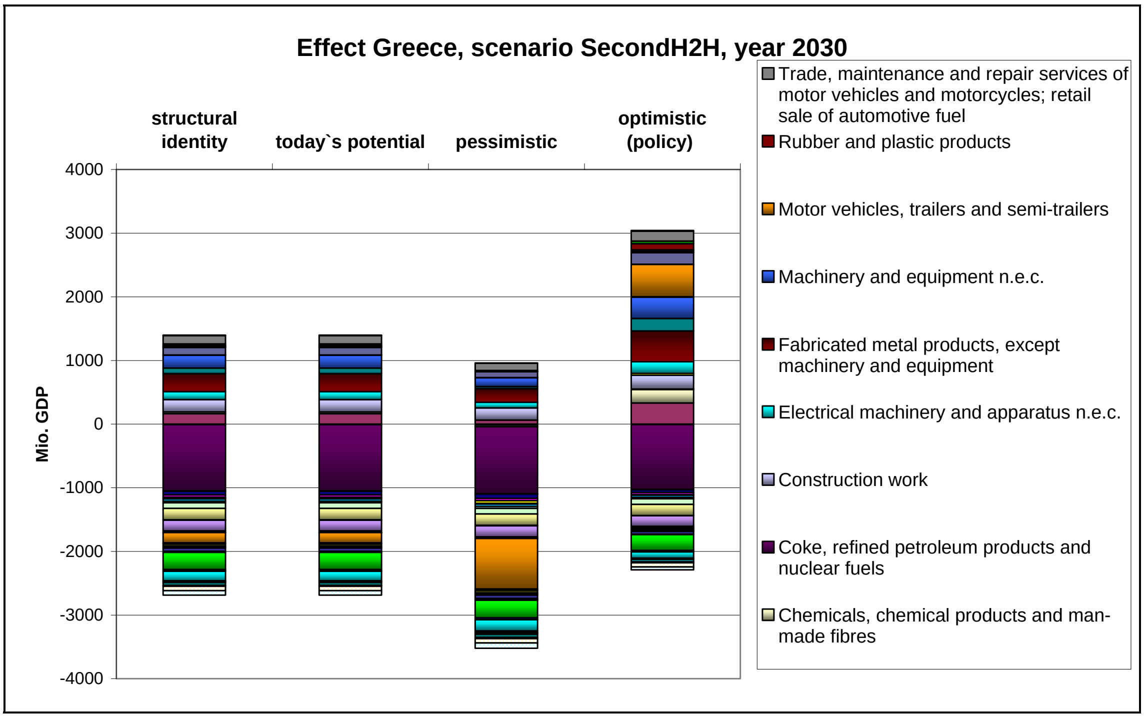

Figure 70: Sectoral economic effects Greece 2030 optimistic learning high penetration (H2H)

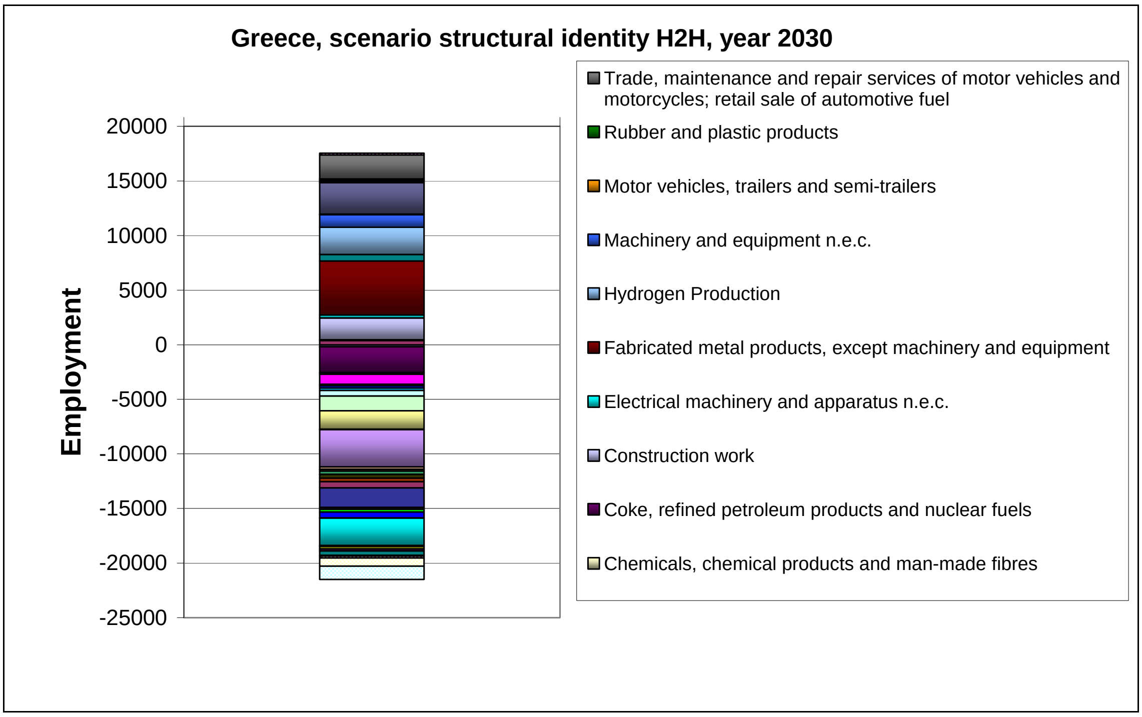

Figure 71: Sectoral employment shifts for Greece optimistic learning high penetration (H2H)

5.3.4.2 High learning scenario low penetration rates

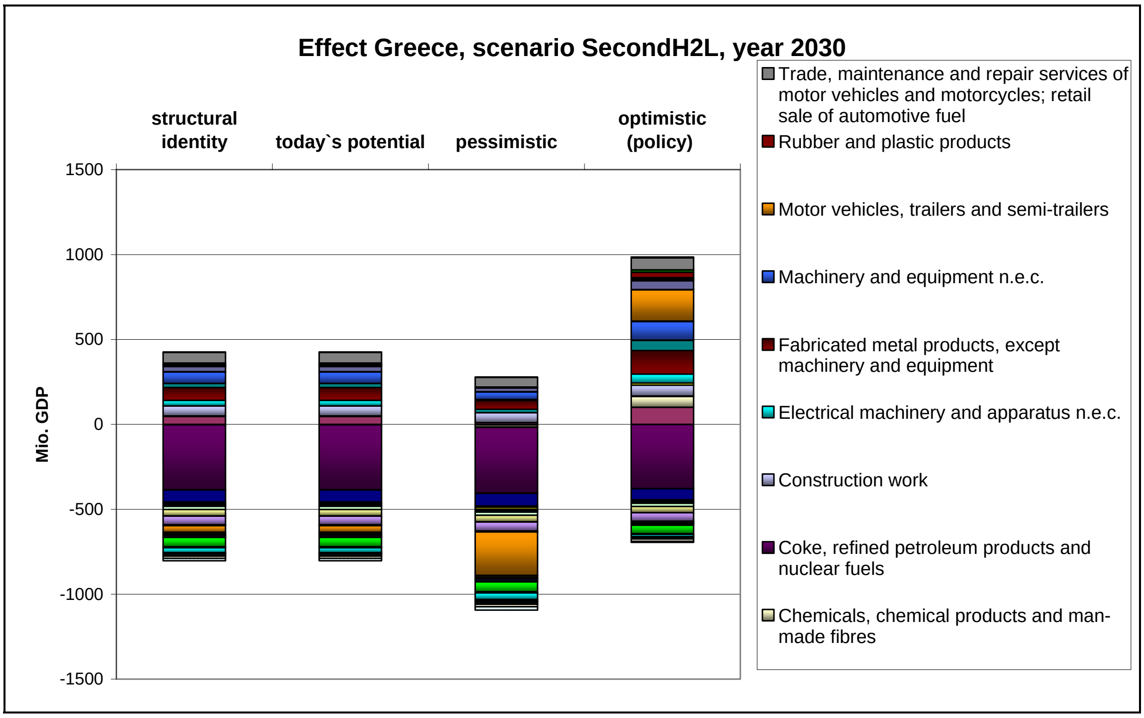

Figure 72: Sectoral economic effects Greece 2030 optimistic learning low penetration (H2L)

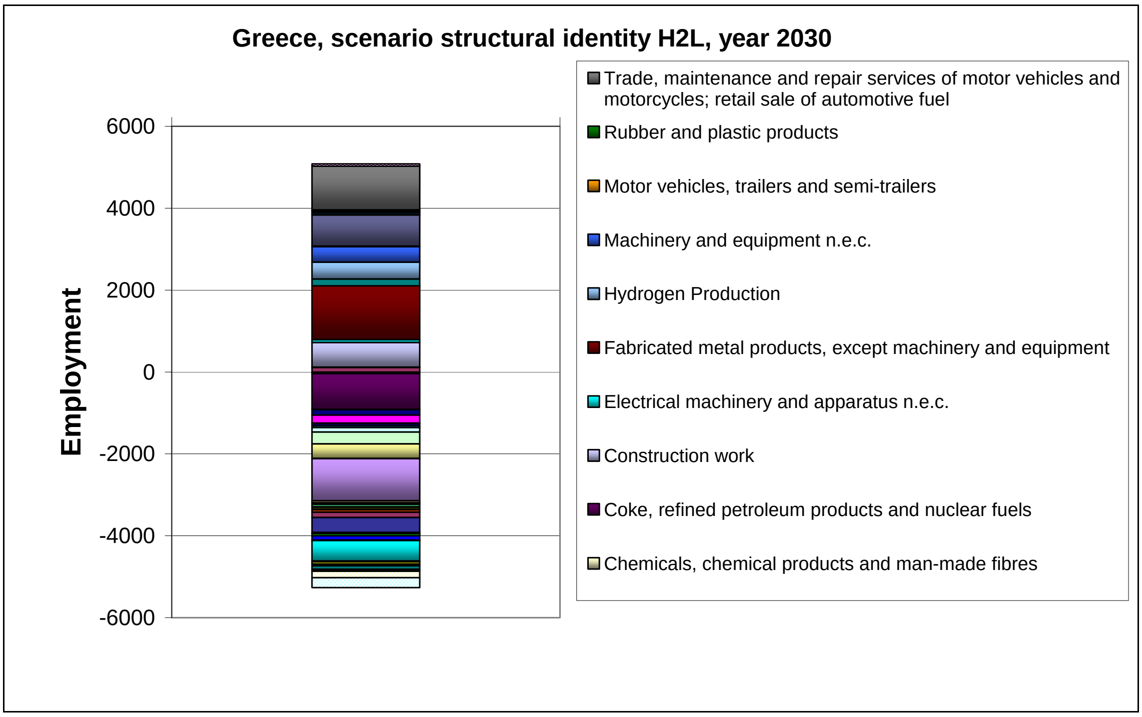

Figure 73: Sectoral employment shifts for Greece optimistic learning low penetration (H2L)

5.3.4.3 Conclusion

- The scenarios are dominated by the automobile industry structure of the countries.
- Main employment gains or losses due to import and export development of the vehicle sector.
- Significant shifts between the economic sectors could be identified, therefore the necessary workforce skills in hydrogen have to be available already.
- The scenarios showed that the manufacturing of stacks seems to be less important in terms of employment than vehicle production.
- The dilemma situation: There are some uncertainties regarding the market success of hydrogen vehicles and there is a risk of losing several billion Euros due to investments in a hydrogen infrastructure and hydrogen car development. However, if Italy with a large automobile industry lose market shares due to too late market entry, the job losses and GDP losses could be drastic.

- Compared with relevant competitors the lead market potential for hydrogen vehicle production and stack production in Italy is limited.

5.3.5 MS Results: Italy

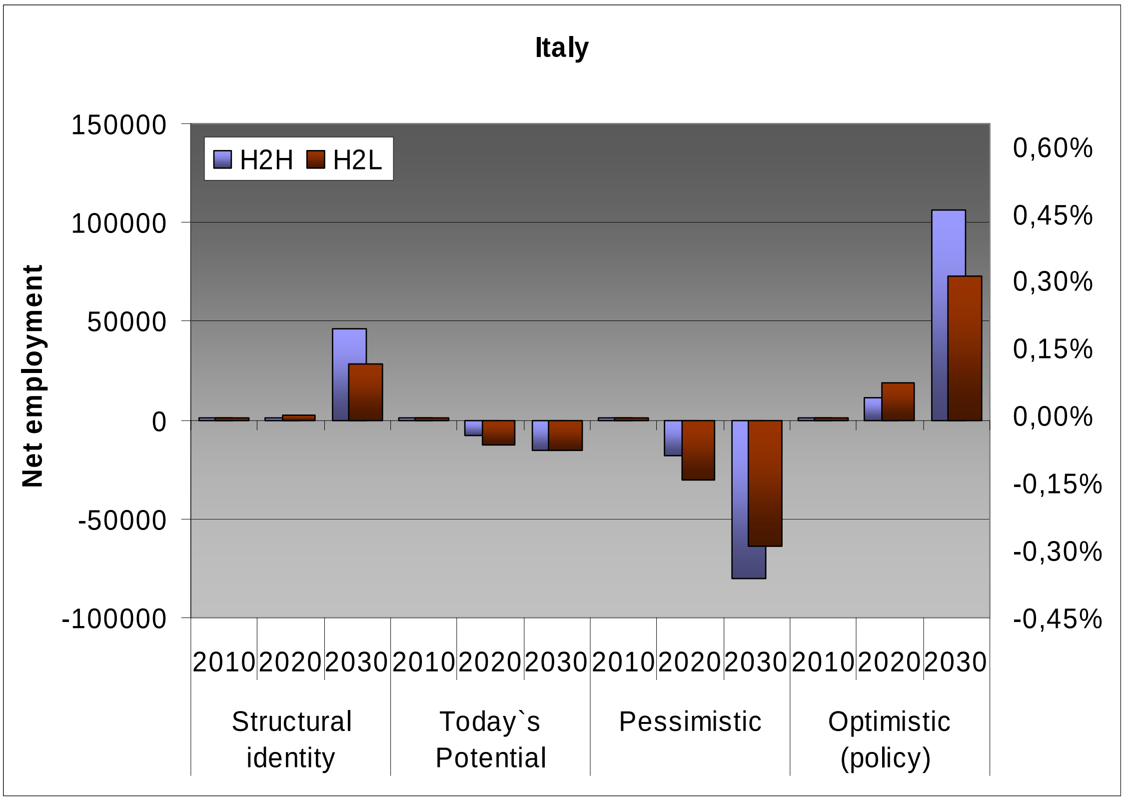

Figure 74: Employment effects for Italy Optimistic Learning high (H2H) and low (H2L) penetration

5.3.5.1 High learning scenario high penetration rates

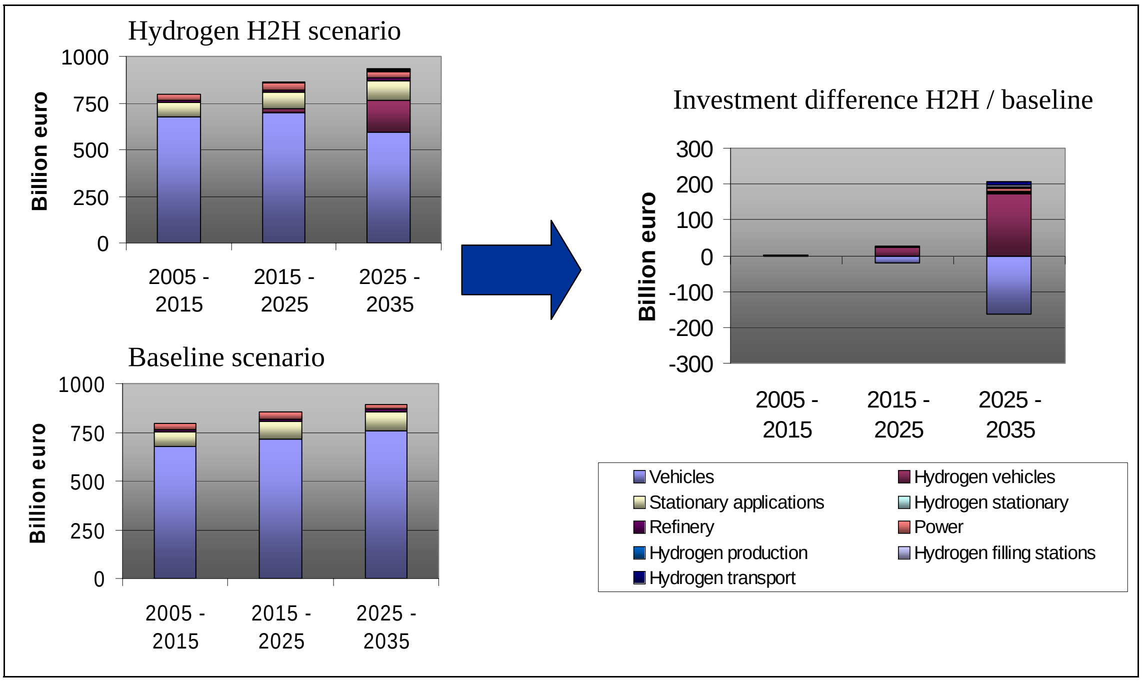

Figure 75: Hydrogen investment structure for Italy

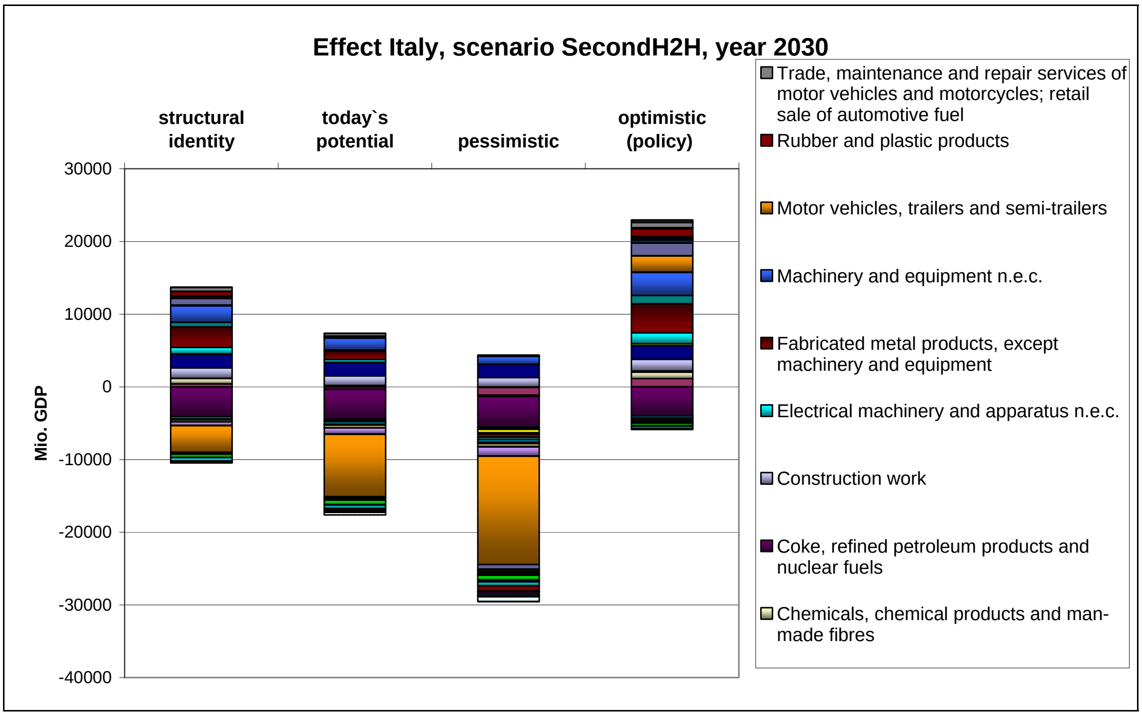

Figure 76: Sectoral economic effects Italy 2030 optimistic learning high penetration (H2H)

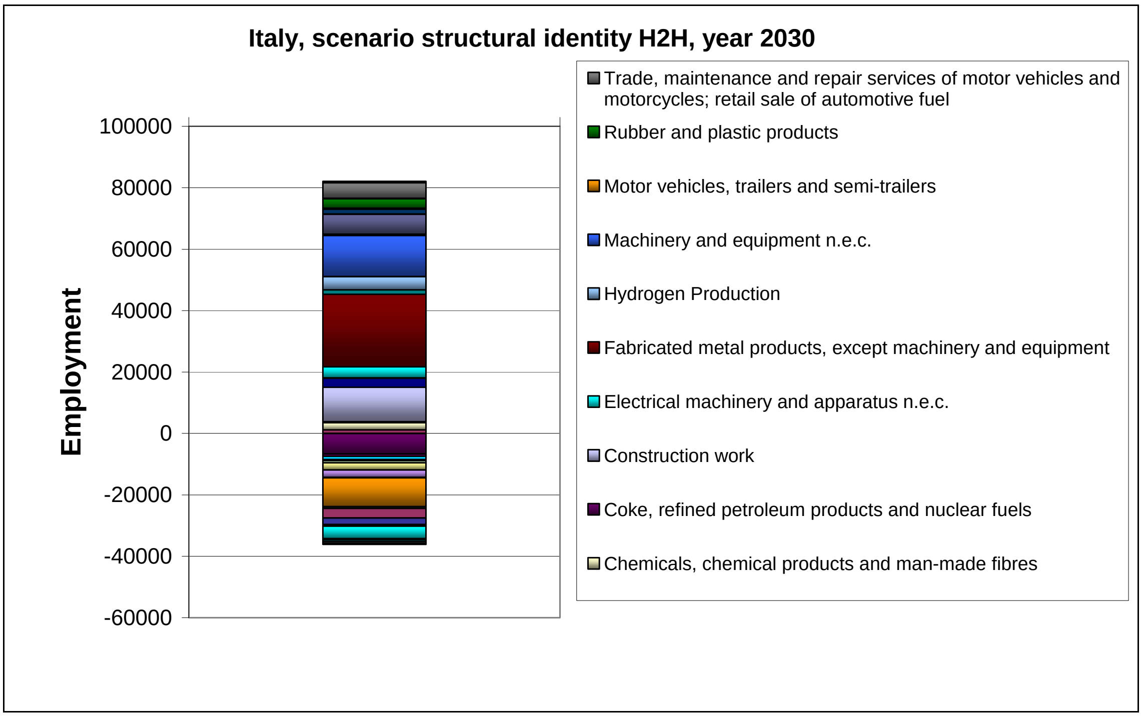

Figure 77: Sectoral employment shifts for Italy optimistic learning high penetration (H2H)

5.3.5.2 High learning scenario low penetration rates

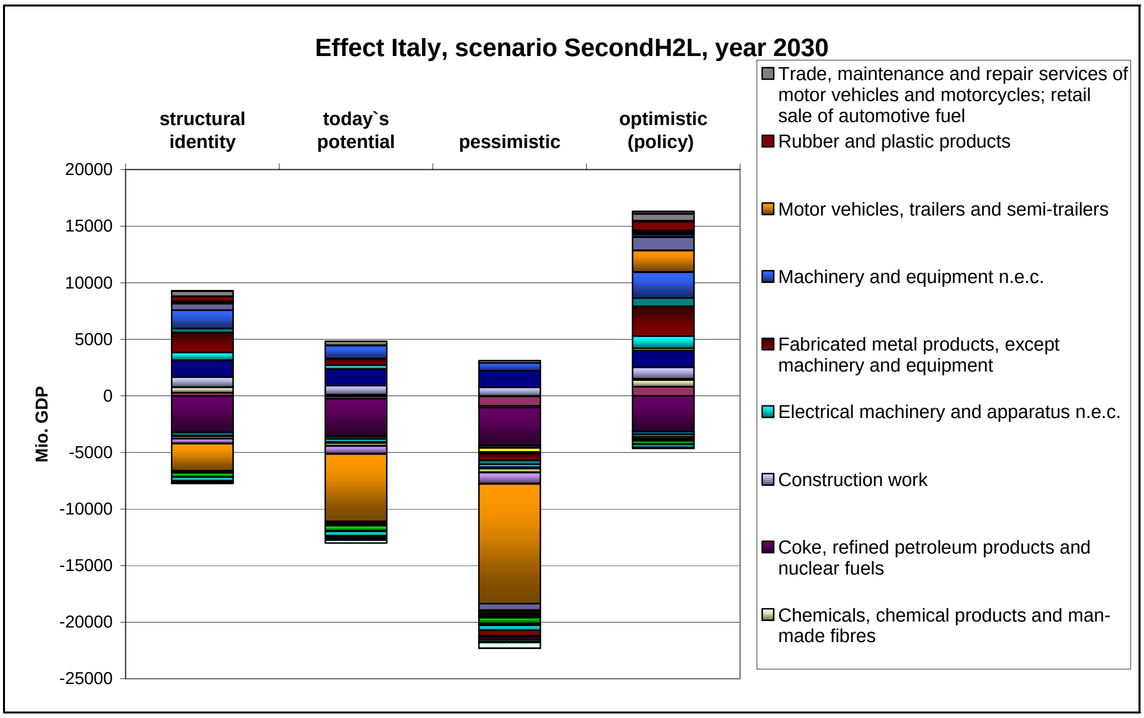

Figure 78: Sectoral economic effects Italy 2030 optimistic learning low penetration (H2L)

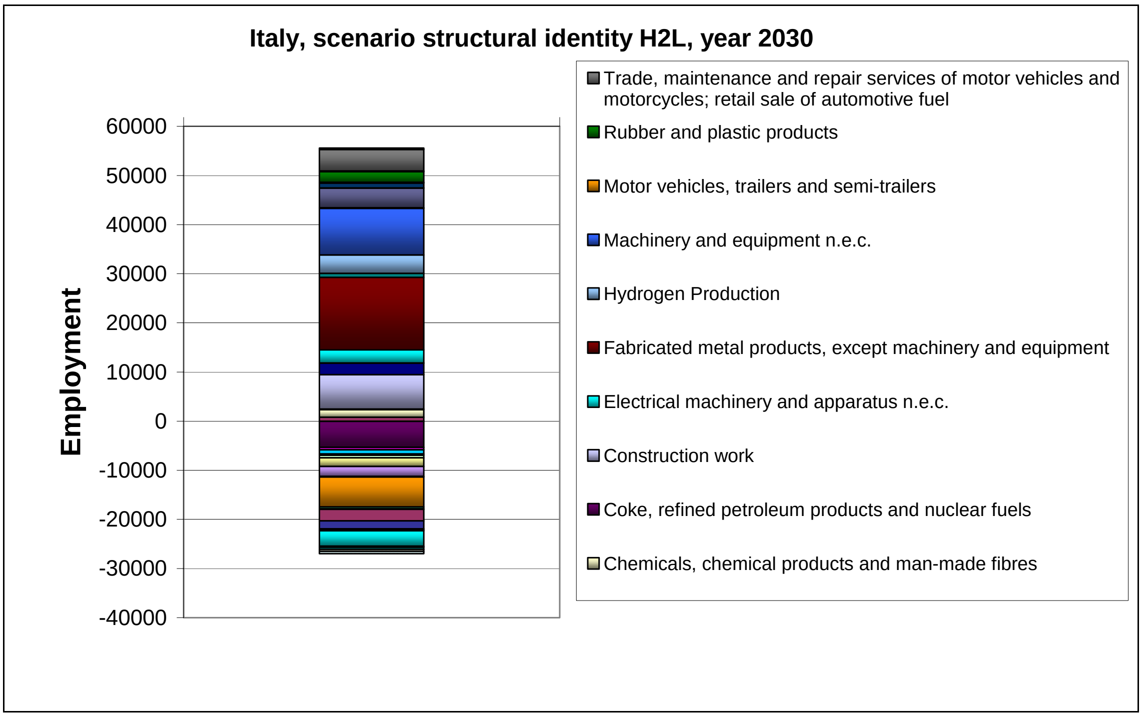

Figure 79: Sectoral employment shifts for Italy optimistic learning low penetration (H2L)

5.3.5.3 Conclusion

- The scenarios are dominated by the automobile industry structure of the countries.
- Main employment gains or losses due to import and export development of the vehicle sector.
- Significant shifts between the economic sectors could be identified, therefore the necessary workforce skills in hydrogen have to be available already.
- The scenarios showed that the manufacturing of stacks seems to be less important in terms of employment than vehicle production.
- The **dilemma situation**: There are some uncertainties regarding the market success of hydrogen vehicles and there is a risk of losing several billion Euro due to investments in a hydrogen infrastructure and hydrogen car development. However, if Italy with a large automobile industry lose market shares due to too late market entry, the job losses and GDP losses could be drastic.

- Compared with relevant competitors the lead market potential for hydrogen vehicle production and stack production in Italy is limited.

5.3.6 MS Results: Norway

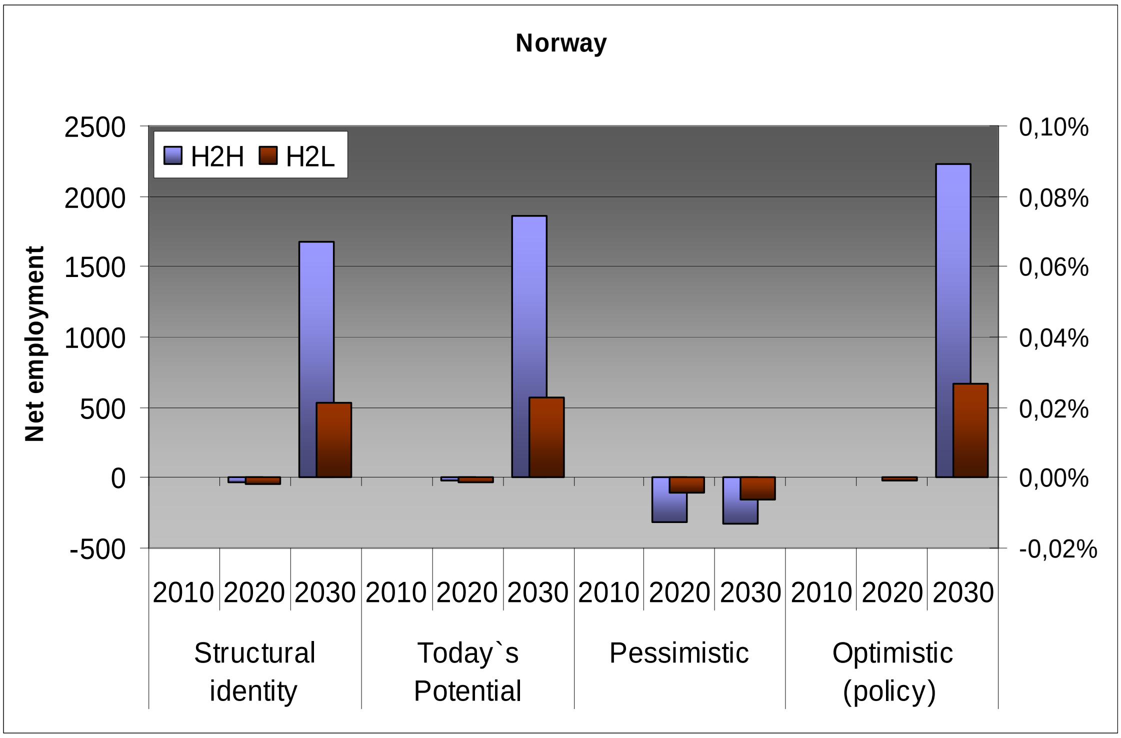

Figure 80: Employment effects for Norway Optimistic Learning high (H2H) and low (H2L) penetration

5.3.6.1 High learning scenario high penetration rates

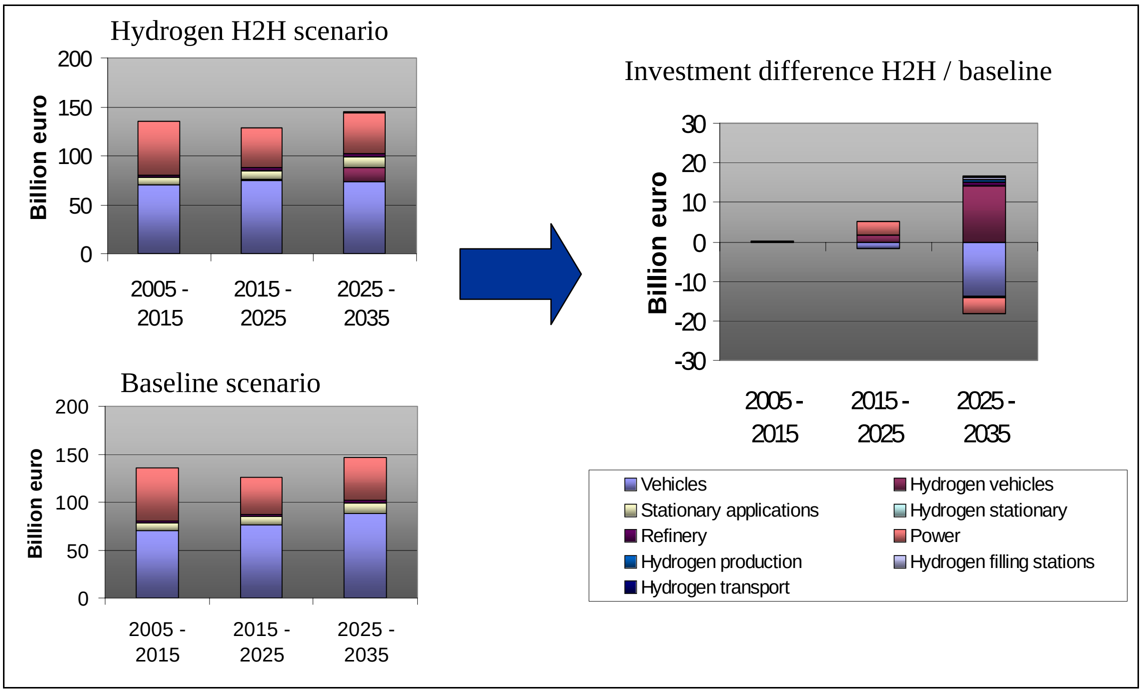

Figure 81: Hydrogen investment structure for Norway

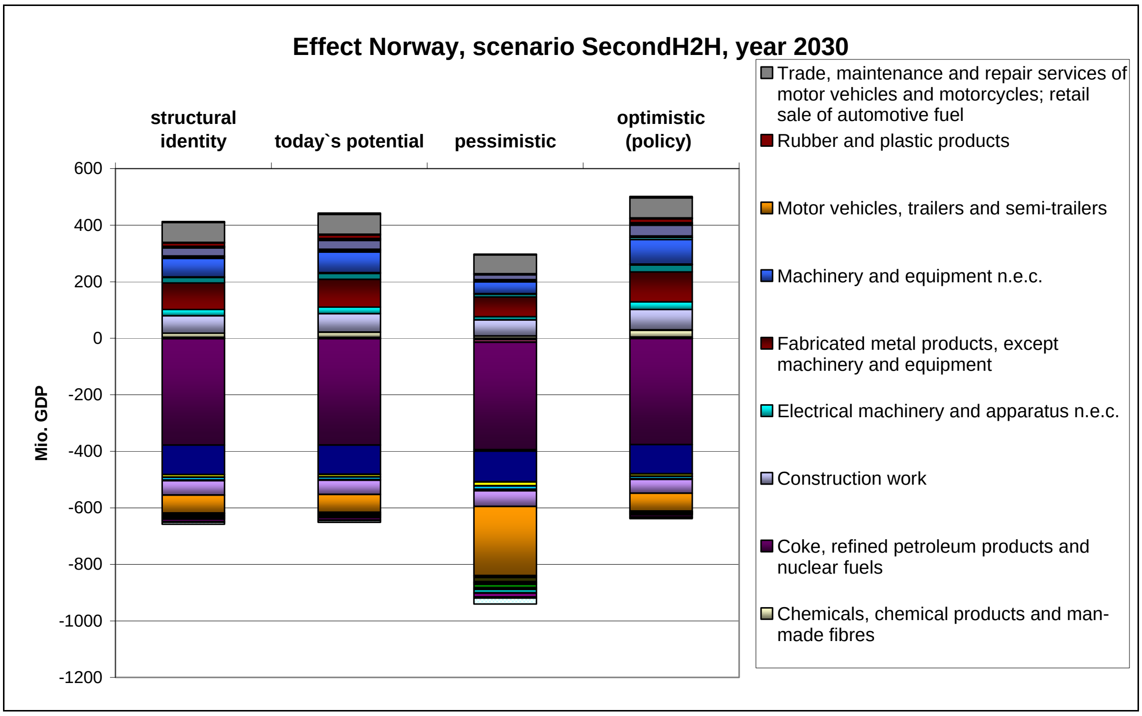

Figure 82: Sectoral economic effects Norway 2030 optimistic learning high penetration (H2H)

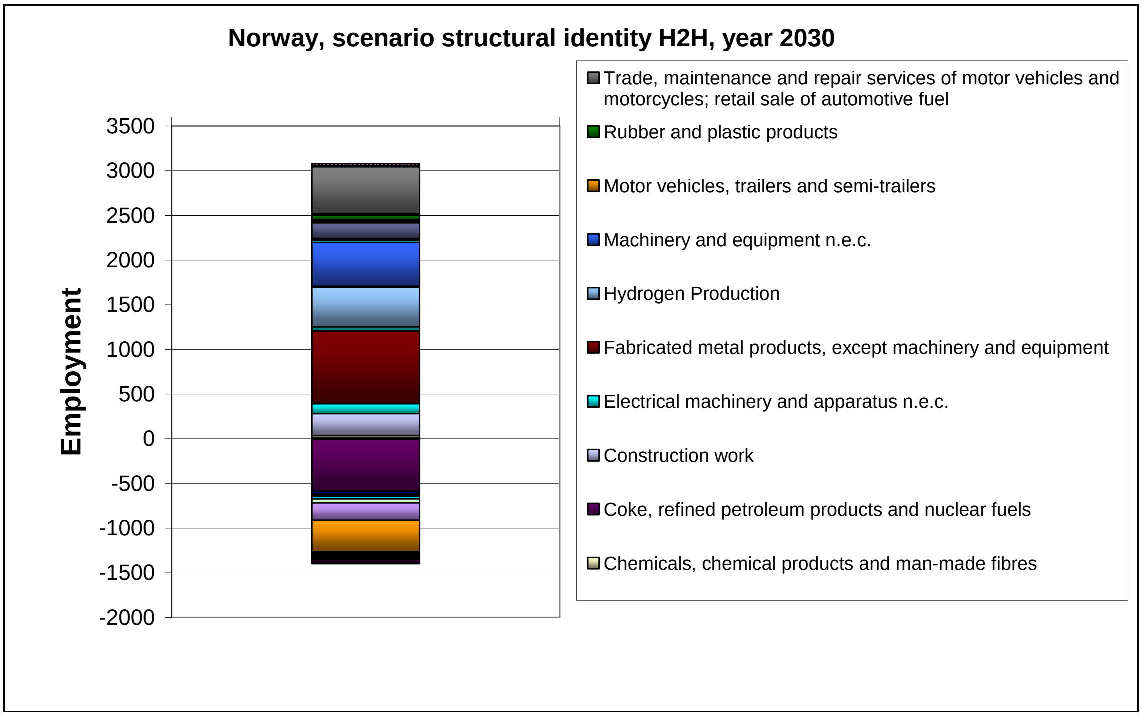

Figure 83: Sectoral employment shifts for Norway optimistic learning high penetration (H2H)

5.3.6.2 High learning scenario low penetration rates

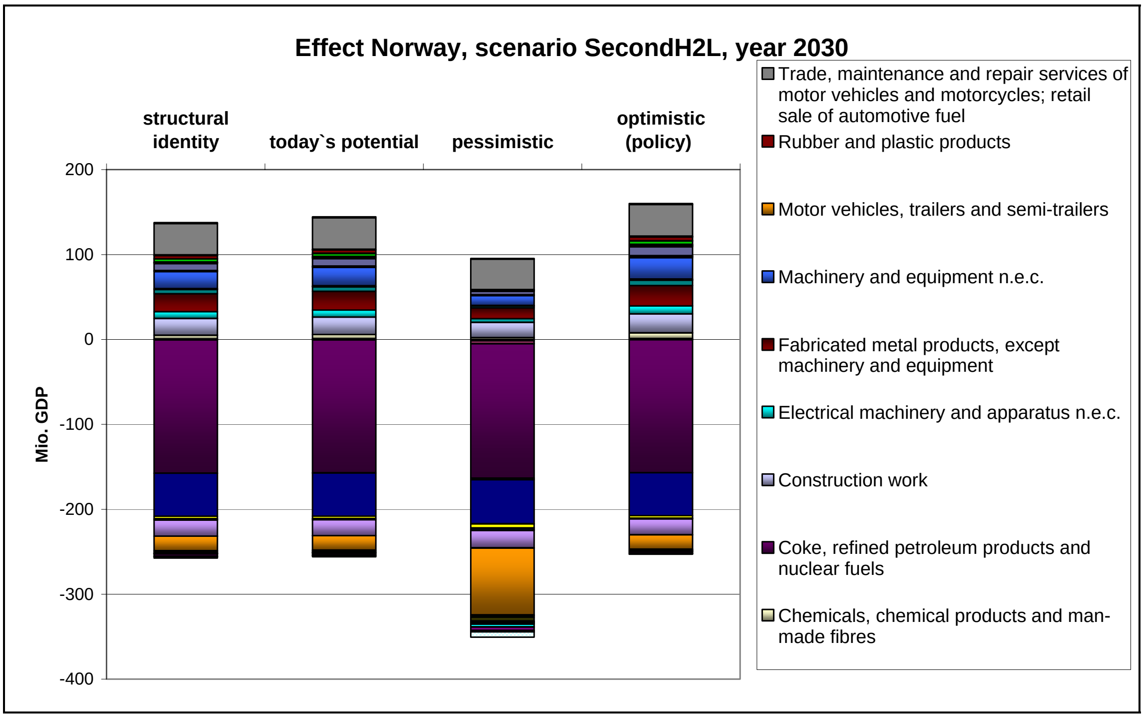

Figure 84: Sectoral economic effects Norway 2030 optimistic learning low penetration (H2L)

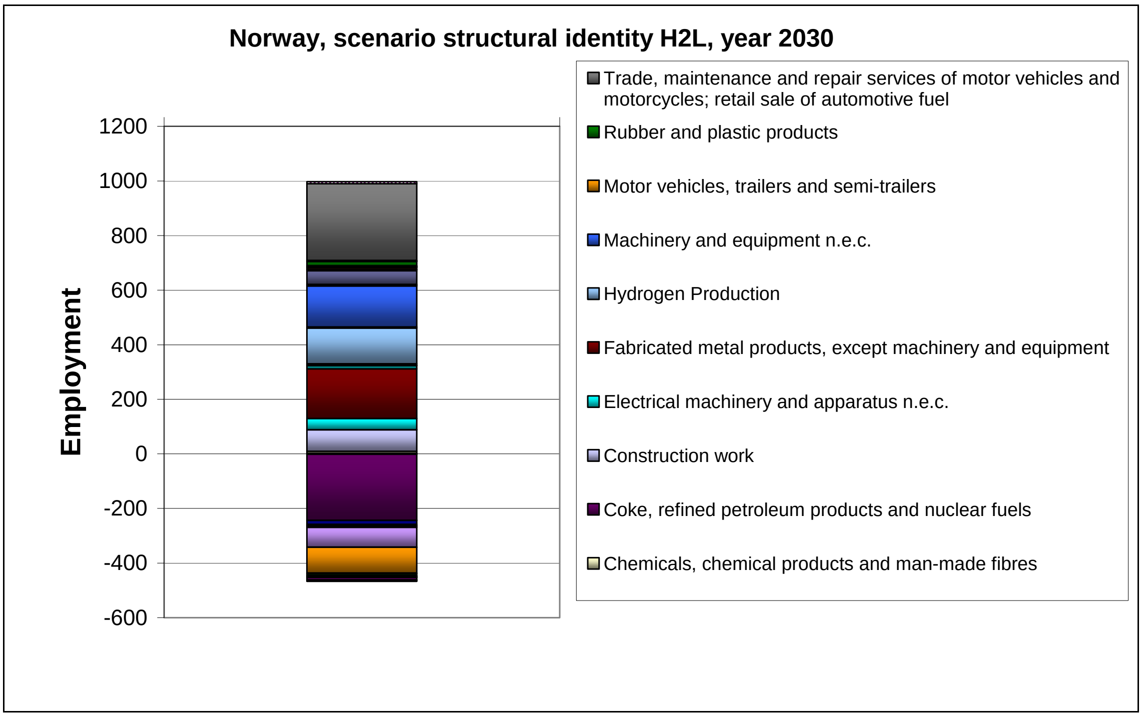

Figure 85: Sectoral employment shifts for Norway optimistic learning low penetration (H2L)

5.3.6.3 Conclusion

- The scenarios are dominated by the automobile industry structure of the countries.
- Main employment gains or losses due to import and export development of the vehicle sector.
- Significant shifts between the economic sectors could be identified, therefore the necessary workforce skills in hydrogen have to be available already.
- The scenarios showed that the manufacturing of stacks seems to be less important in terms of employment than vehicle production.
- Compared with large automobile countries the economic risks of a hydrogen economy are much smaller for Norway and following the right strategy promise a significant gain in employment, welfare and GDP effects.
- Especially in the field of hydrogen production technologies Norway has a relevant lead market potential

5.3.7 MS Results: The Netherlands

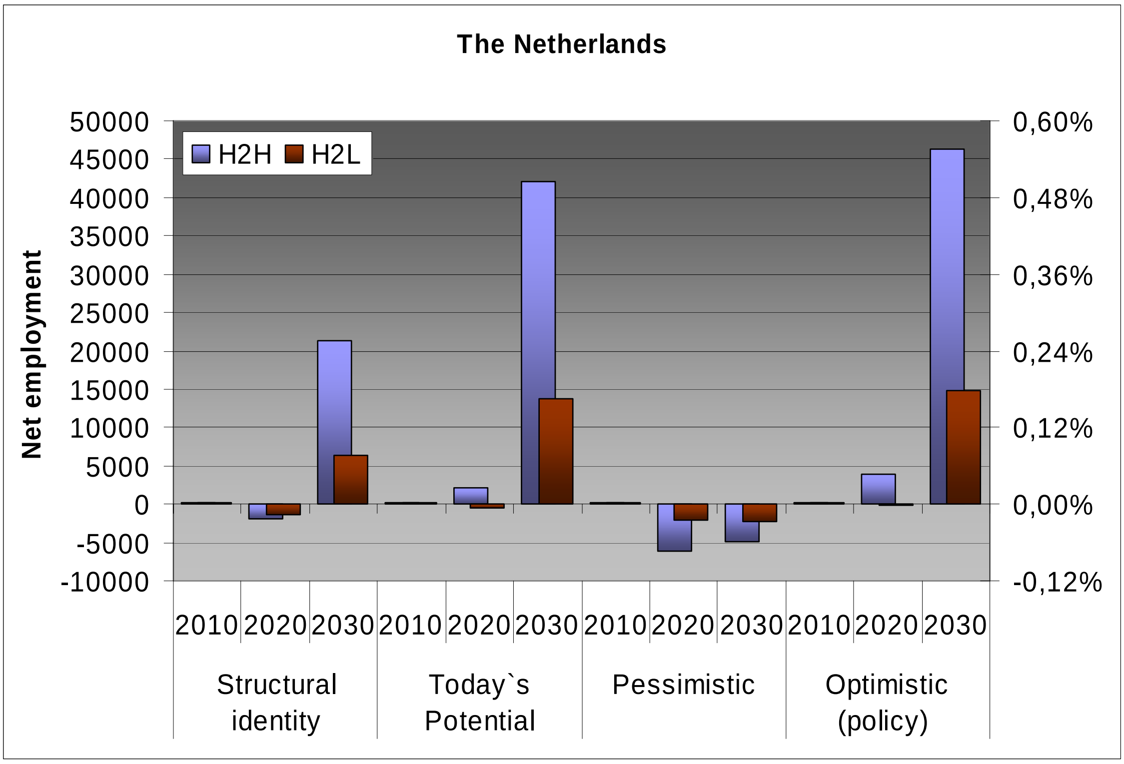

Figure 86: Employment effects for Netherlands Optimistic Learning high (H2H) and low (H2L) penetration

5.3.7.1 High learning scenario high penetration rates

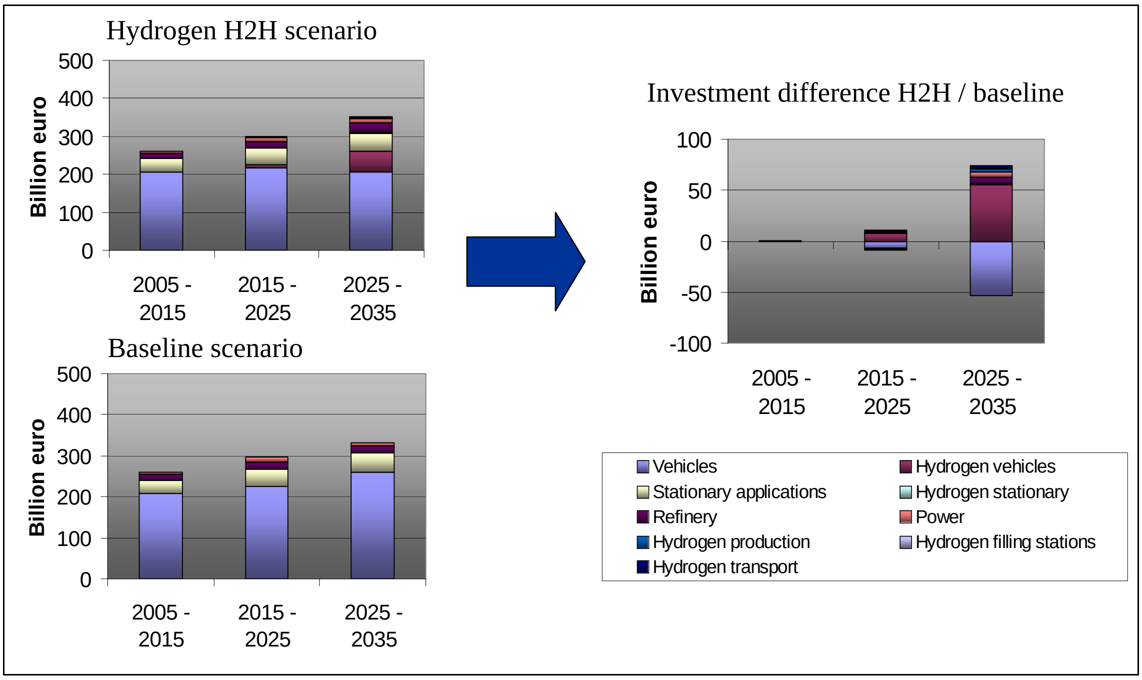

Figure 87: Hydrogen investment structure for the Netherlands

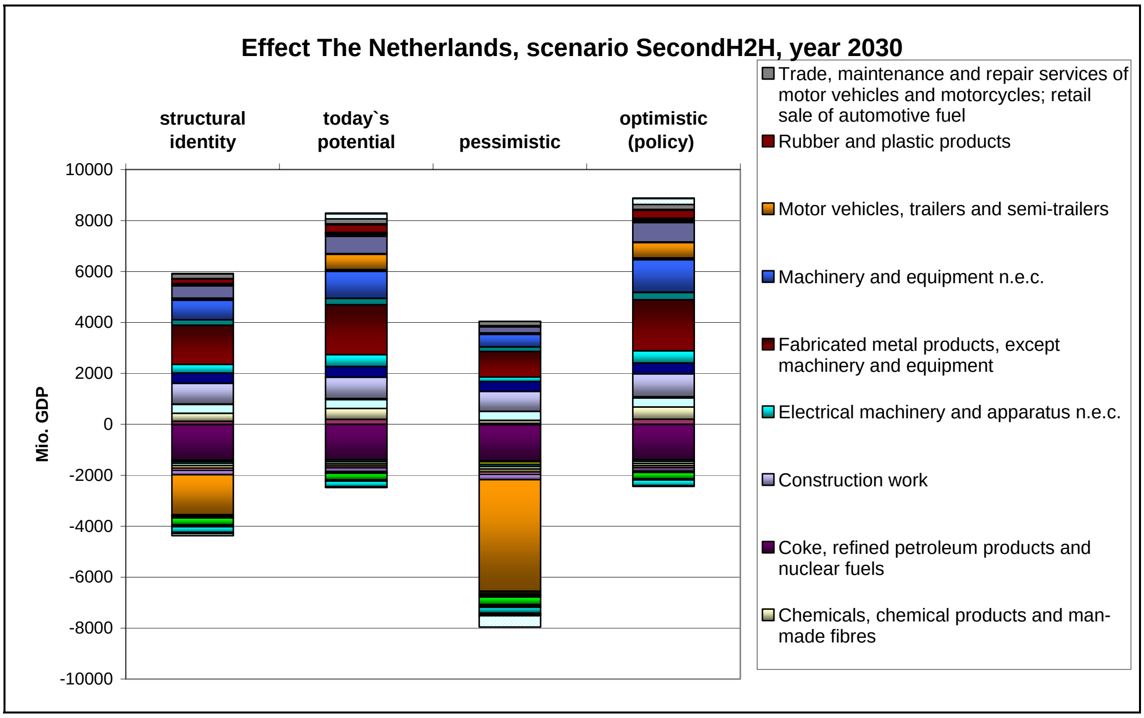

Figure 88: Sectoral economic effects The Netherlands 2030 optimistic learning high penetration (H2H)

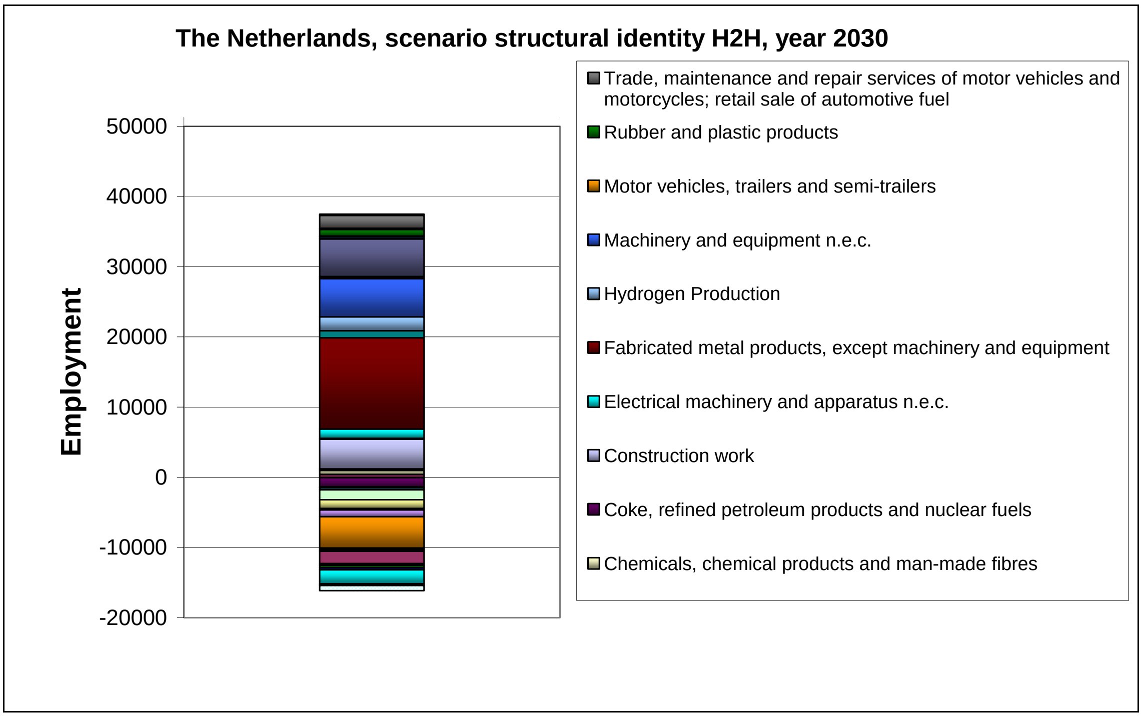

Figure 89: Sectoral employment shifts for The Netherlands optimistic learning high penetration (H2H)

5.3.7.2 High learning scenario low penetration rates

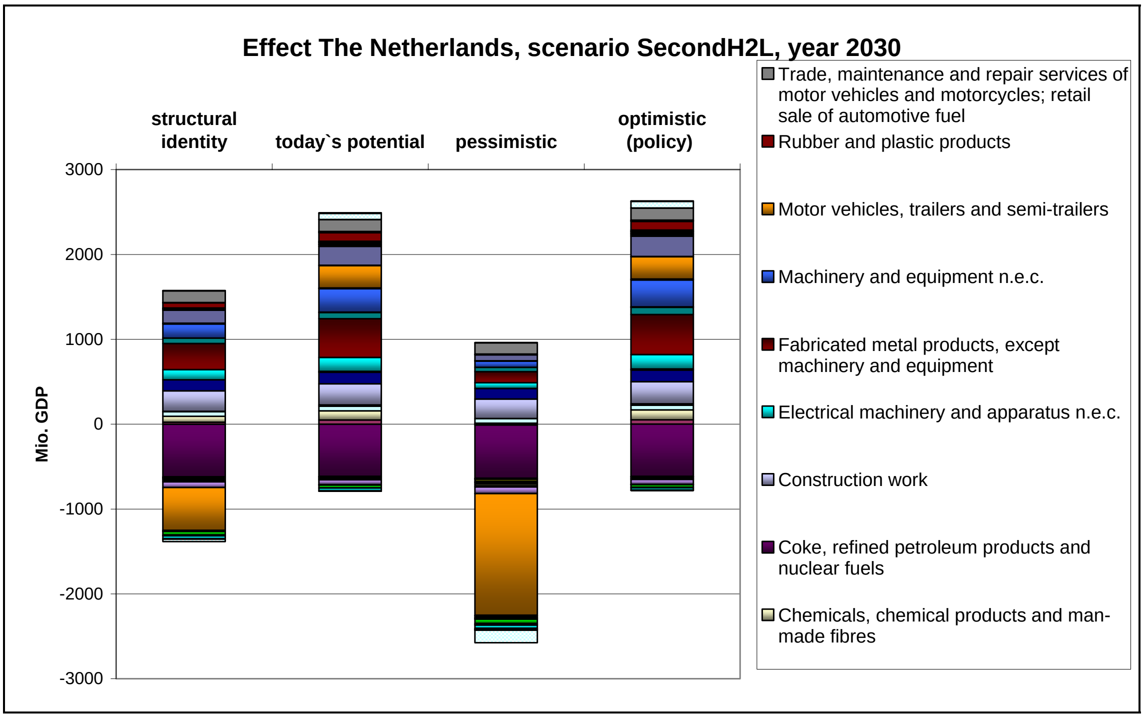

Figure 90: Sectoral economic effects The Netherlands 2030 optimistic learning low penetration (H2L)

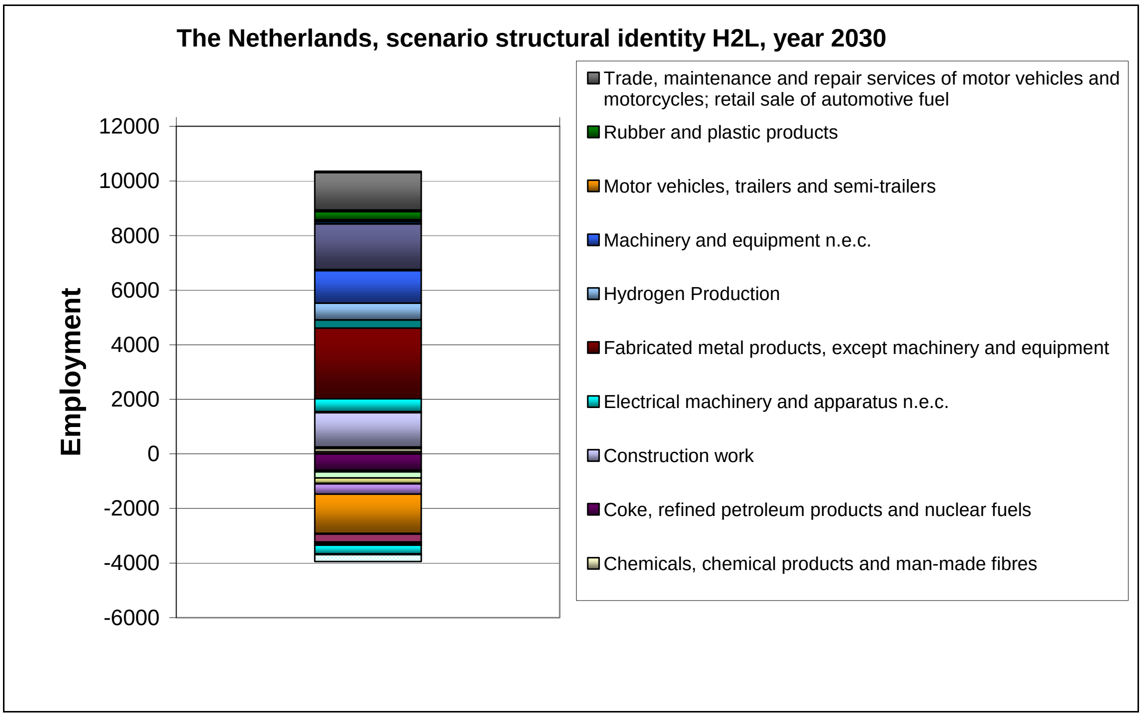

Figure 91: Sectoral employment shifts for The Netherlands optimistic learning low penetration (H2L)

5.3.7.3 Conclusion

- The scenarios are dominated by the automobile industry structure of the countries.
- Main employment gains or losses due to import and export development of the vehicle sector.
- Significant shifts between the economic sectors could be identified, therefore the necessary workforce skills in hydrogen have to be available already.
- The scenarios showed that the manufacturing of stacks seems to be less important in terms of employment than vehicle production.
- Compared with large automobile countries the economic risks of a hydrogen economy are much smaller for the Netherlands and following the right strategy promise a significant gain in employment, welfare and GDP effects.
- Especially in the field of stack production but also for hydrogen production plants the Netherlands has a relevant lead market potential. If in addition also a large hydrogen car manufacturer will be placed in the Netherlands, relevant economic gains could be realized.

6 Lessons learnt

- The vehicle technology turned out to be the importand technology for a hydrogen future under the econoimc view point. Therfore this technology should be checked in the next phase again with the industry partners.
- A further link between the general equilibrium model PACE-T and the ISIS model regarding the import export scenarios could from further intrest to inco-operate the equilibrium effects also in the ISIS specific analysis.
- The economic results are more or less stabile considering small changes in the Markal model. Therfore it is not necessary to follow each Markal result update in the next phase.

7 Conclusions

Following conclusions can be drawn:

- Future development of H_2 drive system costs and crude oil price development pose major uncertainties.
- Price of FCV reaching that of conventional cars is major challenge for H_2.
- FCVs will reach cost advantage in all scenarios analysed, but necessary cumulative investments in FCVs show wide range for different scenarios (20 - 180 billion Euro worldwide). Who will take over this financial burden?
- Significant CO_2 reductions result from H_2 cars becoming competitive, leading to win-win situation for economy and environment.
- Automobile industry structure of a country dominates economic and industrial effects: Losing a vehicle to a foreign competitor looses the complete vehicle, not only the hydrogen drive system comprising ~90 % of all investments in H_2 for all calculated scenarios.
- Major employment gains/losses expected from import/export ratio development of automobile sector.
- Significant shifts between economic sectors are identified. Required workforce skills in H_2 have to be available already.
- Small gains in employment can be reached in all countries for similar import/export shares for H_2 technologies as for conventional technologies, but the same level of competitiveness as for conventional technologies must be reached on world markets first.
- For the large automobile countries (Germany, France and Italy) following dilemma situation is identified:
  - Job losses (0.7% in 2030 for pessimistic scenario) could be drastic should Germany with the largest automobile industry in Europe lose market shares due to a late market entry.
  - Uncertainties regarding market success of H_2 cars and potential risk of losing several billion Euro due to investments in premature H_2 infrastructure and H_2 car development.

- From the large automobile countries Germany has the highest lead market potential in nearly all hydrogen and fuel cell areas, followed by France and then Italy.
- Compared with large automobile countries the economic risks of a hydrogen economy are much smaller for the Netherlands, Norway, and Greece and following the right strategy promise a significant gain in employment. Especially the Netherlands and Norway have a significant lead market potential in selected hydrogen and fuel cell areas.

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