



SECOND PHASE OF THE PROJECT

***REPORT ON LEAD MARKET APPROACH
AND THE INPUT/OUTPUT ANALYSIS OF
ENERGY SYSTEM***

(DELIVERABLE D3.17)

VERSION FINAL

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Disclaimer

The results in this report are a reflection of a non-final stage of the HyWays project, with substantial stakeholder consultation still under way. Significant modifications are still due, and consequently none of the results given in this report should in any way be considered as final HyWays results.

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Abstract: The two objectives of this deliverable of HyWays are to identify possible sectoral shifts and employment effects due to the application of hydrogen in the energy system for selected European countries till 2030. This is based on assumptions about the market penetration of hydrogen as an energy carrier, an analysis of the competitiveness of EU countries in this technology field and input-output model calculations.

The analysis showed that the introduction of hydrogen leads to significant shifts between economic sectors and, as a policy recommendation, it is concluded that the required workforce skills in hydrogen technologies should be available in time in order to be properly prepared for this. Some employment gains are possible for the EU Member States analysed if the introduction of hydrogen does not result in significant changes in export/import flows. However, the lead market analysis also showed that the competitiveness of EU countries varies significantly and that, viewed as a whole, Europe is in danger of falling behind its main competitors. This may lead to job losses because the industry branches affected – automotive and plant manufacturers – represent key sectors for the EU. One policy goal, therefore, especially for countries with a large share of automobile and plant manufacturing, is to aim to be a lead market for hydrogen and fuel cells.

1 Introduction

A lot of research in the hydrogen and fuel cell field has a strong technology focus (e. g. technology research, application of technologies, technology roadmap and infrastructure build-up). The analysis of economic impacts tends to concentrate on the necessary investments for hydrogen infrastructure build-up. Other very important impacts of hydrogen as an energy fuel such as those on employment, gross domestic product (GDP), international competitiveness, or welfare are not usually well analysed.

This deliverable focuses on the following two topics:

- Identification of possible sectoral shifts between industrial branches affected by the introduction of a mass market for hydrogen.
- Employment impacts on national economies of hydrogen as an energy fuel.

In order to be able to analyse the second topic, it is necessary to first analyse the international competitiveness of countries because import/export effects trigger many of the positive or negative impacts of hydrogen on employment figures, but also on other economic values.

This work is part of the EU project HyWays (HyWays; 2006a). HyWays aims to develop a validated and well-accepted roadmap for the introduction of hydrogen in the energy system. The main characteristic of this roadmap is that it reflects real life conditions by taking into account not only technological but also country-specific institutional, geographic and socio/economic barriers and opportunities. An action plan for supporting the introduction of hydrogen technologies will be derived from this Roadmap.

The assessment framework includes the use of a well-balanced set of models addressing impacts on the energy system and industry, an actor analysis as well as an analysis of a hydrogen infrastructure build-up. Validation workshops both within the consortium and with wider stakeholder groups in the participating countries play a crucial role in the HyWays process for collecting the required input for the scientific analysis as well as for first order validation of the results. HyWays comprises two phases of 18 months each. In the first phase, an analysis of six countries (France, Germany, Greece, Italy, the Netherlands, and Norway) is carried out and in Phase II, 4 additional countries (Finland, Poland, Spain and the UK) are included to cover a total of 80 % of the EU's land area and 71 % of its population.

This deliverable focuses on sectoral and employment effects for the HyWays countries of Phase I and II. It is structured as follows: Chapter 2 describes the necessary input for the sectoral and employment study. It starts with an overview of scenarios of hydrogen penetration as an energy fuel for the next decades in the EU. These figures have to be determined first to see when and to what extent hydrogen may play a role as an energy carrier. Chapter 2 also includes estimates for the investments in hydrogen technologies (for hydrogen production, transport, distribution, storage, and application) because these trigger employment effects and industrial shifts.

Chapter 3 deals with the methodological aspects of the analysis. It starts with a description of the assignment of hydrogen technologies to industrial branches. Then the methodological background and data sources for analysing international competitiveness are given. This analysis is necessary to determine reliable scenarios about the impacts of hydrogen on international trade. Finally, the input output analysis is introduced, which is used as an instrument to evaluate sectoral and employment shifts.

Chapter 4 presents and discusses the results of the analysis. Conclusions are then drawn in Chapter 5.

2 Hydrogen penetration scenarios and investments in hydrogen technologies

Due to still existing uncertainties on a technical level, a market development forecast for mobile and stationary hydrogen and fuel cell applications cannot be made with any reasonable probability. Crucial sub-systems such as fuel cell stacks or hydrogen storage systems but also key components like catalysts and membrane-electrode-assemblies have already achieved significant progress, but still require further breakthroughs on their way towards mass commercialisation so that a more evolutionary based forecast is not within the scope of this work. Considering the key findings of the European Hydrogen & Fuel Cell Technology Platform (HFP) Deployment Strategy and the Strategic Research Agenda¹, in HyWays a set of different penetration rates reflecting either a very optimistic or a more conservative development that has been adapted to the specific needs of both mobile and stationary applications² was developed.

Table 2.1 *Scenarios for the potential development of hydrogen vehicles, share in vehicle stock (for more details on the scenario (see for more information HyWays deliverable D3.13 on HyWays website <http://www.hyways.de>)*

Total share of fleet	2010	2020	2030	2040	2050
High Penetration	-*	3.3%	23.7%	54.4%	74.5%
Medium Penetration	-*	1.2%	11.9%	35.9%	69.4%
Low Penetration	-*	0.1%	2.8%	12.9%	36.0%

* Demonstration vehicles and fleets only

Table 2.2 *Scenarios for the potential development of stationary hydrogen applications in the residential sector (see for more information HyWays deliverable D3.13 on HyWays website)*

Total share of households	2010	2020	2030	2040	2050
High penetration	-	1%	4%	8%	10%
Medium penetration	-	1%	4%	8%	10%
Low penetration	-	0.1%	0.5%	2%	5%

¹ See (European Hydrogen & Fuel Cell Technology Platform, 2005).

² For more background information on the scenarios see (HyWays, 2006b).

Table 2.3 *Scenarios for the possible development of stationary hydrogen applications in the commercial and services sector (see for more information HyWays deliverable D3.13 on HyWays website)*

Total share of commercial demand	2010	2020	2030	2040	2050
High penetration	-	0.3%	1.3%	2.7%	3.3%
Medium penetration	-	0.3%	1.3%	2.7%	3.3%
Low penetration	-	>0%	0.2%	0.7%	1.7%

Having exogenously fixed the demand for hydrogen, the infrastructure build-up necessary to satisfy this demand then has to be determined (in terms of numbers of vehicles, pipelines and fuelling stations as well as of hydrogen production plants across the country). To do this, an energy system model (MARKAL³) is used. This is a typical bottom-up engineering-based linear activity model with a large number of energy technologies to capture the substitution of energy carriers at the primary and final energy levels, process substitution, process improvements (gross efficiency improvements, emission reductions), technology learning, spillover effects and energy savings. It is mostly used to compute the least-cost way of meeting a given demand for final energy or energy services subject to various system constraints such as exogenous emission reduction targets or prescribed energy technology paths (such as an administered phase-out of nuclear power or phase-in of green energy). The use of mathematical programming in the context of energy planning is a well-known field of research (see (Gately, 1970)), but is still of great interest (see e. g. (Gonzalez-Monroy et al., 2002), (Song, 1999), and (Wietschel, 2000)), especially due to the new situation in liberalised energy markets. The extension or adaptation of such models to hydrogen use in the energy system is a recent research development in this field (see, e. g. (Cascade minds, 2005), and (HyWays, 2006b)).

For the following analysis, the investment figures and the selected technologies from MARKAL are an important input. The structure of the investments necessary for a transition to a hydrogen economy is clearly dominated by the expenditures for hydrogen vehicles (see Figure 1). 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.

In the start-up phase, decentralised production options play an important role. Later on, central production options from fossil fuels with carbon capture and storage (CCS) are

³ See (Seebregts et al., 2001) for a description of MARKAL.

expected to be the leading production source in Europe, with renewable hydrogen then being phased in. In this later stage, hydrogen pipelines also seem to be the most important transport mode. For more details on the methodology, database and results (see for more information (HyWays, 2006b) and HyWays deliverables on HyWays website)).

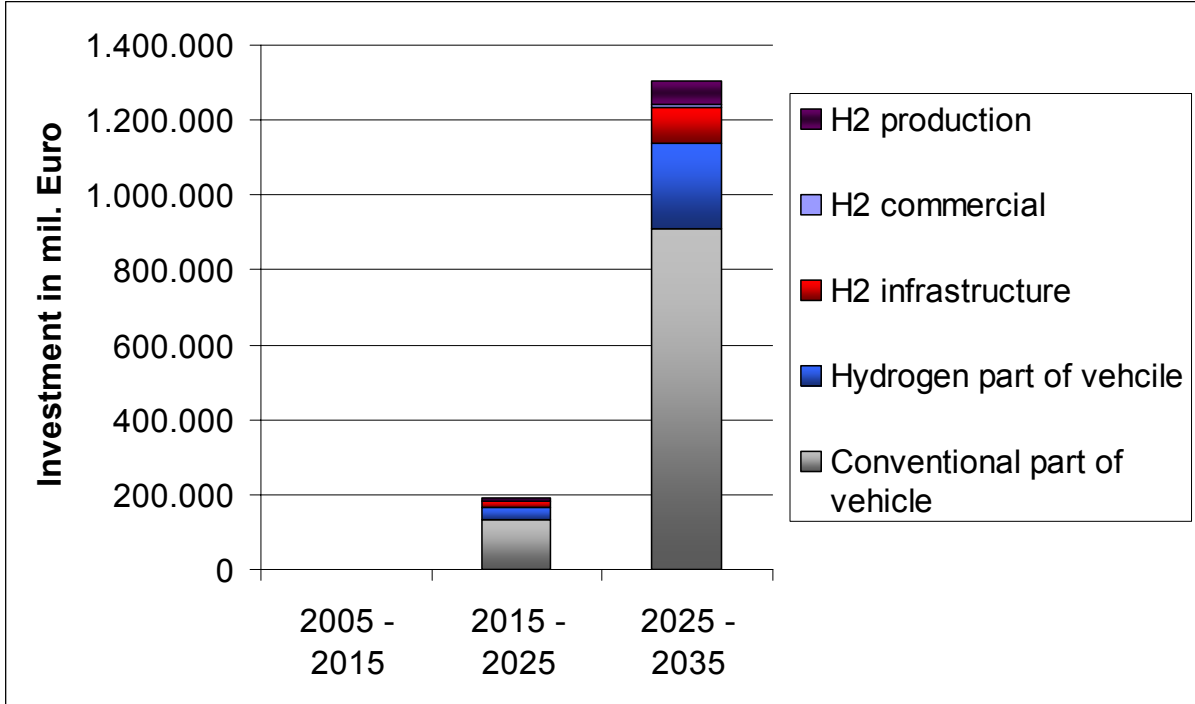


Figure 1: Structure of the investments of the six HyWays countries in a hydrogen economy (cumulative for a ten year period, hydrogen high penetration scenario)

3 Methodological approach

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

When selecting appropriate instruments to model economic impacts (impact analysis), the level of analysis chosen has to be taken into account. The discussion 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 typically analysed on an aggregated macroeconomic level using econometric or general equilibrium models.

In contrast, the studies conducted with input-output models are mesoeconomic analyses in which macroeconomic impacts such as changes in income flow effects only play a subordinate role. The spotlight here is on impacts triggered by structural shifts. These types of analysis constitute a classical field of application for an input-output model (see (Leontief, 1986) and (Duchin, 1994) which aims to fully map 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 (see (Petit, 1995) or (Meyer-Krahmer, 1999)).

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 can 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. a decrease of cars with conventional combustion engines and an increase of cars with fuel cells as drive systems leads to changes in the automotive sector, but also to different supplier structures for the automotive sector). 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 material suppliers.

The main elements of the used input-output model ISIS are described in the following. At the core of ISIS is a statistical input-output model (IO model) used to examine the structural impacts of the various 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.

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. It 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 (see Table 2 for the structure of input output tables). This IO model is used to calculate sectoral differences in production between the reference and the transition

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.

Table 2: Layout of an input-output table

		Manufacturing sector	Final demand sector				Production value
		Sectors 1 – 59	Private consumption	Public consump.	Fixed investments	Exports	
Manufacturing sector	Sectors 1 – 59	Interrelation matrix: supplies of goods and services among the sectors (intermediate demand) (million Euro)					
Imports							
Gross value							
Production value							

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. Of course the constant input output coefficients are a strong assumption and could be criticised (Zhang, Folmer, 1998). However structural effects could be analysed in a ceteribus paribus analysis with the chosen approach.

It is analysed which employment effects can be listed in the individual sectors. In an *impulse-based approach*, the total employment effects are assigned to the economic impulses which trigger them. These impulses consist of the demand shifts triggered by a hydrogen scenario, e. g. the rise in producing hydrogen vehicles on the one hand (positive impulse) and the drop in production of conventional vehicles 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 goods linked with the impulse. They thus specifically incorporate upstream production. The ratio relating the change in the number of employed to the impulse triggering the change is characterized as the specific total employment effect.

The projection analyses are based on the years 2020 and 2030. In order to avoid overestimating the employment effects it is necessary to take into account the growth in productivity which will have taken place by this time. 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 “The Impact of Technological and Structural Change on Employment” (see (Christidis P et al., 2002)).

3.2 Technology analysis

An important step is to integrate the new technologies like fuel cell vehicles and electrolyzers into the input output model, because in a standardised input-output table they are missing. Therefore an in-depth technological analysis is necessary to integrate new technologies into the input output disaggregation. This deliverable analysed the investments and also the operation and maintenance costs of technologies.

Different stakeholders have been interviewed about future technology developments. Over 20 industry partners have been interviewed and given input to assemble a technology picture of the future hydrogen technologies (for e.g. hydrogen pipelines, stacks or electrolyser).

The different technologies and tasks are separated into single parts. Some parts which are similar to existing technologies could easily be integrated into the sectoral form of an input output analysis. Other new parts, such as fuel cells, are split up in more detail. On the basis of single components, a sectoral analysis is then carried out by an expert group composed of engineers, industrial engineers and economists to define the possible economic sectors which “produce” this kind of economic commodity.

Of course the analysis is afflicted with uncertainties about the future development of single technologies. Some unforeseen breakthroughs in single technology developments could not be foreseen within this approach. This may lead to some wrong allocation of technology components to industrial sectors.

As an example of a sectoral technology split, see the central electrolysis technology in Figure 2.

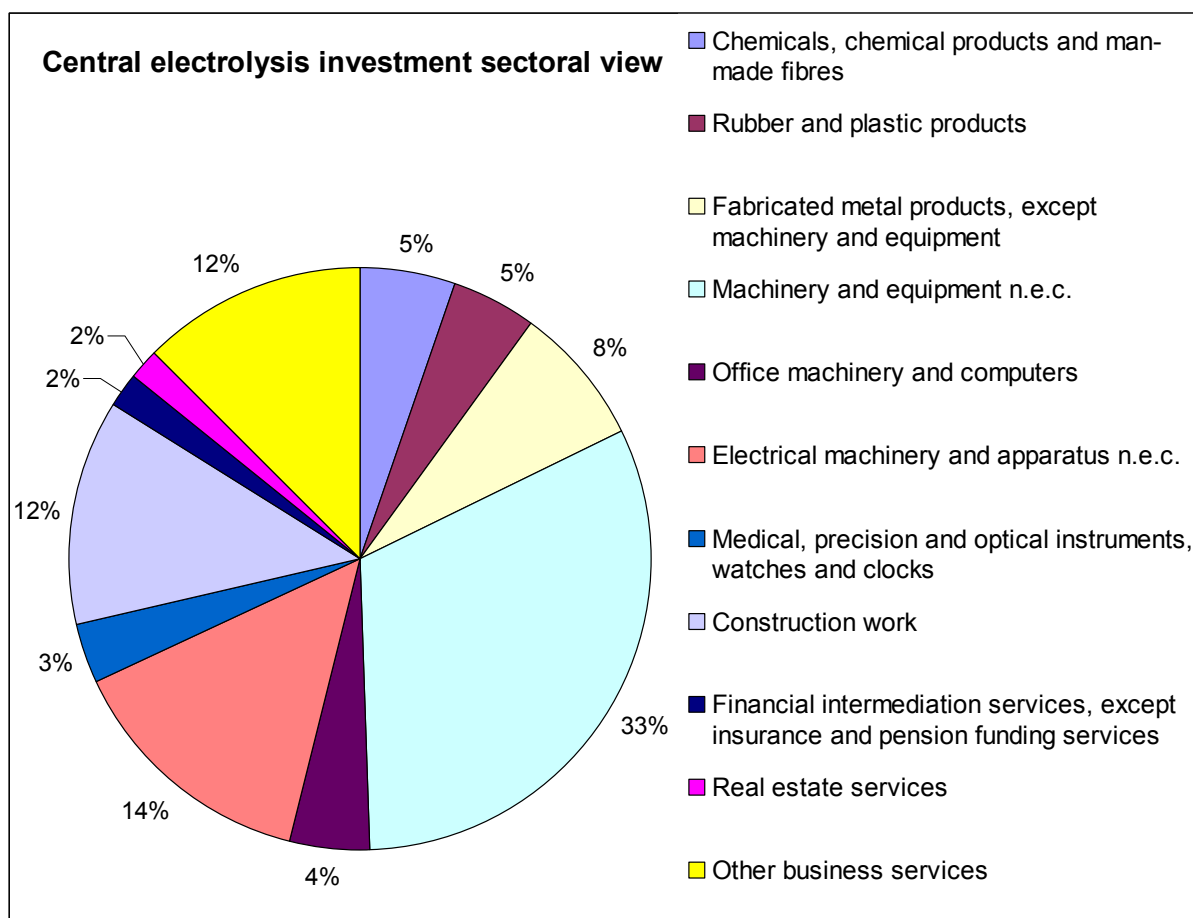


Figure 2: Example for technology analysis, e. g. 5 % in rubber and plastic products means that five percent of the investments in a central electrolyser are produced in the rubber and plastic products sector in economic terms

3.3 Lead market approach

Trade developments have a significant influence on the economic impacts of using hydrogen as an energy vector in a national economy. Therefore the so-called lead market concept is used to estimate the international competitiveness of a country and to forecast the international trade development (import/export shares) of hydrogen technologies. Lead markets are defined as the regional markets to first adopt an innovative design in a technology field which has specific characteristics that enhance the probability that the same design will be adopted broadly in other countries as well (see (Beise, 2005) and (Meyer-Krahmer 2003)). Different approaches can be used to explain such lead markets. These will be discussed in the following.

In traditional (neo-classical) trade theory, the theorem of factor proportionality plays an important role in explaining trade flows (see (Ohlin, 1933 and (Samuelson, 1948))). This theorem postulates that there will be gains from trade through increased specialization in sectors which make intensive use of those factors with which countries are relatively well

endowed (e. g. capital availability or labour cost). However, the well-known Leontief paradox⁴ (against the theorem of factor proportionality, the USA actually import labour- and capital-intensive products) and other empirical research⁵ opened up a debate on the value of this theorem and new hypotheses were developed on factors influencing international competitiveness. One idea was that it is technological rather than price competition in capitalist economies that matters most. Therefore technology factors like productivity and research and development were taken into account to explain market success (see (Wakelin, 1997, (Fagerberg, 1997) and (Sell, 2001))). The technology gap theory (e. g. (Posner, 1961)) and the product cycle theory (e. g. (Vernon, 1966)) postulated that especially well developed countries introduce new products and can win innovation yields for a limited time. Explanations for this are differences in the technological capabilities of countries (technology gap) and higher know-how requirements during the market introduction phase of a technology.

Next to the superior technological capability of firms/industry branches, other aspects are also important: market introduction strategies for new technologies, market introduction advantages due to access to regular customers, internal capability of a firm to identify and use the market chances of new developments and reputation (see (Beise, 2004), (Beise, 2005a) and (Meyer-Krahmer, 2004)).

Whereas these approaches are supply-oriented, others also take the demand side into account (see (Linder, 1961), (Blümle, 1994), (Fagerberg, 1995a) and (Sell, 2001))). They argue that the origins of innovations are based on the development of a new demand which is not able to be satisfied by existing products. Innovations require lead users (see (Hippel, 1988), (Franke et al., 2005) and (Morrison et al., 2004)), who expect novel and high benefits from the new products, are trendsetters for commercial developments and radical innovations and have connections with producers. Other market factors are also important (see (Porter, 1990) and (Dosi et al., 1990)). High competition between firms leads to increased inventions (which has been empirically validated) and the development of alternative technology designs which increase the probability of selecting the most appropriate technology design (market structure advantages). Market size, market dynamics and market growth all have a significant impact on cost reduction and international competitive advantages. The transfer (export) to other regions is advantageous if the risks of technology adoption are minimized via demonstration effects and similar consumer preferences.

Apart from supply side and demand side factors, the regulative framework (e. g. standardisation, approval requirements) may also be of relevance to explain the success of innovations (see (Porter, 1990), (Blind et al., 2005), (Beise et al., 2005b)).

⁴ See (Leontief, 1956).

⁵ (Kaldor, 1978) and (Robson, 1987) showed that market shares of exports and increasing relative unit costs went hand in hand for a number of countries.

For the identification of lead markets for hydrogen and fuel cells a holistic approach is chosen which takes supply and demand side factors into account as well as regulative impacts. A quantification of lead market factors is often not possible (e.g. how are technology capability or transfer advantages measurable?).

Most of the empirical research in technology-dominated sectors focuses on the correlation of international trade and technological capability. R&D budgets and patents are mainly used as indicators to explain the success of a country in international trade figures (see Table 3). In general, the empirical results of these studies support the positive correlation between technology (measured by R&D intensity and patents) and export performance for a large number of industrial branches and countries. For the research work on hydrogen and fuel cells it is important to notice the strong evidence linking export success and technology in the car, chemical, and machinery industries (see (Fagerberg, 1996)), because these sector are relevant for hydrogen and fuel cells.

Table 3: Impact of technology and other factors on trade performance (source (Fagerberg, 1995))

	R&D intensity (spending in % of production, 1985)	Technology						Price/cost			Investment					Scale	
		R&D			Patents												
		L	F	M	S	F	A	F	M	A	L	S	F	M	A	S	F
Aerospace	20	-	-	x	x	-	-	-	x	-	-	-	-	(-)	x	-	x
Computers	10	X ^e	-	x	x	-	x	-	x	-	- ^e	-	-	x	x	-	x
Electronics	8	X ^e	x	-	x		-	x ^d	x	-	- ^e	-	-	x	-	-	x ^d
Instruments	6	X ^e	x	-	x	x	x	-	x	x	- ^e	-	-	x	-	-	-
Electrical machinery	3	X ^e		-	x	x	-	x	-	-	- ^e	-	-	-	-	-	-
Non-electrical machinery	2	X		x	x	x	x	x ^b	-	-	-	-	-	-	-	x/-	x ^c
Cars	3	X ^f	-	x	x	-	x	-	-	-	- ^f	-	-	-	(-)	x	x
Other transport	3	X ^f		-					x	-	- ^f			-	-		
Ships	0	X ^f	(-)		-	-	-	-		-	- ^f	-	x		-	-	-
Drugs	9	X		-	x	x	x	x	x	-	-	-	(-)	x	-	-	(-)
Industrial chemicals	3	X	x ^a	x	x		x	x ^a	x	x	-	-	- ^a	-	-	x	- ^a
Plastics	1	X	x	-	x		x	x	-	x	-	x	-	x	-	x	-
Petroleum refining	1	-		-	-		-		x		-	x		-		-	
Ferrous metals	1	X ^g	-	-	x		x	-	x	x	- ^g	-	-	-	-	x	-

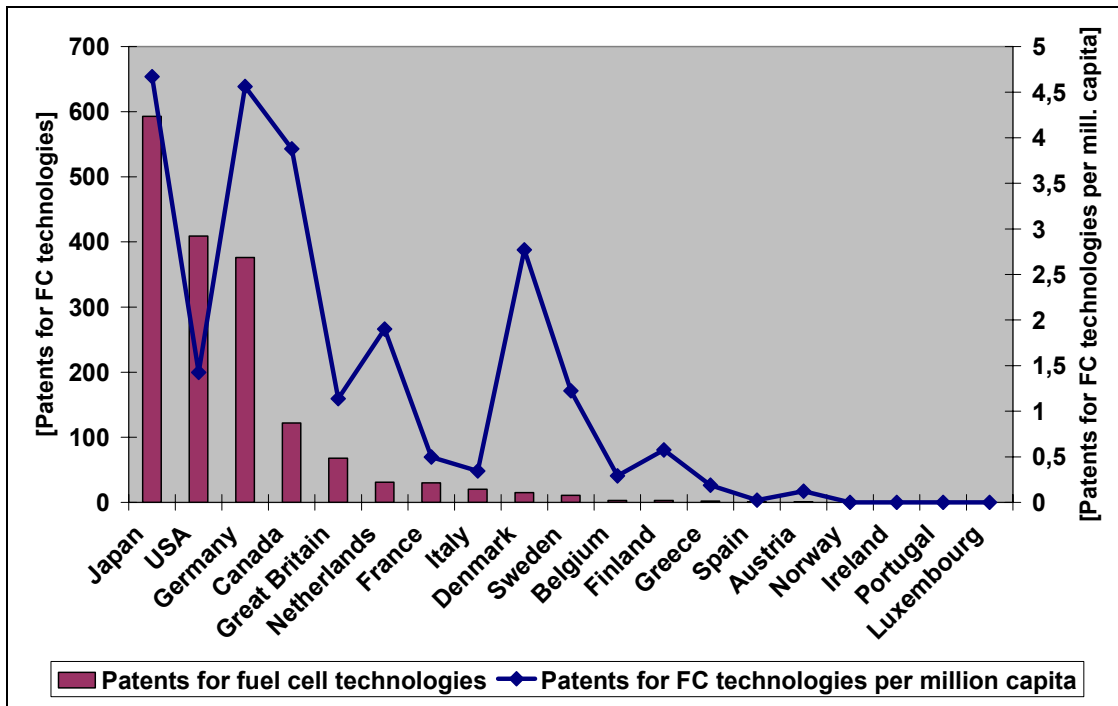


Figure 3: Total number of hydrogen patents and hydrogen patents per million capita (1990 – 2002) (world patents (WO) and European patents (EP), (source: own patent analysis; more background information can be found in (Wietschel, 2005))

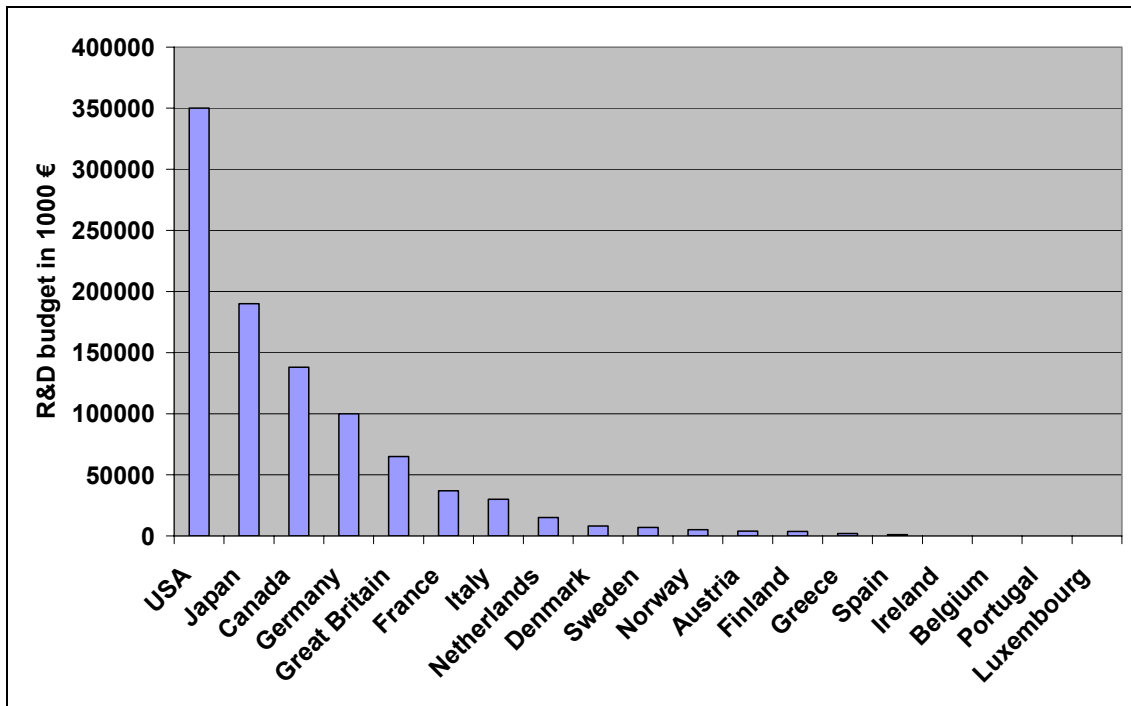


Figure 4: Public R&D budget in fuel cells and hydrogen (source (Amorelli, 2004))

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. The lead market potential of the 10 HyWays Member States of Phase I and II was identified based on an analysis of the indicators.

4 Results

4.1 Lead Market analysis

The results of the lead market analysis show that, of all the European countries, Germany has the highest figures for nearly all indicators (all country details can be found in Annex A). In the field of hydrogen production, especially based on steam reforming, Germany holds a good competitive position and is also well placed in the field of stationary 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 the US, Canada and Japan.

From all other bigger European countries also UK seems to be in a relatively good position in Europe. Among others a lot of activities can be identified in the area of fuel cell development and in hydrogen production (with a focus on steam reforming). With additional effort UK can become in some areas a lead market for hydrogen.

All the absolute indicators show that France is in a relatively good position in Europe, although there is no prominent potential visible in any one category. However, if relative indicators taking the country size into account are regarded, smaller countries like the Netherlands, Denmark, Finland and Norway are able to catch up with it. 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 in the near future.

Italy has the 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, Italy has the potential to be a fast follower.

From all large European member states Spain has today the lowest identified lead market potential.

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 prominent 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 lies in hydrogen production and the access to feedstocks (gas, cheap electricity). For Finland mainly in the field of fuel cells the relative indicators shows a remarkable lead market potential.

When contemplating the overall picture painted by the selected indicators, today 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 hydrogen infrastructure could offer greater advantages (combination of renewables (e. g. wind power) and hydrogen production using electrolysis).

Due to missing database for Poland no lead market analysis is carried out.

4.2 Scenarios

The structure of the investments necessary for a transition to a hydrogen economy is clearly dominated by the expenditure on hydrogen vehicles (see Figure 1). If a hydrogen vehicle is imported, it is very likely that not only the hydrogen drive system will be imported but the whole vehicle. Therefore the structure of the domestic vehicle industry turned out to be one of the key factors for the employment analysis, and also for GDP and welfare development.

Three import/export scenarios have been analysed. Each scenario describes a possible future for the competitiveness of hydrogen technologies produced within the EU.

The so-called "Structural Identity Scenario" is based on the assumption that the international competitiveness of domestic hydrogen technologies is mainly influenced by today's competitiveness of industrial sectors producing goods which are very similar to hydrogen technologies. For example, if a country makes and exports conventional cars, this country is likely to do so in the future as well. Or if a country has a leading position at present in producing gas turbines, this country is likely to produce hydrogen turbines in the future.

These assumptions are open to criticism because today's domestic industry based on conventional technologies does not automatically equate to a leading position for hydrogen technologies in the future. For example, if a country has the current manufacturing capacity to construct conventional internal combustion engines this does not necessarily mean that it will also have a relevant industry for stack production in the future due to the technological differences between the technologies (e. g. different materials, production processes, and education). Two alternative scenarios were developed to take this into account.

The "Pessimistic Scenario" shows what could happen if other regions of the world assume the leading position and Europe has to import hydrogen vehicles. In this scenario it was assumed that all hydrogen vehicle technology will be imported (see Figure 6). In contrast, the "Optimistic Scenario" assumes that major efforts will be undertaken which result in increased EU exports in hydrogen vehicles and technologies. Indeed, it is supposed that hydrogen vehicles, as well as stacks and hydrogen production technology, could be exported even more than conventional technology (see Table 4).

An overview of the assumed import/export ratios is shown in Figure 5

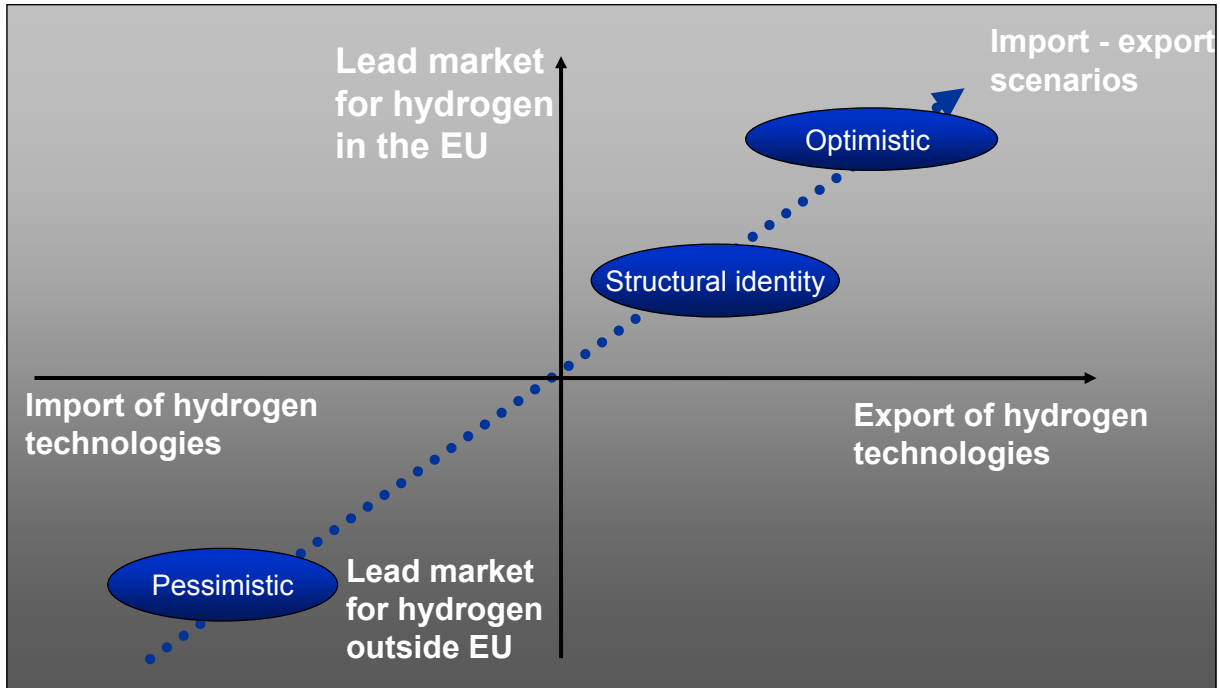


Figure 5: Import/export scenarios

Table 4: Import- export scenario assumptions (*e. g. 1.4 for cars means that for every car sold in the domestic market, the domestic producer exported an additional 1.4 cars) (FC = fuel cell, ICE = Internal Combustion Engine)

H2 car production (FC, ICE)	Structural identity	Pessimistic	Optimistic
Finland	0.4	0.0	0.4
France	1.4	0.0	2.0
Germany	2.0	0.0	3.0
Greece	0.1	0.0	0.1
Italy	0.9	0.0	1.3
Netherlands	0.8	0.0	1.2
Norway	0.2	0.0	0.2
Poland	1.1	0.0	1.7
Spain	1.9	0.0	2.9

United Kingdom	1.0	0.0	1.6
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4.3 Employment and industrial shift impacts

Figure 6 shows the employment development for the ten countries analysed (details for each country can be found in Annex B). Small gains can be achieved if the import/export shares for H₂ technologies are similar to conventional technologies. This result is mainly influenced by a lower level of atomisation and standardisation for hydrogen technologies in the start-up phase. However, the same level of competitiveness as for conventional technologies must be reached on world markets first and this will be a challenging task looking at the results of the lead market analysis. Based on the situation at present, a small drop in employment figures can be expected.

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. 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, Spain, UK and Italy could be seen as candidates for the dilemma situation. The differences between the winnings 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 other countries. 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.

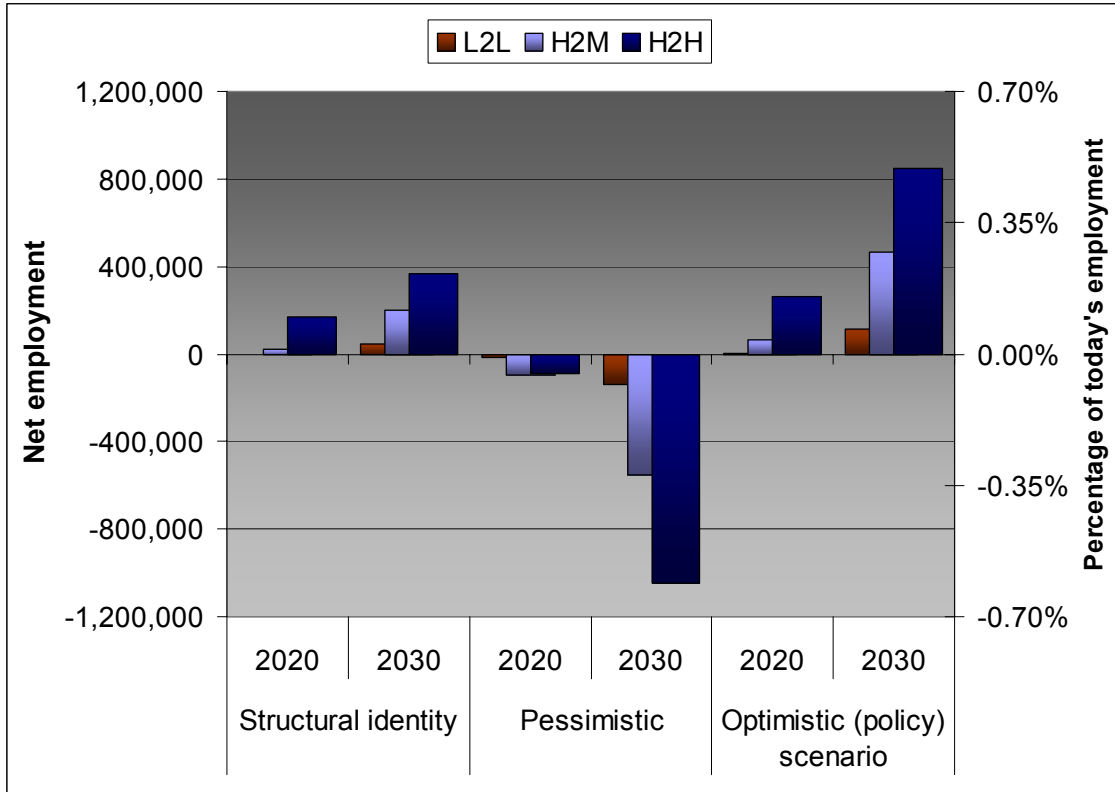


Figure 6: Net employment effects for the hydrogen high penetration (H2H), and medium penetration (H2M) scenarios with optimistic learning rates for hydrogen passenger cars. As well as hydrogen low penetration (L2L) scenarios with moderate learning rates for hydrogen passenger cars for the year 2020 and 2030. Shown are the overall net employment effects for the ten HyWays countries in three import and export scenarios.

Replacing conventional vehicles by fuel cell vehicles (FCVs) induces sectoral employment shifts away from traditional car manufacturing (see Figure 7, and for country details Annex B).

The most important shift is from the historical automotive sector to the new hydrogen vehicle technology sectors. This conglomerate consists mainly of fabricated metals, the electrical and the machinery plastic sector and the chemical sector.

A small shift away from the refinery sector towards the new and more labour-intensive hydrogen production sector could also be identified. Employment gains could also be made out in the construction and the machinery and equipment sectors because of hydrogen infrastructure investments.

This shift requires considerable education and training of the workforce and, in combination with possible mass production by 2020, necessitates early political action because of the required gradual build-up of manufacturing capacity and skilled labour. Further research work is necessary to analyse the today's weak and strong aspects of the education system in European countries and to develop an action plan for the adaptation on the new

requirements. This analysis should take into account the demographics of the European nations which is an important factor. Will Europe be able to find the necessary skilled labour such as engineers and technicians or will they “import” skilled labour from countries like China and India?

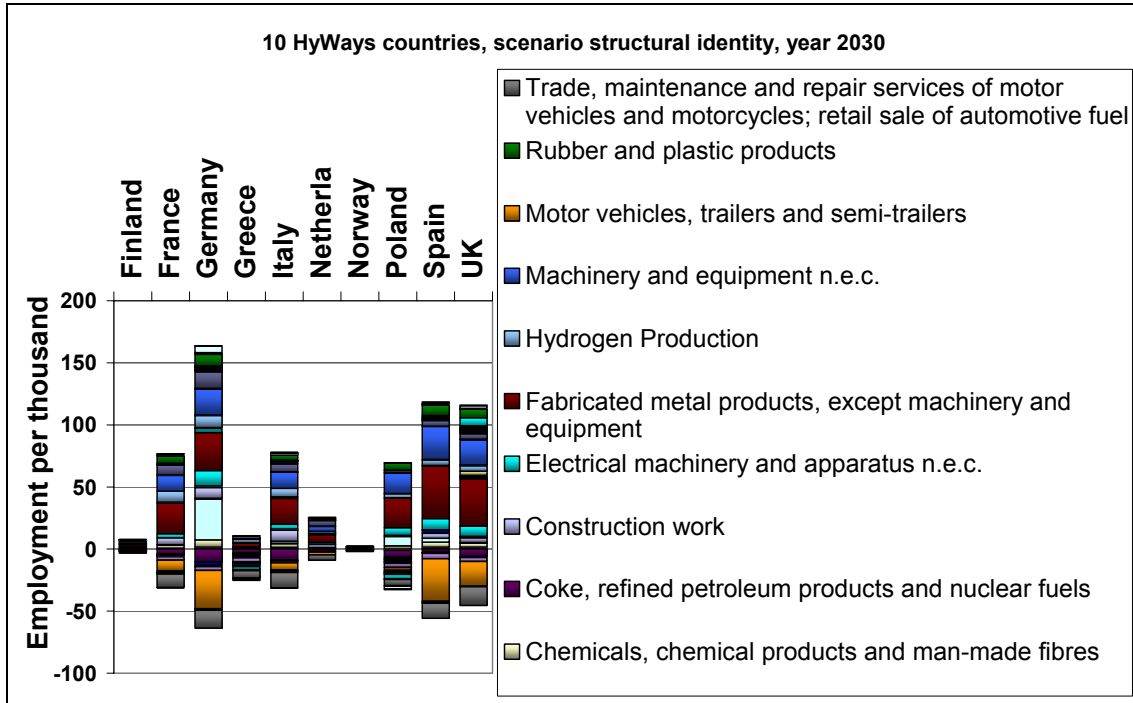


Figure 7: Employment effects for the hydrogen high penetration (H2H) in the structural identity scenario for the different economic sectors of the ten HyWays MS countries.

5 Findings

Replacing conventional vehicles by FCVs induces a sectoral employment shift away from traditional automobile manufacturing among others to the fabricated metal, electrical, machinery and rubber/plastic sectors. Because of the required gradual build-up of manufacturing capacity and hence a skilled labour force, preparing for expected mass production makes early political action essential.

The largest direct effects on employment due to the transition to a hydrogen economy are seen for the automotive industry and, to a lesser extent, for the plant and equipment sector. This is due to the fact that losing (or winning) market shares to/from a foreign competitor may lead to lost (or gained) sales of the complete vehicle, not just the hydrogen drive system. The automobile industry related effect comprises ~90 % of all investments (infrastructure and applications) in H₂ for all the calculated scenarios. Small employment gains are possible for the EU Member States analysed if the introduction of hydrogen does not result in significant changes in export/import flows. This means that the EU should be able to keep its current world market share in vehicle and plant production. But these shares have to be achieved first in the new technology field. The lead market analysis shows that the competitiveness of EU countries varies significantly and that, viewed as a whole, Europe is facing the danger of falling behind its main competitors.

For the large automotive countries (Germany, France, Spain, UK, and Italy), the following dilemma can be identified: On the one hand, job losses (up to 0.7 % in 2030 for the Pessimistic Scenario) could be drastic if these countries were to lose market shares due to late market entry. On the other hand, there are uncertainties regarding the market success of H₂ cars and the potential risk of losing several billion Euro due to investments in premature H₂ infrastructure and H₂ car development. Form the automotive countries Germany seems to be well placed (with some disadvantages in fuel stack production compared to other international competitors), followed by UK and France.

Compared with large automotive countries, the economic risks of a hydrogen economy are much smaller for the Netherlands, Norway, Finland, Poland, and Greece and promise significant increases in employment here if the right strategy is pursued. The Netherlands, , and Norway, in particular, have a significant lead market potential in selected hydrogen and fuel cell areas.

Similar conclusions can be drawn for the plant and equipment branches. Mainly Germany, Italy and France are affected here.

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7 Annex A: Lead market approach - Input data, assumptions and indicator interpretation

7.1 Input data, assumptions and indicator interpretation

7.1.1 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.

7.1.2 Overall indicators for Europe

7.1.2.1 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

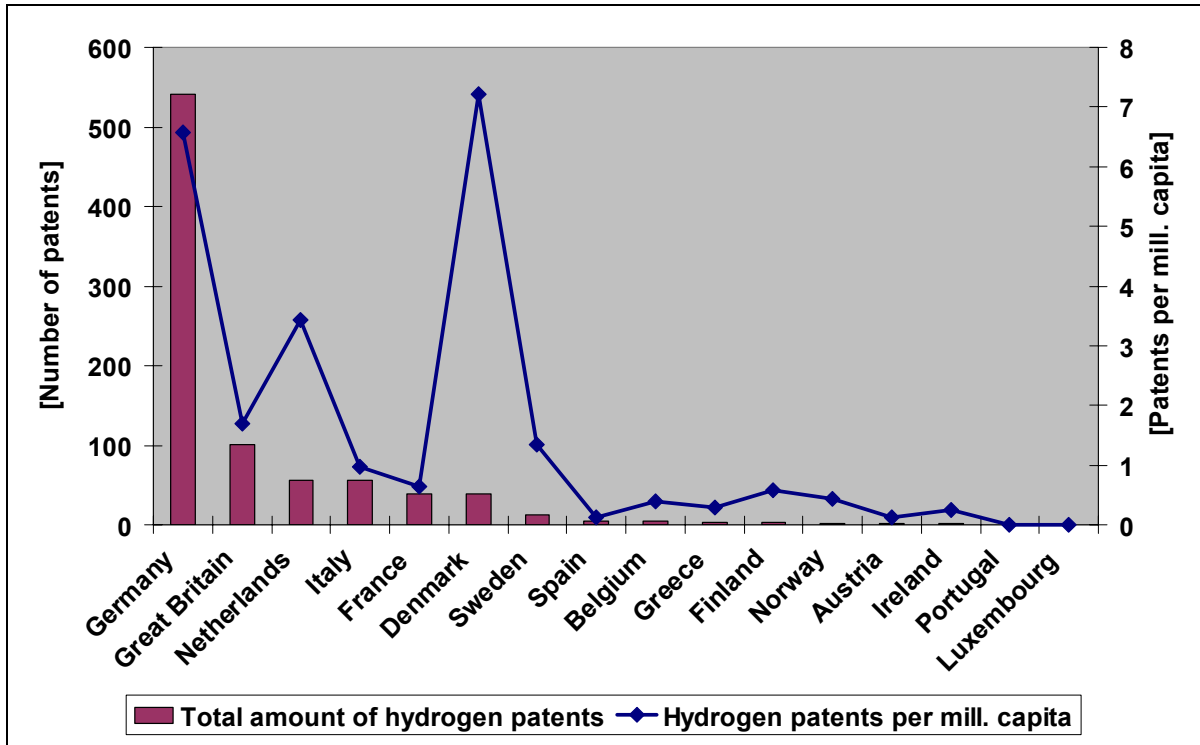


Figure 8: Total amount of hydrogen patents and hydrogen patents per million capita (1990 – 2002)

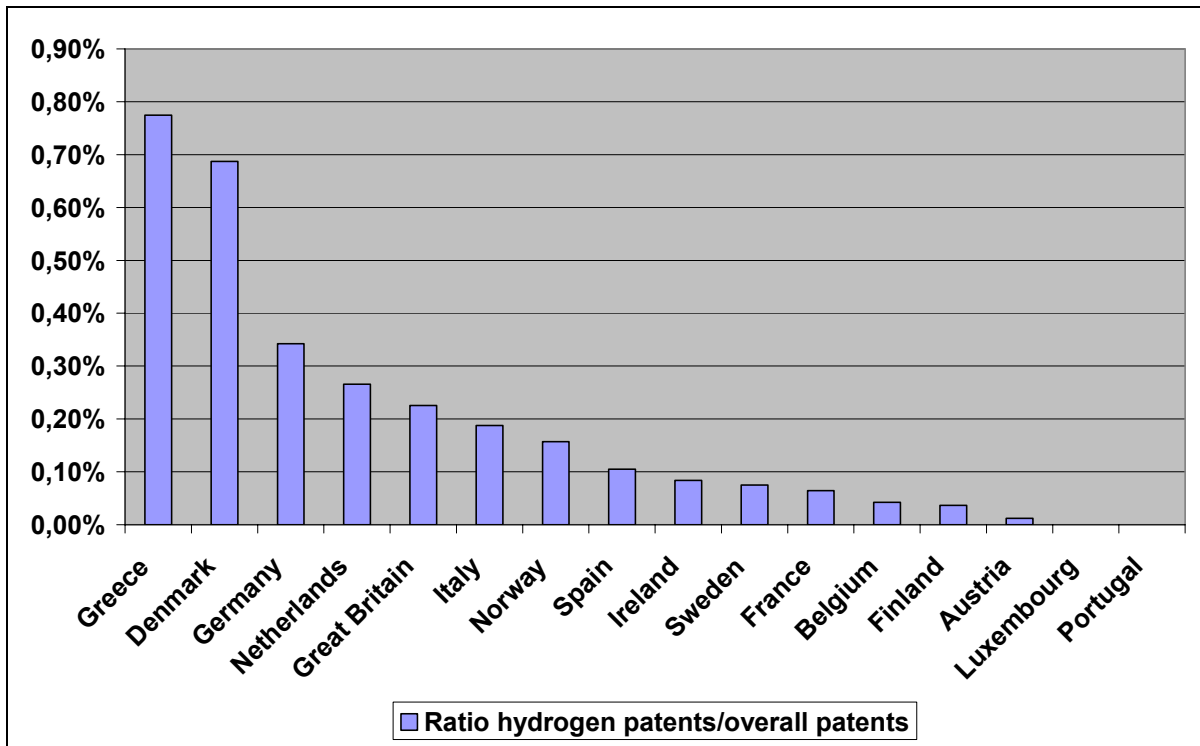


Figure 9: Ratio of hydrogen patents to overall patents

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.

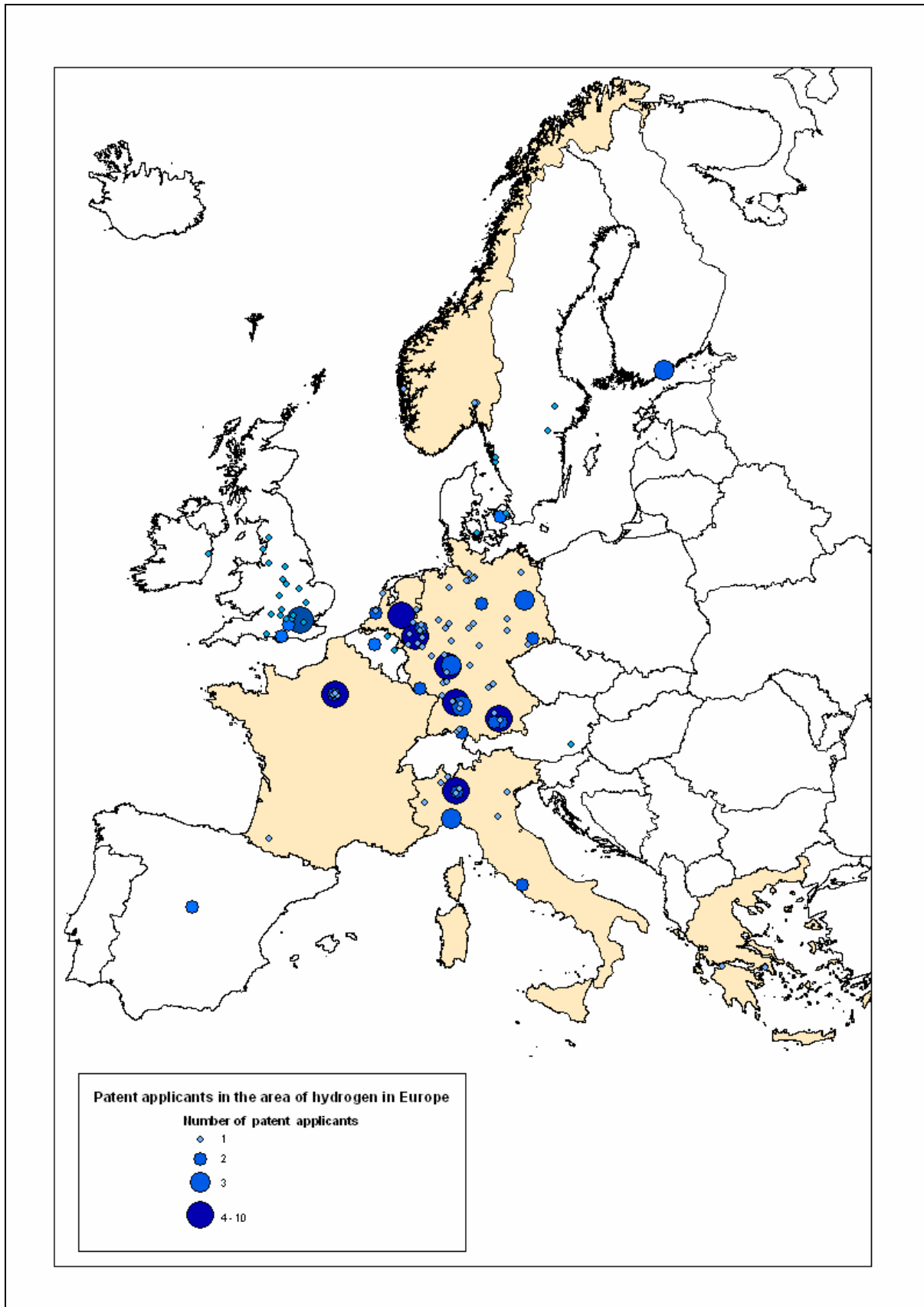


Figure 10: Geographical distribution of firms with hydrogen patents

7.1.2.2 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

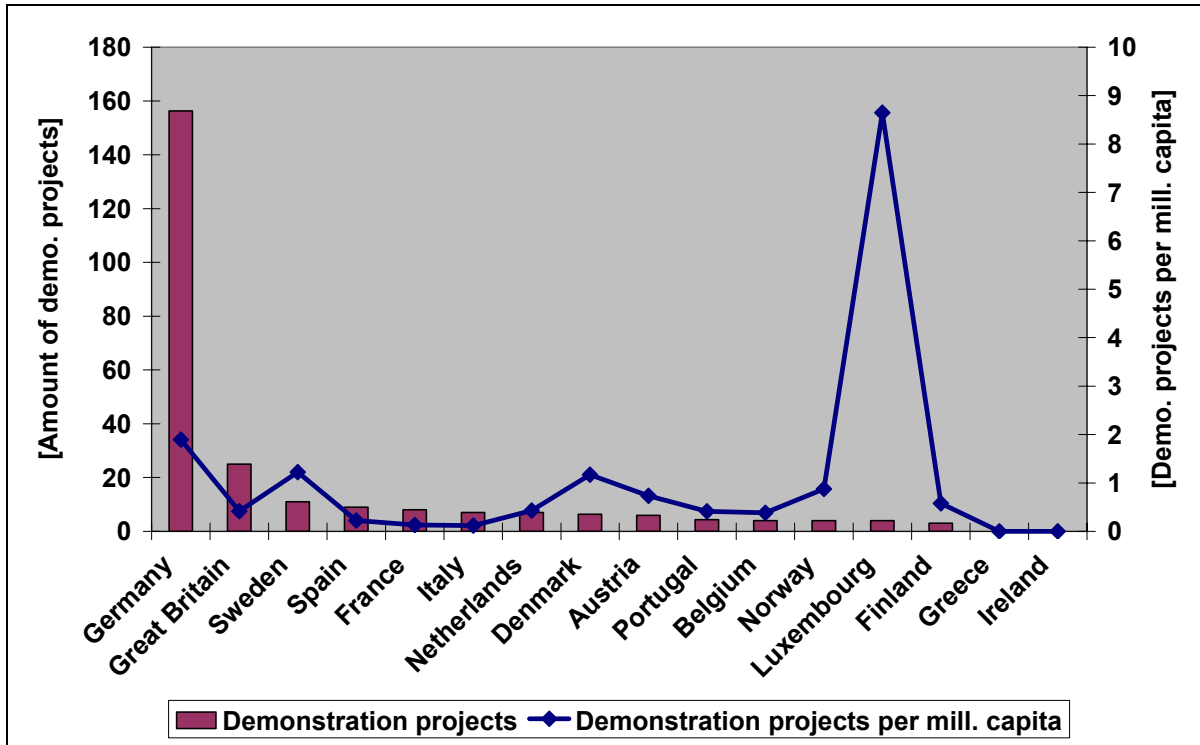


Figure 11: Amount of total demonstration projects and demonstration projects per million capita (realised projects till 2004)

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.

7.1.2.3 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 weak 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 [SENER 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 [SENER 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

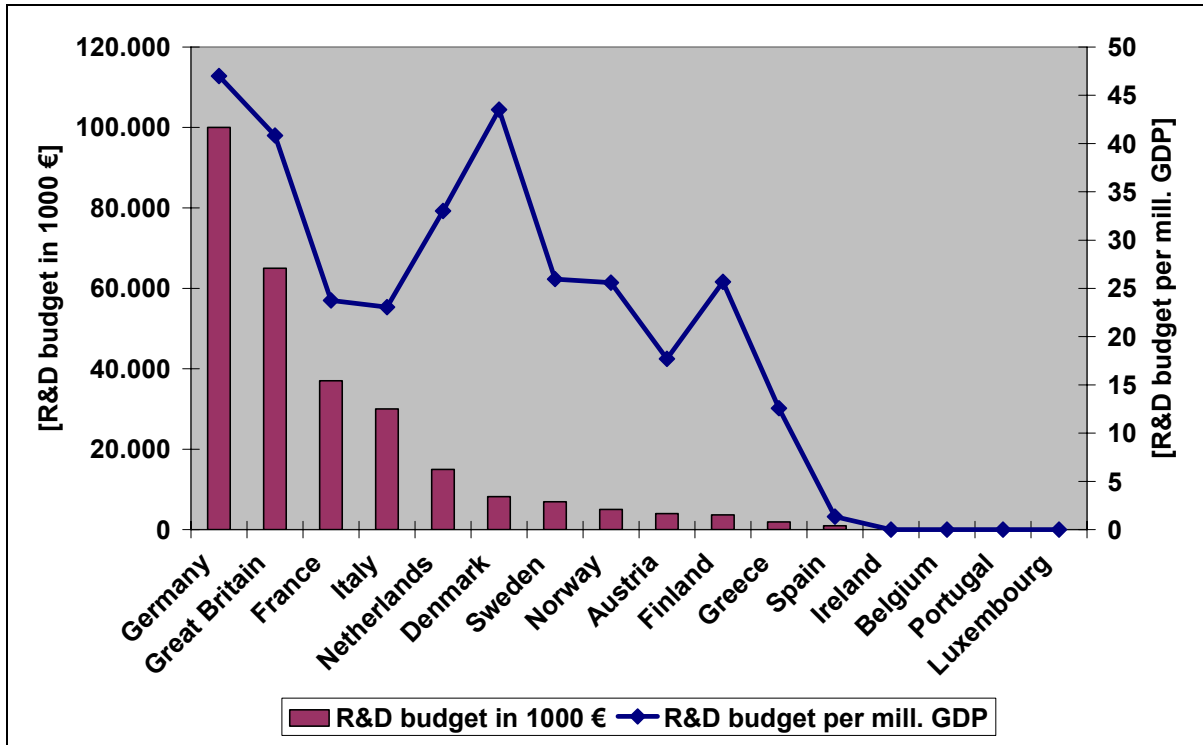


Figure 12: Total amount of public R&D budget and R&D budget per GDP (based on average date 2000 – 2002)

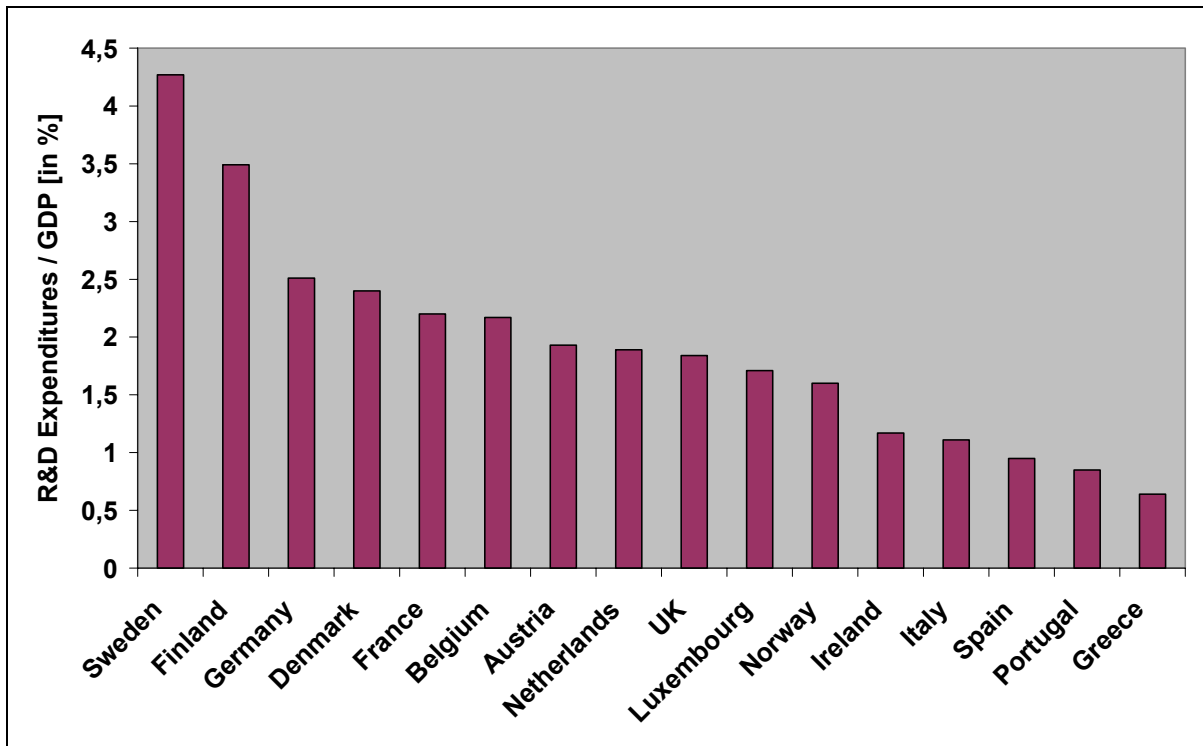


Figure 13: Total amount of overall R&D budget per GDP (for the year 2002)

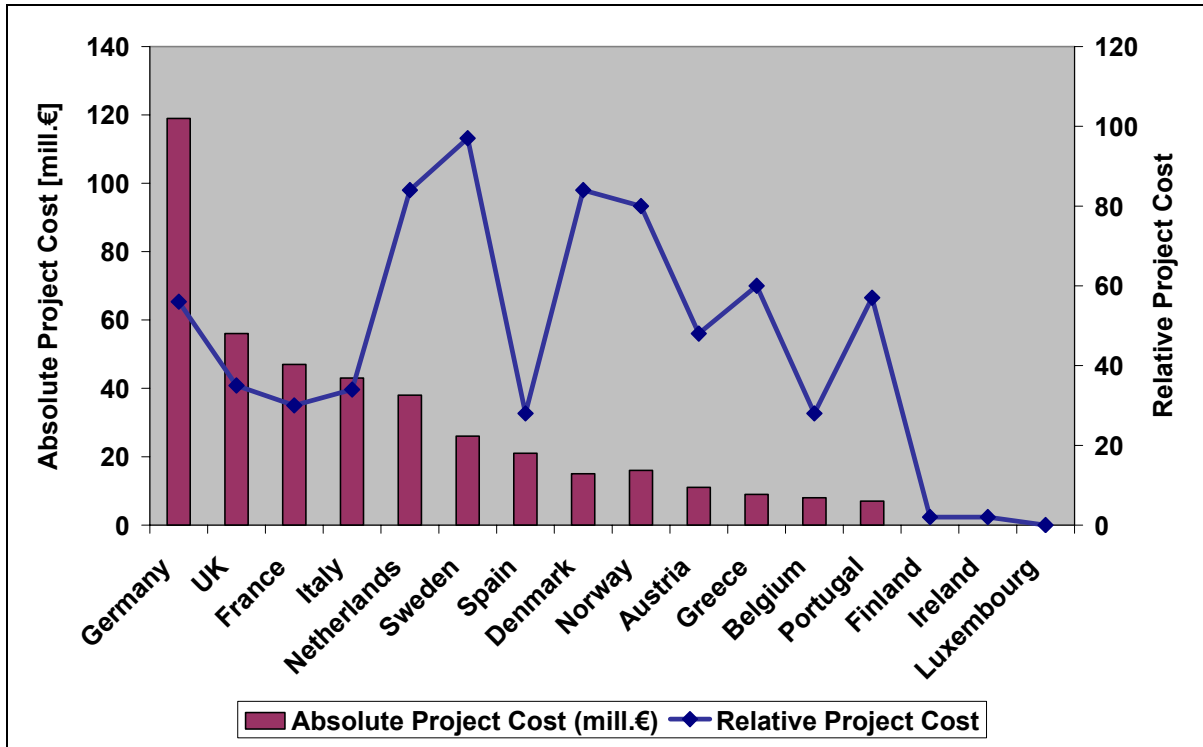


Figure 14: Absolute and relative project cost (per GDP) for EU FP5 and FP6 between 1998 and 2003

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.

7.1.2.4 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:

$$RCA_{ij} = (X_{ij} / \sum_i X_{ij}) / (\sum_i X_{ij} / \sum_j \sum_i X_{ij})$$

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

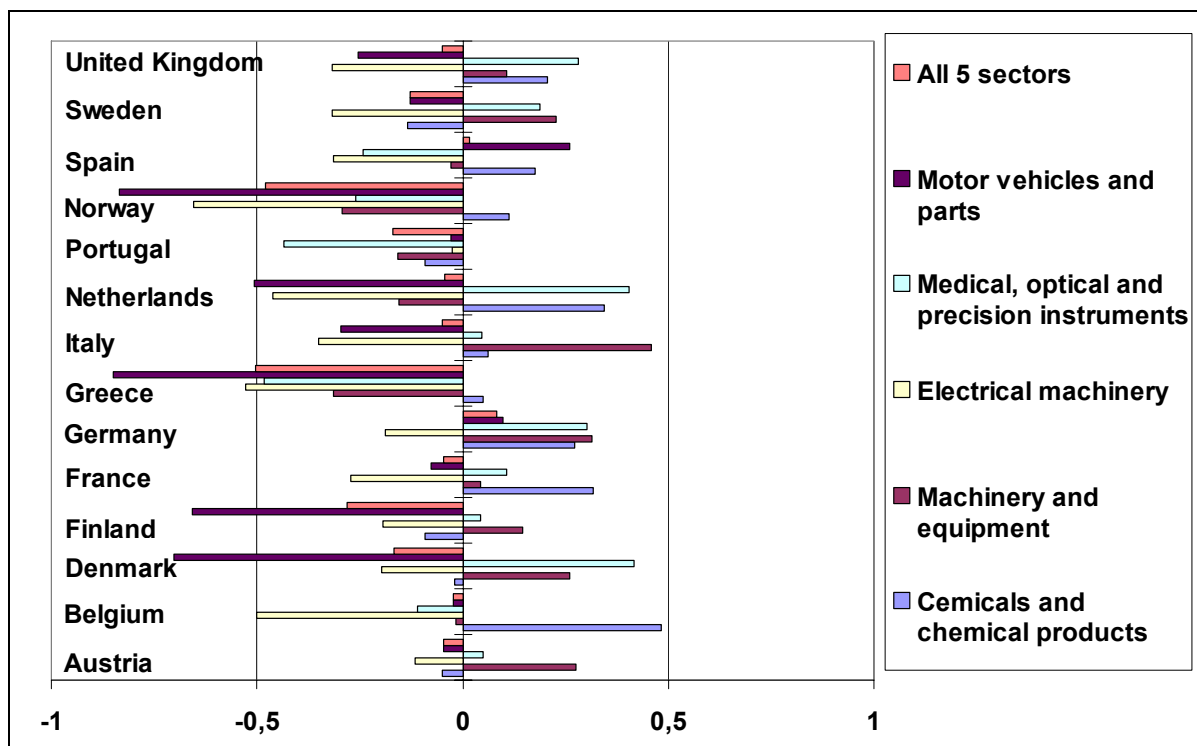


Figure 15: Revealed Symmetric Comparative Advantage of different countries by relevant industry branches

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.

7.1.2.5 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

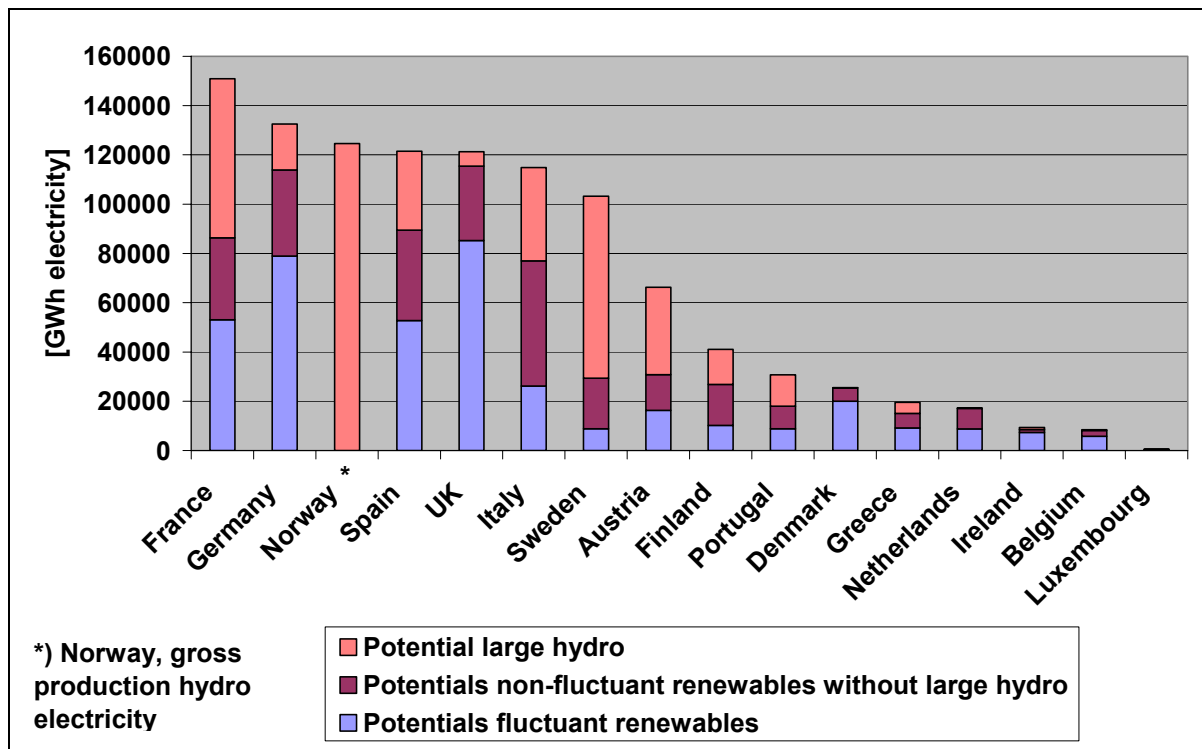


Figure 16: Renewable electricity potentials

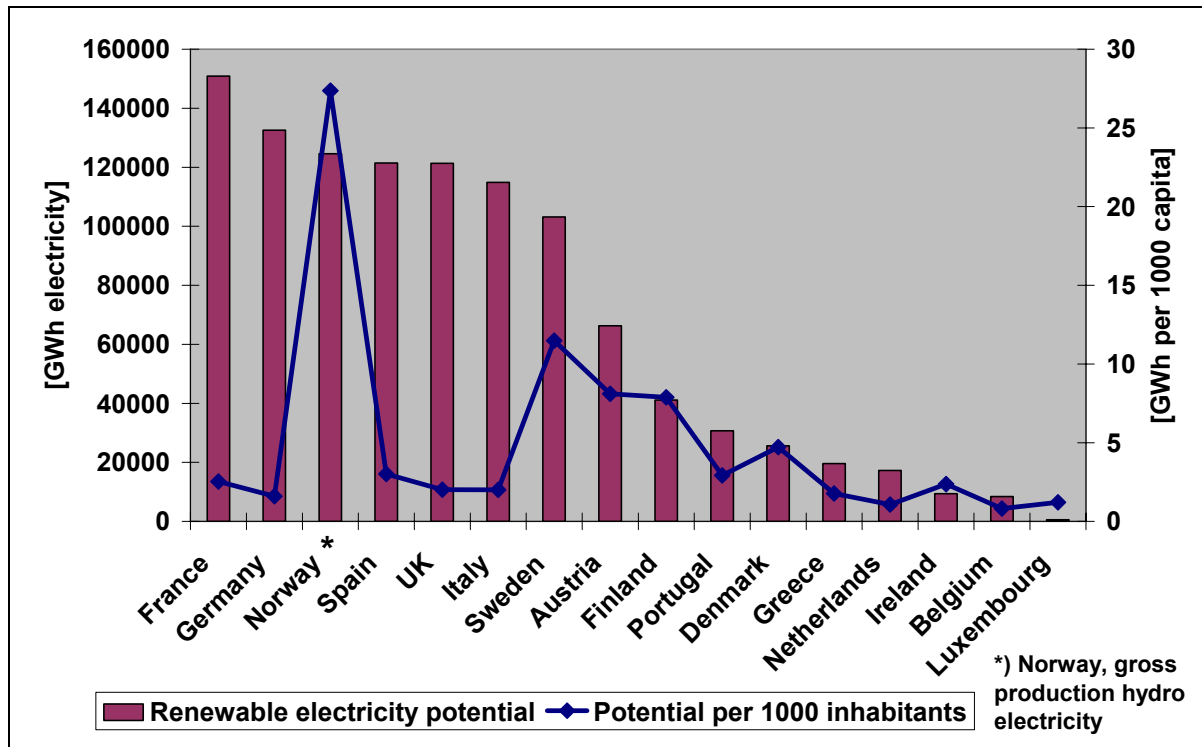


Figure 17: Renewable electricity potentials and relative potentials

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.

7.1.2.6 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

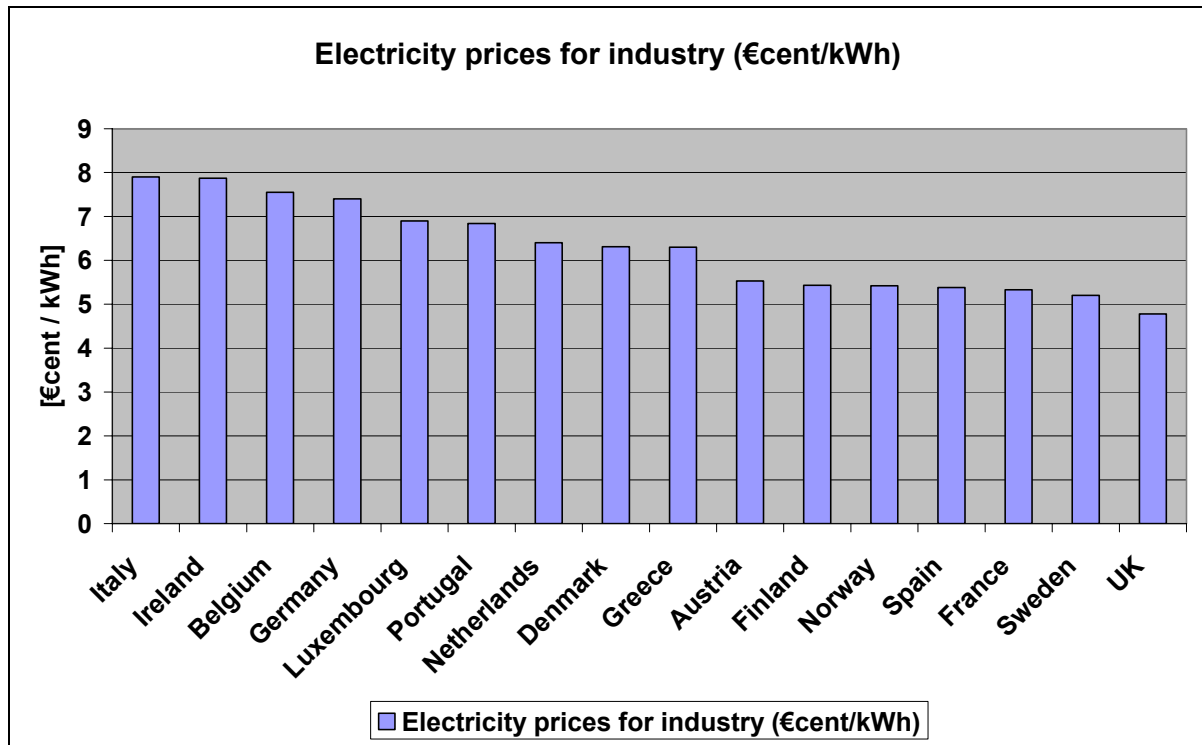


Figure 18: Electricity prices for industry

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.

7.1.2.7 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

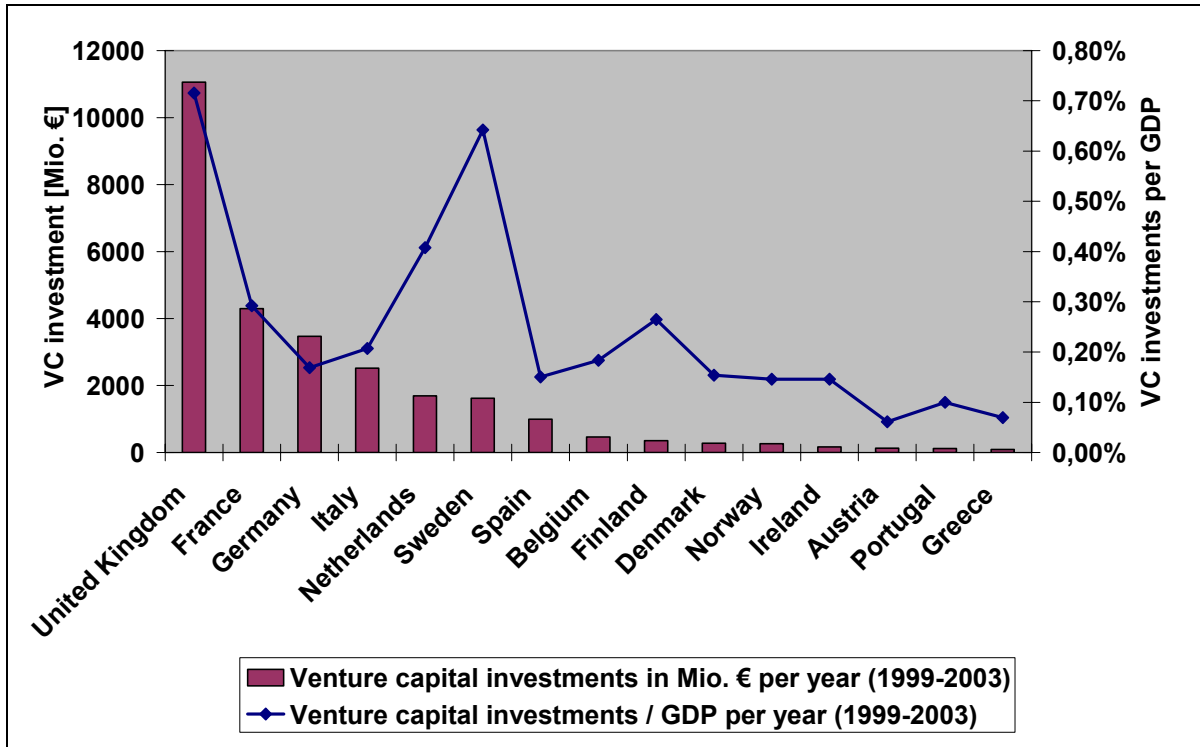


Figure 19: Total amount of Venture Capital (VC) Investments and Venture Capital Investments per GDP (based on average date 1999-2003)

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.

7.1.3 Indicators for hydrogen production

7.1.3.1 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.

7.1.3.2 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

7.1.3.3 Results for the selected indicators

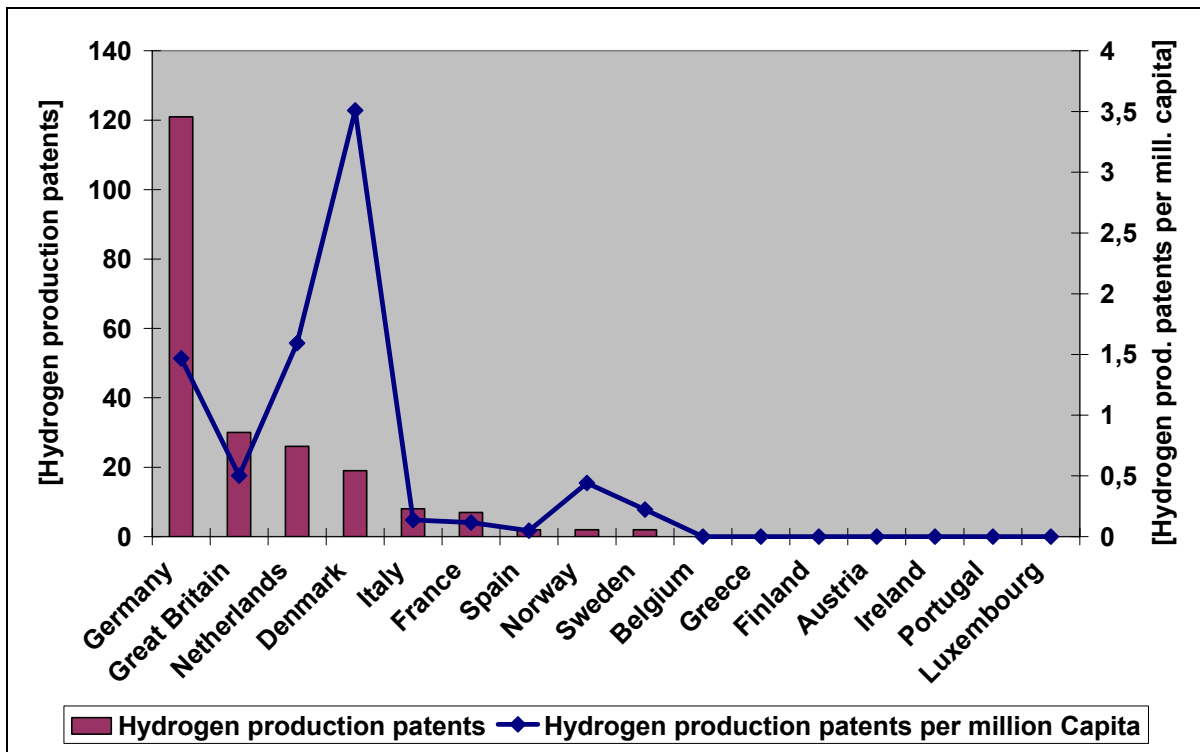


Figure 20: Total amount of patents for hydrogen production and hydrogen production patents per million capita (1990 – 2002)

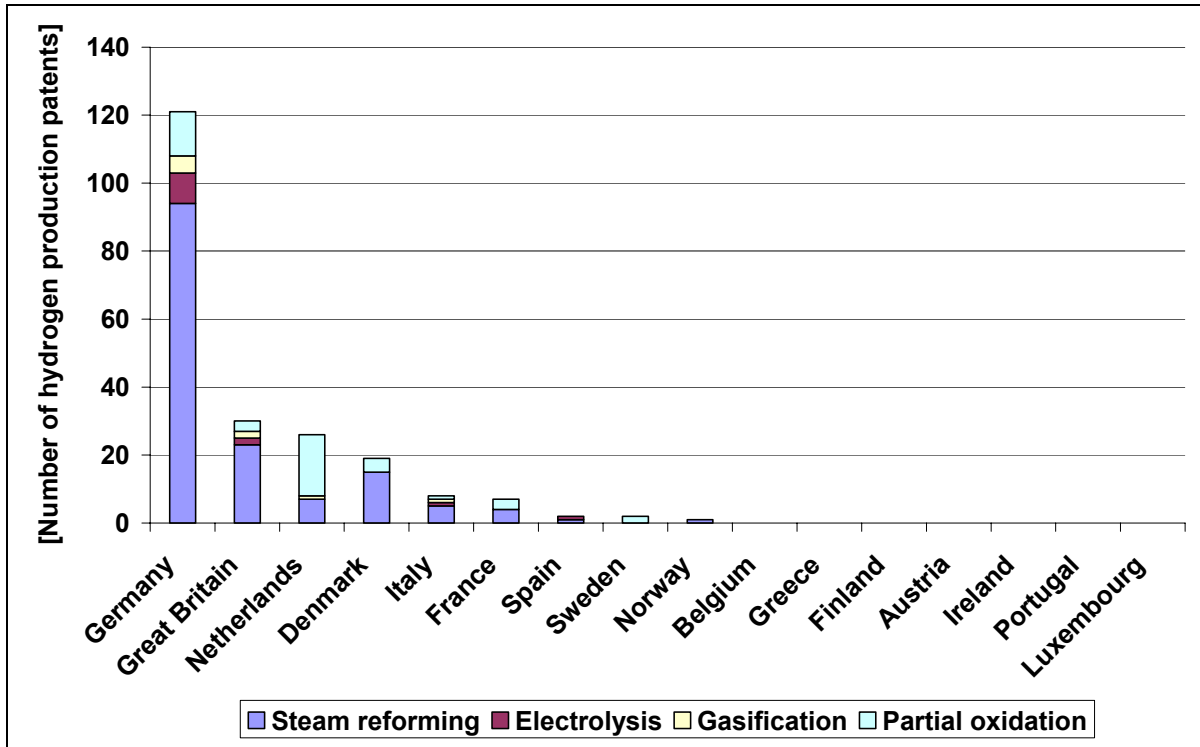


Figure 21: Total amount of patents for different hydrogen production options (1990 – 2002)

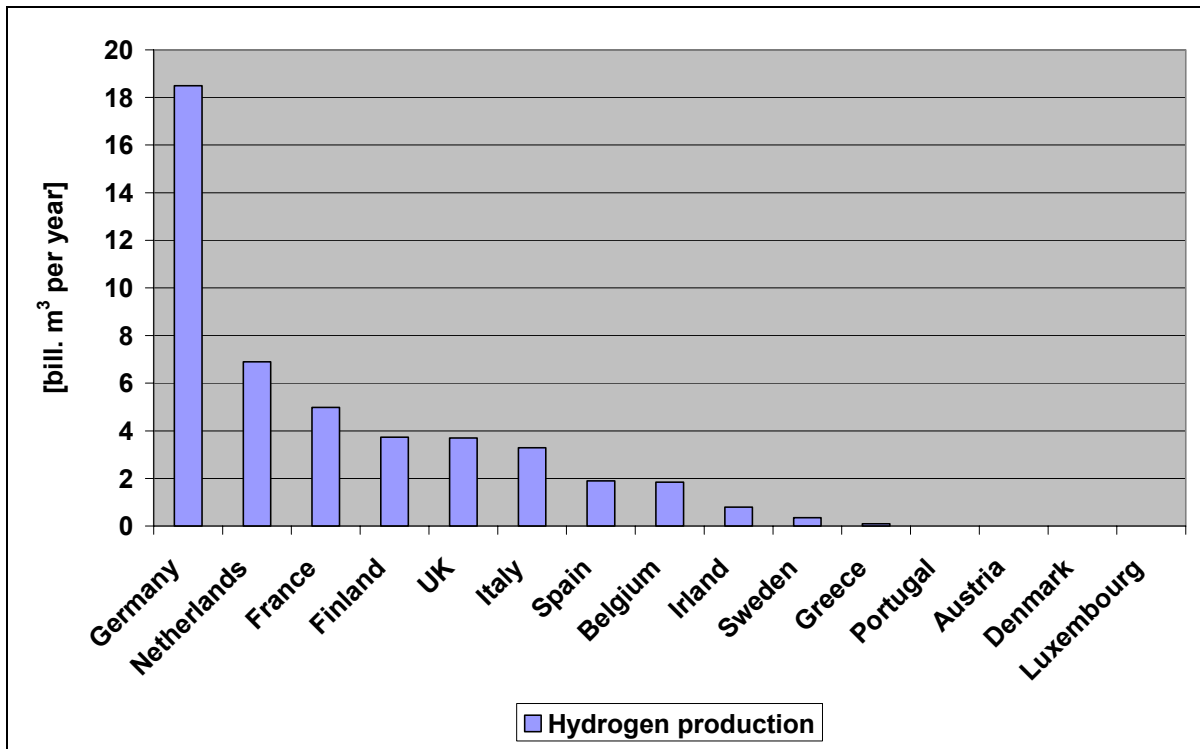


Figure 22: Annual hydrogen production (for Norway no data are available)

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.

7.1.4 Indicators for stationary applications

7.1.4.1 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

7.1.4.2 Results for the selected indicators

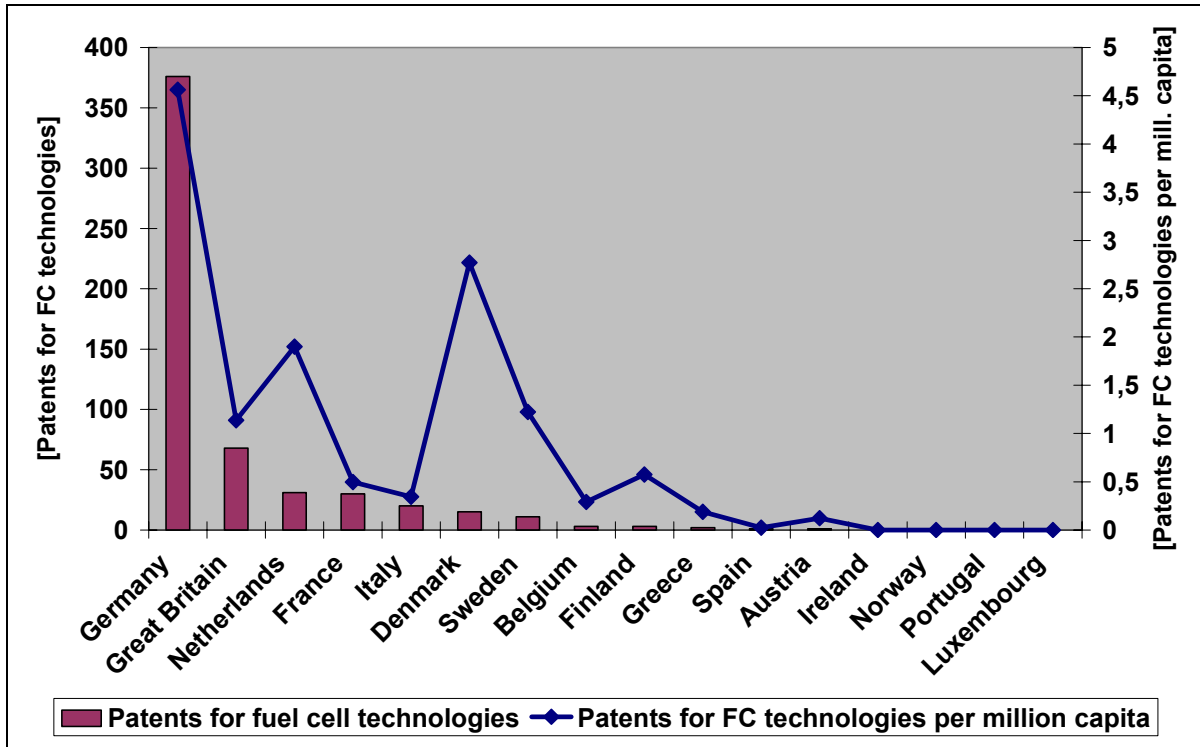


Figure 23: Total amount of patents for fuel cell technologies and patents for fuel cell technologies per million capita (1990 – 2002)

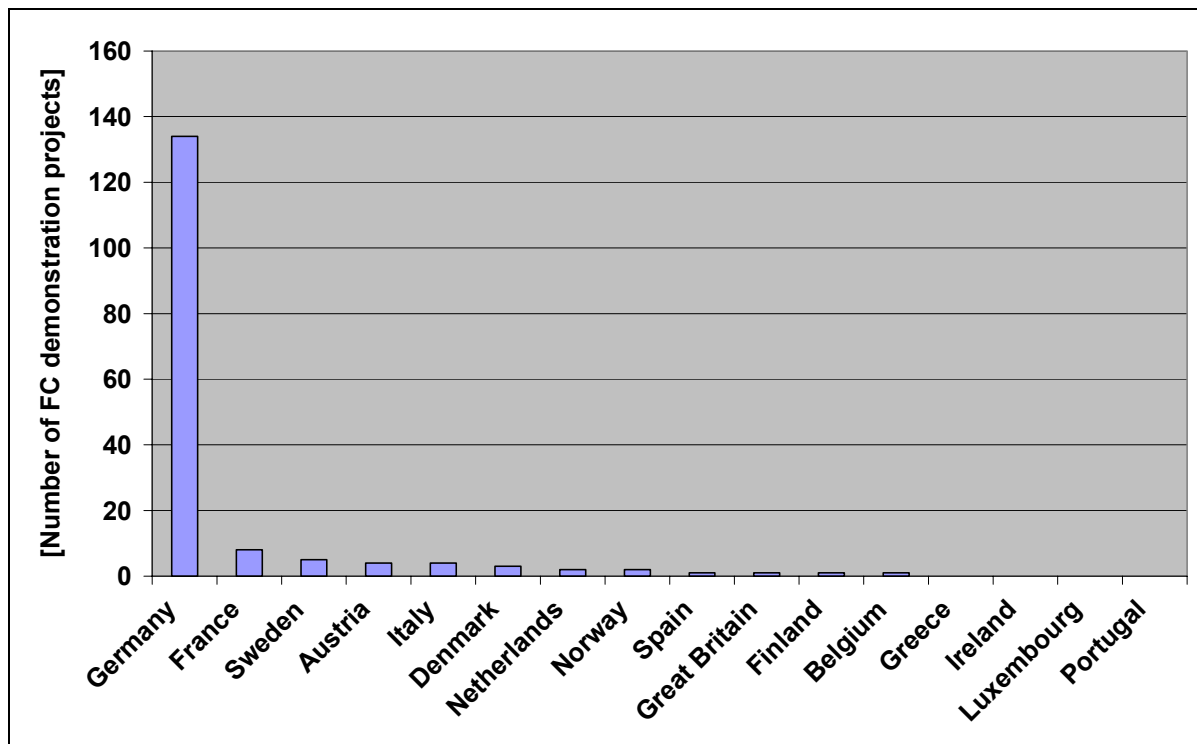


Figure 24: Number of fuel cell demonstration projects

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]).

7.1.5 Indicators for mobile applications

7.1.5.1 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.

7.1.5.2 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

7.1.5.3 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)

7.1.5.4 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]

Indicator

- Regional population density per capita and square kilometres

7.1.5.5 Results for the selected indicators

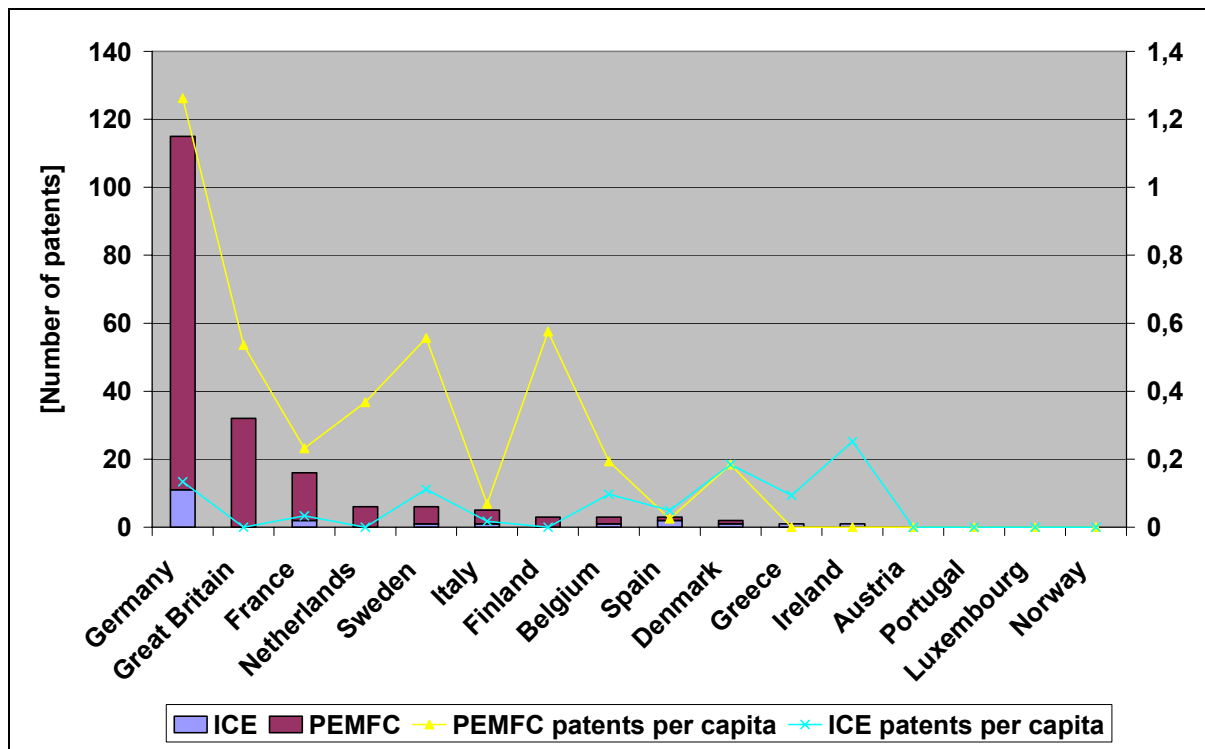


Figure 25: Amount of patents for hydrogen ICE and PEM

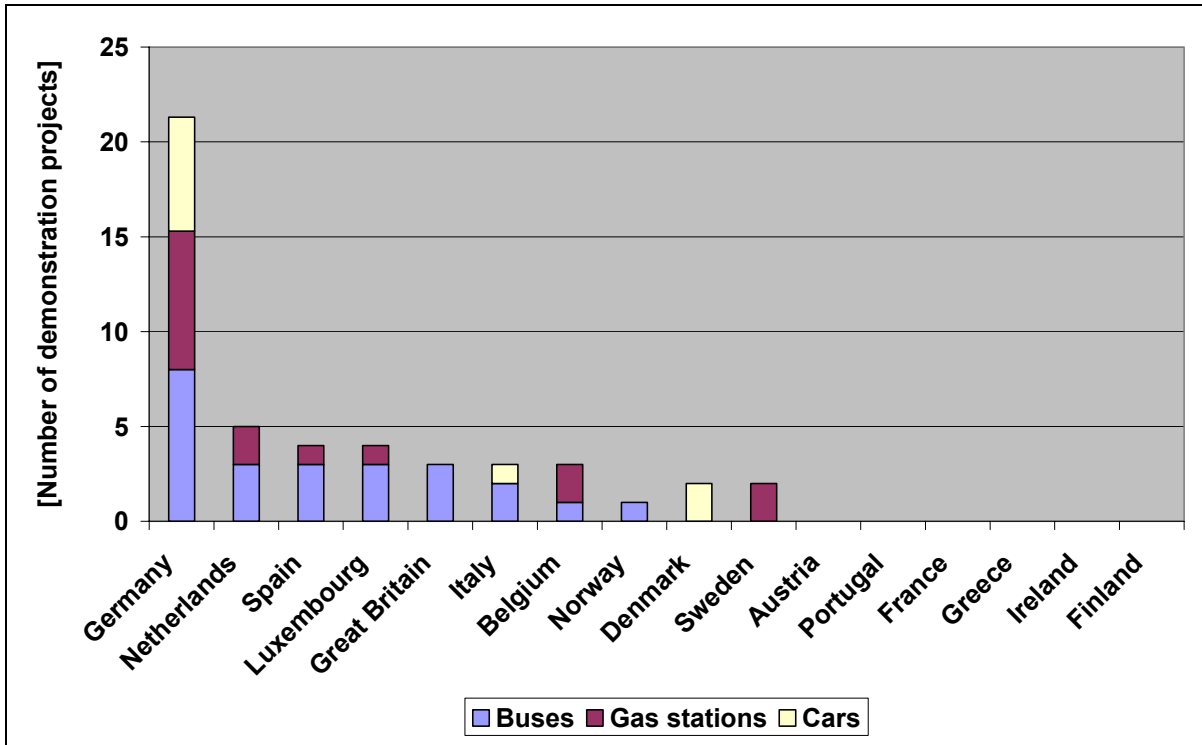


Figure 26: Amount of demonstration projects in the mobile sector (buses, cars, gas stations)

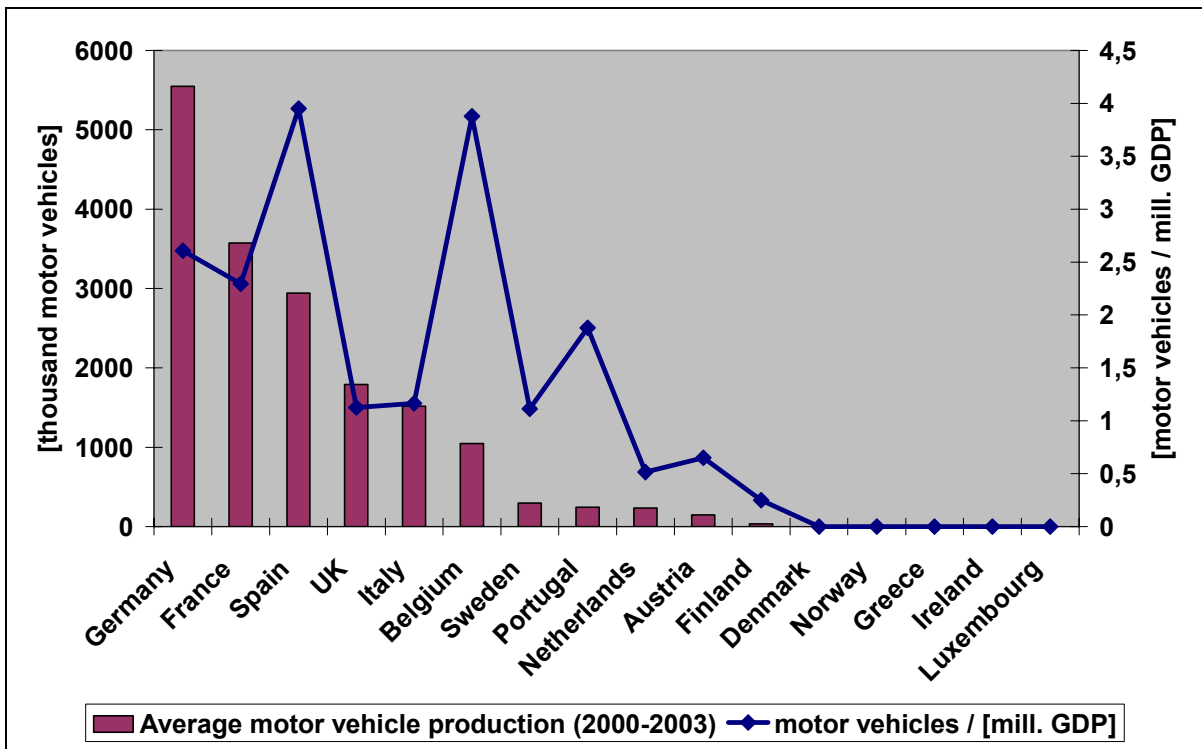


Figure 27: Average motor vehicle production and motor vehicle production per million GDP (average data 2000-2003)

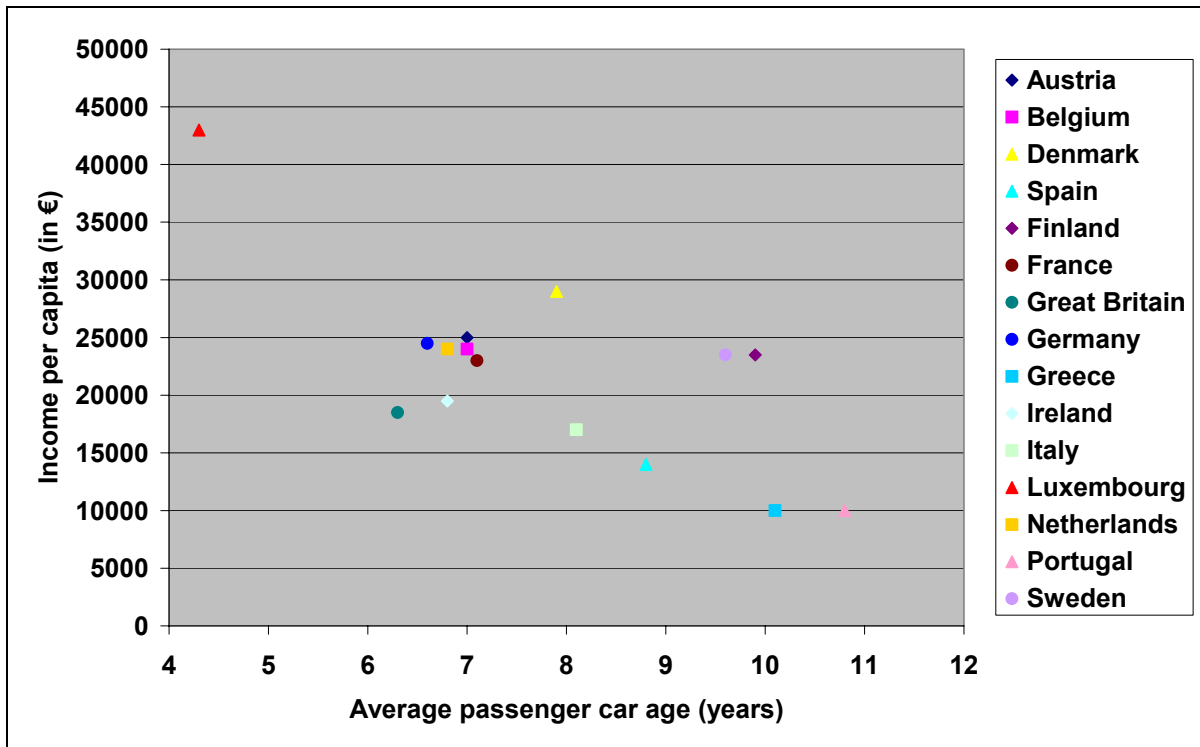


Figure 28: Average passenger car age and income per capita (2002)

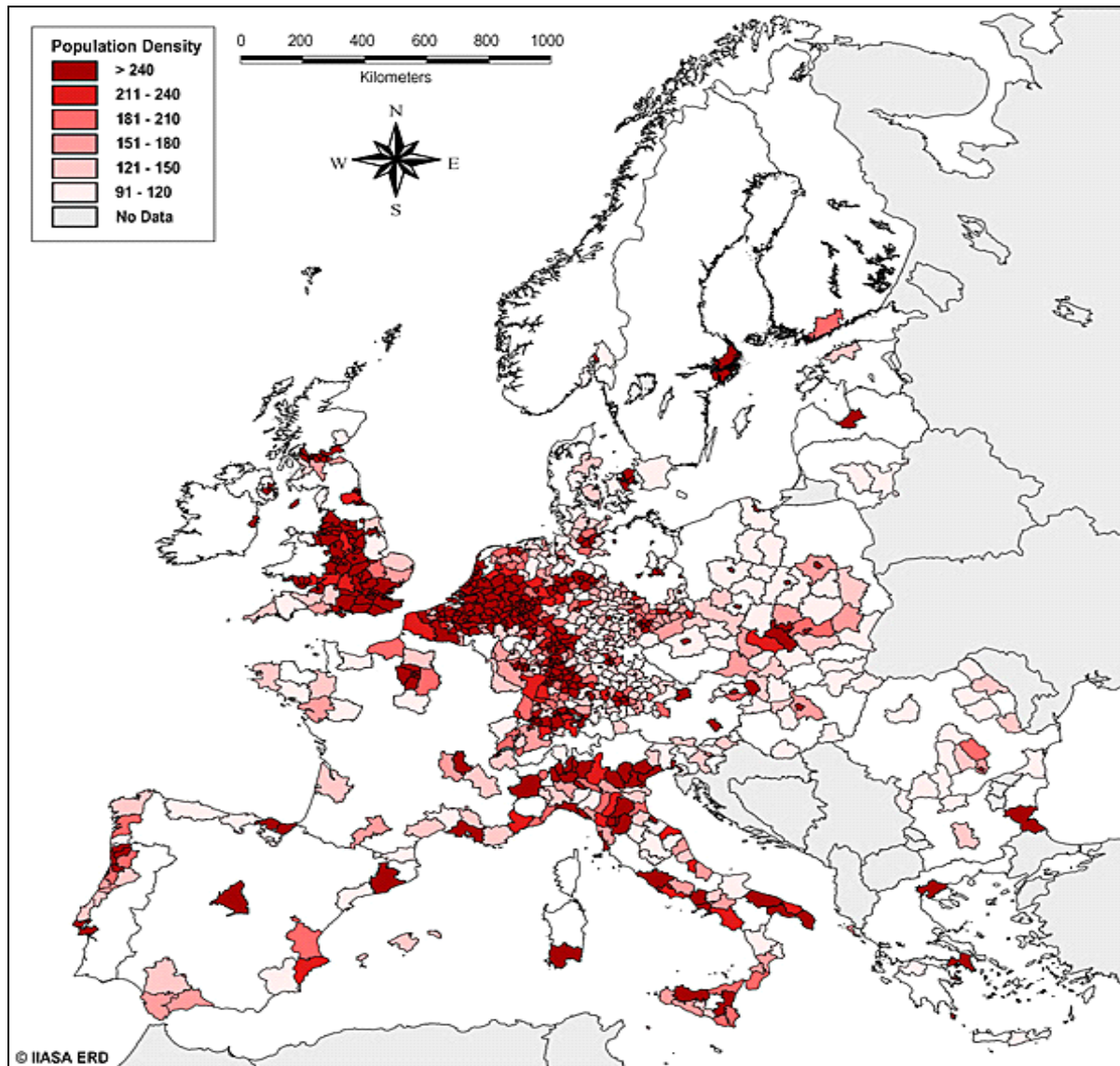


Figure 29: Regional population density in Europe per capita and square kilometers

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.

7.2 Comparison with Japan, USA and Canada

7.2.1 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.

7.2.2 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.

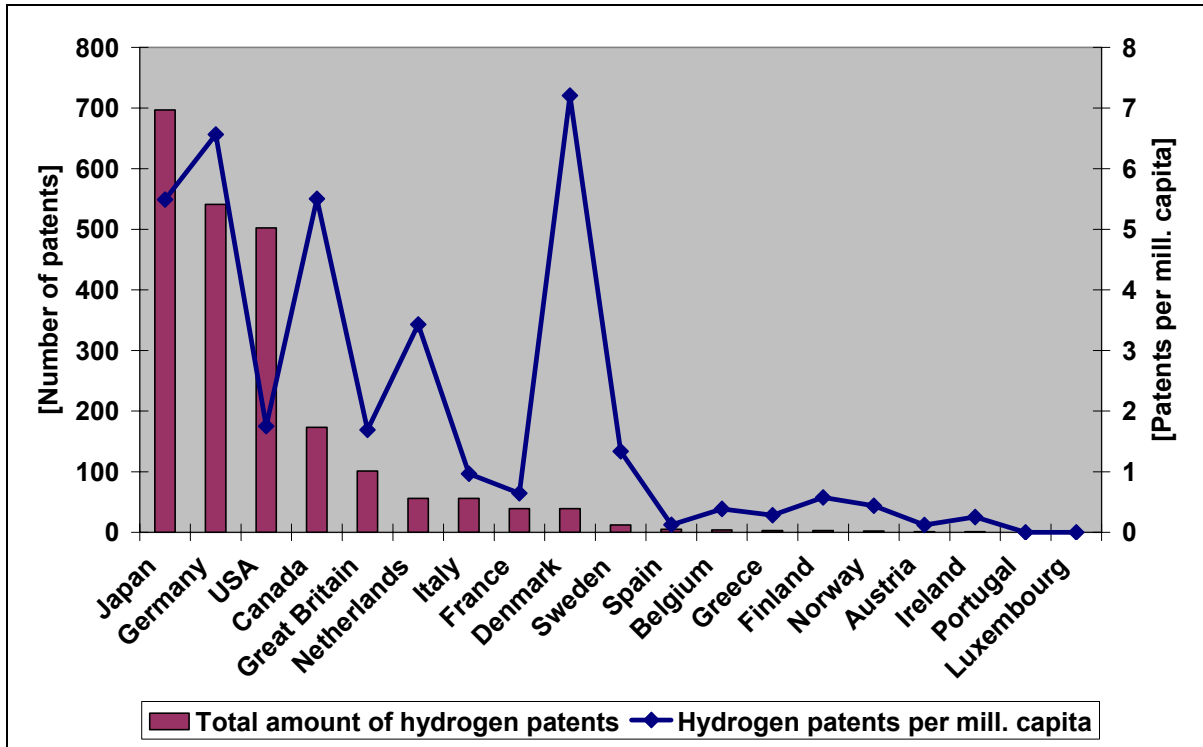


Figure 30: Total amount of hydrogen patents and hydrogen patents per million capita including USA, Japan, Canada (1990 – 2002)

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.

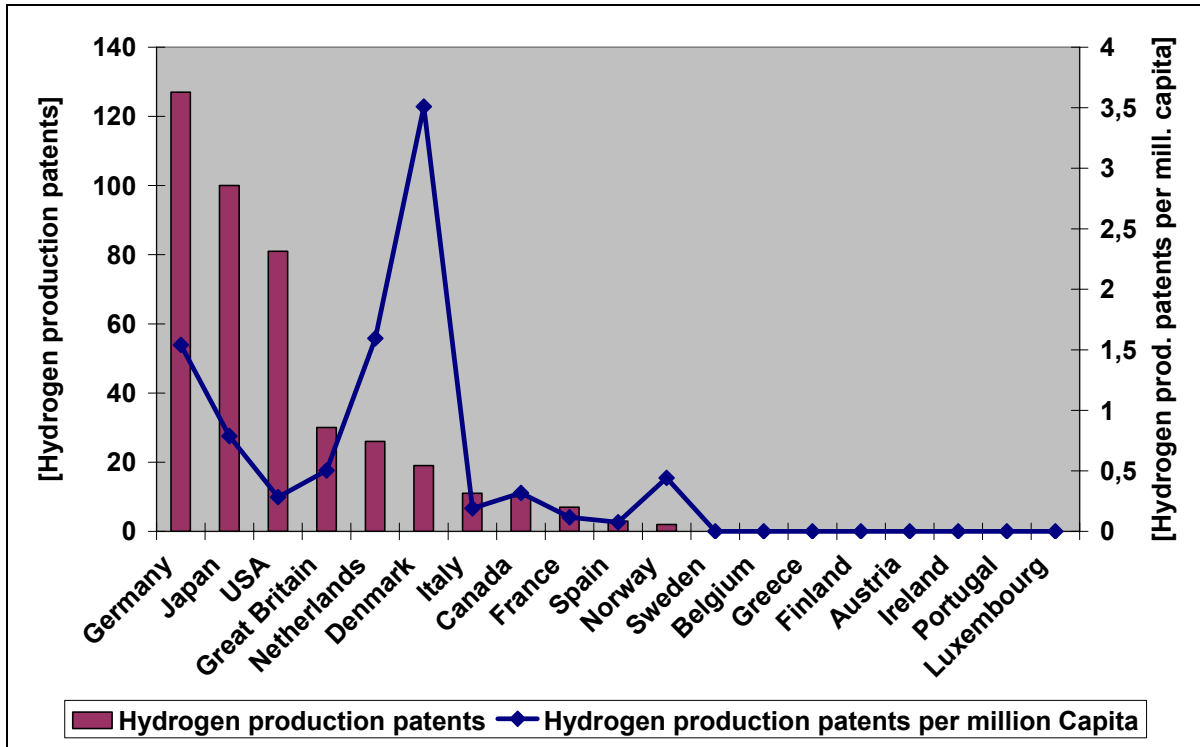


Figure 31: Total amount of patents for hydrogen production and hydrogen production patents per million capita including Japan, USA, Canada (1990 – 2002)

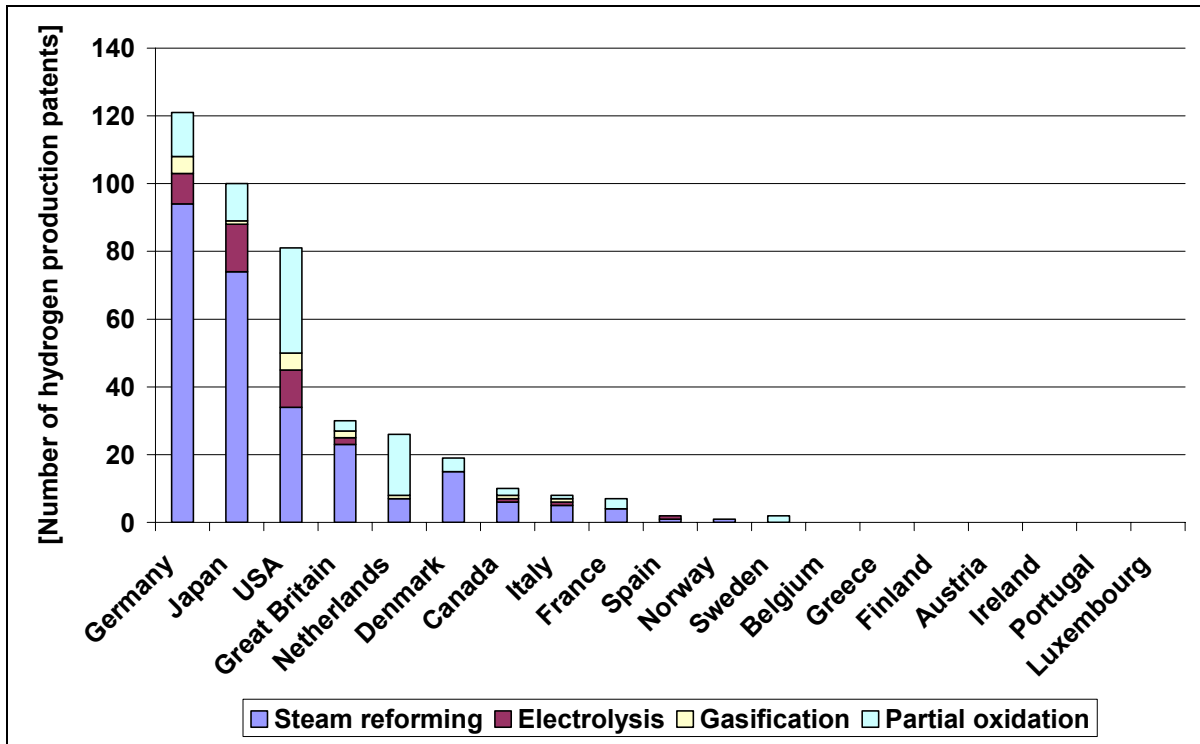


Figure 32: Total amount of patents for different hydrogen production options including Japan, USA, Canada (1990 – 2002)

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.

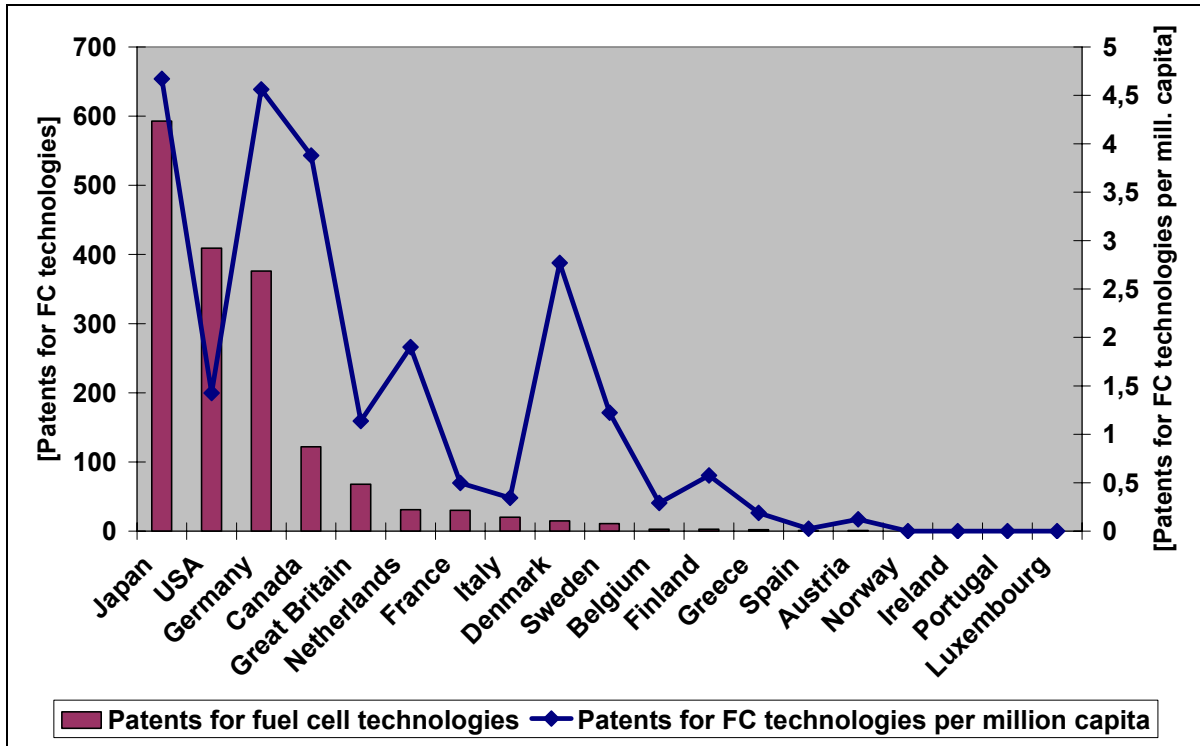


Figure 33: Total amount of patents for fuel cell technologies and patents for fuel cell technologies per million capita including Japan, USA, Canada (1990 – 2002)

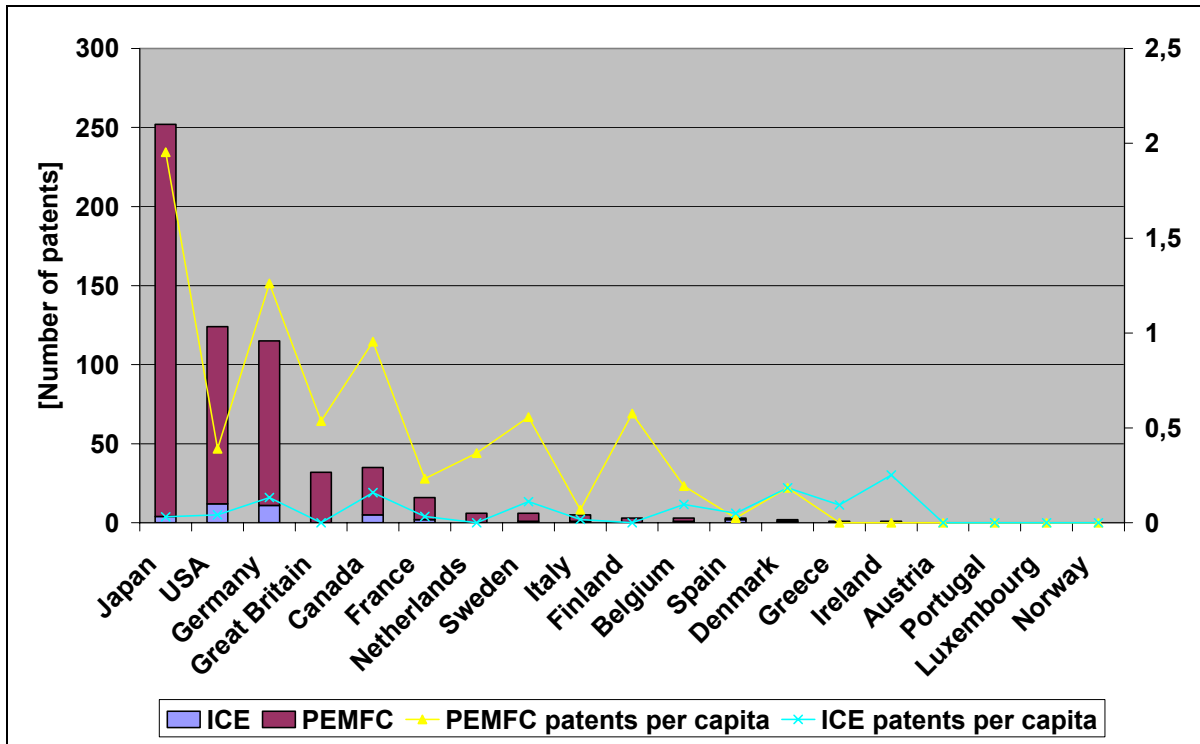


Figure 34: Amount of patents for hydrogen ICE and PEM including Japan, USA, Canada

7.2.3 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.

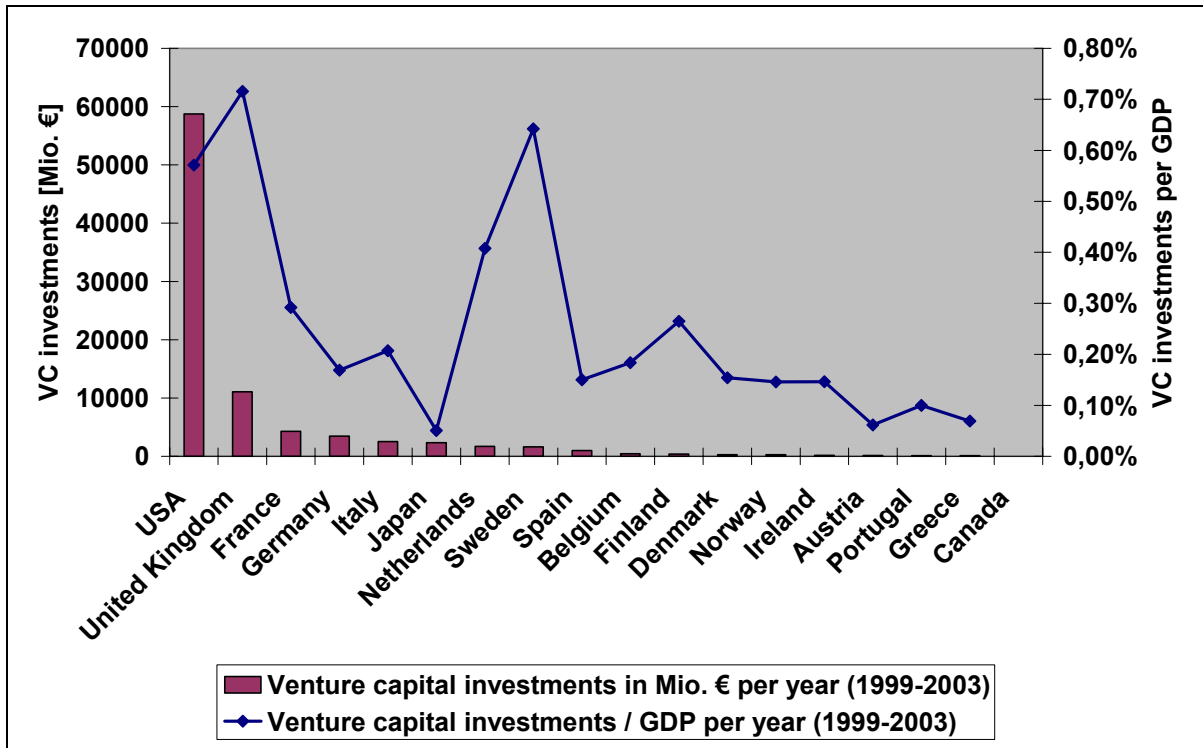


Figure 35: Total amount of Venture Capital Investments and Venture Capital Investments per GDP (based on average date 1999-2003)

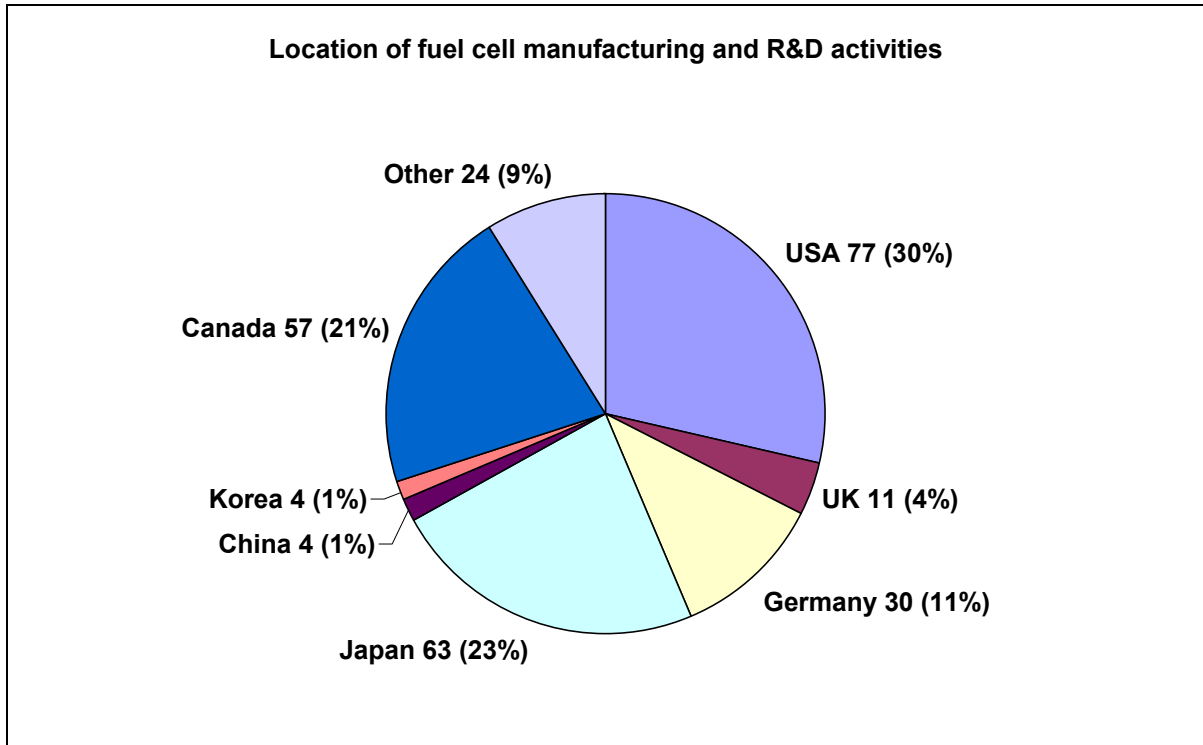


Figure 36: Location of fuel cell manufacturing and R&D activities (source: [WFCIS2004])

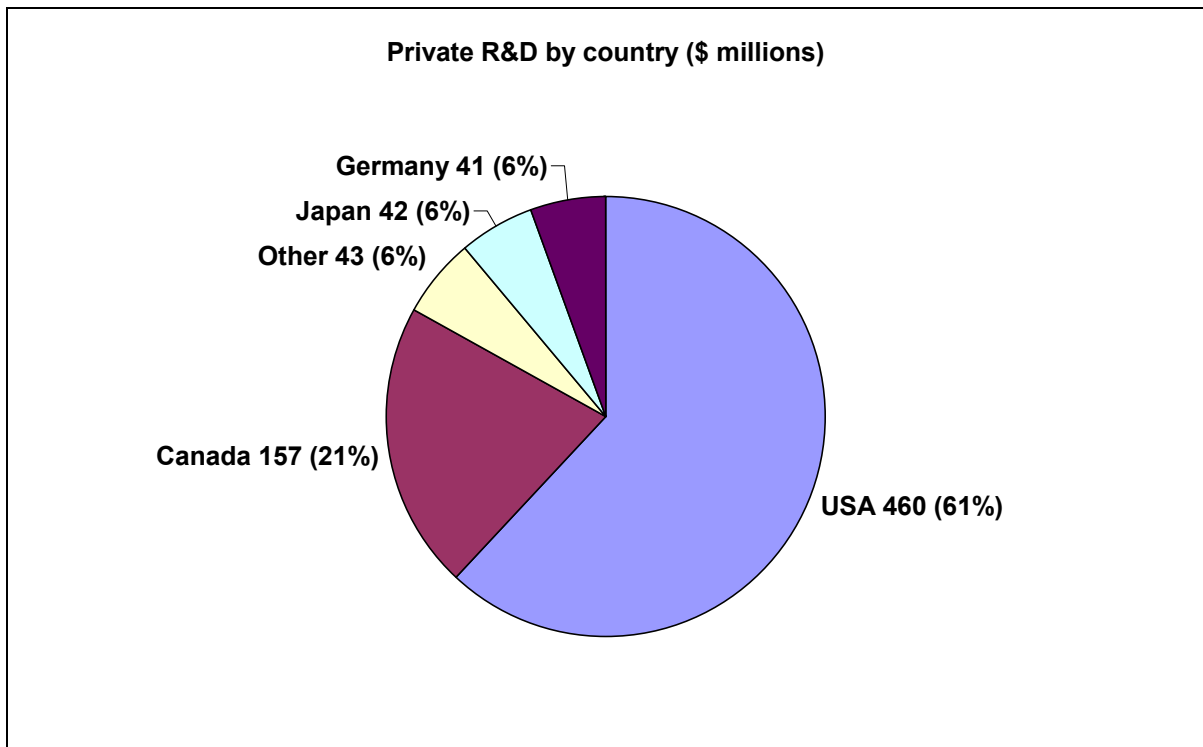


Figure 37: Private fuel cell R&D expenditures by country (source: [WFCIS2004])

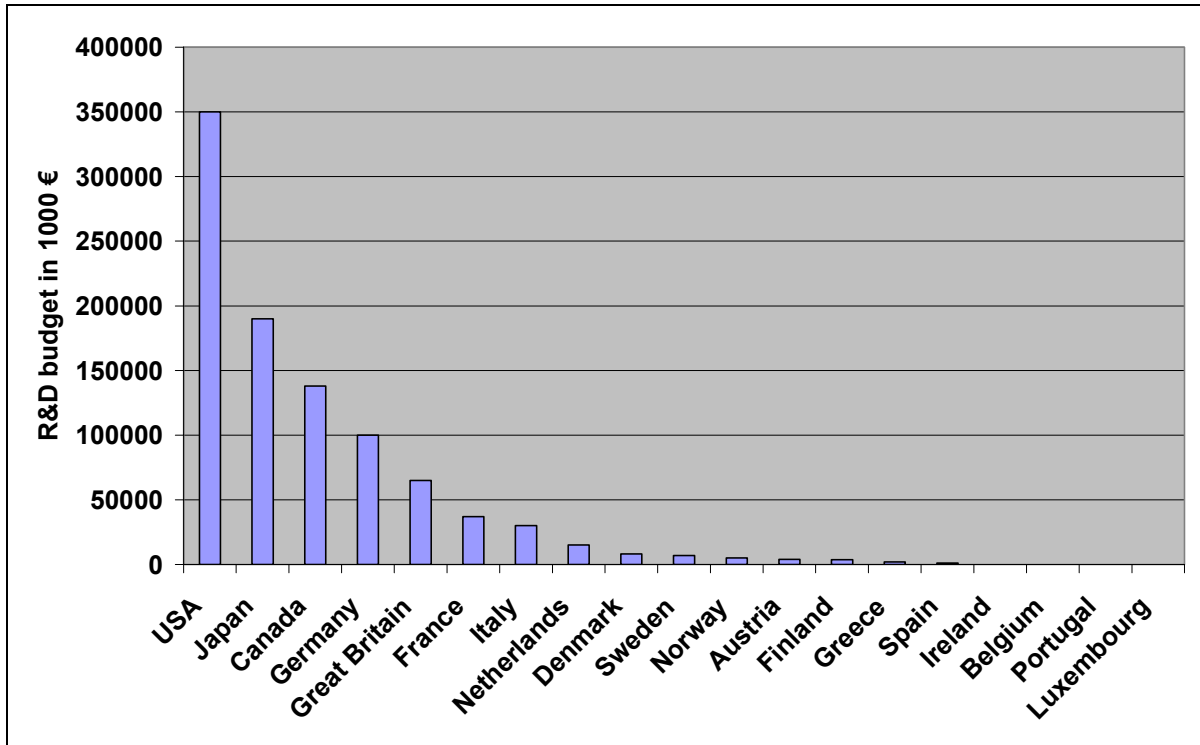


Figure 38: Public R&D budget in fuel cells and hydrogen [AMORELLI 2004]

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.

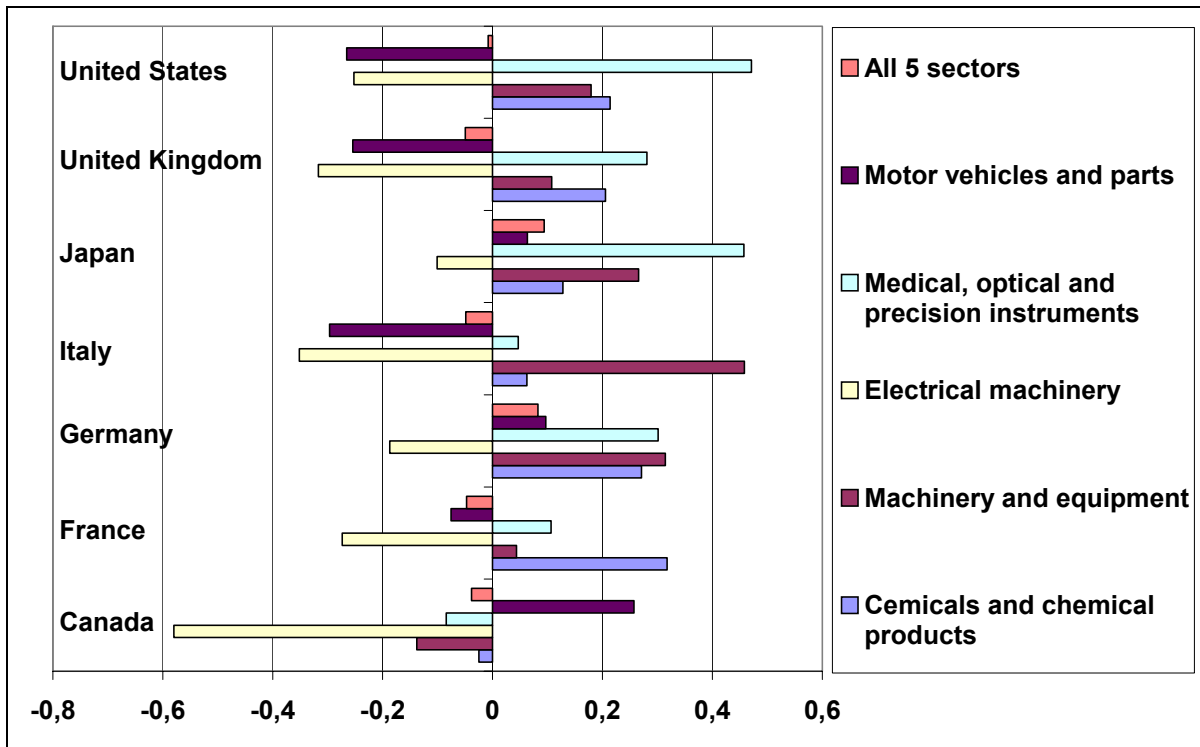


Figure 39 Revealed Symmetric Comparative Advantage of different countries by relevant industry branches

7.2.4 Summary

The main outcomes of the SWOT-analysis⁶ 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.
- 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.

⁶ 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].

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8 Annex B: Input Output analysis: country results

8.1 MS Results: Finland

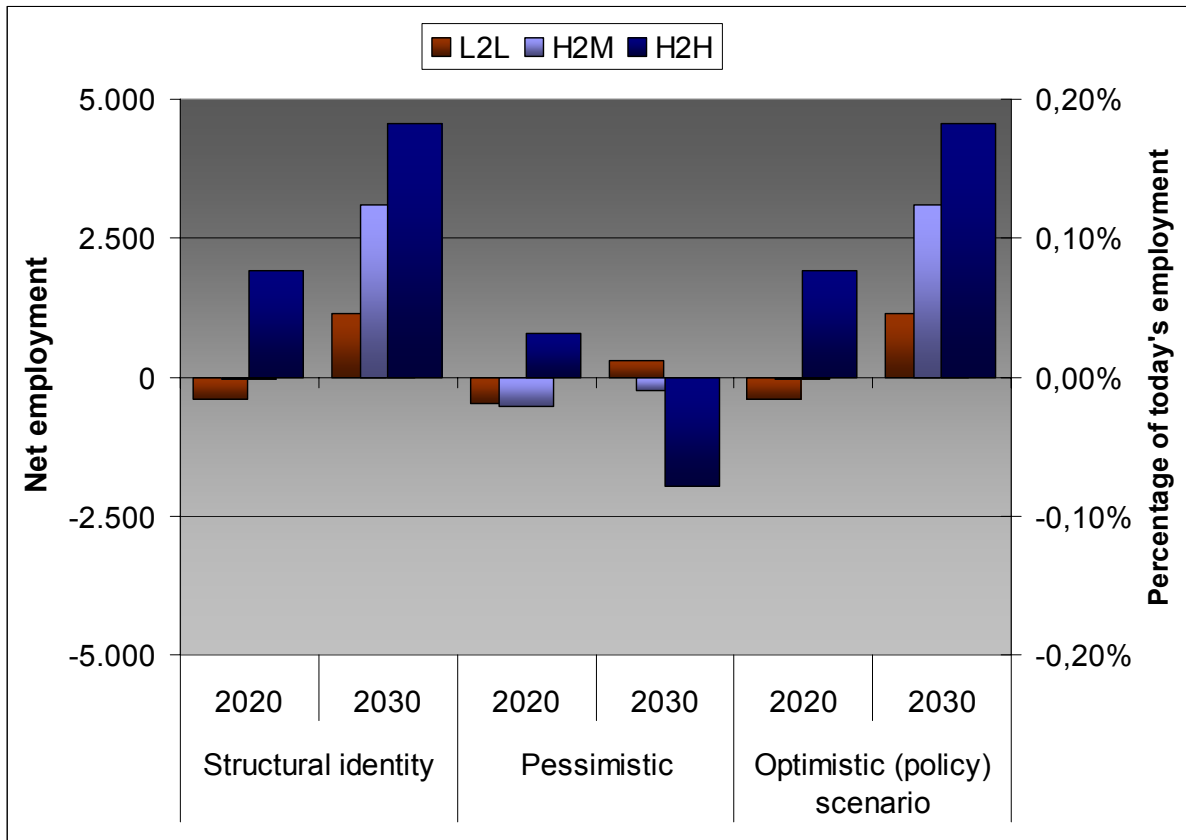


Figure 40: Net employment effects for the hydrogen high penetration (H2H), and medium penetration (H2M) scenarios with optimistic learning rates for hydrogen passenger cars. As well as hydrogen low penetration (L2L) scenarios with moderate learning rates for hydrogen passenger cars for the year 2020 and 2030. Shown are the overall net employment effects for Finland in three import and export scenarios.

8.1.1 High learning scenario high penetration rates

Effect Finland, scenario structural identity, year 2030

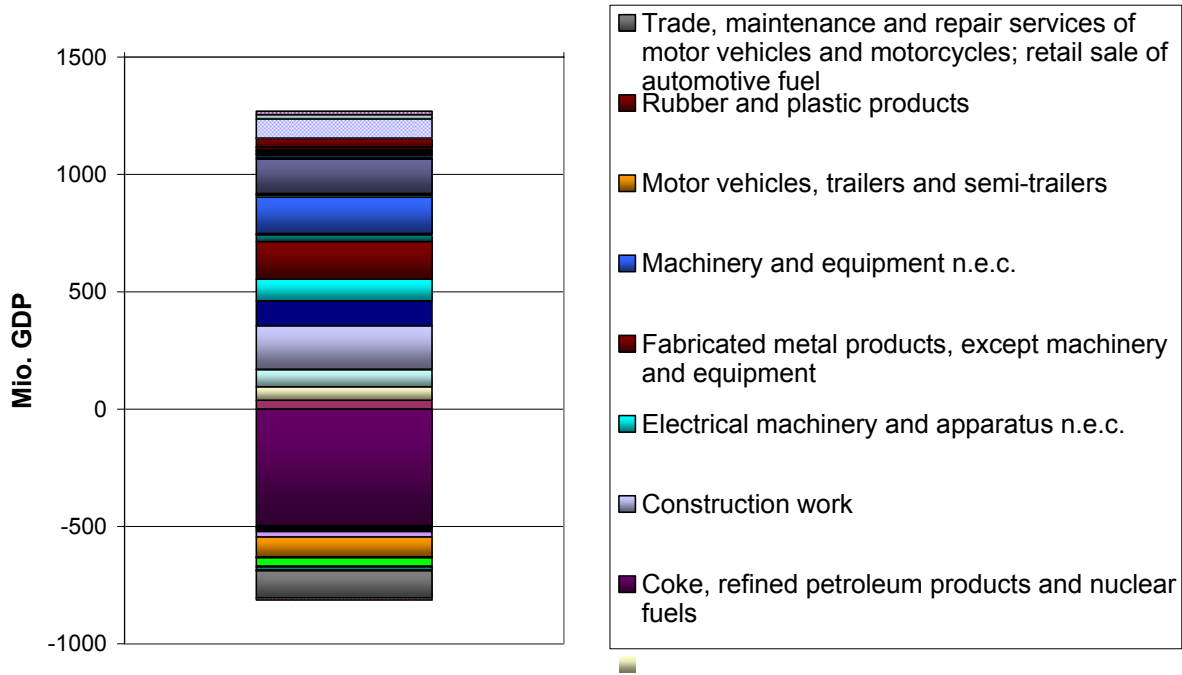


Figure 41: Sectoral economic effects Finland 2030 optimistic learning high penetration (H2H)

Finland, scenario structural identity, year 2030

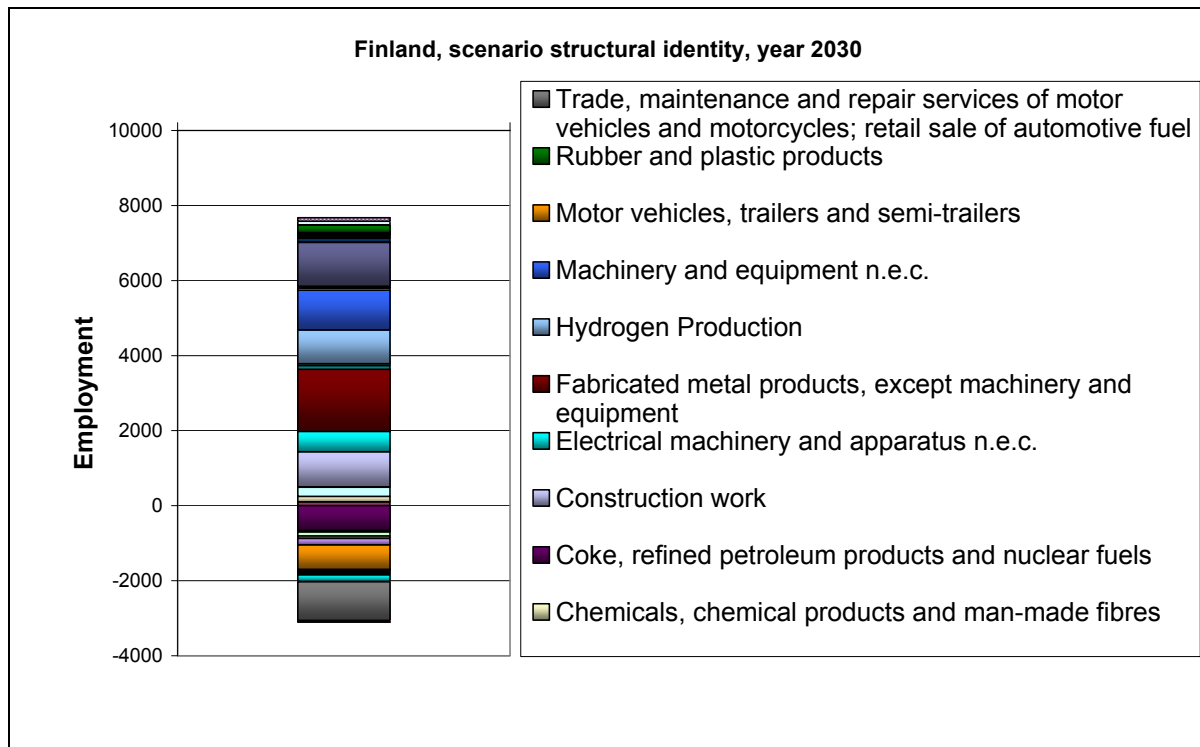


Figure 42: Sectoral employment shifts for Finland optimistic learning high penetration (H2H)

8.1.2 High learning scenario moderate penetration rates

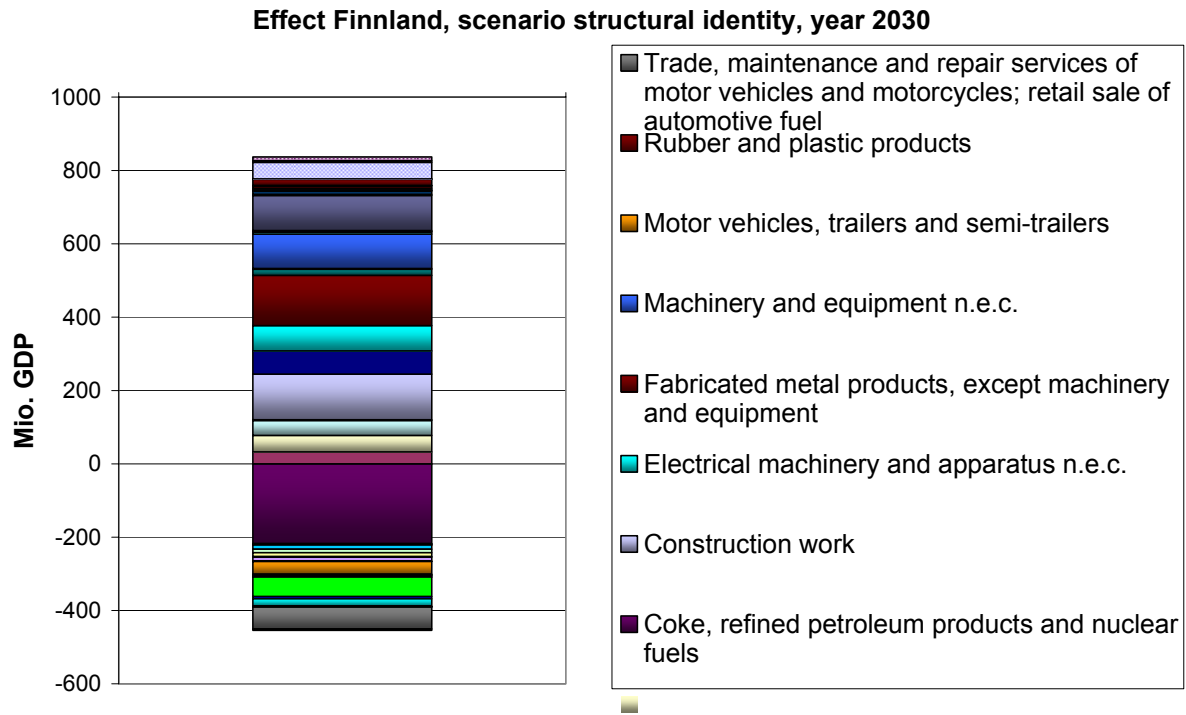


Figure 43: Sectoral economic effects Finland 2030 optimistic learning medium penetration (H2M)

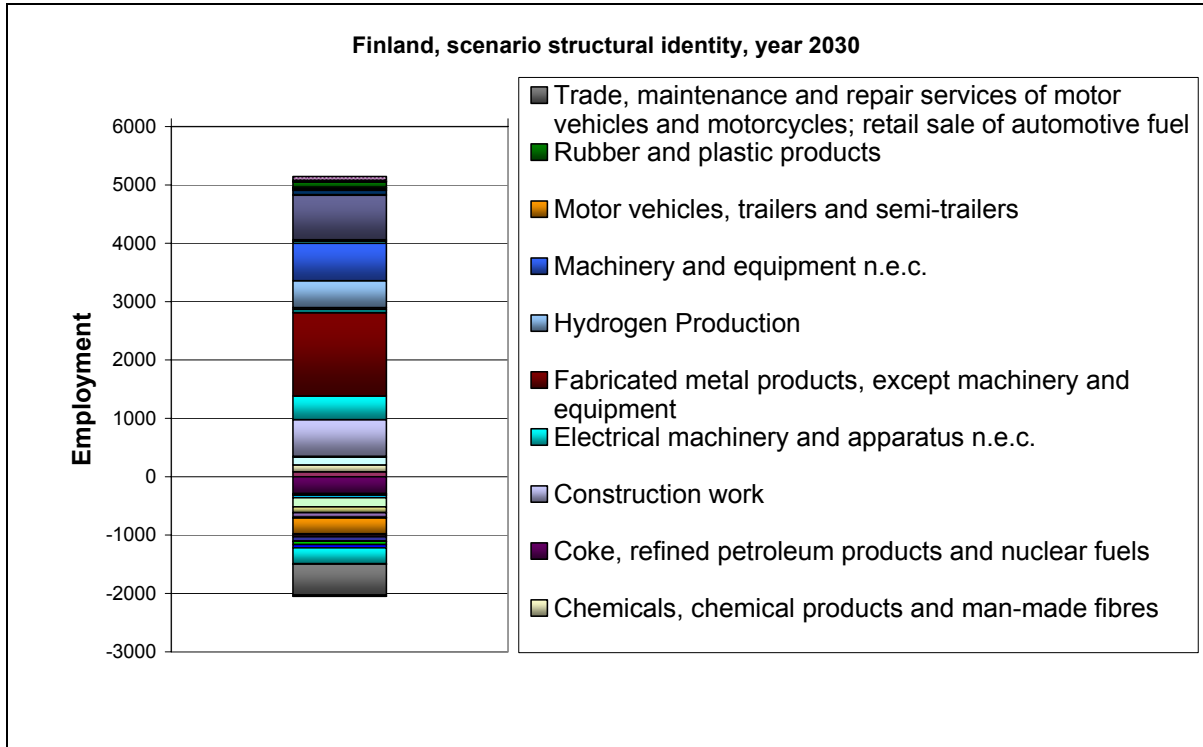


Figure 44: Sectoral employment shifts for The Finland optimistic learning medium penetration (H2M)

8.1.3 Moderate learning scenario low penetration rates

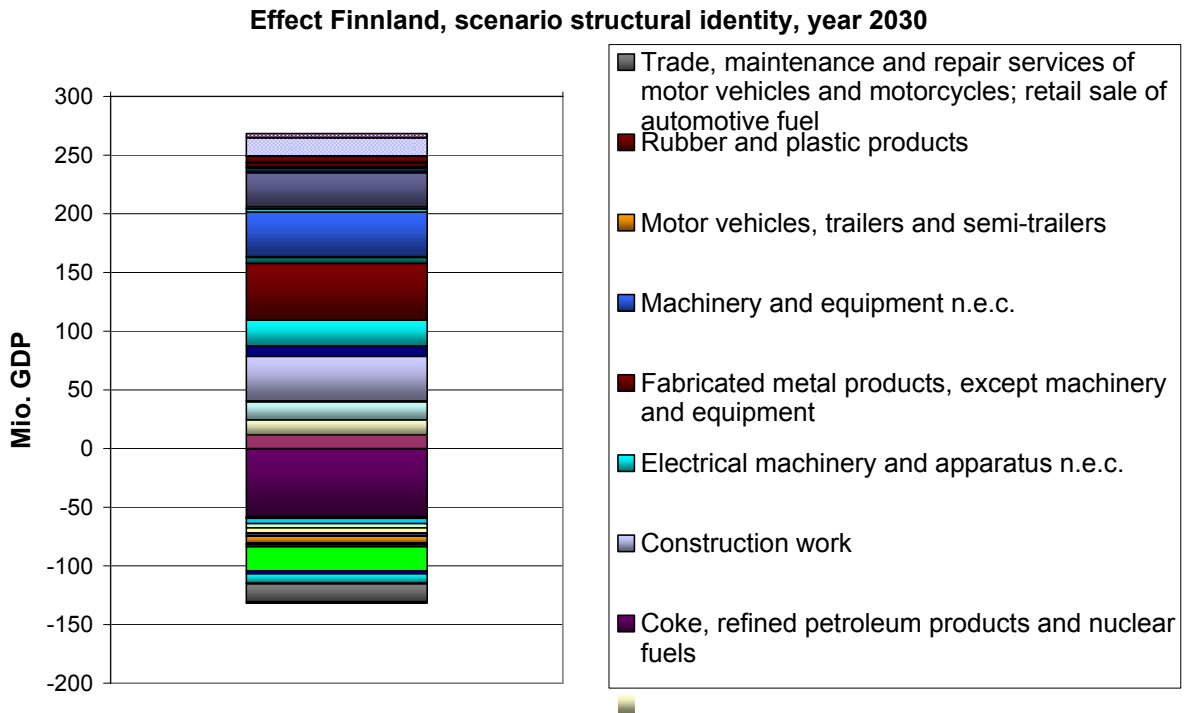


Figure 45: Sectoral economic effects Finland 2030 moderate learning low penetration (M2L)

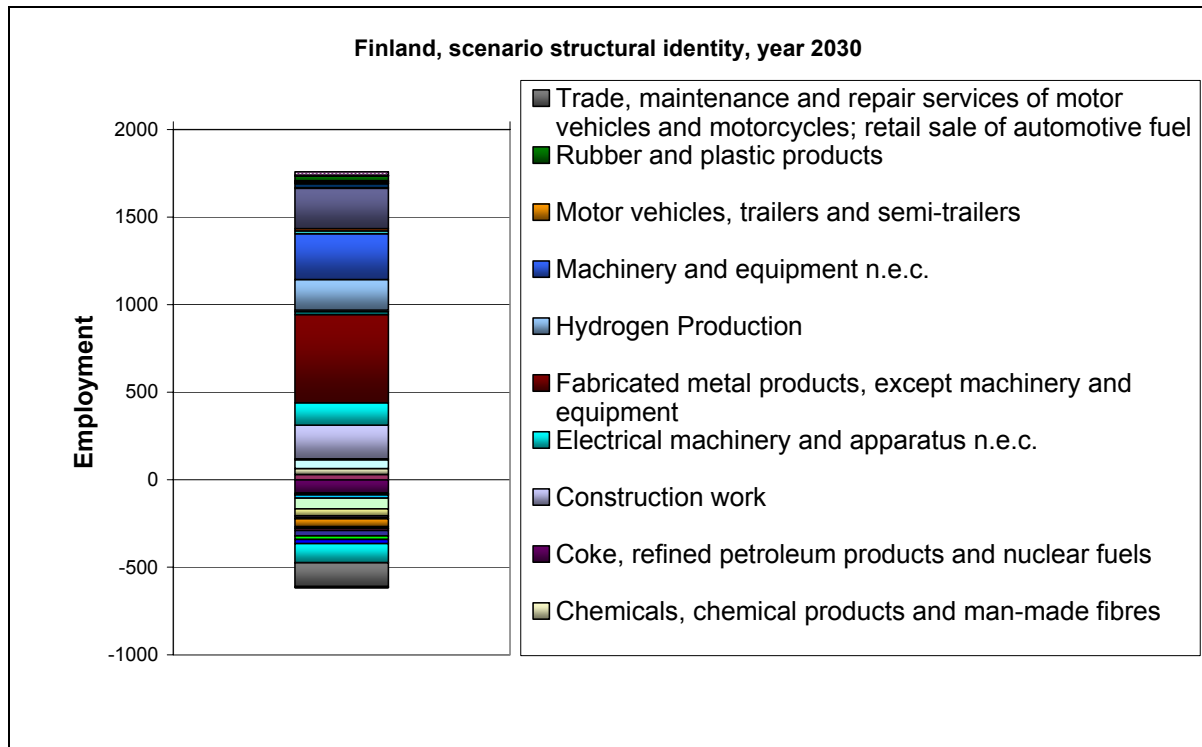


Figure 46: Sectoral employment shifts for Finland moderate learning low penetration (M2L)

8.1.4 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.
- Compared with large automobile countries the economic risks of a hydrogen economy are much smaller for Greece and following the right strategy promise a significant gain in employment, welfare and GDP effects.
- Compared with relevant competitors the lead market potential for hydrogen vehicle production and stack production in Greece is limited.

8.2 MS Results: France

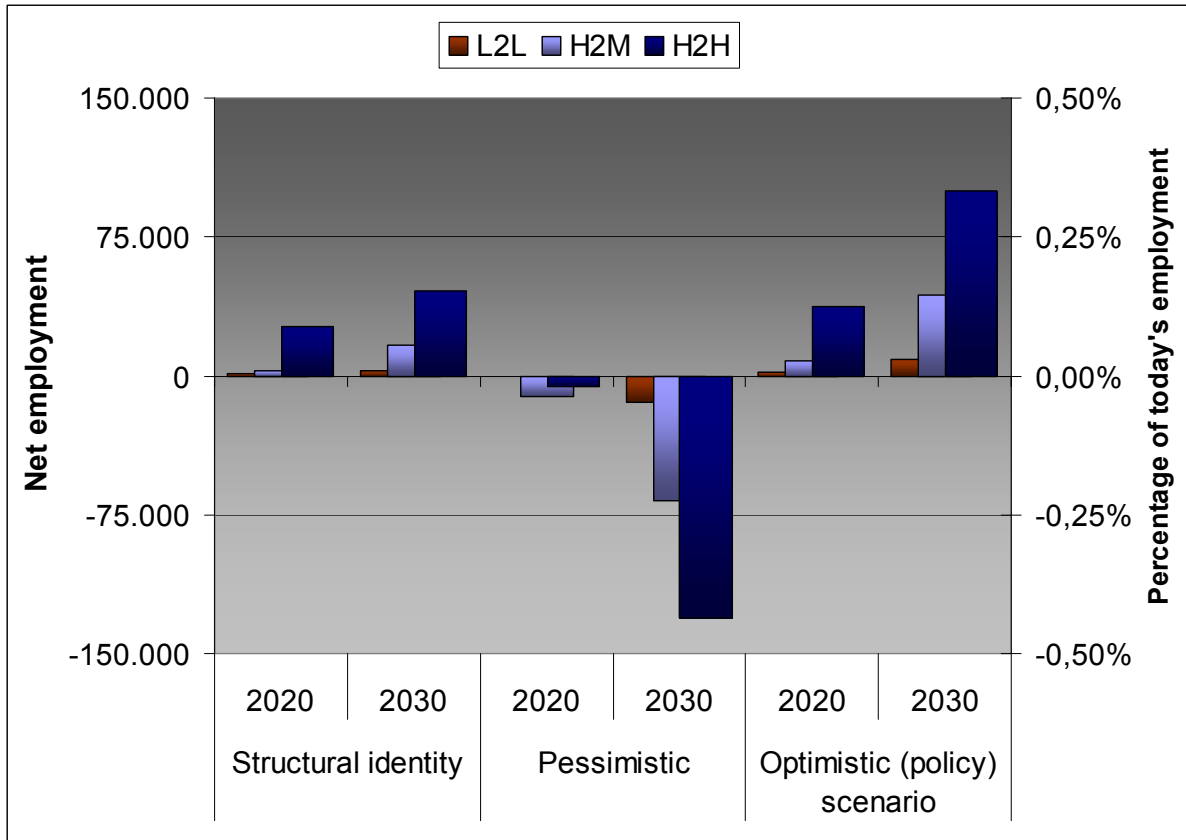


Figure 47: Net employment effects for the hydrogen high penetration (H2H), and medium penetration (H2M) scenarios with optimistic learning rates for hydrogen passenger cars. As well as hydrogen low penetration (L2L) scenarios with moderate learning rates for hydrogen passenger cars for the year 2020 and 2030. Shown are the overall net employment effects for France in three import and export scenarios.

8.2.1 High learning scenario high penetration rates

Effect France, scenario structural identity, year 2030

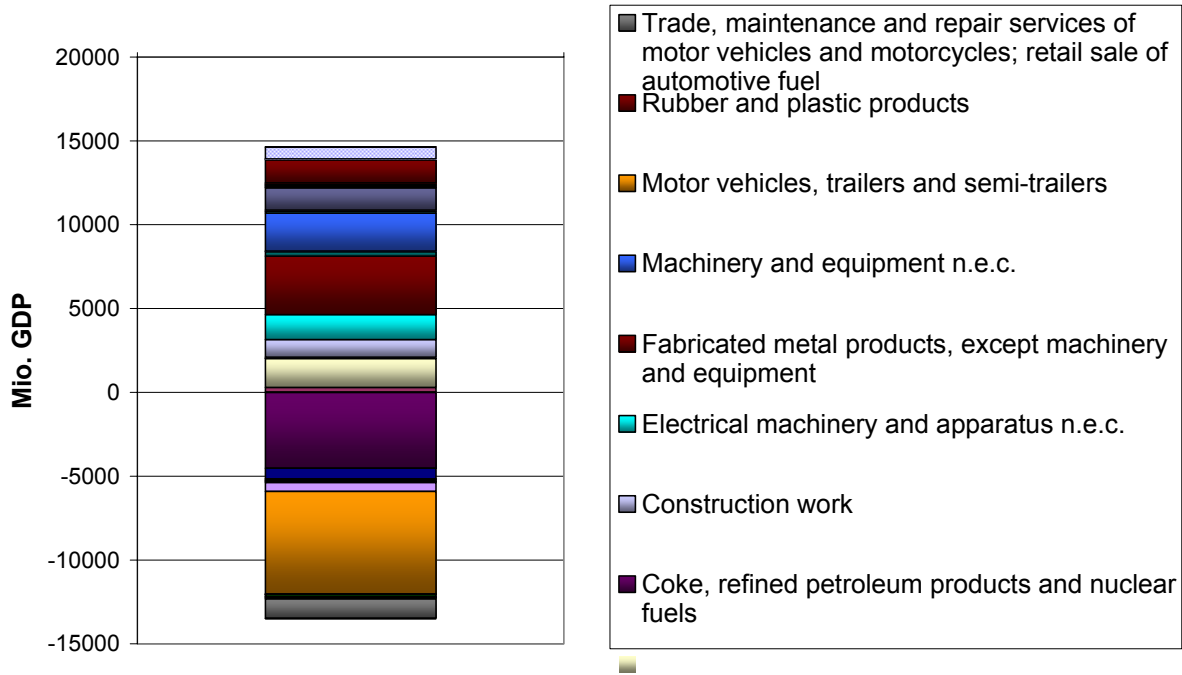


Figure 48: Sectoral economic effects France 2030 optimistic learning high penetration (H2H)

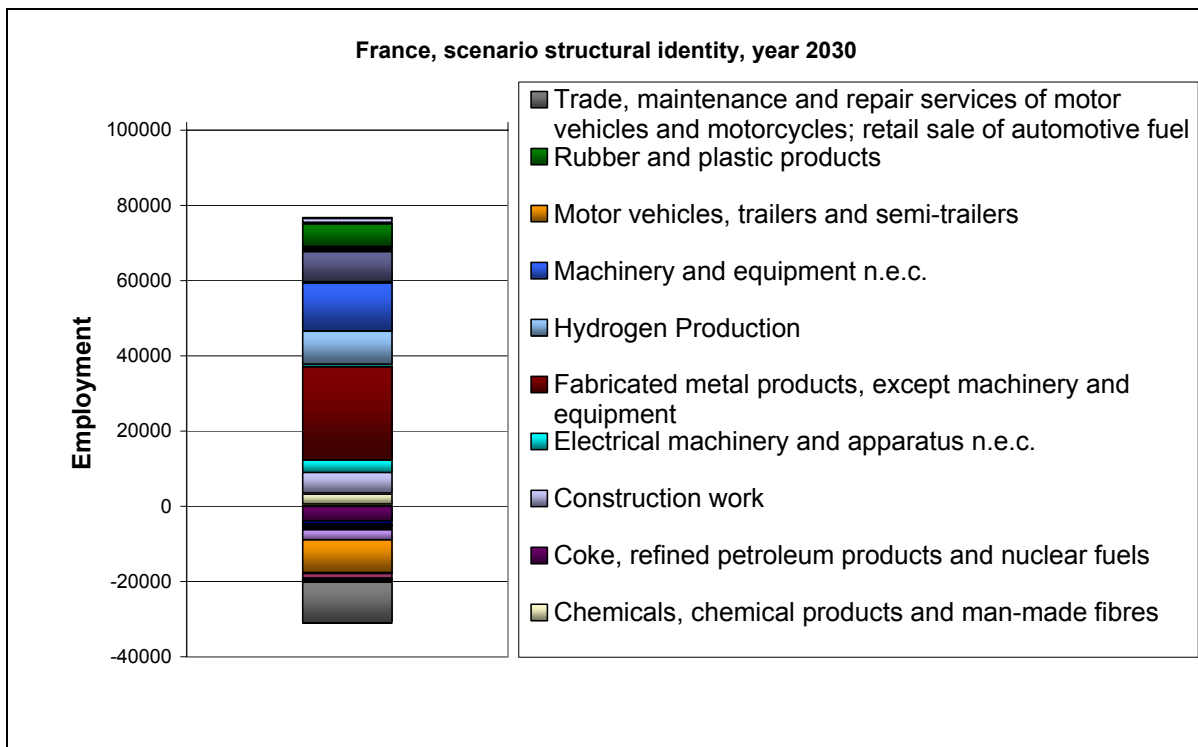


Figure 49: Sectoral employment shifts for France optimistic learning high penetration (H2H)

8.2.2 High learning scenario medium penetration rate

Effect France, scenario structural identity, year 2030

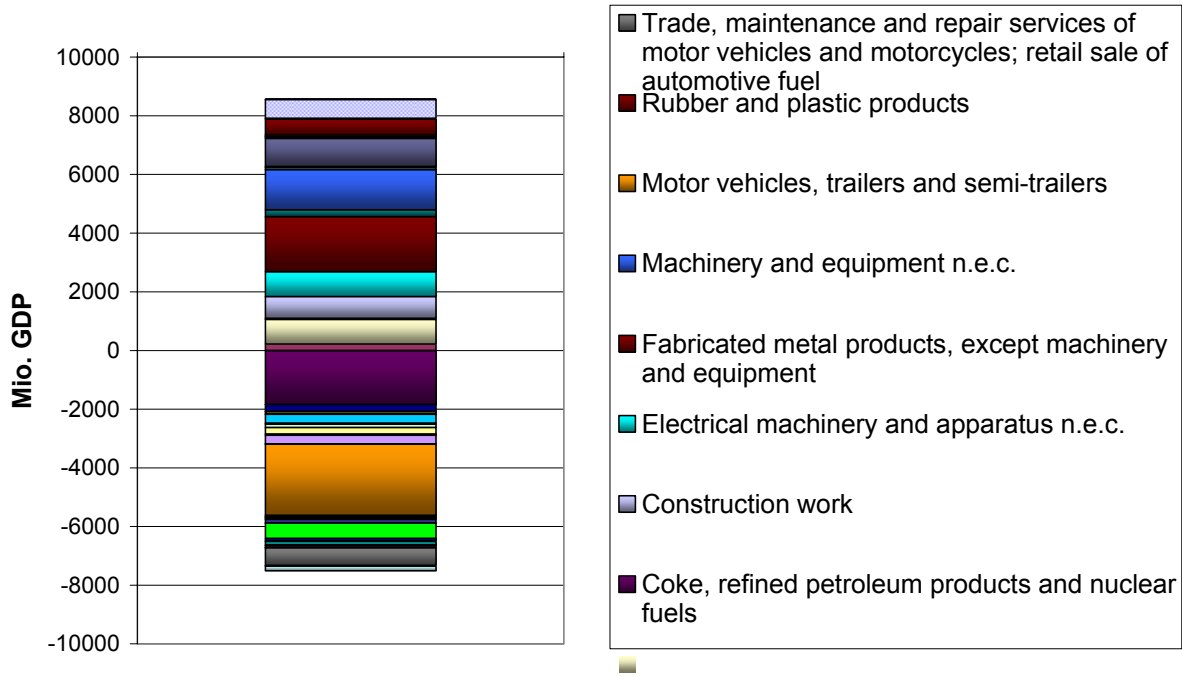


Figure 50: Sectoral economic effects France 2030 optimistic learning medium penetration (H2M)

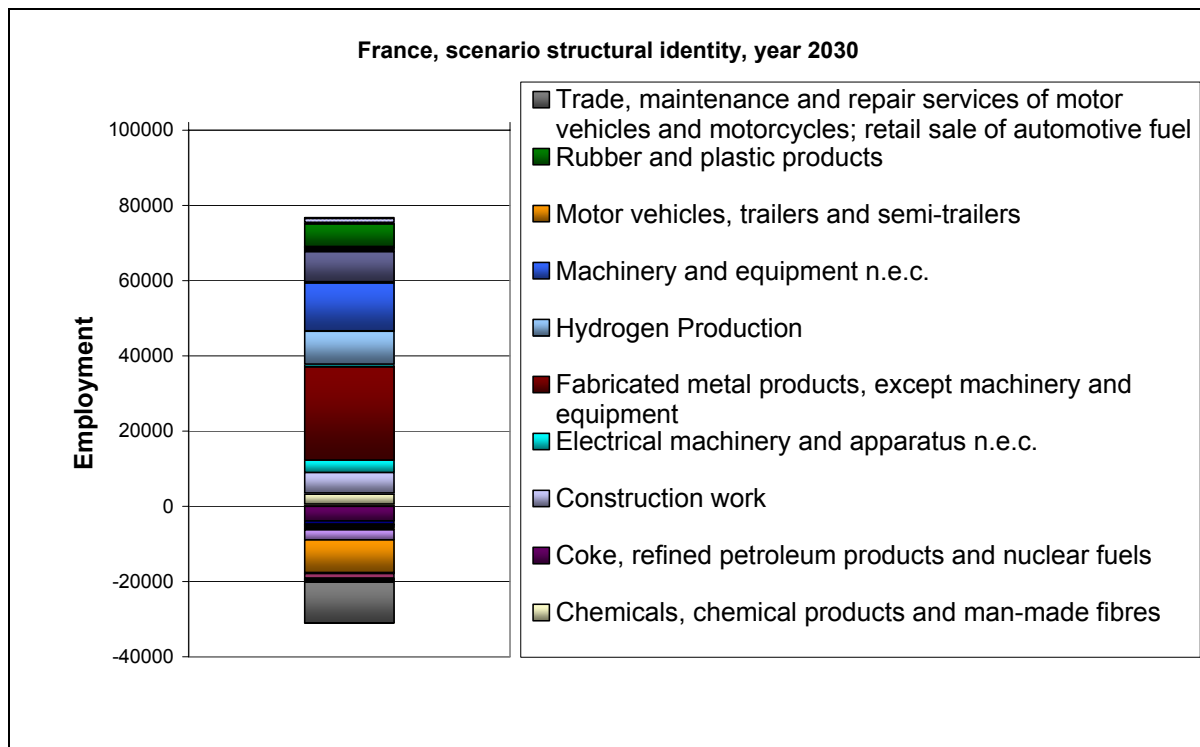


Figure 51: Sectoral employment shifts for France optimistic learning medium penetration (H2M)

8.2.3 Moderate learning scenario low penetration rates

Effect France, scenario structural identity, year 2030

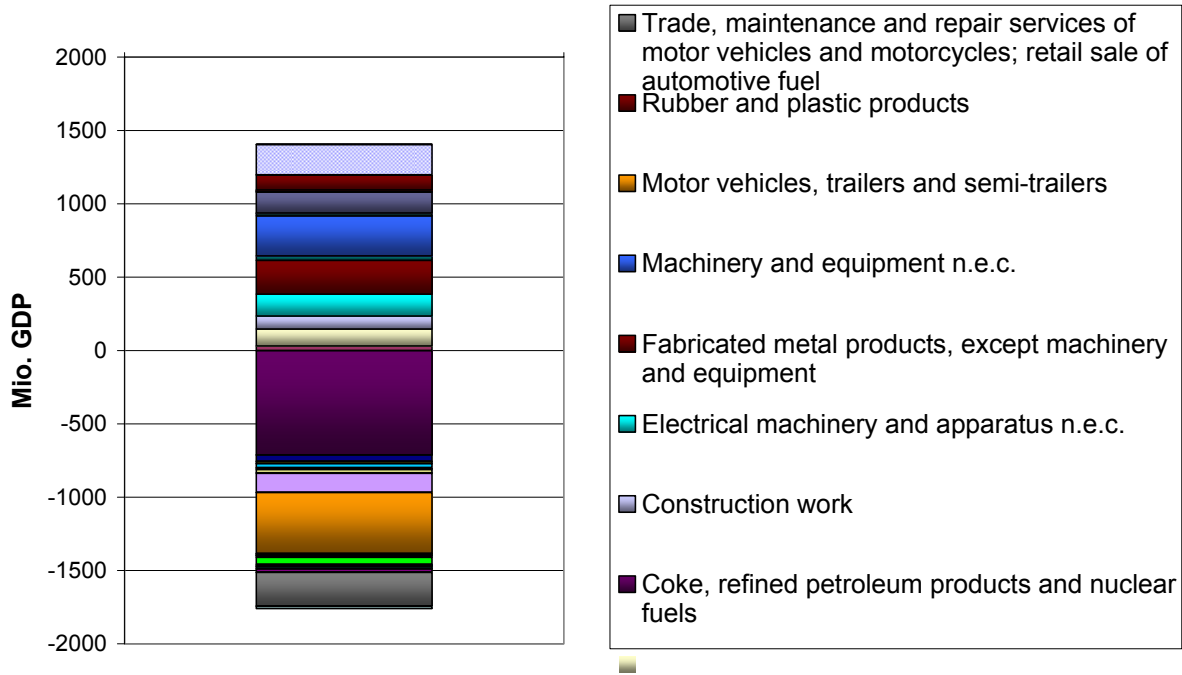


Figure 52: Sectoral economic effects France 2030 moderate learning low penetration (M2L)

France, scenario structural identity, year 2030

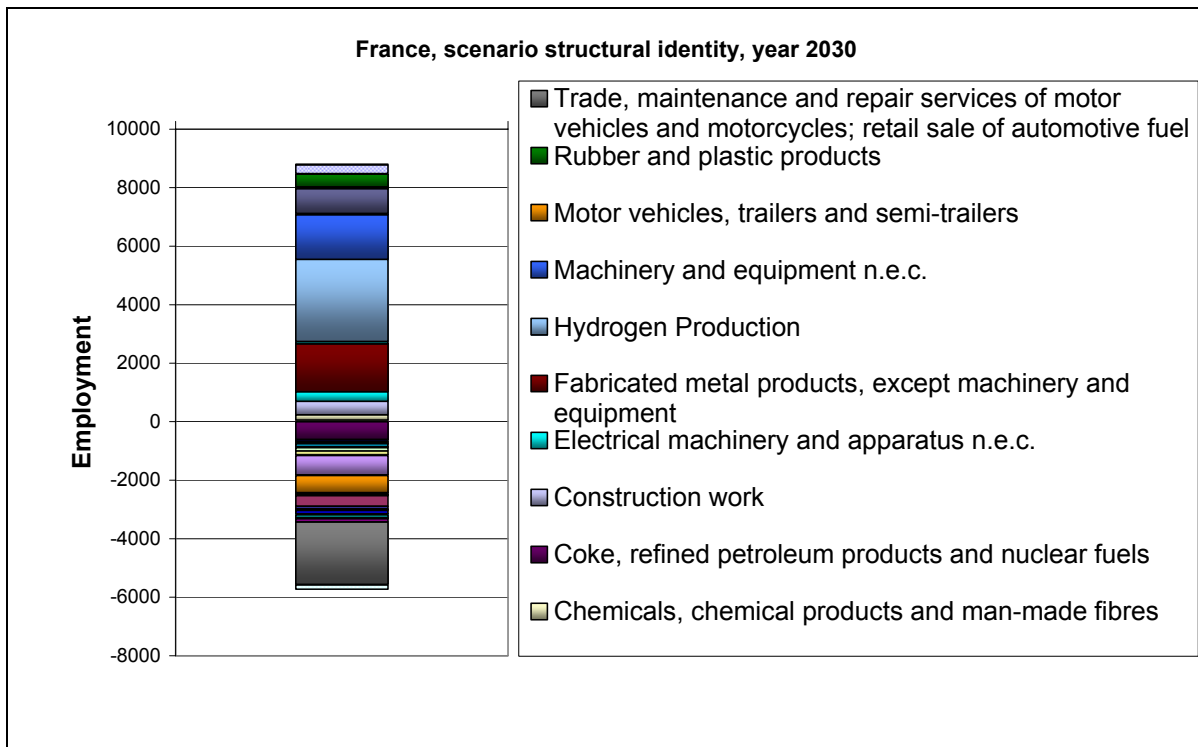


Figure 53: Sectoral employment shifts for France moderate learning low penetration (M2L)

8.2.4 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.

8.3 MS Results: Germany

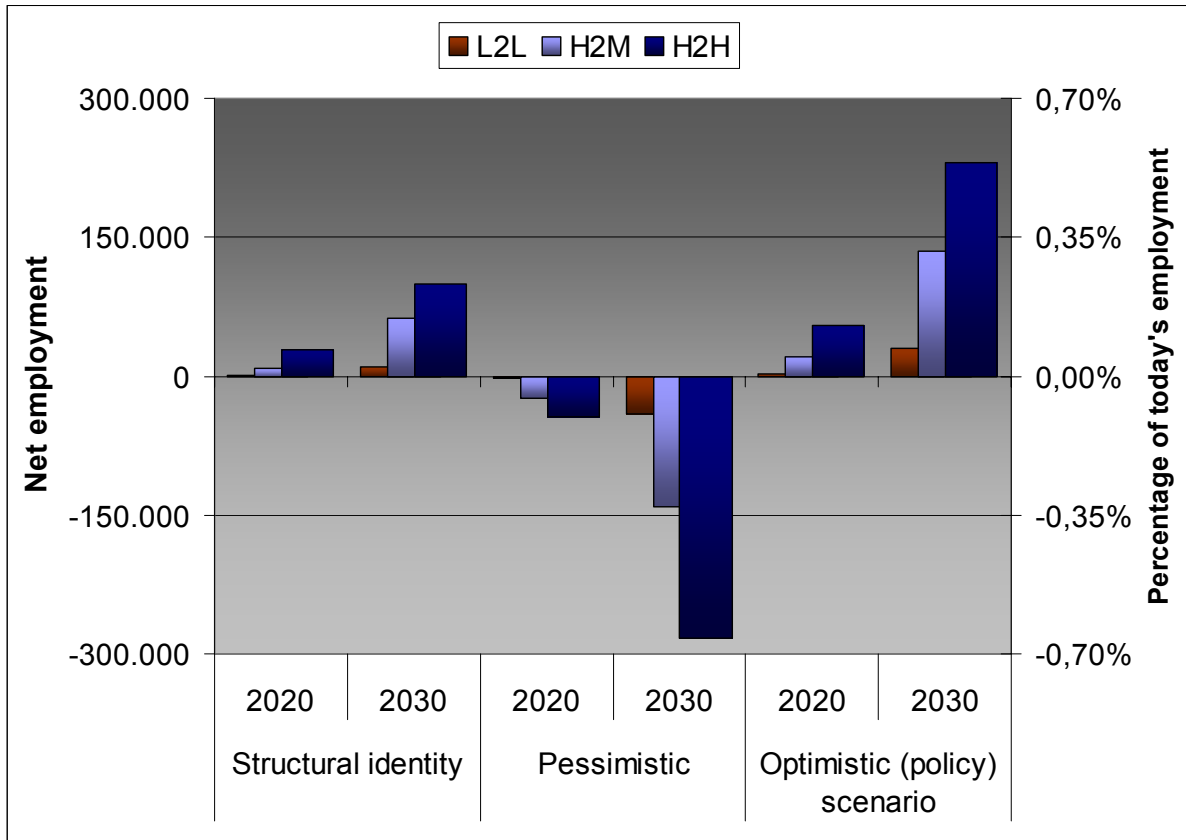


Figure 54: Net employment effects for the hydrogen high penetration (H2H), and medium penetration (H2M) scenarios with optimistic learning rates for hydrogen passenger cars. As well as hydrogen low penetration (L2L) scenarios with moderate learning rates for hydrogen passenger cars for the year 2020 and 2030. Shown are the overall net employment effects for Germany in three import and export scenarios.

8.3.1 High learning scenario high penetration rates

Effect Germany, scenario structural identity, year 2030

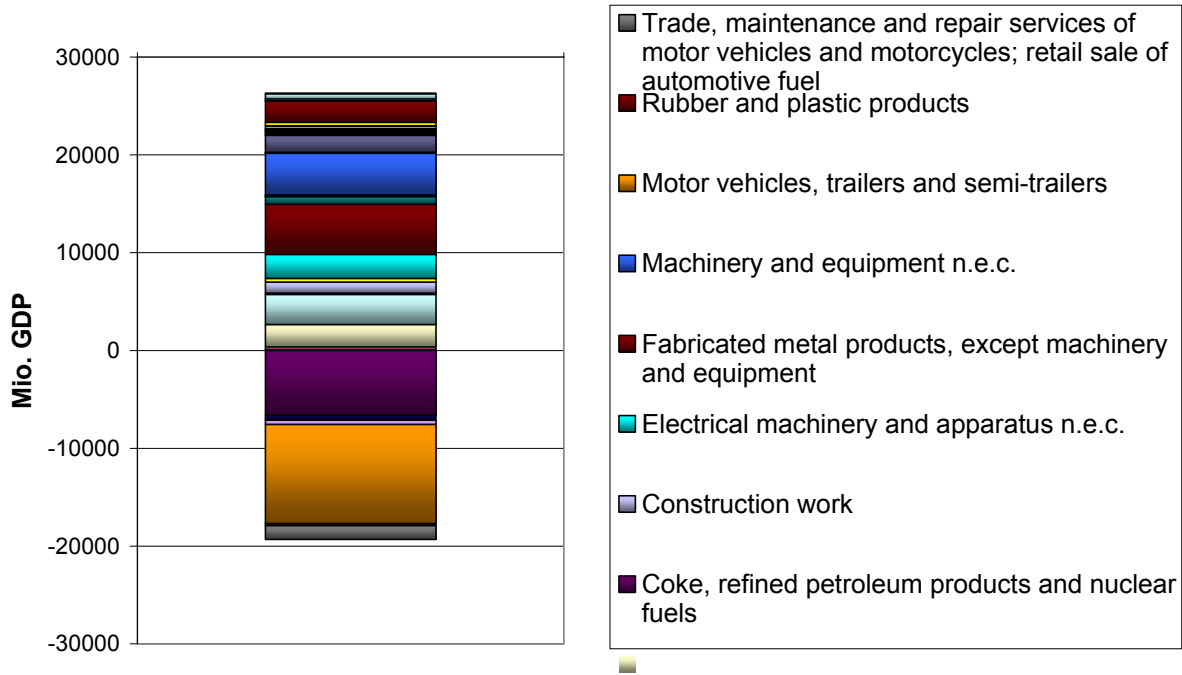


Figure 55: Sectoral economic effects Germany 2030 optimistic learning high penetration (H2H)

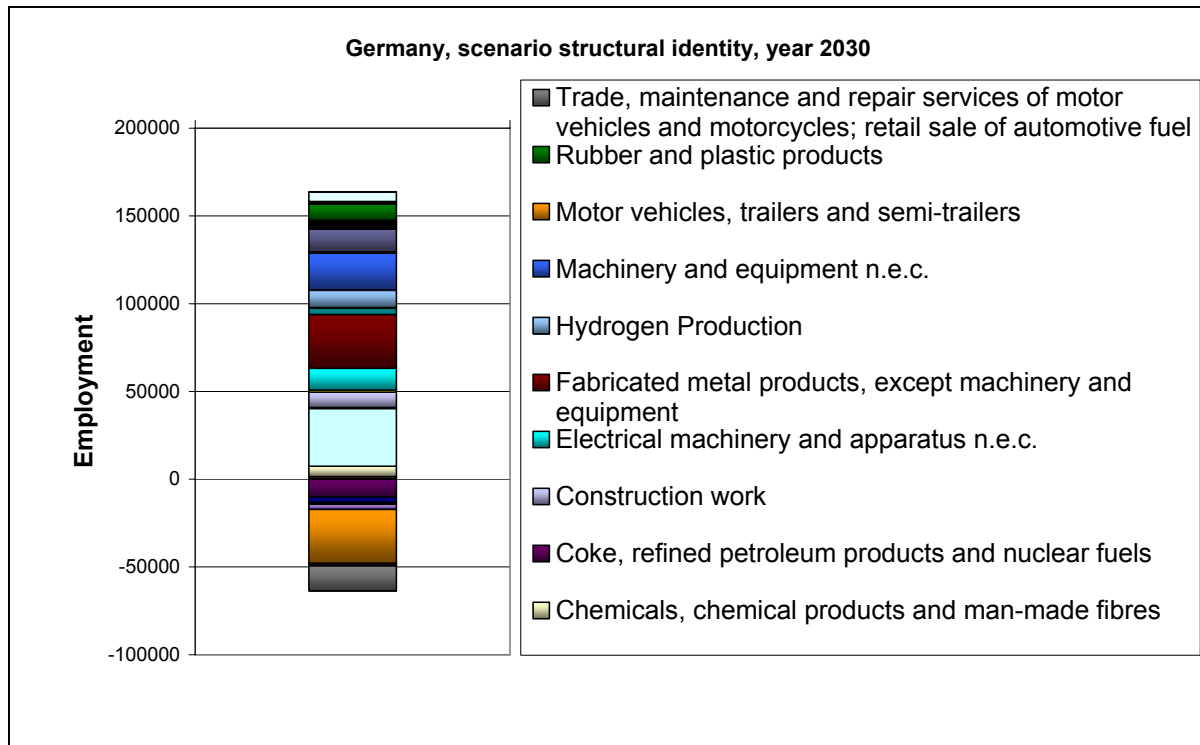


Figure 561: Sectoral employment shifts for Germany optimistic learning high penetration (H2H)

8.3.2 High learning scenario medium penetration rates

Effect Germany, scenario structural identity, year 2030

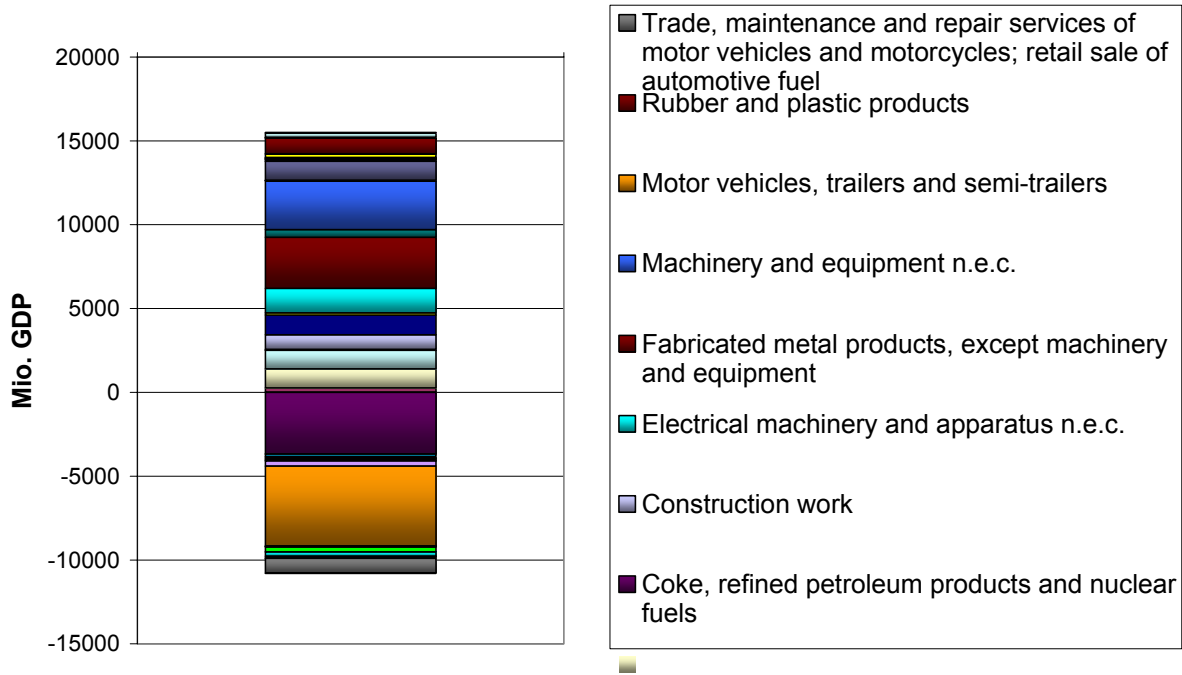


Figure 57: Sectoral economic effects Germany 2030 optimistic learning medium penetration (H2M)

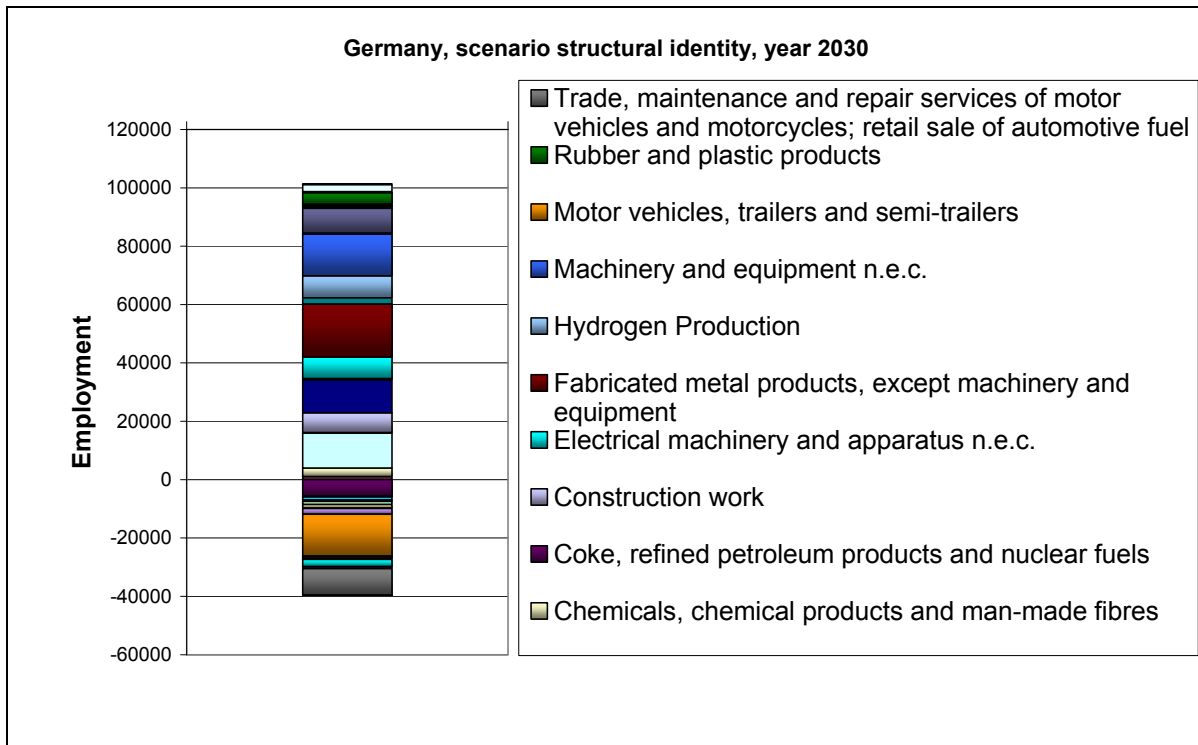


Figure 58: Sectoral employment shifts for Germany optimistic learning medium penetration (H2M)

8.3.3 Moderate learning scenario low penetration rates

Effect Germany, scenario structural identity, year 2030

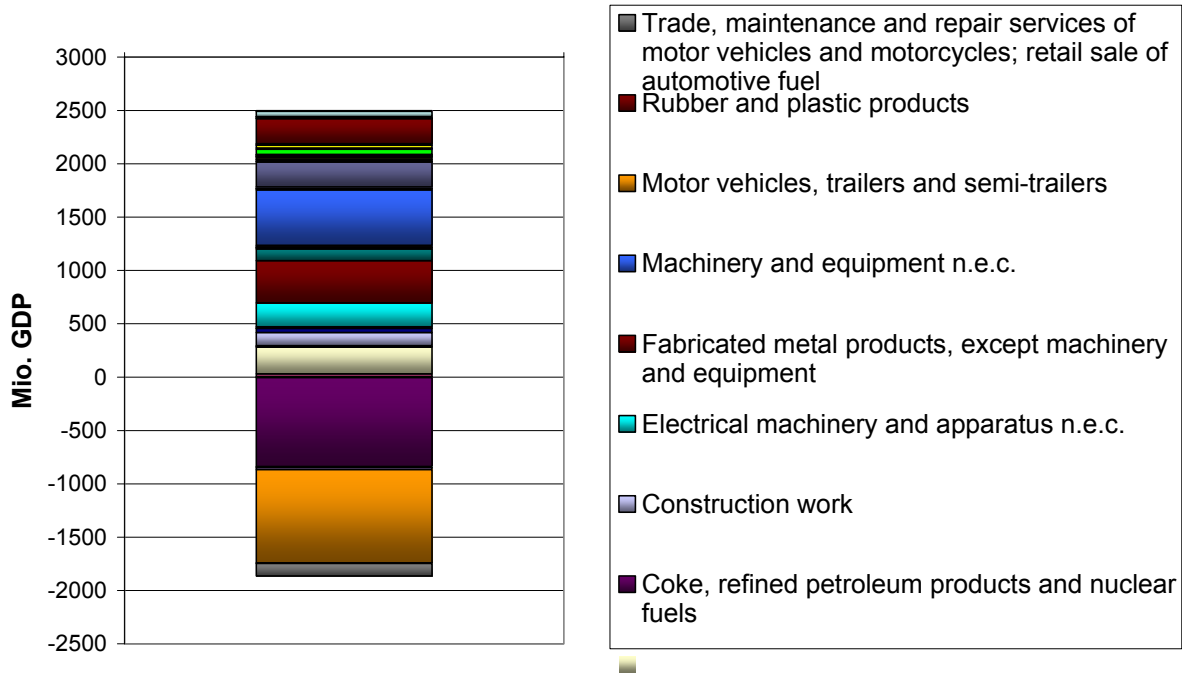


Figure 59: Sectoral economic effects Germany 2030 moderate learning low penetration (M2L)

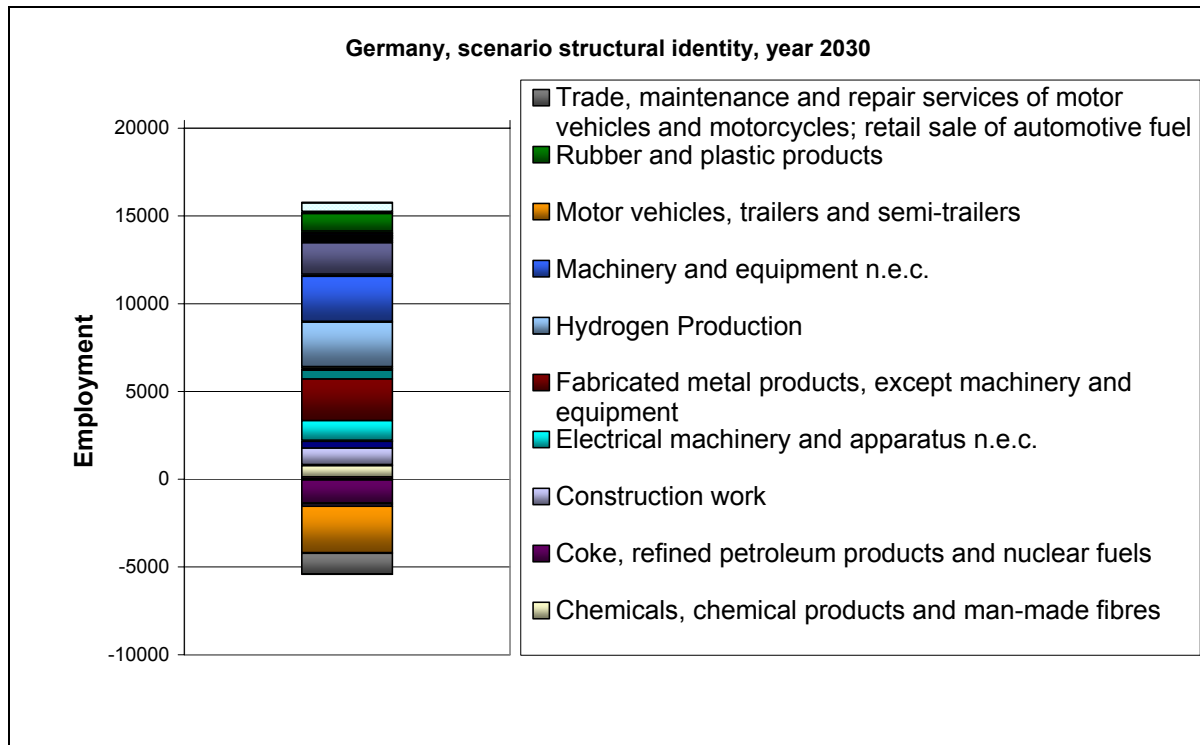


Figure 60: Sectoral employment shifts for Germany moderate learning low penetration (H2L)

8.3.4 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

8.4 MS Results: Greece

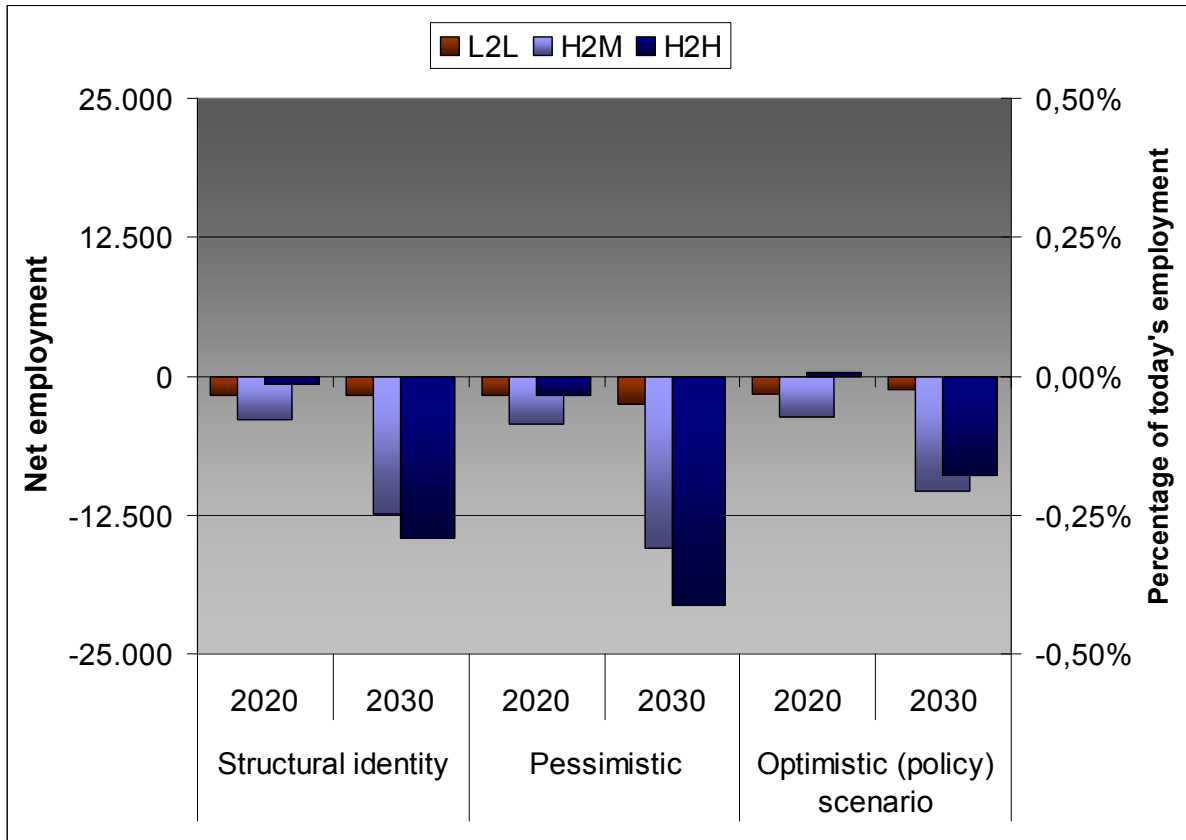


Figure 61: Net employment effects for the hydrogen high penetration (H2H), and medium penetration (H2M) scenarios with optimistic learning rates for hydrogen passenger cars. As well as hydrogen low penetration (L2L) scenarios with moderate learning rates for hydrogen passenger cars for the year 2020 and 2030. Shown are the overall net employment effects for Greece in three import and export scenarios.

8.4.2 High learning scenario medium penetration rates

Effect Greece, scenario structural identity, year 2030

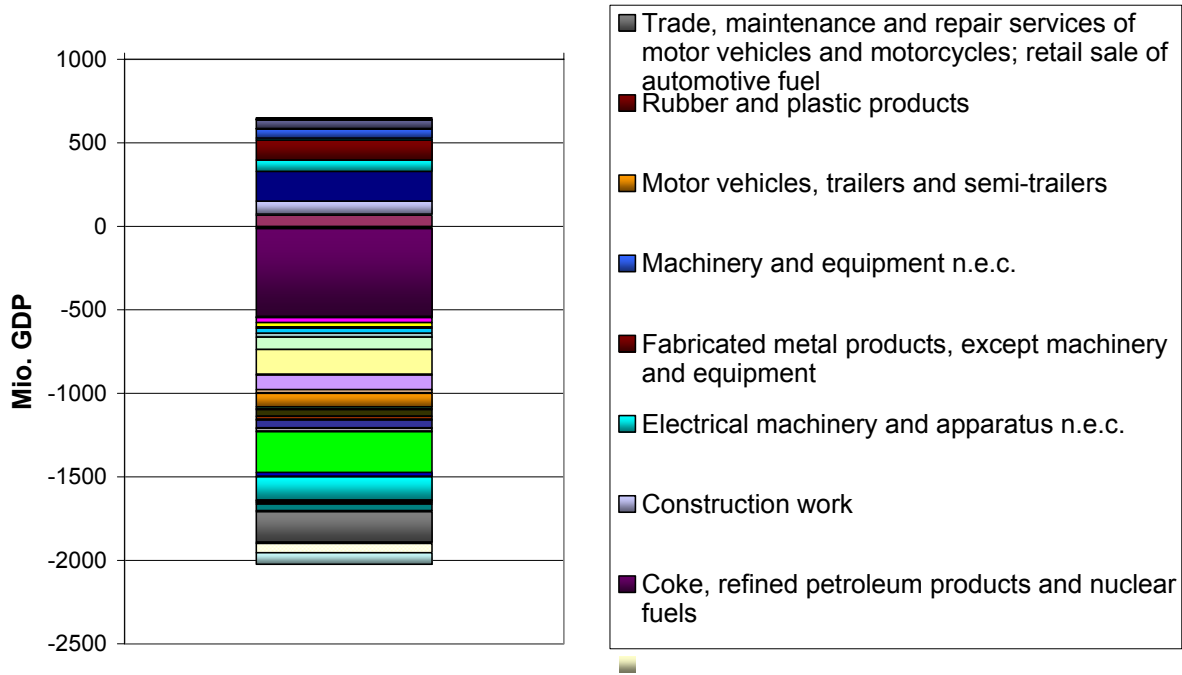


Figure 64: Sectoral economic effects Greece 2030 optimistic learning medium penetration (H2M)

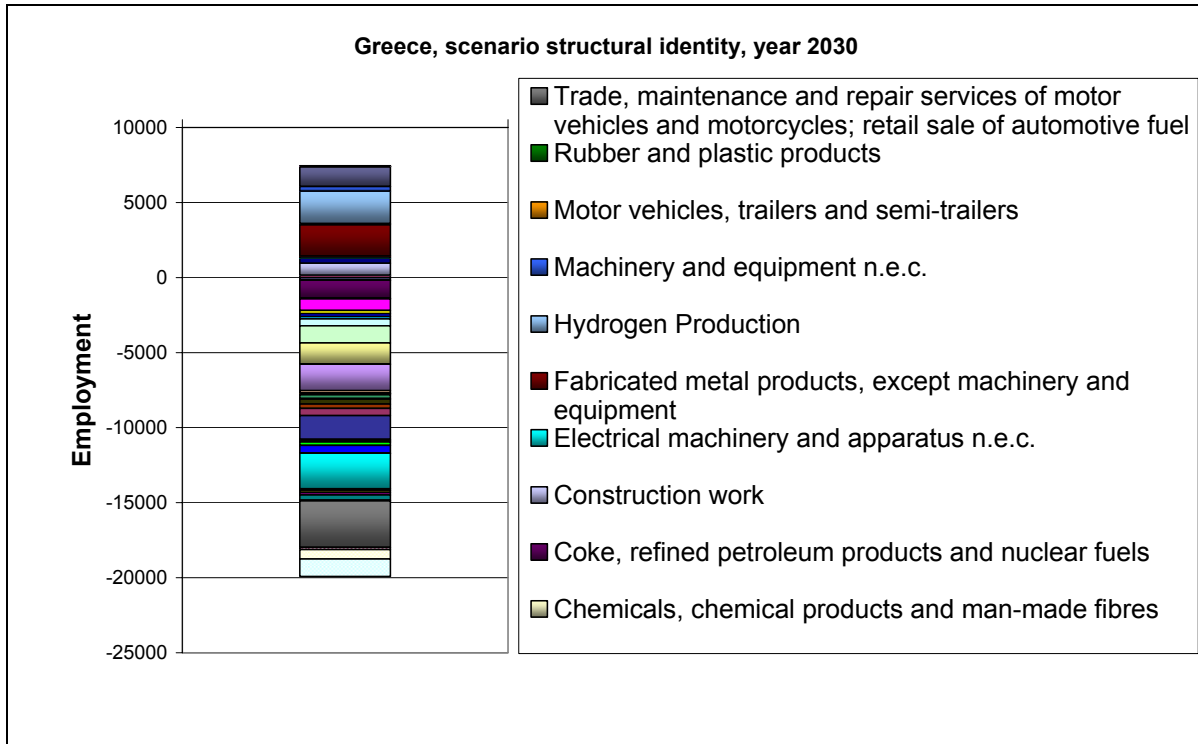


Figure 65: Sectoral employment shifts for Greece optimistic learning medium penetration (H2M)

8.4.3 Moderate learning scenario low penetration rates

Effect Greece, scenario structural identity, year 2030

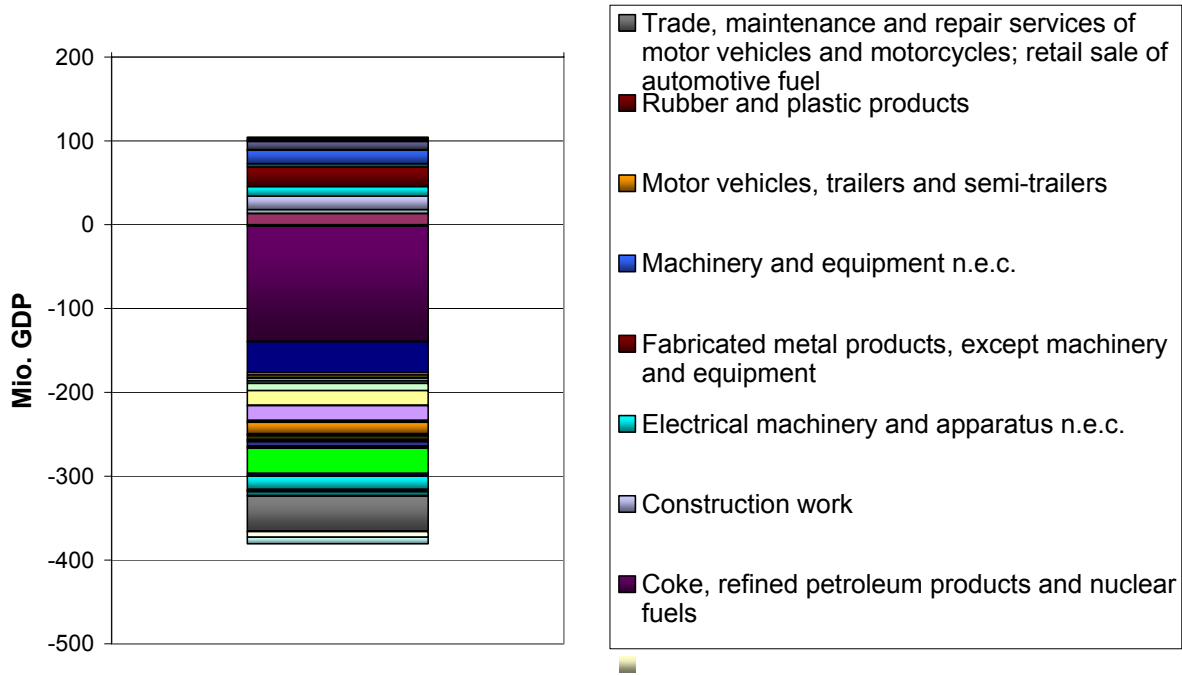


Figure 66: Sectoral economic effects Greece 2030 moderate learning low penetration (M2L)

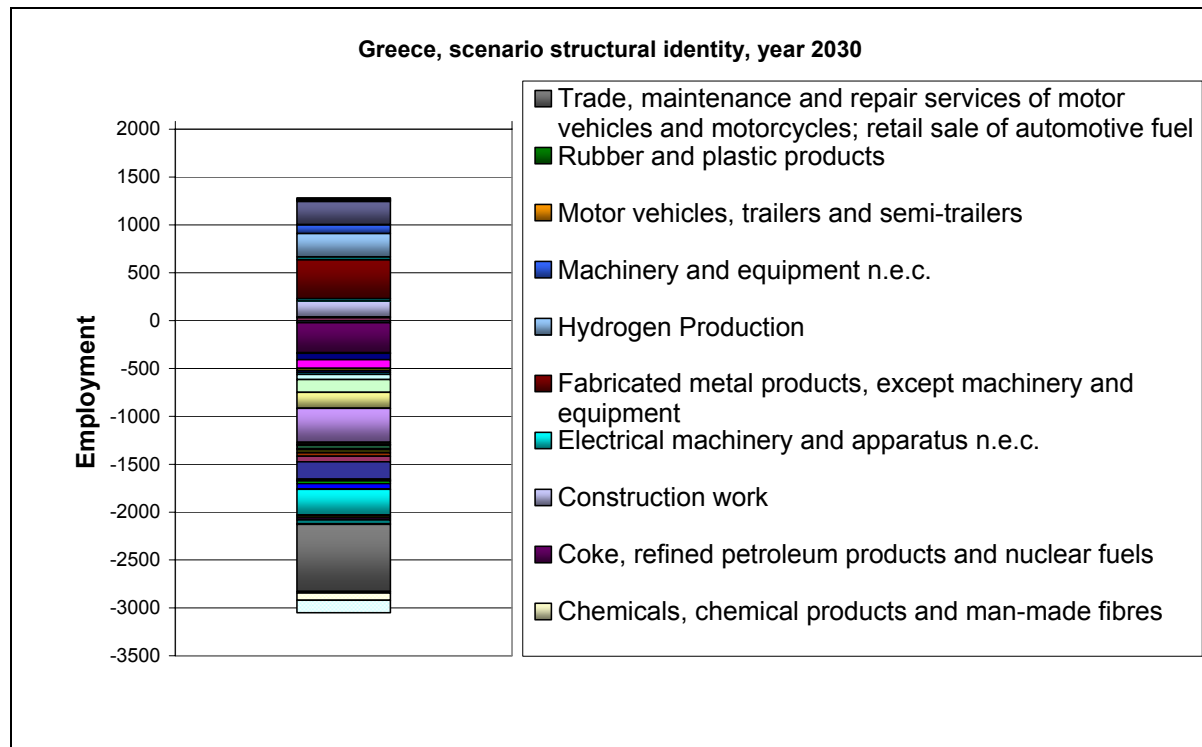


Figure 67: Sectoral employment shifts for Greece moderate learning low penetration (M2L)

8.4.4 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.
- Compared with large automobile countries the economic risks of a hydrogen economy are much smaller for Greece and following the right strategy promise a significant gain in employment, welfare and GDP effects.
- Compared with relevant competitors the lead market potential for hydrogen vehicle production and stack production in Greece is limited.

8.5 MS Results: Italy

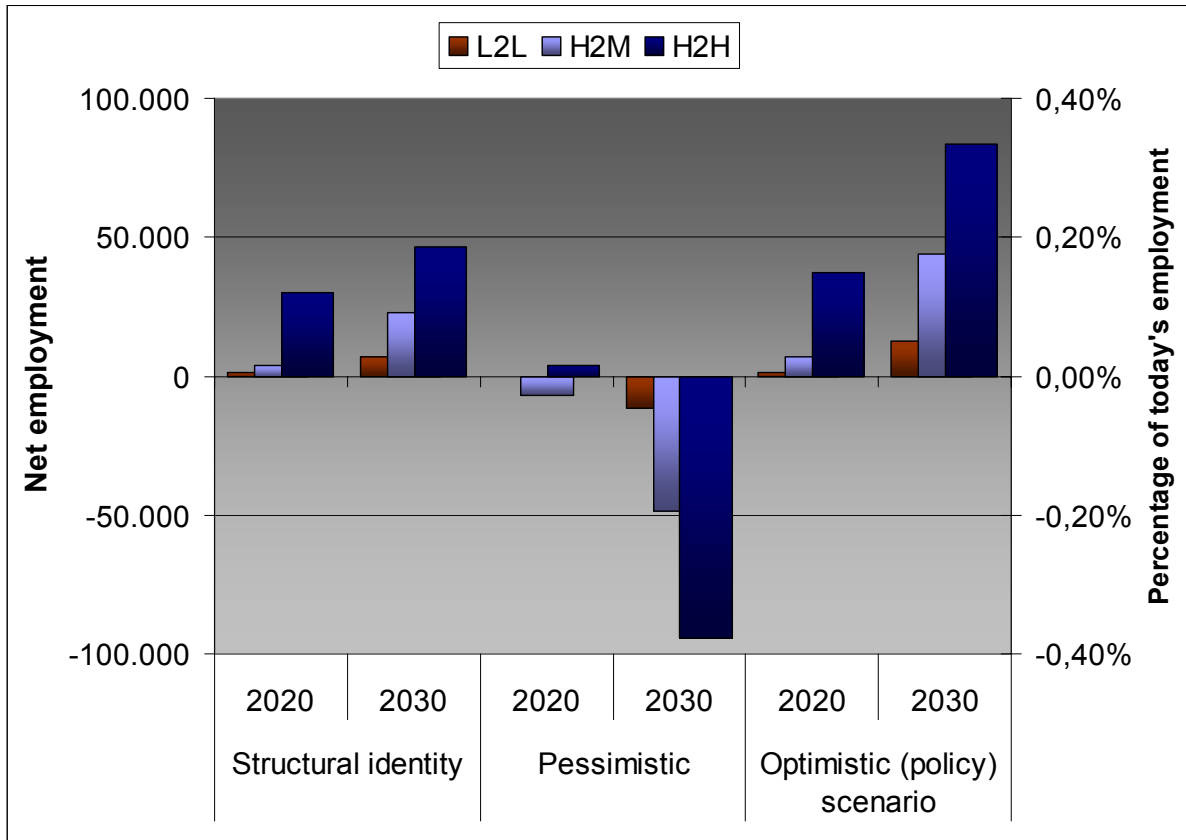


Figure 68: Net employment effects for the hydrogen high penetration (H2H), and medium penetration (H2M) scenarios with optimistic learning rates for hydrogen passenger cars. As well as hydrogen low penetration (L2L) scenarios with moderate learning rates for hydrogen passenger cars for the year 2020 and 2030. Shown are the overall net employment effects for Italy in three import and export scenarios.

8.5.1 High learning scenario high penetration rates

Effect Italy, scenario structural identity, year 2030

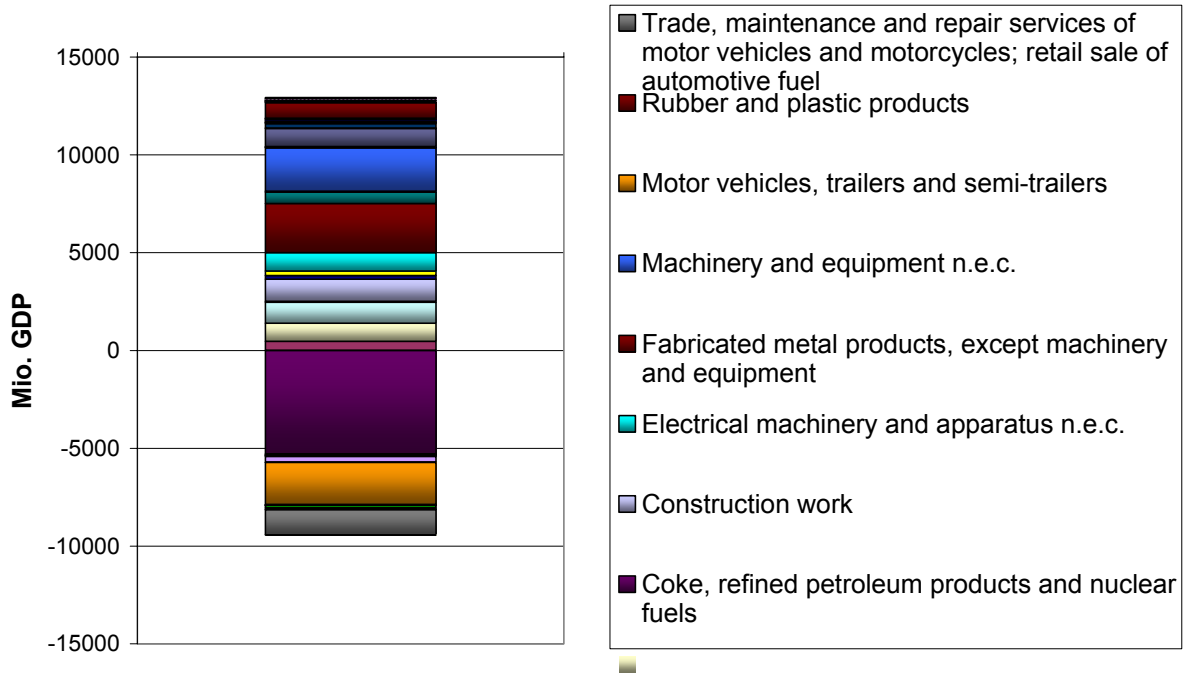


Figure 69: Sectoral economic effects Italy 2030 optimistic learning high penetration (H2H)

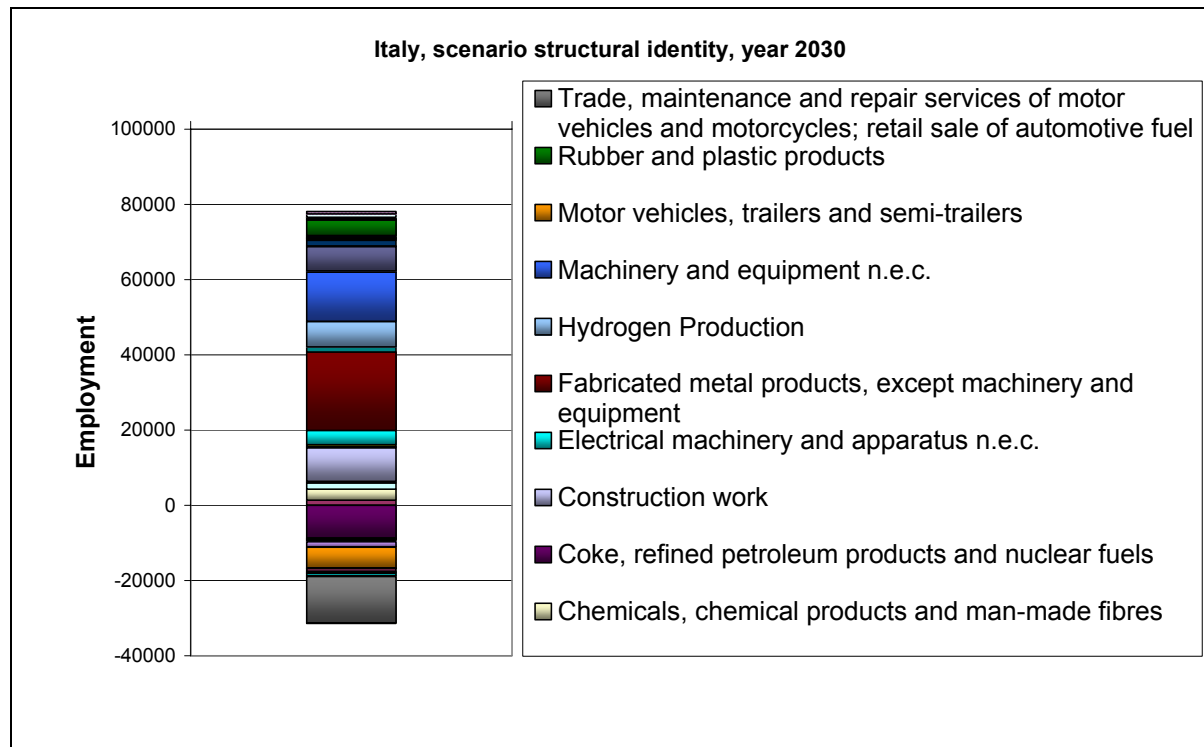


Figure 70: Sectoral employment shifts for Italy optimistic learning high penetration (H2H)

8.5.2 High learning scenario medium penetration rates

Effect Italy, scenario structural identity, year 2030

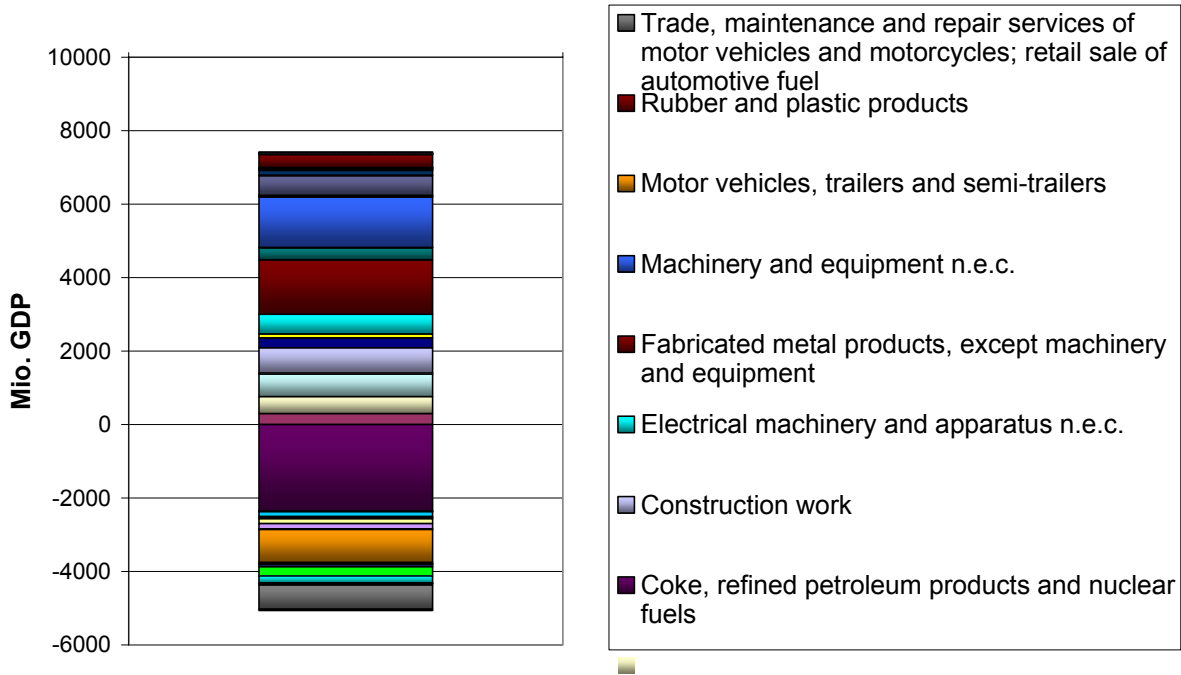


Figure 71: Sectoral economic effects Italy 2030 optimistic learning medium penetration (H2M)

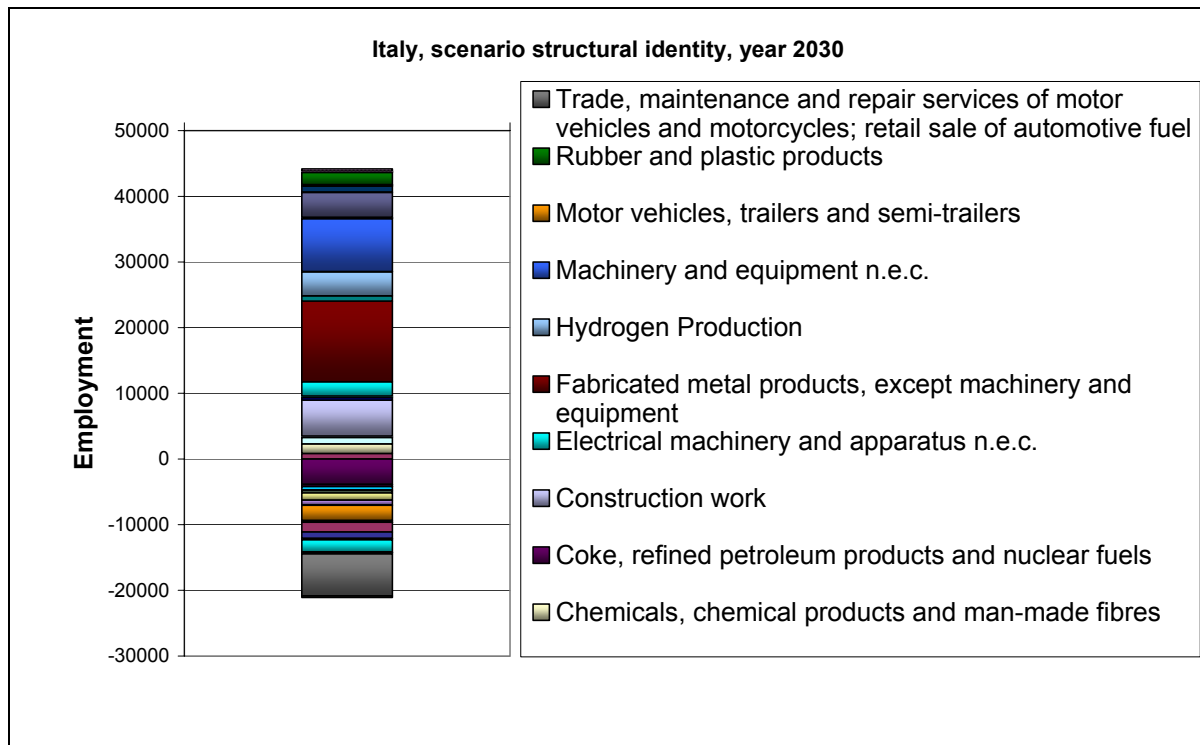


Figure 72: Sectoral employment shifts for Italy optimistic learning medium penetration (H2M)

8.5.3 Low learning scenario low penetration rates

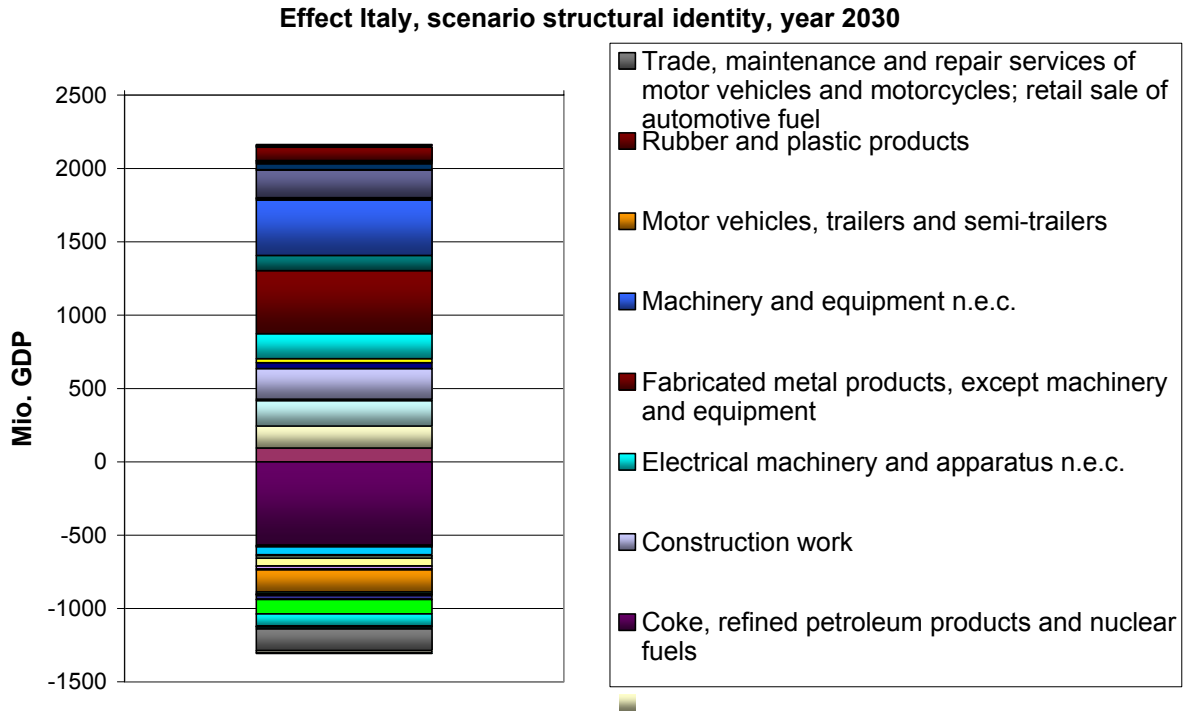


Figure 73: Sectoral economic effects Italy 2030 moderate learning low penetration (H2L)

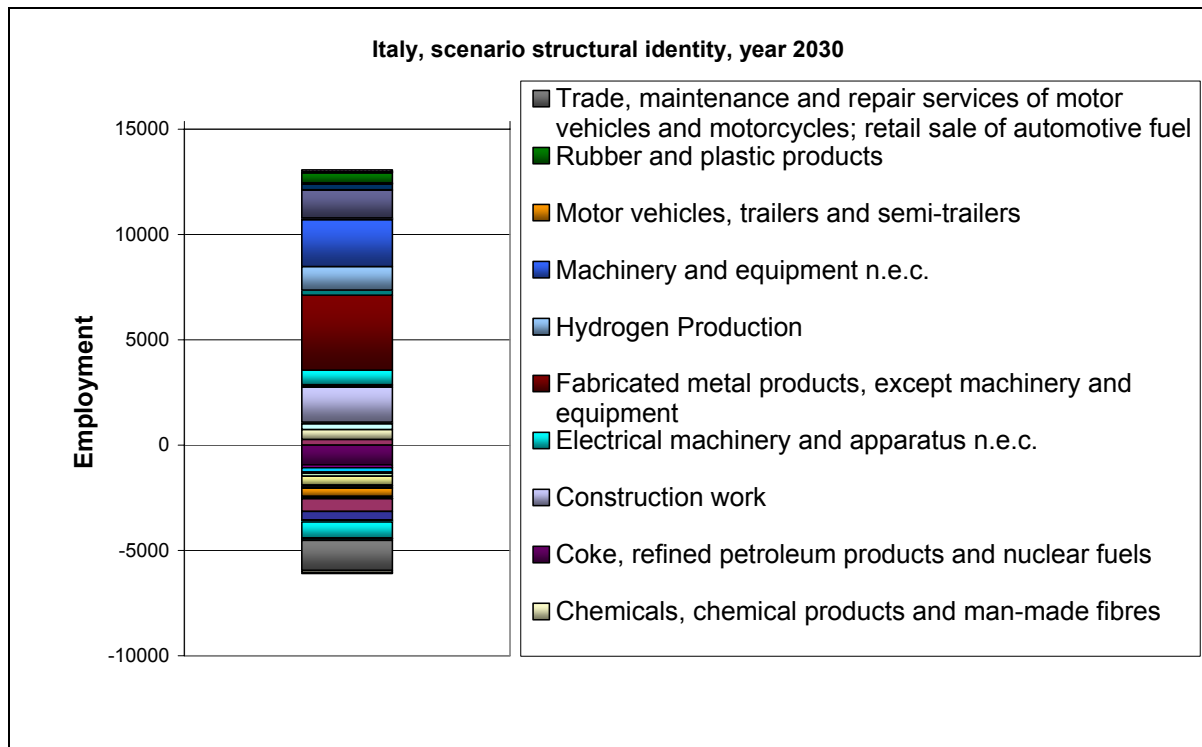


Figure 74: Sectoral employment shifts for Italy moderate learning low penetration (H2L)

8.5.4 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.

8.6 MS Results: The Netherlands

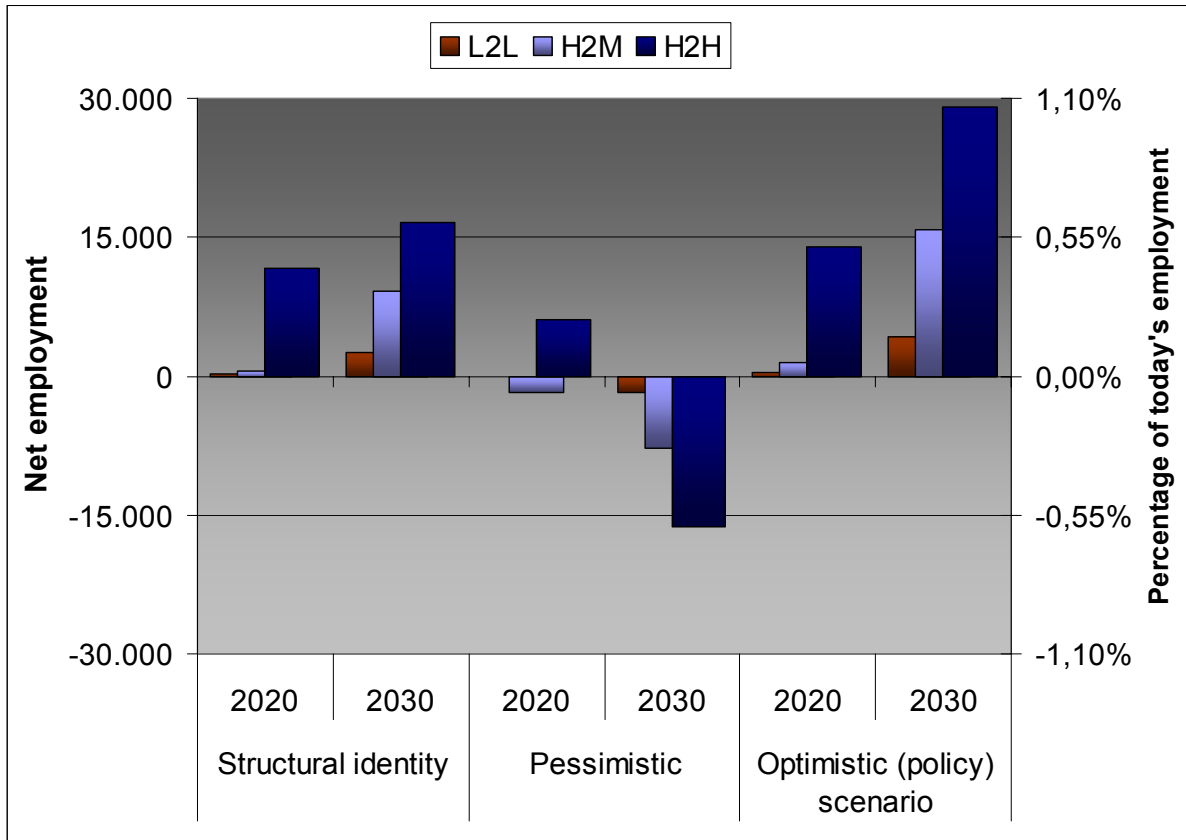


Figure 75: Net employment effects for the hydrogen high penetration (H2H), and medium penetration (H2M) scenarios with optimistic learning rates for hydrogen passenger cars. As well as hydrogen low penetration (L2L) scenarios with moderate learning rates for hydrogen passenger cars for the year 2020 and 2030. Shown are the overall net employment effects for Netherlands in three import and export scenarios.

8.6.1 High learning scenario high penetration rates

Effect The Netherlands, scenario structural identity, year 2030

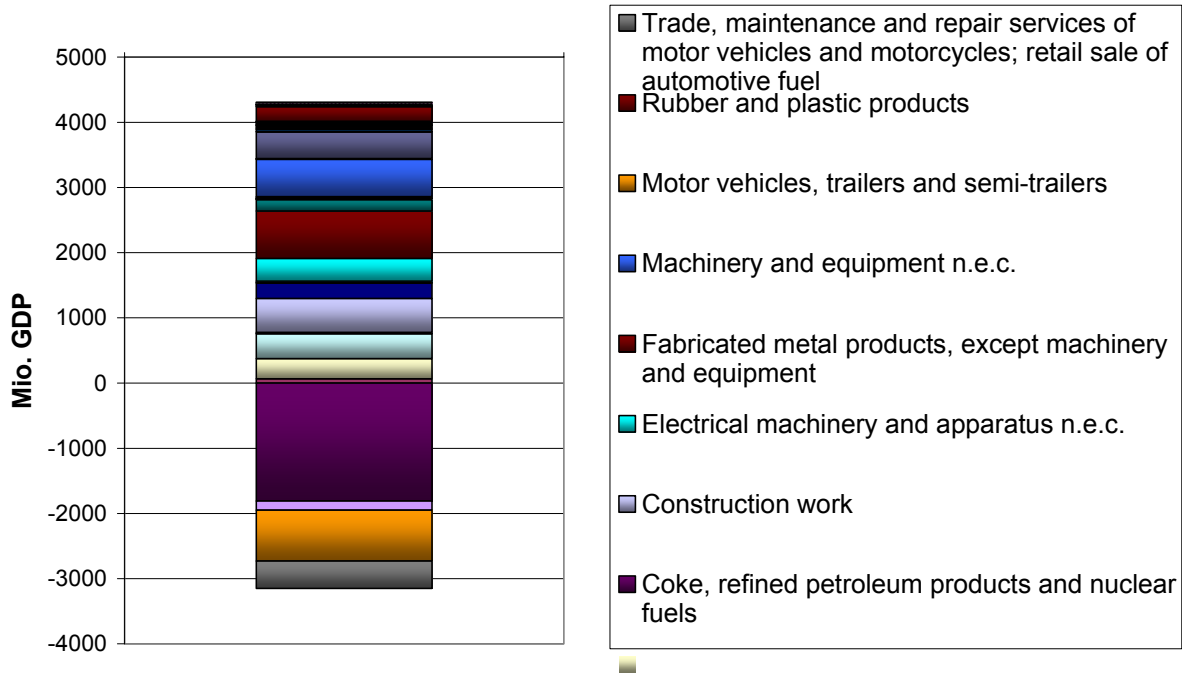


Figure 76: Sectoral economic effects The Netherlands 2030 optimistic learning high penetration (H2H)

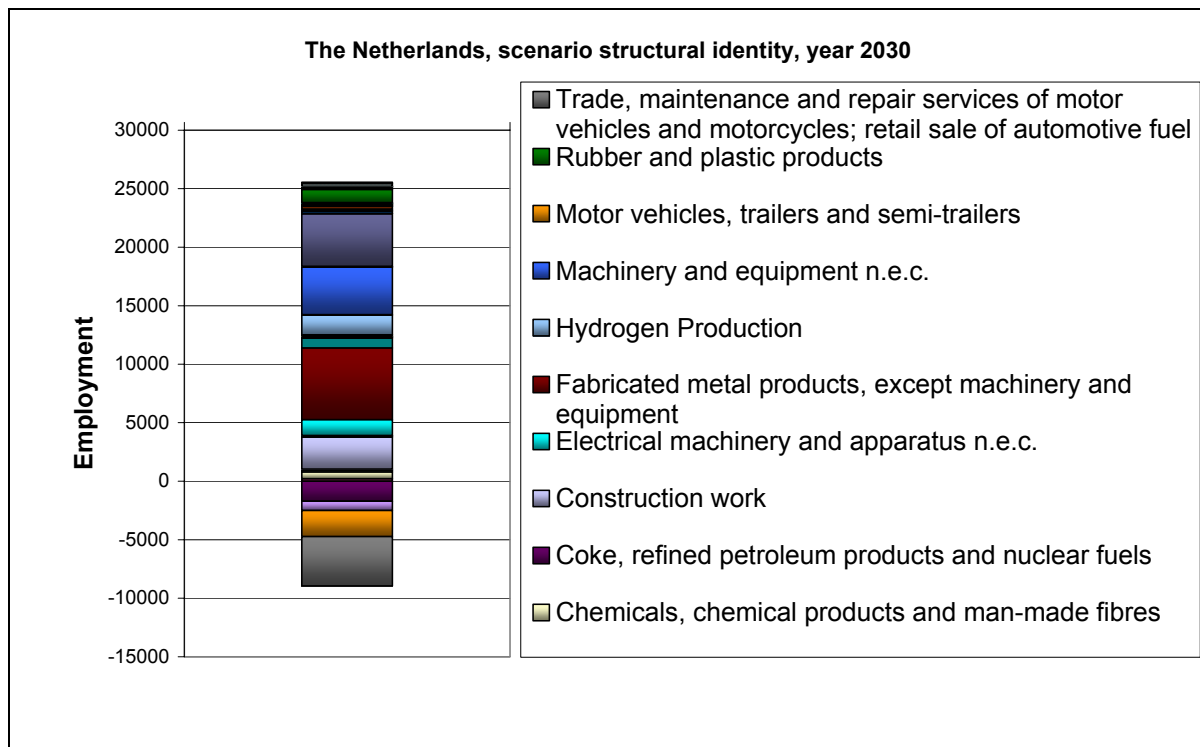


Figure 77: Sectoral employment shifts for The Netherlands optimistic learning high penetration (H2H)

8.6.2 High learning scenario medium penetration rates

Effect The Netherlands, scenario structural identity, year 2030

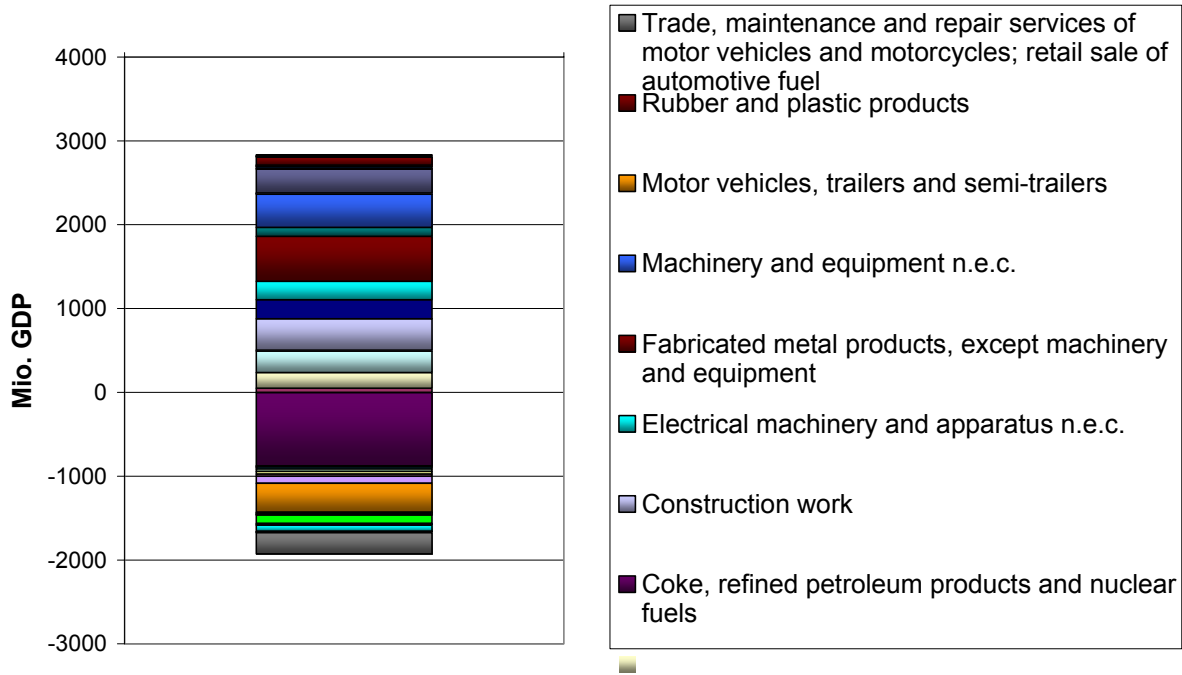


Figure 78: Sectoral economic effects The Netherlands 2030 optimistic learning medium penetration (H2M)

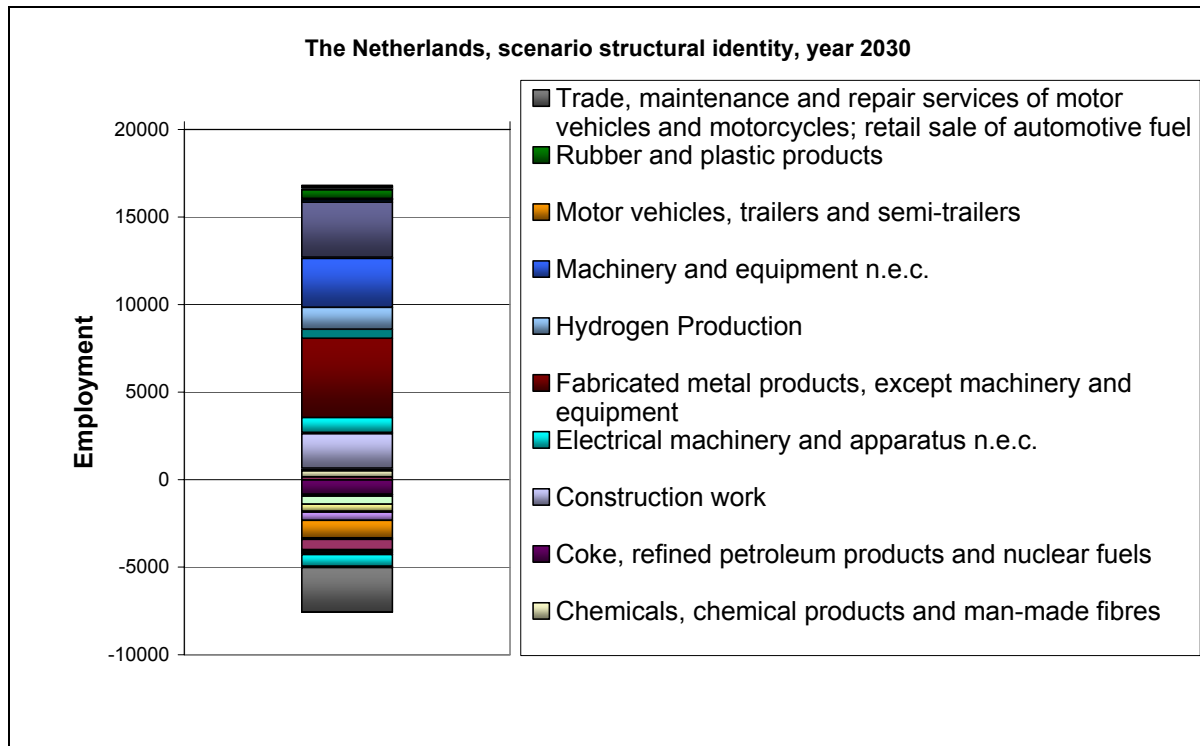


Figure 79: Sectoral employment shifts for The Netherlands optimistic learning medium penetration (H2M)

8.6.3 Moderate learning scenario low penetration rates

Effect The Netherlands, scenario structural identity, year 2030

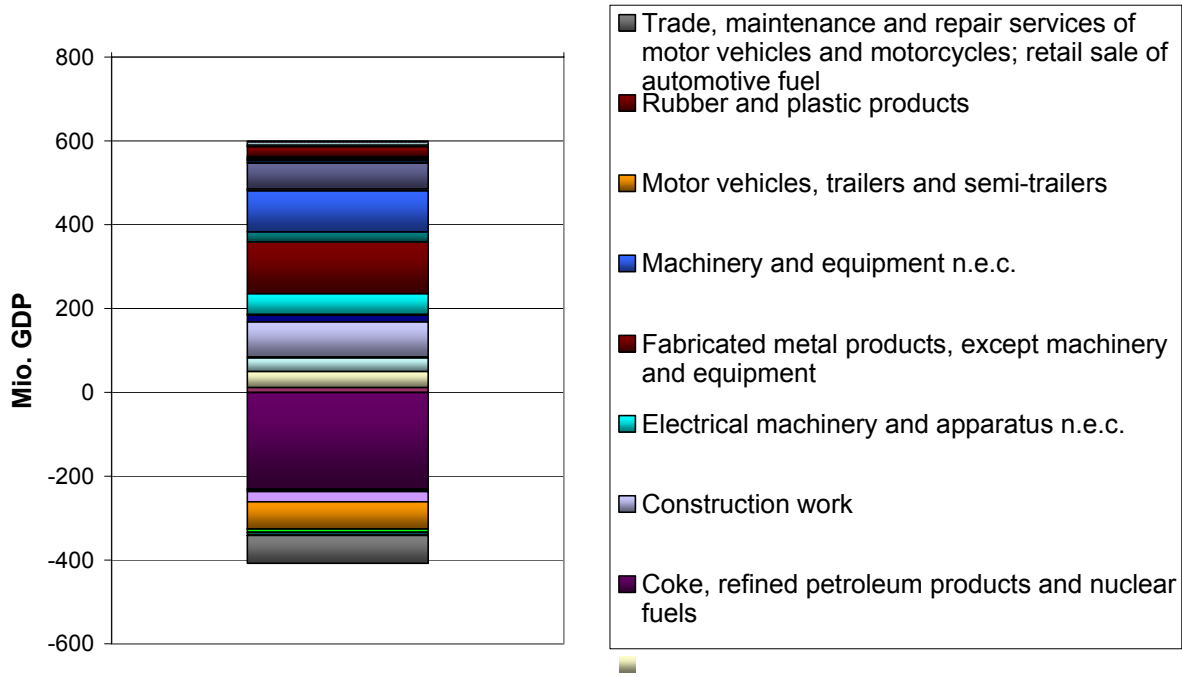


Figure 80: Sectoral economic effects The Netherlands 2030 moderate learning low penetration (M2L)

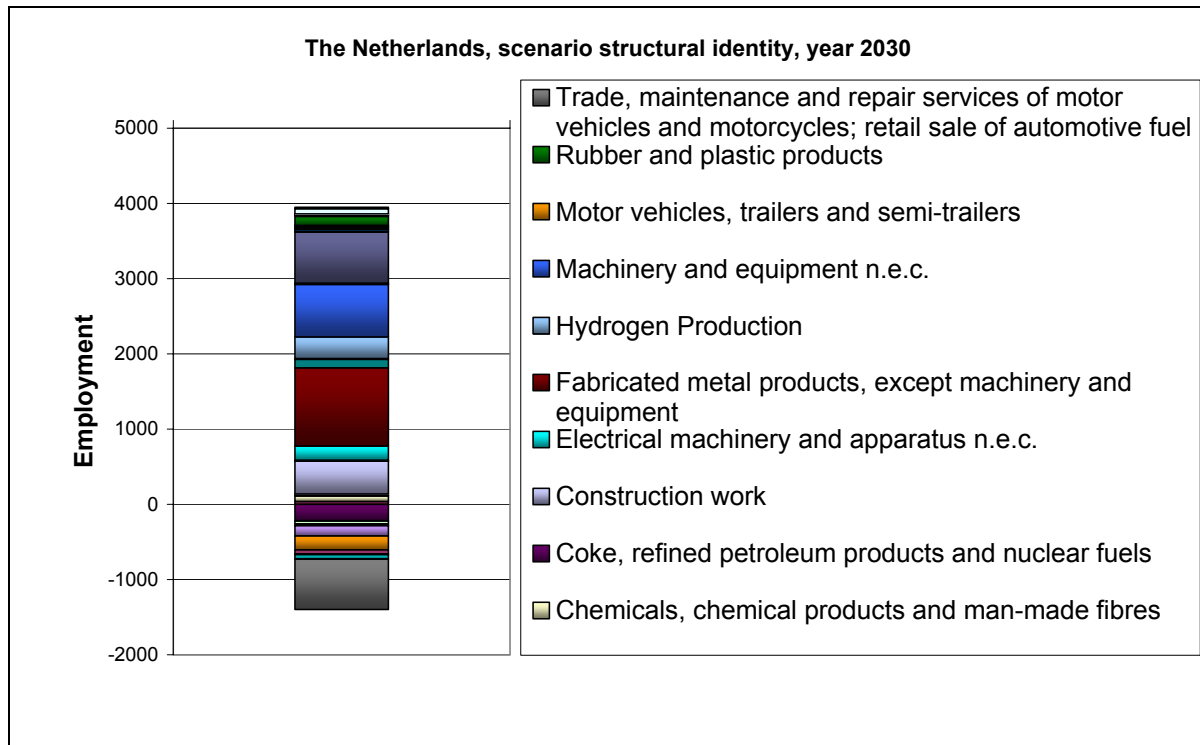


Figure 81: Sectoral employment shifts for The Netherlands moderate learning low penetration (M2L)

8.6.4 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.

8.7 MS Results: Norway

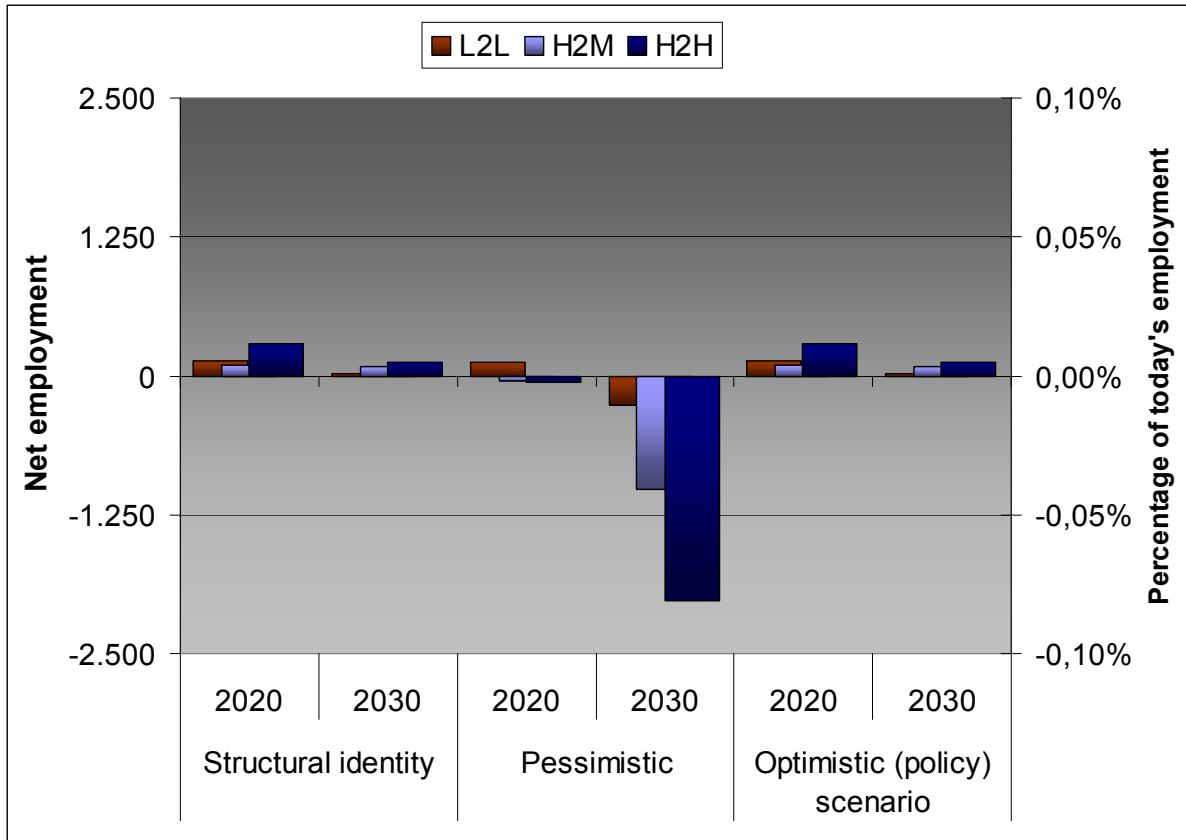


Figure 82: Net employment effects for the hydrogen high penetration (H2H), and medium penetration (H2M) scenarios with optimistic learning rates for hydrogen passenger cars. As well as hydrogen low penetration (L2L) scenarios with moderate learning rates for hydrogen passenger cars for the year 2020 and 2030. Shown are the overall net employment effects for Norway in three import and export scenarios.

8.7.1 High learning scenario moderate penetration rates

Effect Norway, scenario structural identity, year 2030

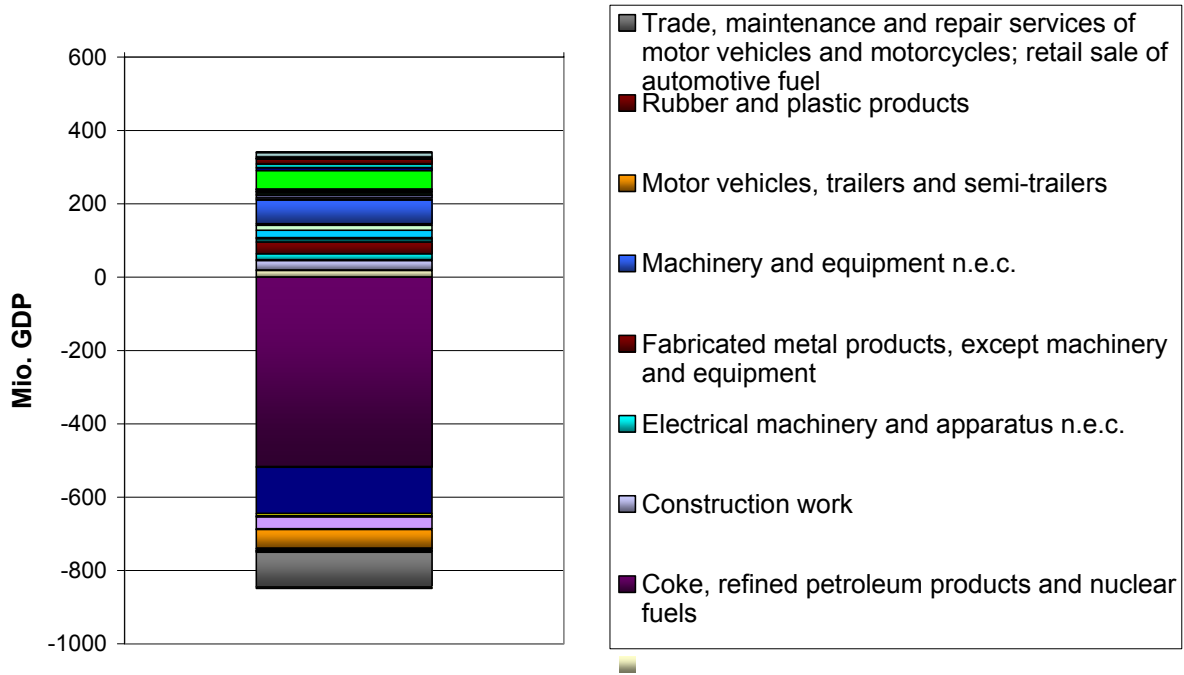


Figure 83: Sectoral economic effects Norway 2030 optimistic learning high penetration (H2H)

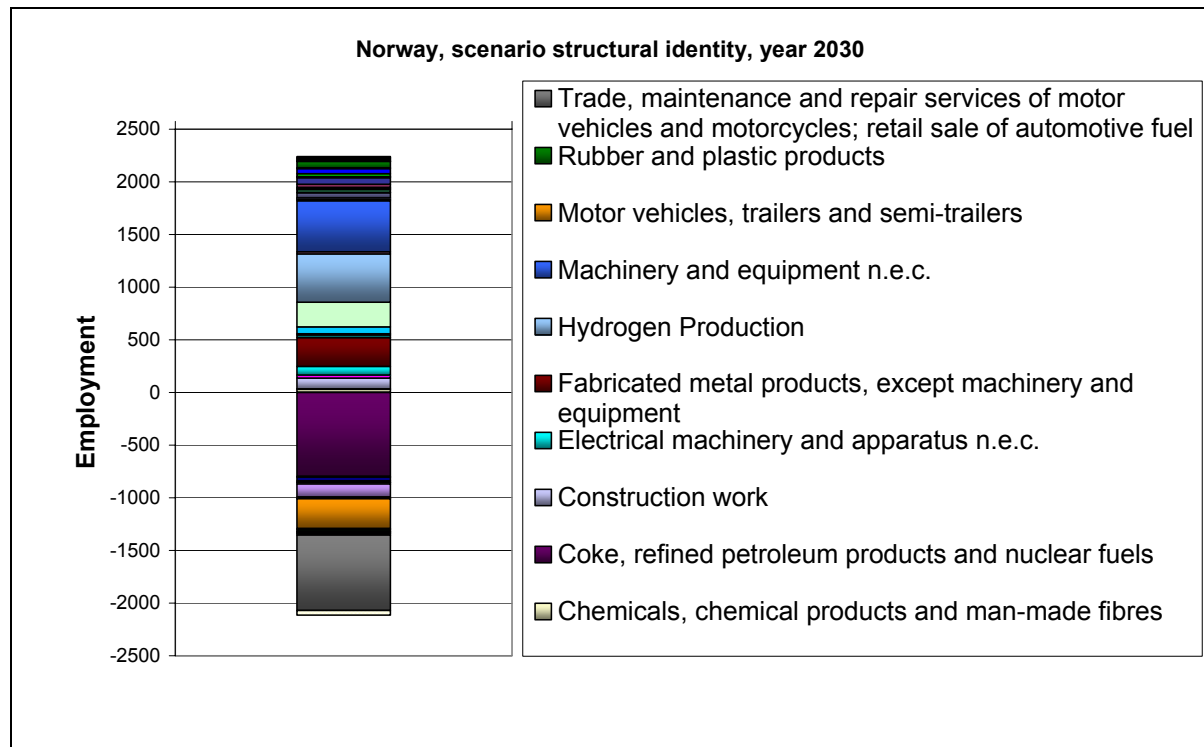


Figure 84: Sectoral employment shifts for Norway optimistic learning high penetration (H2H)

8.7.2 High learning scenario medium penetration rates

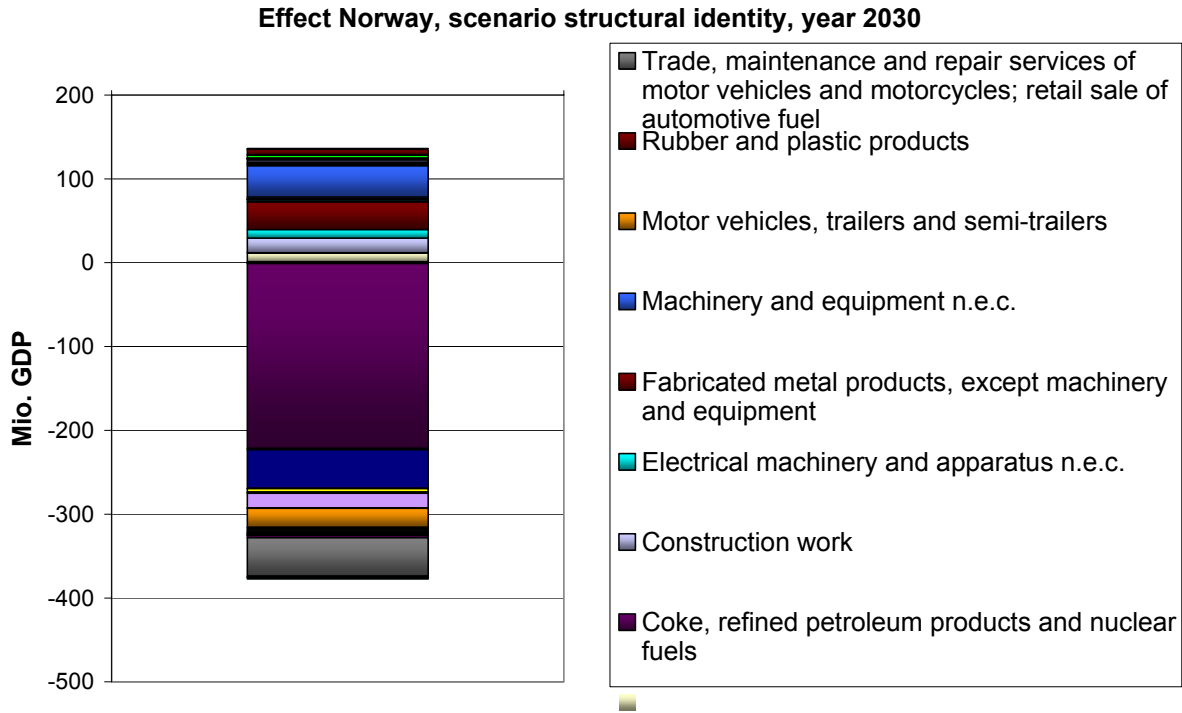


Figure 85: Sectoral economic effects Norway 2030 optimistic learning medium penetration (H2M)

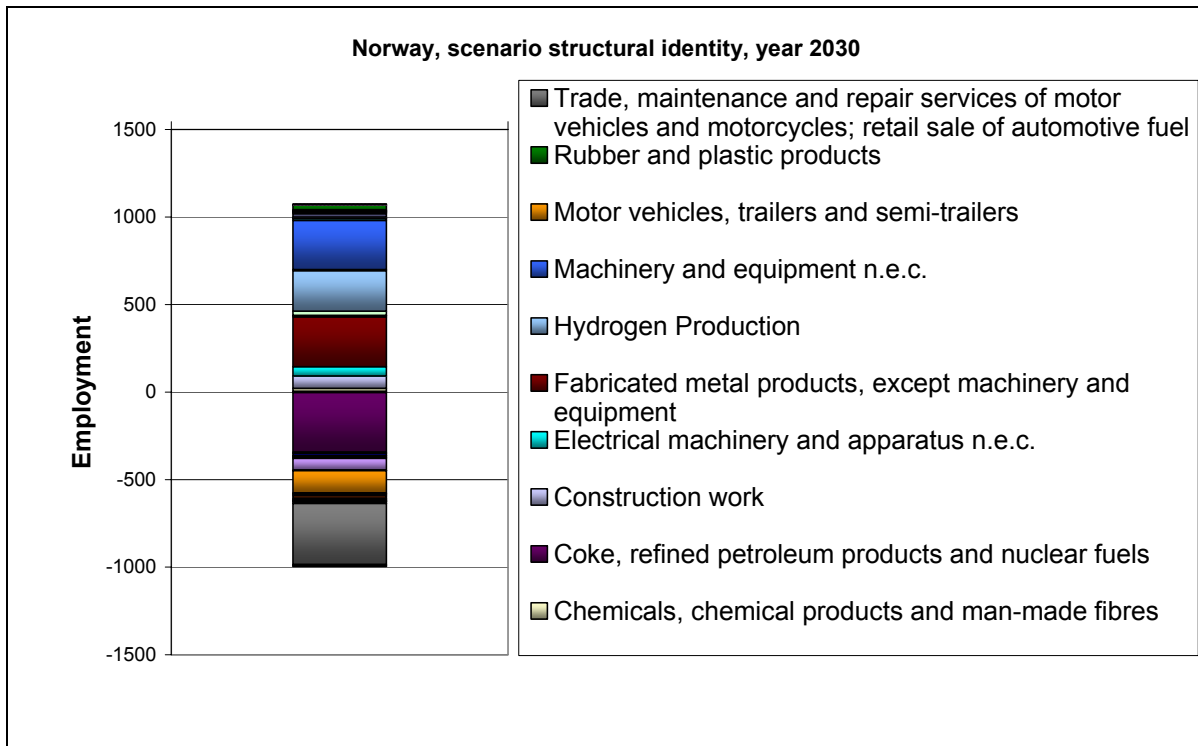


Figure 86: Sectoral employment shifts for Norway optimistic learning medium penetration (H2M)

8.7.3 Moderate learning scenario low penetration rates

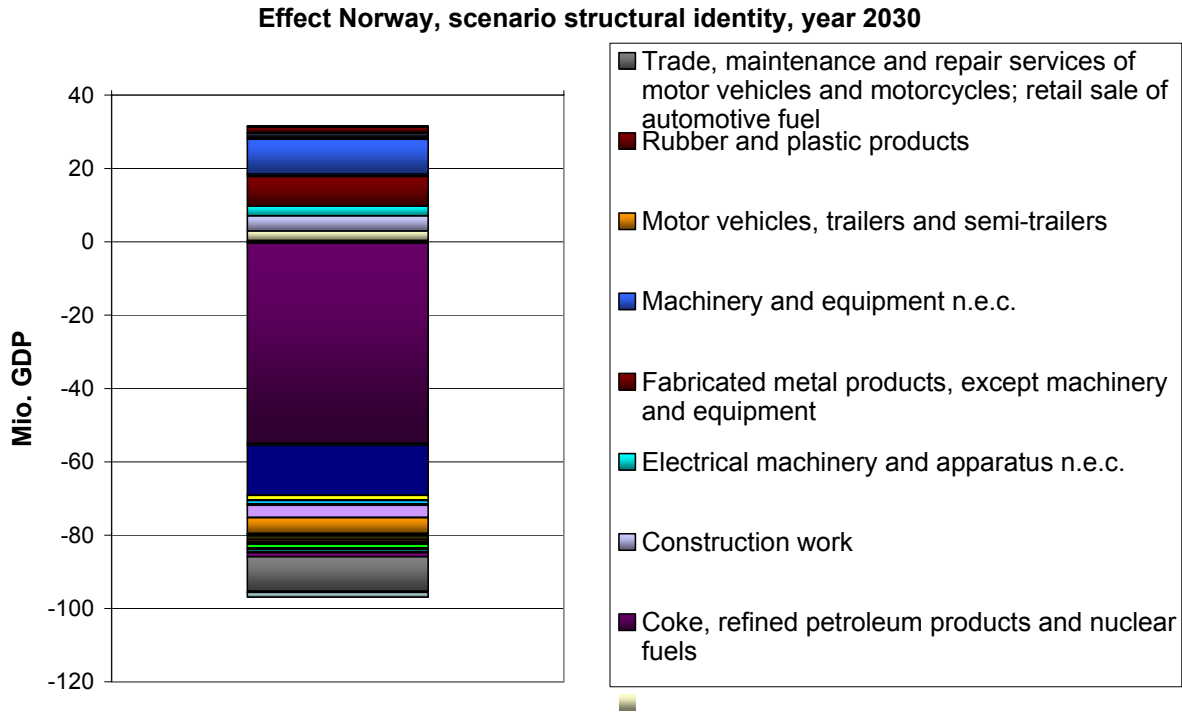


Figure 87: Sectoral economic effects Norway 2030 moderate learning low penetration (M2L)

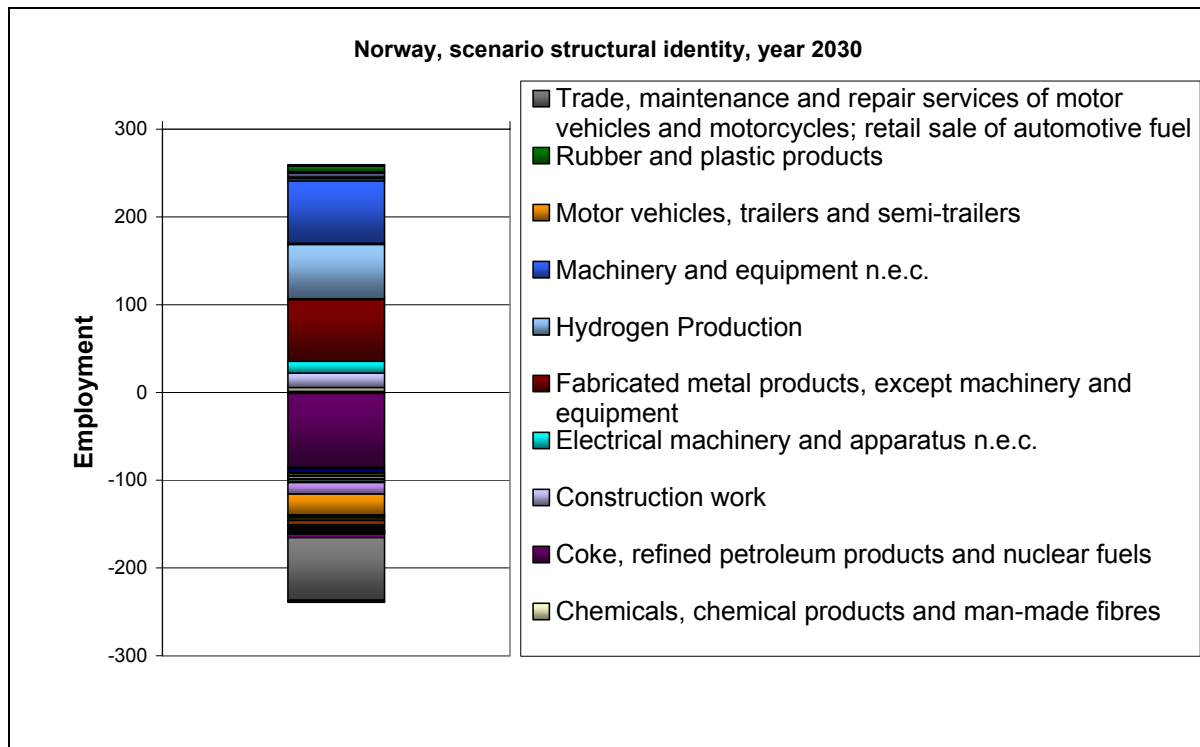


Figure 88: Sectoral employment shifts for Norway moderate learning low penetration (M2L)

8.7.4 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

8.8 MS Results Poland

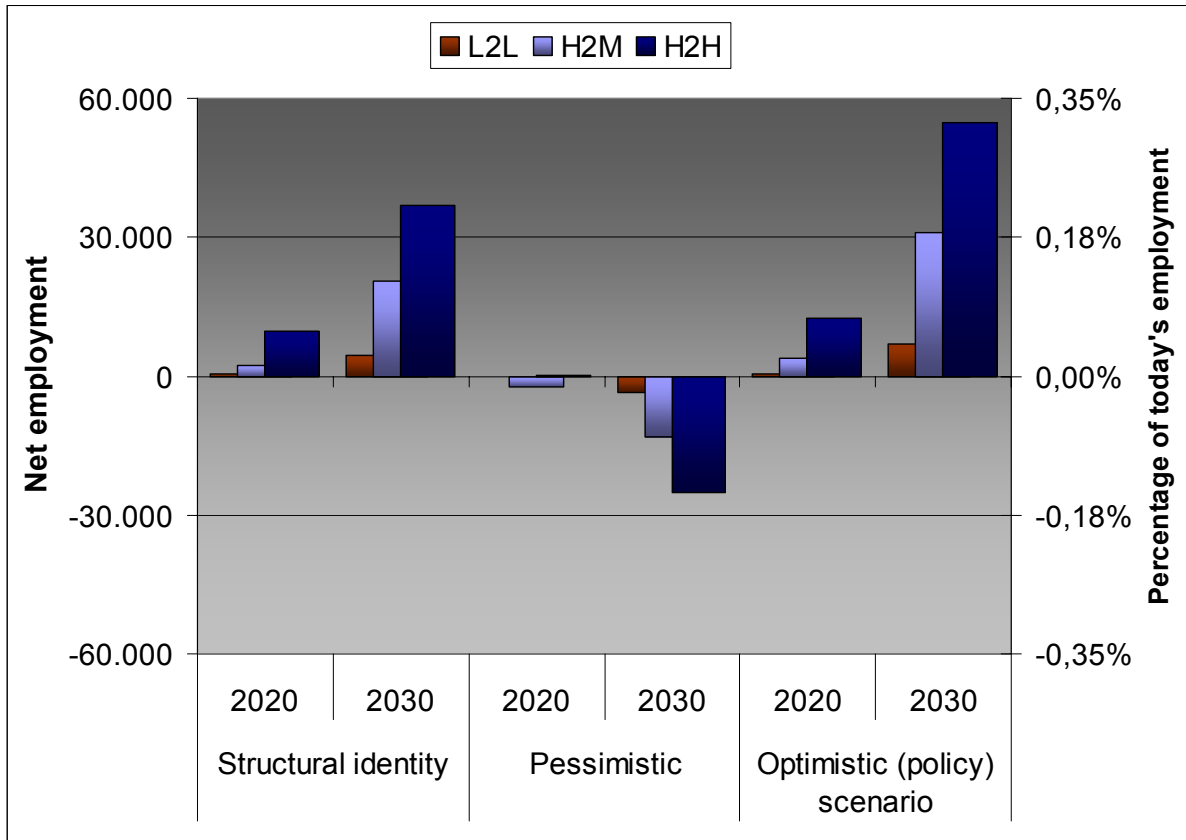


Figure 89: Net employment effects for the hydrogen high penetration (H2H), and medium penetration (H2M) scenarios with optimistic learning rates for hydrogen passenger cars. As well as hydrogen low penetration (L2L) scenarios with moderate learning rates for hydrogen passenger cars for the year 2020 and 2030. Shown are the overall net employment effects for Poland in three import and export scenarios.

8.8.1 High learning scenario high penetration rates

Effect Poland, scenario structural identity, year 2030

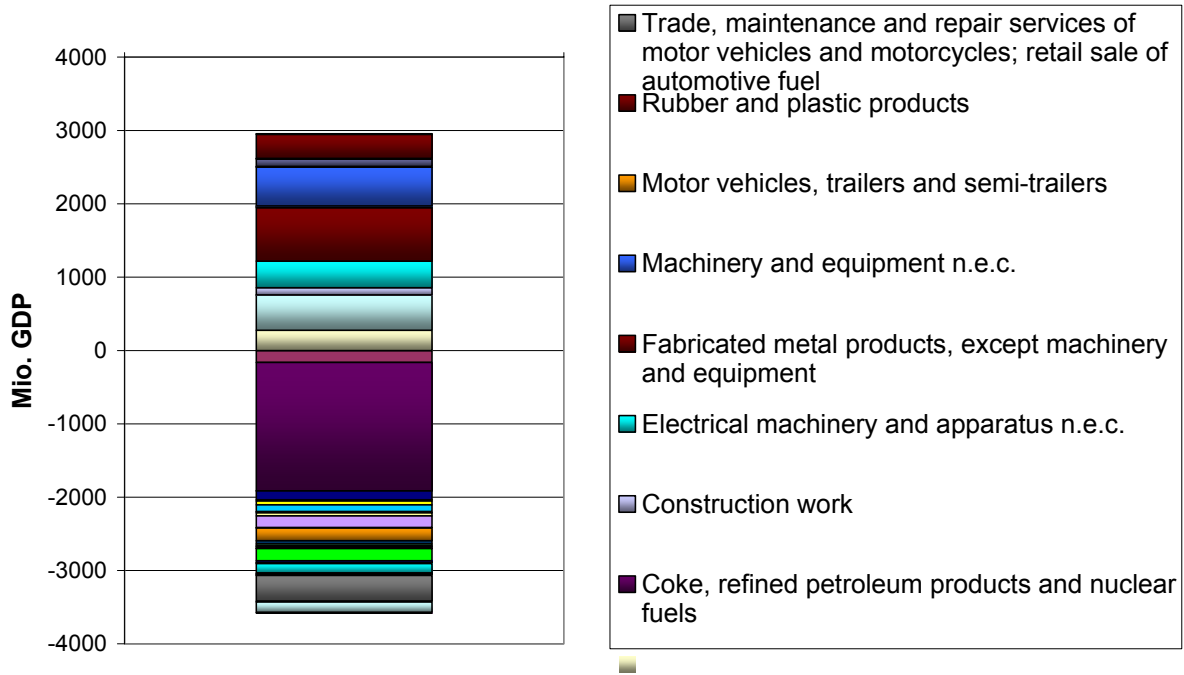


Figure 90: Sectoral economic effects Poland 2030 optimistic learning high penetration (H2H)

Poland, scenario structural identity, year 2030

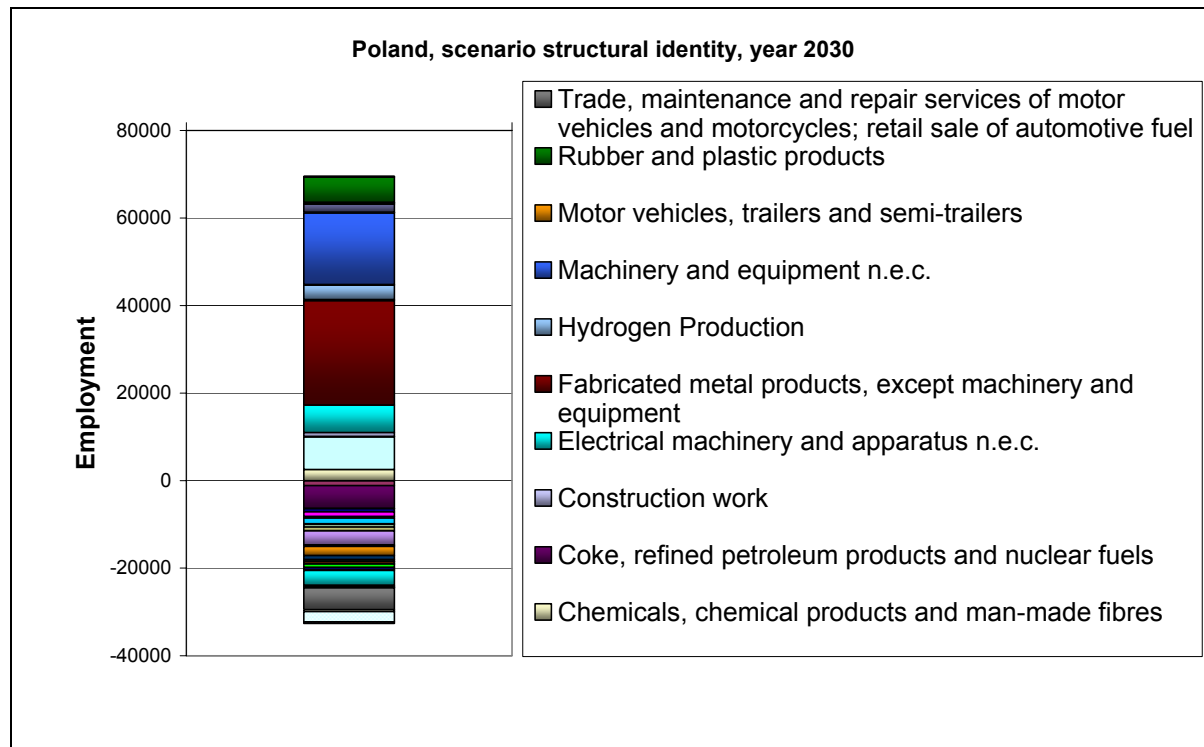


Figure 91: Sectoral employment shifts for Poland optimistic learning high penetration (H2H)

8.8.2 High learning scenario medium penetration rates

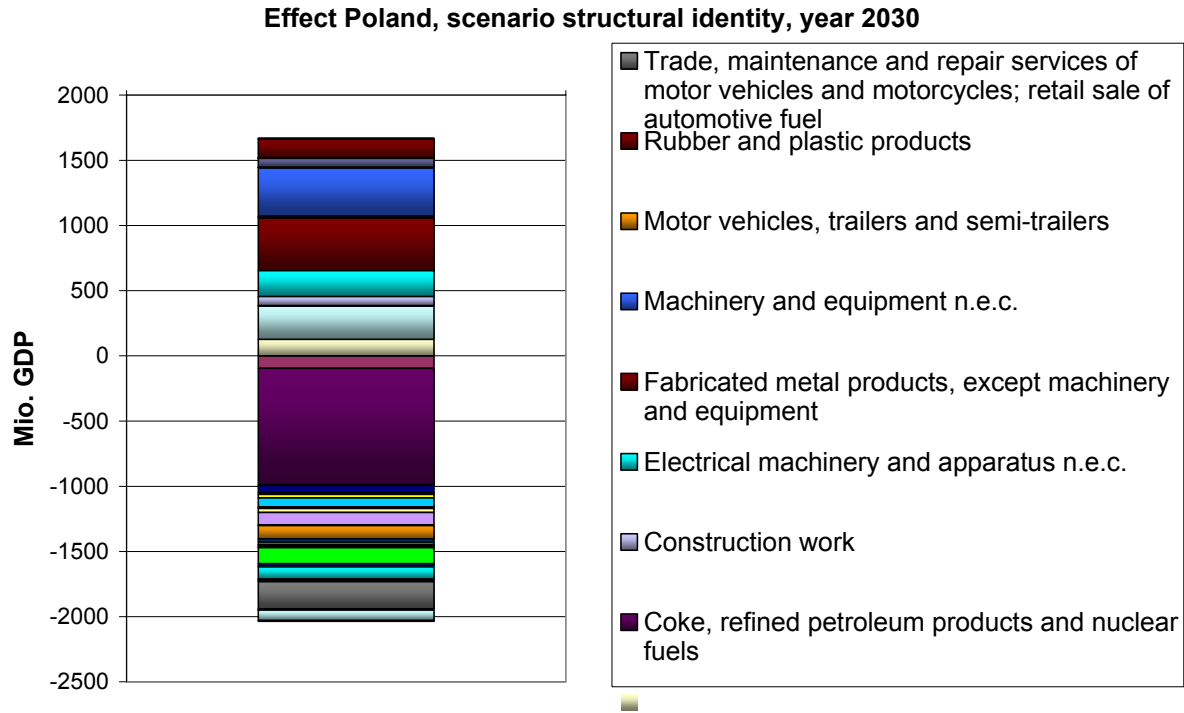


Figure 92: Sectoral economic effects Poland 2030 optimistic learning medium penetration (H2M)

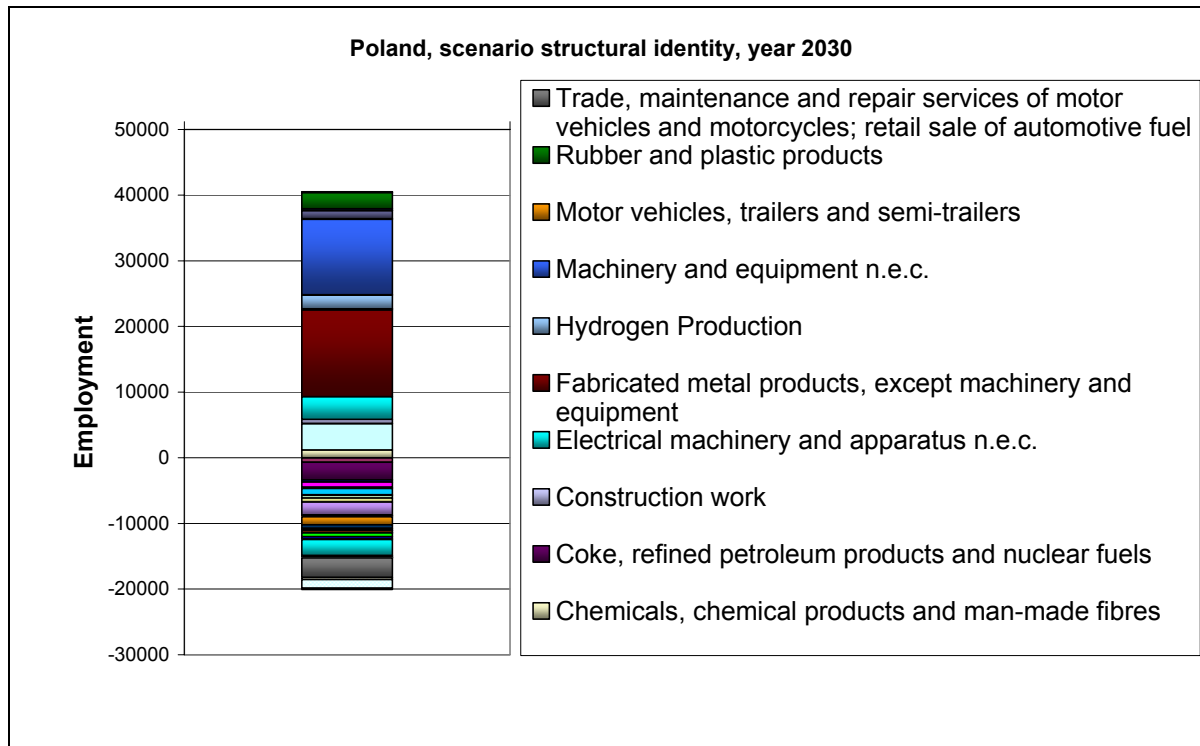


Figure 93: Sectoral employment shifts for Poland optimistic learning medium penetration (H2M)

8.8.3 Moderate learning scenario low penetration rates

Effect Poland, scenario structural identity, year 2030

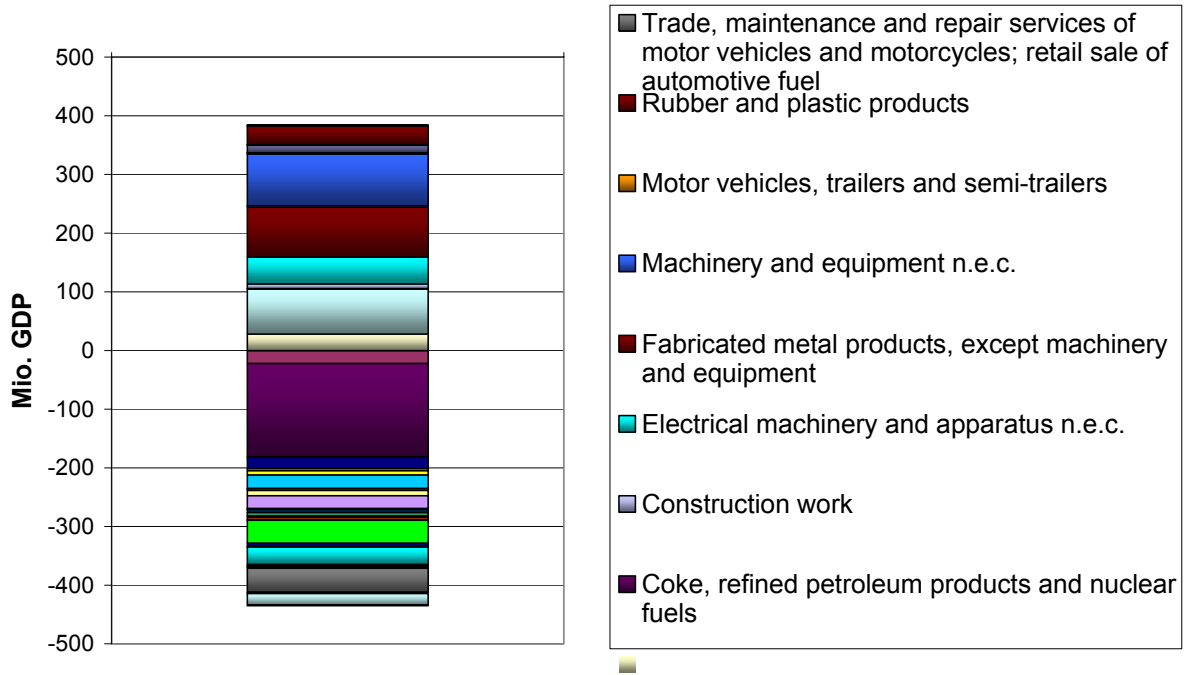


Figure 94: Sectoral economic effects Poland 2030 moderate learning low penetration (M2L)

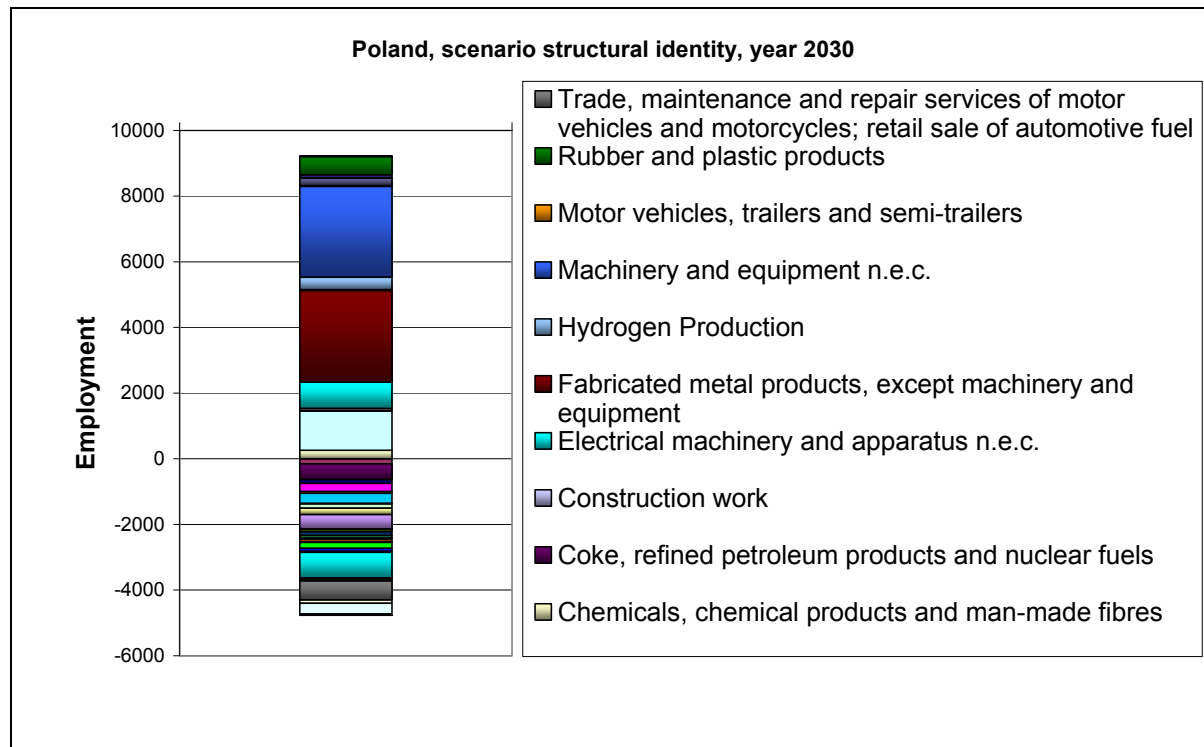


Figure 95: Sectoral employment shifts for Poland moderate learning low penetration (M2L)

8.8.4 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 Poland and following the right strategy promise a significant gain in employment, welfare and GDP effects.

8.9 MS Results: Spain

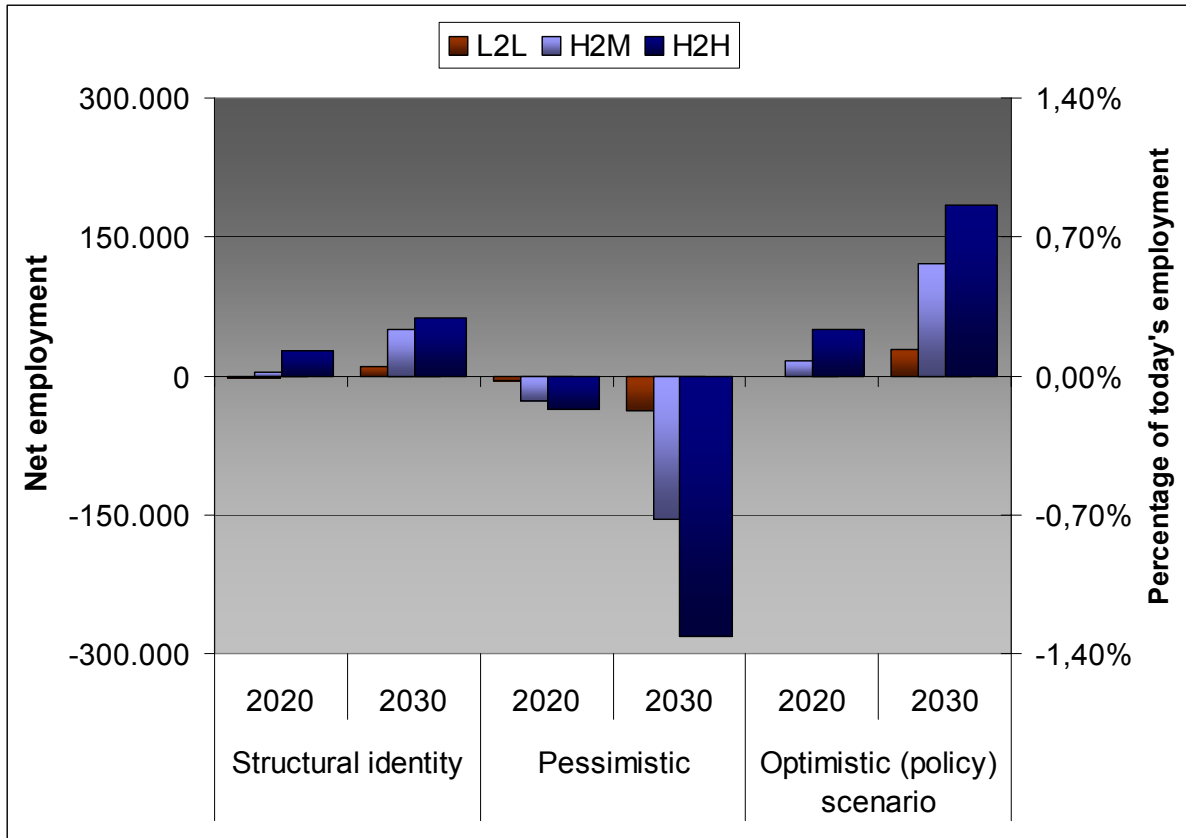


Figure 96: Net employment effects for the hydrogen high penetration (H2H), and medium penetration (H2M) scenarios with optimistic learning rates for hydrogen passenger cars. As well as hydrogen low penetration (L2L) scenarios with moderate learning rates for hydrogen passenger cars for the year 2020 and 2030. Shown are the overall net employment effects for Spain in three import and export scenarios.

8.9.1 High learning scenario high penetration rates

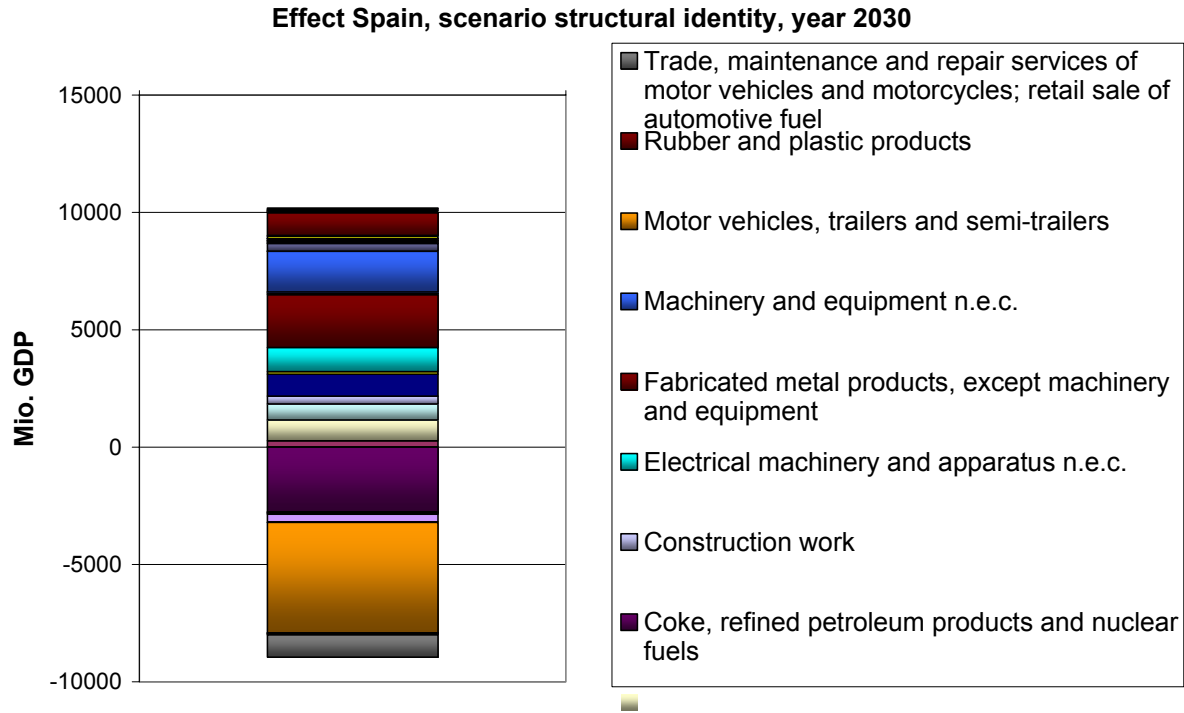


Figure 97: Sectoral economic effects Spain 2030 optimistic learning high penetration (H2H)

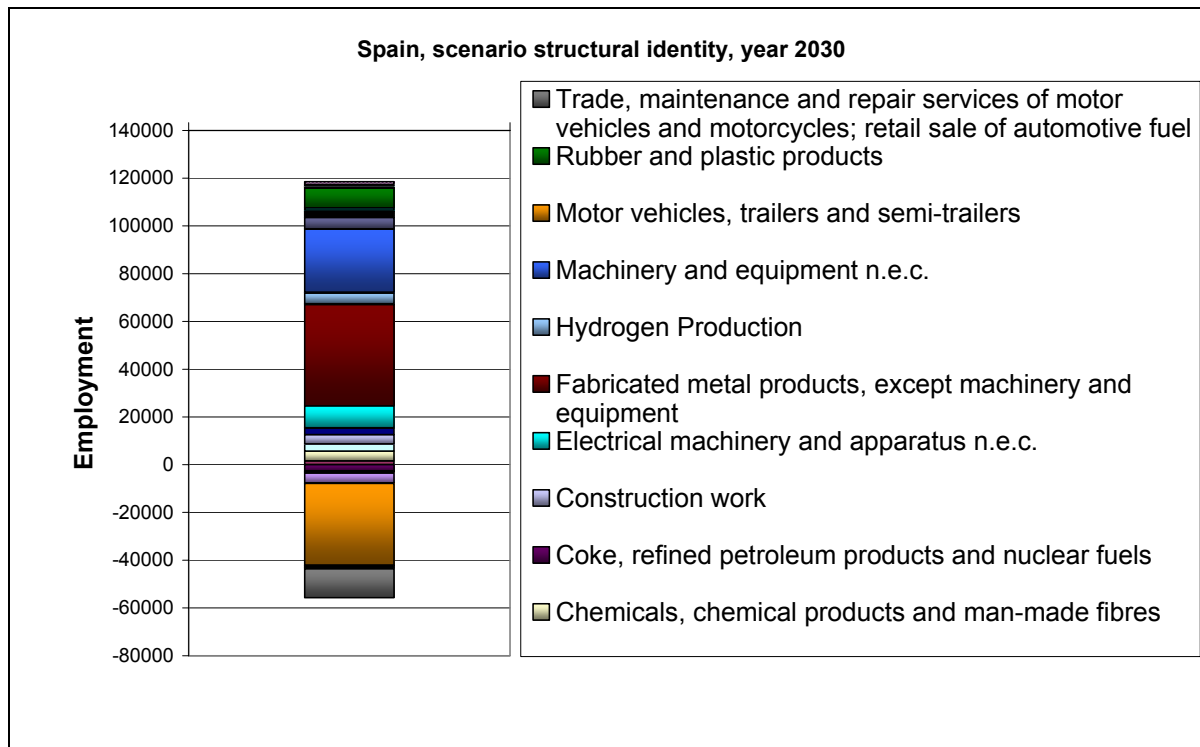


Figure 98: Sectoral employment shifts for Spain optimistic learning high penetration (H2H)

8.9.2 High learning scenario medium penetration rates

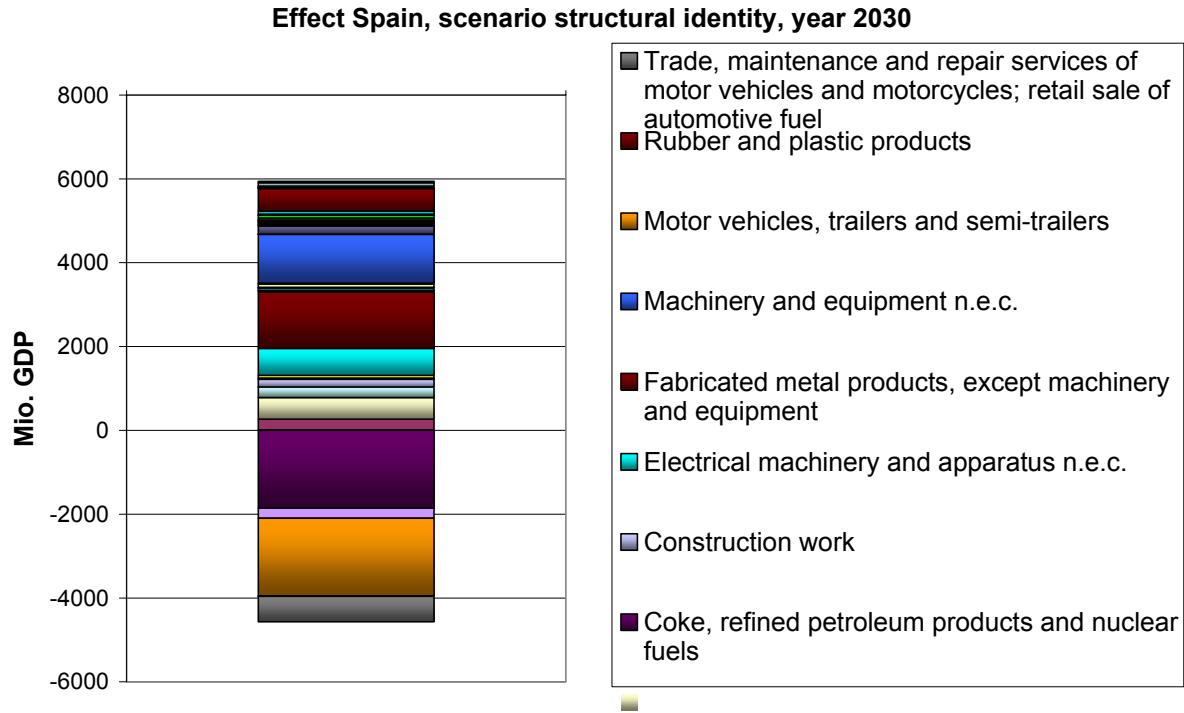


Figure 99: Sectoral economic effects Spain 2030 optimistic learning medium penetration (H2M)

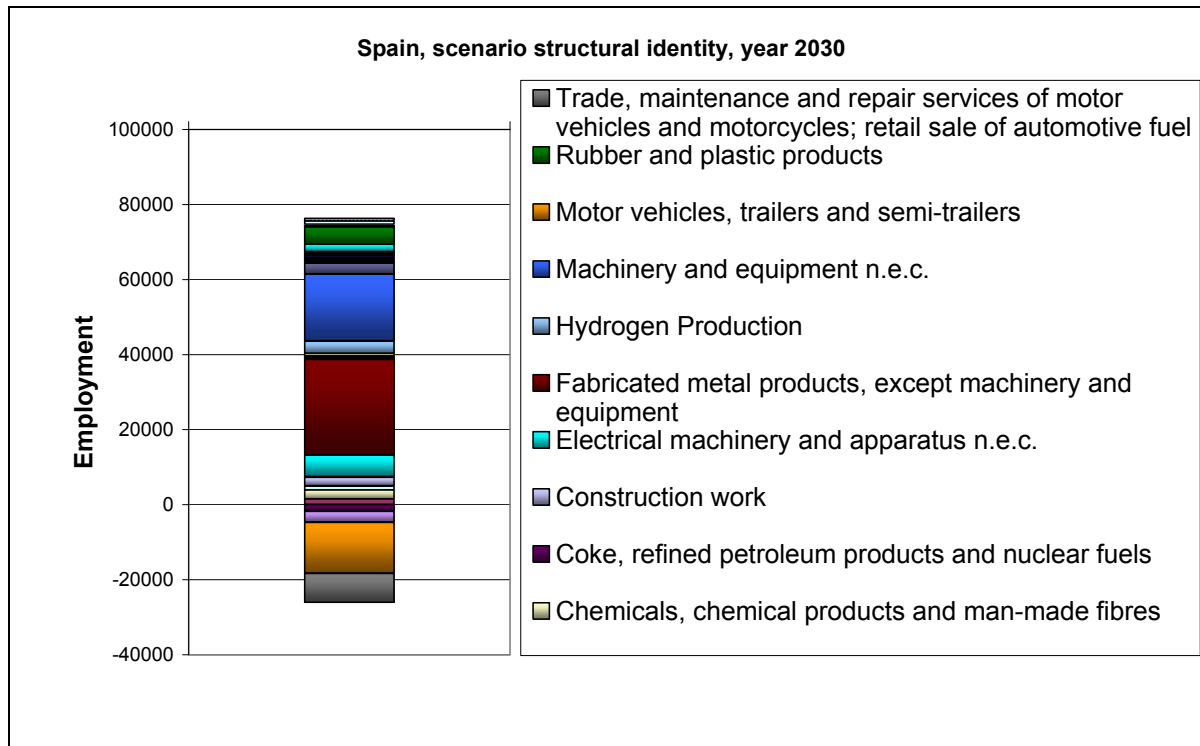


Figure 100: Sectoral employment shifts for Spain optimistic learning medium penetration (H2M)

8.9.3 Moderate learning scenario low penetration rates

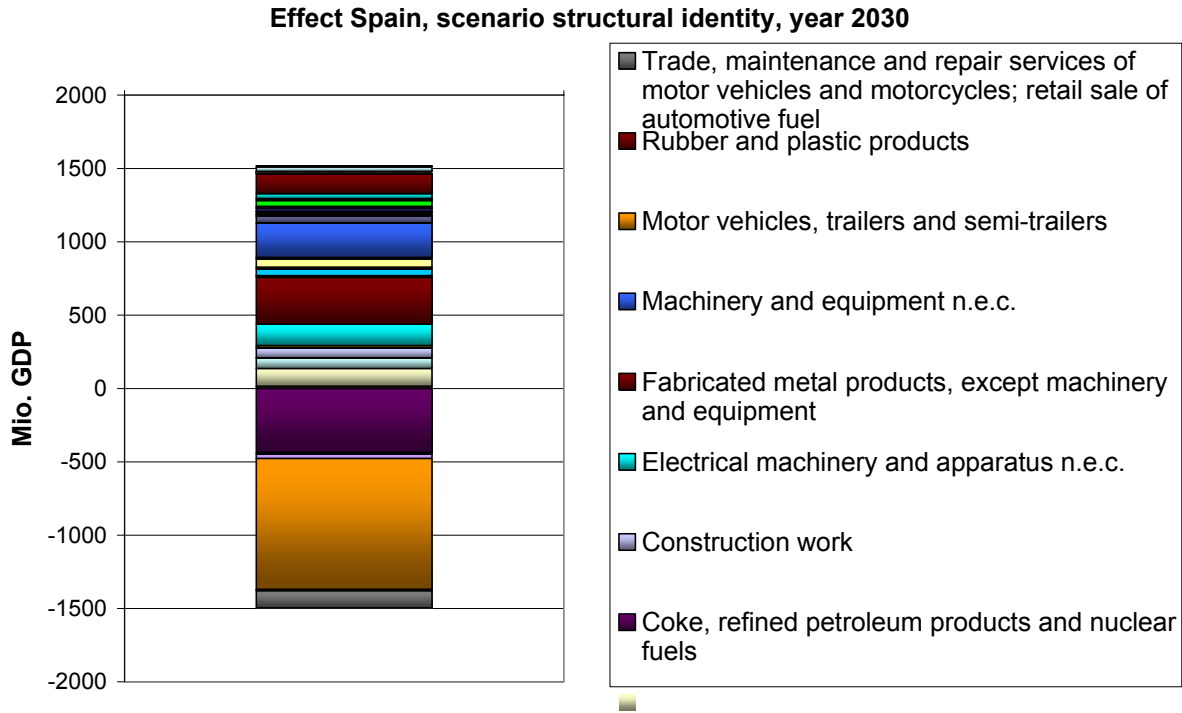


Figure 101: Sectoral economic effects Spain 2030 moderate learning low penetration (M2L)

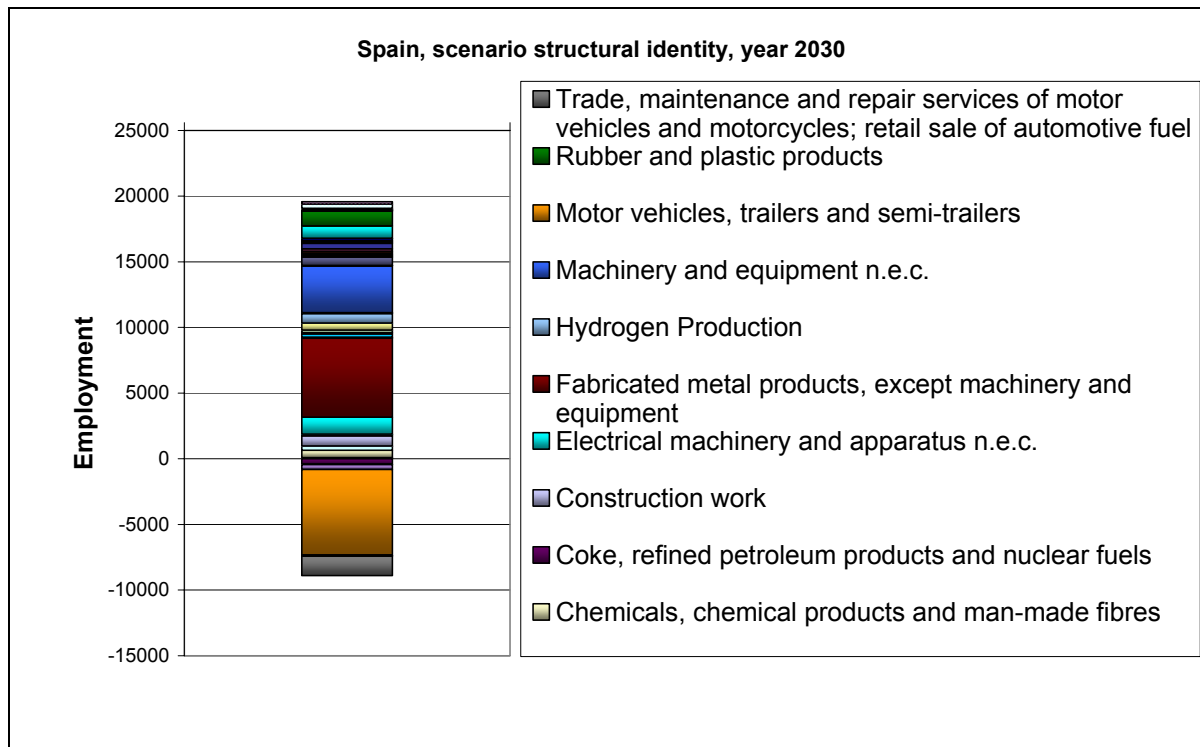


Figure 102: Sectoral employment shifts for Spain moderate learning low penetration (M2L)

8.9.4 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 Spain is limited

8.10 MS Results: UK

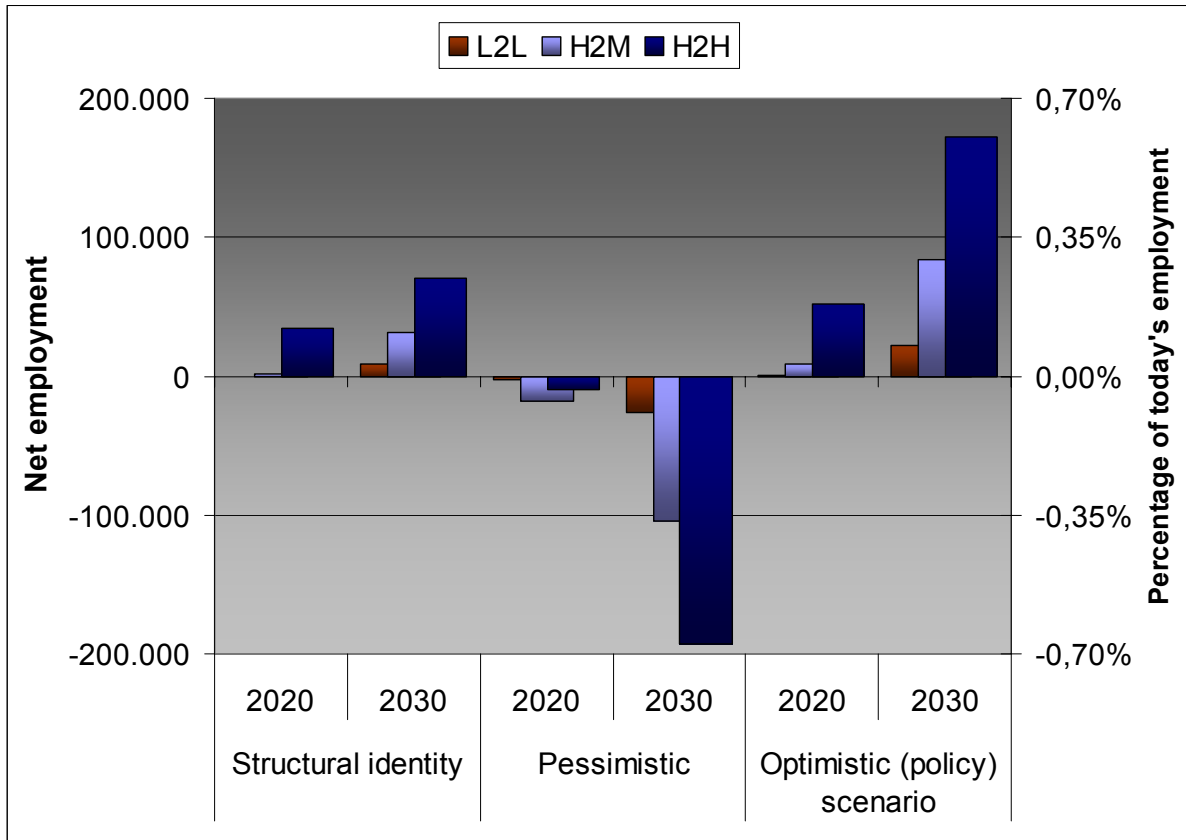


Figure 103: Net employment effects for the hydrogen high penetration (H2H), and medium penetration (H2M) scenarios with optimistic learning rates for hydrogen passenger cars. As well as hydrogen low penetration (L2L) scenarios with moderate learning rates for hydrogen passenger cars for the year 2020 and 2030. Shown are the overall net employment effects for United Kingdom in three import and export scenarios.

8.10.1 High learning scenario high penetration rates

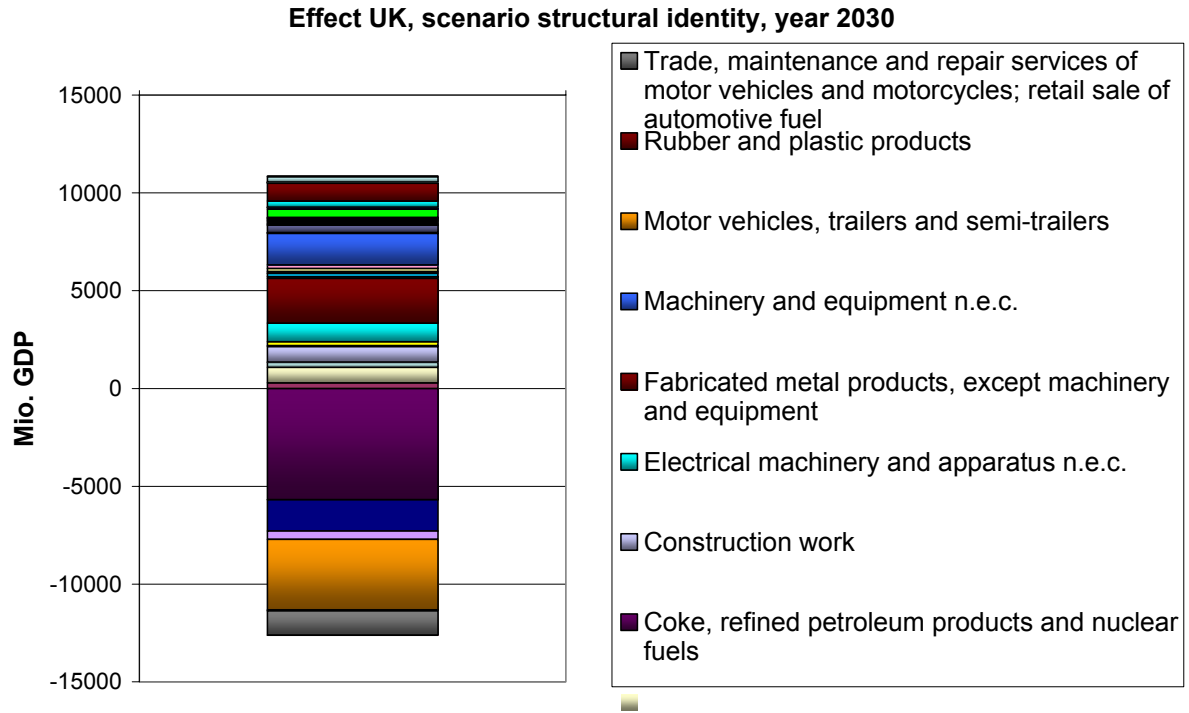


Figure 104: Sectoral economic effects UK 2030 optimistic learning high penetration (H2H)

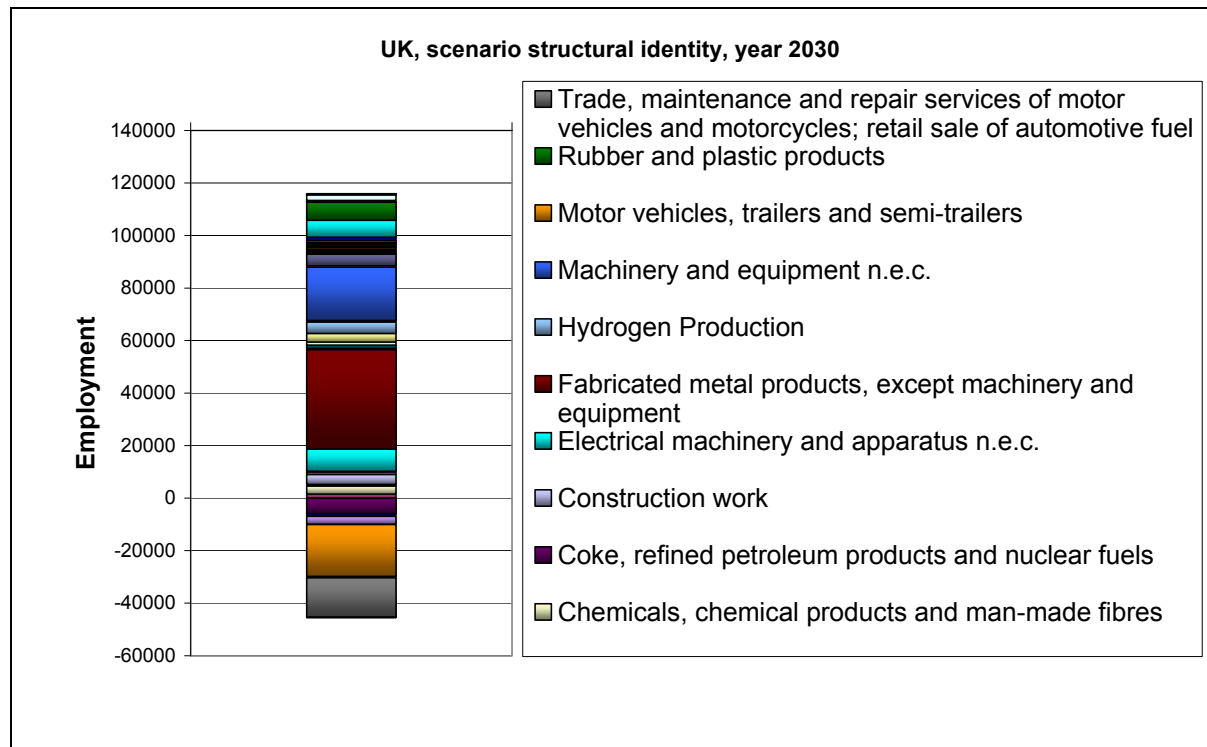


Figure 105: Sectoral employment shifts for UK optimistic learning high penetration (H2H)

8.10.2 High learning scenario medium penetration rates

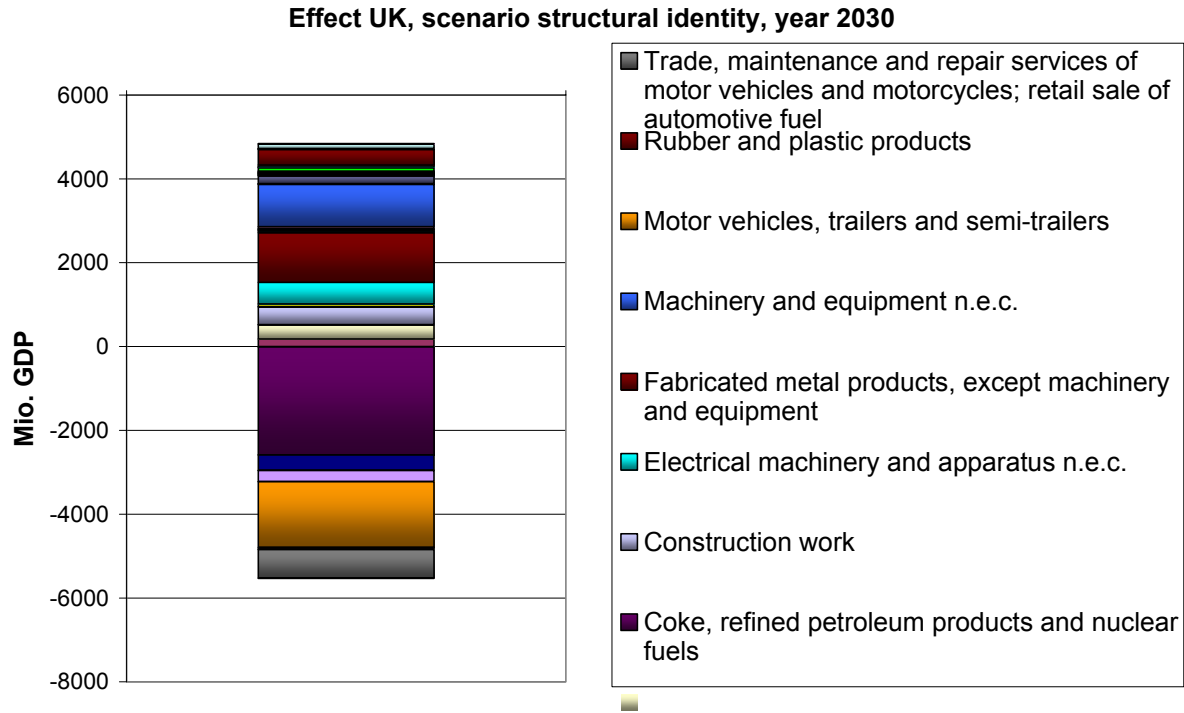


Figure 106: Sectoral economic effects UK 2030 optimistic learning medium penetration (H2M)

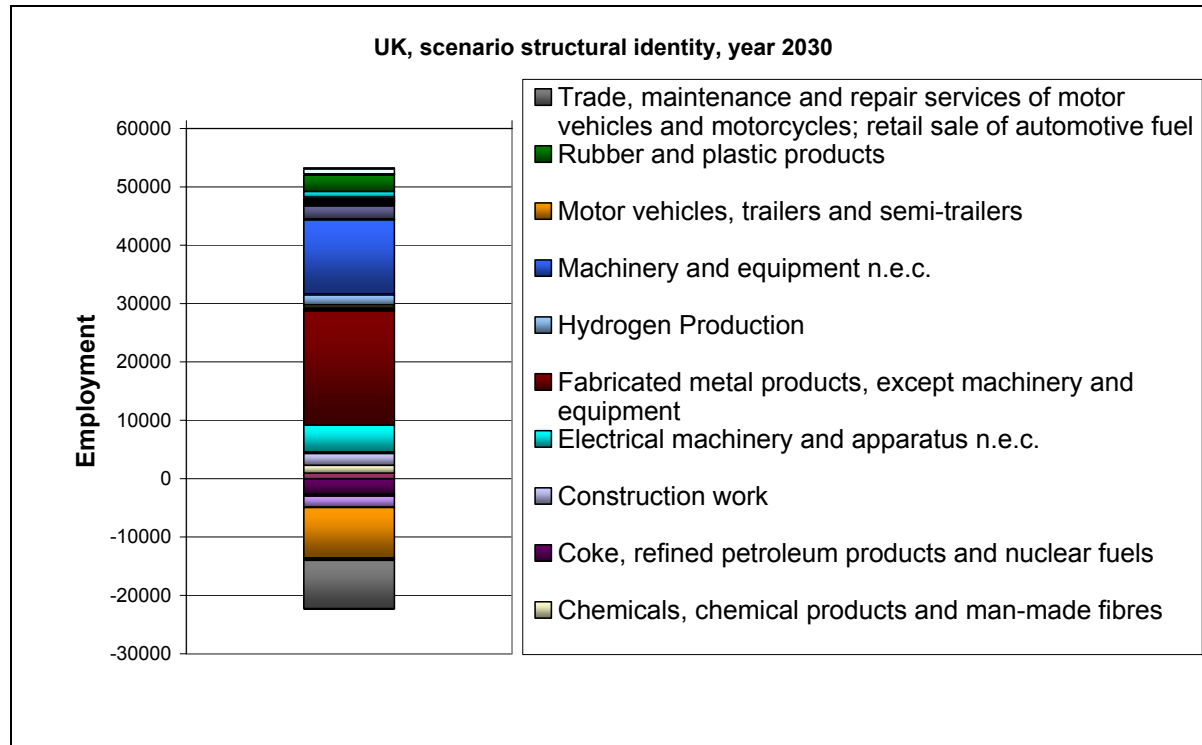


Figure 107: Sectoral employment shifts for UK optimistic learning medium penetration (H2M)

8.10.3 Moderate learning scenario low penetration rates

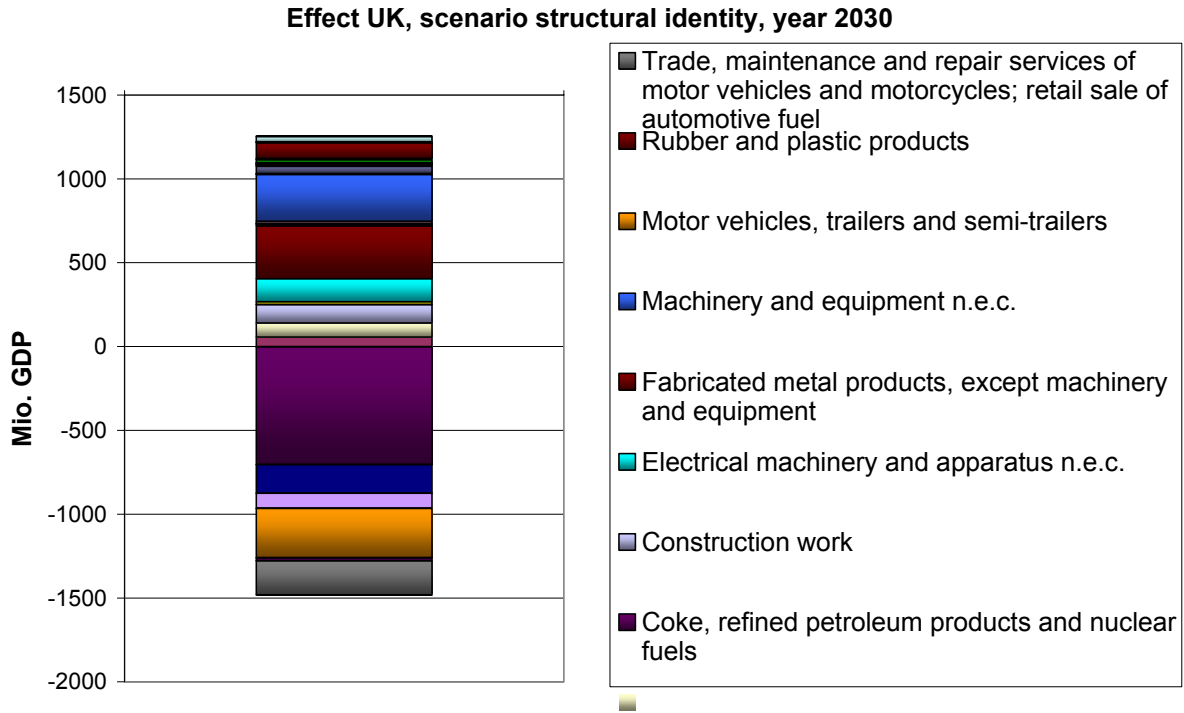


Figure 108: Sectoral economic effects UK 2030 moderate learning low penetration (M2L)

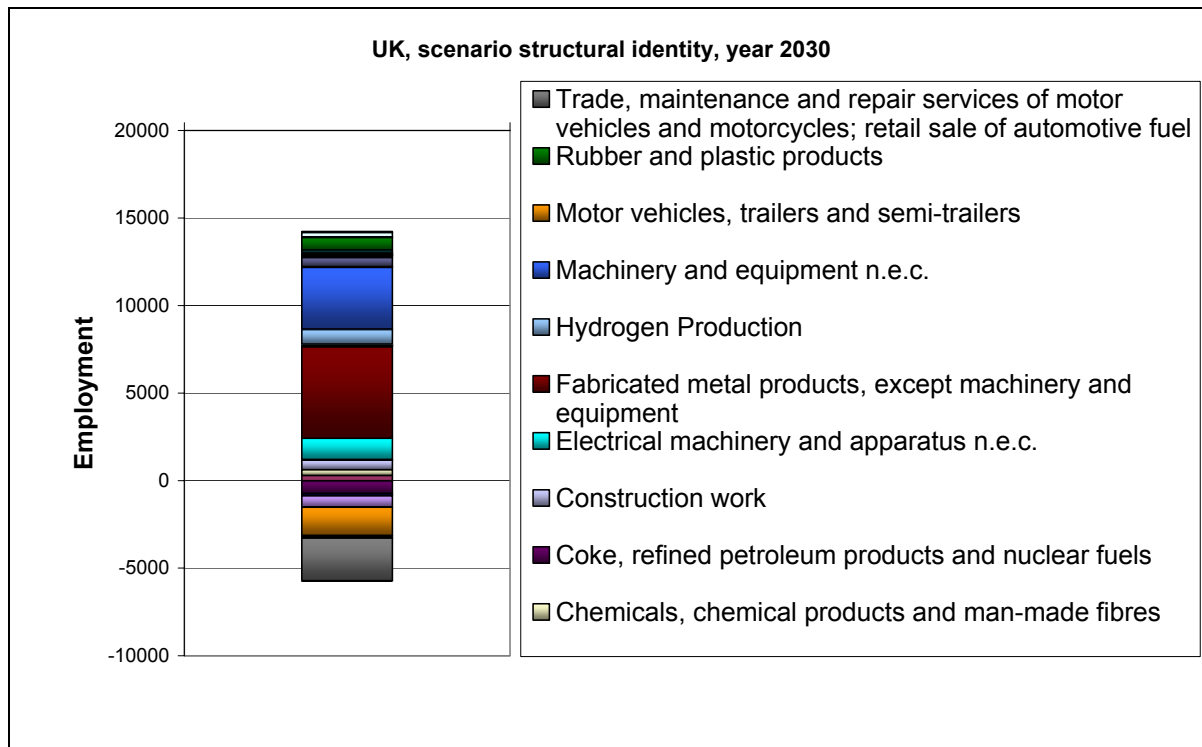


Figure 109: Sectoral employment shifts for UK moderate learning low penetration (M2L)

8.10.4 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 the United Kingdom is limited