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TRENDS IN VEHICLE AND FUEL TECHNOLOGIES

SCENARIOS FOR FUTURE TRENDS

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About the JRC-IPTS

The **Joint Research Centre** (JRC) is a Directorate General of the European Commission, staffed with approximately 2,100 people, coming in the vast majority from the 15 Member States of the European Union. The Brussels Support Services (including the office of the Director General and the Science Strategy Directorate) and seven Institutes located in five different countries compose the main organisational structure of the JRC (http//:www.jrc.org). The Institute for Prospective Technological Studies (IPTS) is one of the seven Institutes making up the JRC. The mission of the JRC is to provide customer-driven scientific and technical support for the conception, implementation and monitoring of EU policies.

The Institute for Prospective Technological Studies (IPTS) is one of the seven Institutes making up the JRC. It was established in Seville, Spain, in September 1994.

The **mission of the IPTS** is to provide prospective techno-economic analyses in support of the European policy-making process. IPTS' prime objectives are to monitor and analyse science and technology developments, their cross-sectoral impact, and their inter-relationship with the socio-economic context and their implications for future policy development. IPTS operates international networks, pools the expertise of high level advisors, and presents information in a timely and synthetic fashion to policy makers (http//:www.jrc.es).

The **IPTS is a unique public advisory body**, independent from special national or commercial interests, closely associated with the EU policy-making process. In fact, most of the work undertaken by the IPTS is in response to direct requests from (or takes the form of long-term policy support on behalf of) the European Commission Directorate Generals, or European Parliament Committees. The IPTS also does work for Member States' governmental, academic or industrial organisations, though this represents a minor share of its total activities.

Although particular emphasis is placed on **key Science and Technology fields**, especially those that have a driving role and even the potential to reshape our society, important efforts are devoted to improving the understanding of the complex interactions between technology, economy and society. Indeed, the impact of technology on society and, conversely, the way technological development is driven by societal changes, are **highly relevant themes within the European decision-making context**.

The **inter-disciplinary prospective approach** adopted by the Institute is intended to provide European decision-makers with a deeper understanding of the emerging science and technology issues, and it complements the activities undertaken by other institutes of the Joint Research Centre.

The IPTS **approach** is to collect information about technological developments and their application in Europe and the world, analyse this information and transmit it in an accessible form to European decision-makers. This is implemented in the following **sectors of activity**:

- Technologies for Sustainable Development
- Life Sciences / Information and Communication Technologies
- Technology, Employment, Competitiveness and Society
- Futures project

In order to implement its mission, the Institute develops appropriate contacts, awareness and skills to anticipate and follow the agenda of the policy decision-makers. **IPTS Staff** is a mix of highly experienced engineers, scientists (life-, social- material- etc.) and economists. Cross-disciplinary experience is a necessary asset. The IPTS success is also based on its **networking capabilities and the quality of its networks** as enabling sources of relevant information. In fact, in addition to its own resources, the IPTS makes use of external Advisory Groups and operates a number of formal or informal networks. The most important is a Network of European Institutes (*the European Science and Technology Observatory*) working in similar areas. These networking activities enable the IPTS to draw on a large pool of available expertise, while allowing a continuous process of external peer-review of the in-house activities.

About ESTO

The European Science and Technology Observatory (ESTO) is a network of organisations operating as a virtual institute under the European Commission's – Joint Research Centre's (JRC's) Institute for Prospective Technological Studies (IPTS) - leadership and funding. The European Commission JRC-IPTS formally constituted, following a brief pilot period, the European Science and Technology Observatory (ESTO) in 1997. After a call for tender, the second formal contract for ESTO started on May 1st 2001 for a period of 5 years.

Today, **ESTO is presently composed of a core of twenty European institutions**, all with experience in the field of scientific and technological foresight, forecasting or assessment at the national level. These nineteen organisations have a formal obligation towards the IPTS and are the nucleus of a far larger network. Membership is being continuously reviewed and expanded with a view to match the evolving needs of the IPTS and to incorporate new competent organisations from both inside and outside of the EU. This includes the objective to broaden the operation of the ESTO network to include relevant partners from EU Candidate Countries. In line with the objective of supporting the JRC-IPTS work, ESTO **aims** at detecting, at an early stage, scientific or technological breakthroughs, trends and events of potential socio-economic importance, which may require action at a European decision-making level.

The ESTO **core-competence** therefore resides in prospective analysis and advice on S&T changes relevant to EU society, economy and policy.

The **main customers** for these activities is the JRC-IPTS, and through it, the European policy-makers, in particular within the European Commission and Parliament. ESTO also recognises and addresses the role of a much wider community, such as policy-making circles in the Member States and decision-makers in both non-governmental organisations and industry.

ESTO members, therefore, **share the responsibility** of supplying the IPTS with up-to-date and high quality scientific and technological information drawn from all over the world, facilitated by the network's broad presence and linkages, including access to relevant knowledge within the JRC' Institutes.

Currently, ESTO is engaged in the following **main activities:**

- A series of **Specific Studies**, These studies, usually consist in comparing the situation, practices and/or experiences in various member states, and can be of a different nature a) *Anticipation/Prospective analysis*, intended to act as a trigger for in-depth studies of European foresight nature, aiming at the identification and description of trends rather than static situations; b) *Direct support of policies in preparation* (ex-ante analysis); and c) *Direct support of policies in action* (ex-post analysis, anticipating future developments).
- Implementation of **Fast-Track** actions to provide quick responses to specific S&T assessment queries. On the other hand, they can precede or complement the above mentioned Specific Studies.
- To produce input to **Monitoring Prospective S&T Activities** that serves as a basis of experience and information for all other tasks.
- ESTO develops a "**Alert/Early Warning**" function by means of Technology Watch/Thematic Platforms activities. These actions are putting ESTO and JRC-IPTS in the position to be able to provide rapid responses to specific requests from European decision-makers.
- Support the production of **"The IPTS Report"**, a monthly journal targeted at European policy-makers and containing articles on science and technology developments, either not yet on the policy-makers' agenda, but likely to emerge there sooner or later.

For more information: http//:www.jrc.esContacts: esto-secretary@jrc.es

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“TRENDS IN VEHICLE AND FUEL TECHNOLOGIES: Scenarios for Future Trends”

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Executive summary

This report is the final deliverable of the IPTS/ESTO study on trends in vehicle and fuel technologies. The objective of the study was to review the past trends and anticipate future developments in vehicle and fuel technologies, in relation mainly to passenger transport. The study provides an overview of the trends in the main families of conventional and alternative technologies and fuels, covering the evolution of their main technical characteristics, fuel economy, user costs (variable and fixed) and environmental impacts. As regards the anticipation of future developments, the main research issues were identified and projections of the possible development of the above variables were made, based on the results of on-going research activities world-wide.

The technologies covered include internal combustion engines (using either gasoline or diesel as fuel), electric vehicles, hybrid vehicles and fuel cells. The time horizon of the study covers the last 20 years for the past trends and extends until year 2020 for the anticipation of possible developments. The study covers developments at a world-wide level, with particular emphasis on the potential of introduction of new technologies in the EU-15 and candidate countries, North America, Japan, China and India.

This report investigates a number of scenarios for the potential of alternative technologies for passenger cars until year 2020. The scenarios investigate the impact of fuel prices and taxes, carbon content-based taxes, subsidies, and emission limits. The case of the car manufacturers concentrating on fewer alternative technologies, i.e. abandoning the development of the least promising ones, was also investigated. The work combines input from theoretical and empirical evidence, past trends, potential breakthroughs resulting from current research, input from industry experts and the results of the IPTS transport technologies model.

The analysis that was carried out identified a number of uncertainty factors that influence the potential of the various technologies in the sector and quantified their impacts. Such factors include the technical and economic characteristics of each available technology, fuel prices, environmental limits, legislation, and manufacturers' strategies. Apart from the outlook of each technology in terms of market share, the scenarios also provided estimates concerning the development of certain policy relevant indicators, such as fuel consumption and CO_2 emissions in the EU and each member state.

The main conclusion from the scenario analysis is that although alternative technologies are promising from the technical point of view, their market potential is questionable if no measures to support them are taken. Most scenarios describe a situation of the market being dominated by conventional internal combustion engines at least until 2010. The gradual shift from gasoline to diesel is expected to continue in the meanwhile and, under certain conditions, an evolution from conventional ICEs to hybrid vehicles (probably ICE- electric) can be expected afterwards. Electric vehicles can be expected to capture a limited market only, while the share of fuel cells can become significant in the longer term.

The scenarios analysed in this report can provide the background analysis for the definition of a suitable policy mix that would support the introduction of alternative technologies in the passenger car sector. There are numerous financial or regulatory measures that could accelerate the introduction of alternative technologies, but the co-operation of car manufacturers is necessary in all cases. The main question, therefore, is to identify the policy measures that would decrease the uncertainty that car manufacturers face concerning the long term prospects of alternative vehicle technologies.

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1 Introduction

This report is the final deliverable of the IPTS/ESTO study on trends in vehicle and fuel technologies. The objective of the study was to review the past trends and anticipate future developments in vehicle and fuel technologies, in relation mainly to passenger transport. The study provides an overview of the trends in the main families of conventional and alternative technologies and fuels, covering the evolution of their main technical characteristics, fuel economy, user costs (variable and fixed) and environmental impacts. As regards the anticipation of future developments, the main research issues were identified and projections of the possible development of the above variables were made, based on the results of on-going research activities world-wide.

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The results of the study were used as input for the transport and energy models maintained and developed by JRC-IPTS. Based on the results of the first two parts of the study[1], a number of scenarios for the potential evolution of the technical and economic characteristics were constructed. The work combined input from theoretical and empirical evidence, past trends, potential breakthroughs resulting from current research, input from industry experts and the IPTS Transport Technologies Model available at JRC-IPTS.

The IPTS Transport Technologies Model describes the dynamics of the passenger car market and of the adoption of new technologies in the sector. It was originally planned as an extension of the POLES energy market model, but it may be used as a standalone model as well. Although the model is considered sufficiently reliable, it should be noted that, since its objective is mainly the comparison of alternative policy measures, these projections should be used as the basis for comparisons or trend analysis, and not as a means for prediction of the future value of the variables.

[1] "Review of past trends" and "Overview of current research activities"

2 Overview of technology penetration scenarios

The set of scenarios presented in this report describes a number of external developments, policy measures and manufacturer strategies that might influence the penetration of the various technological options.

The **baseline scenario** is used as the reference case. It corresponds to the outlook for each technology if the current trends in demand are sustained, if fuel and vehicle prices and fuel economy follow the path predicted by current surveys of trends in vehicle technologies, and if no significant policy measure is implemented. According to the baseline scenario, no clear winner among the non-conventional technologies is identified. Fuel cells are expected to become an option only at the end of the 2010's, while electric vehicles seem capable of securing a niche. Hybrids may play an interim role in the transition between ICEs to fuel cells. Total demand in the passenger car sector (expressed in total number of vehicle kms) is expected to rise (though slower than GDP growth). CO_2 emissions from passenger cars are expected to show a slight increase by 2010 (3%) and a reduction of 13% by 2020. This is the combined result of the improvement of conventional technologies, the gradual removal of older cars from the fleet, and the introduction of alternative technologies.

In the **high oil** scenario an increase of the price of oil is assumed. The increase is applied to the fuel prices predicted by the POLES model during the whole period of the simulation. As a reference, the price increase is considered to be equal to 28% (that would correspond to an increase from 25 to 32 US$ per barrel). Such an increase would have a minimal impact in the medium term (up to 2010), since the alternative technologies would not be mature enough (i.e. have competing costs) by then to benefit and increase their share. In the longer term, an increase in the price of oil would benefit the alternative technologies, since their difference from the conventional technologies in terms of variable cost would become smaller. As regards the conventional technologies, higher oil prices would reinforce the shift from gasoline to diesel, as fuel economy becomes a decisive factor. A higher oil price would also slow down growth in transport demand. The slower growth in demand, combined with the shift towards alternatives and more efficient vehicles, would also lead to further reductions in CO_2 emissions.
The high oil scenario is also equivalent to a fuel tax scenario, i.e. the same results would appear if fuel taxes were raised by 28%.

The **low oil** scenario corresponds to the opposite case of the high oil scenario. A decrease of the price of oil by 28% is assumed (e.g. from 25 to 18 US$ per barrel). The results have in general the opposite direction of those for high oil: the introduction of alternative technologies is delayed and gasoline remains the most attractive option. Transport demand would increase, though still slower than GDP growth (saturation levels are reached). CO_2 emissions would increase significantly by 2010 and in the long term brought down to the levels of 2000 as a result of improved technology.

In the **carbon tax 50** scenario, a carbon content related tax equivalent to 50 euros per ton of CO_2 is imposed. The difference from the high oil price scenario (that also corresponds to imposing a fuel tax) is that it affects gasoline and diesel in a different manner. Diesel has a higher carbon content and is cheaper than gasoline. So while this carbon tax would mean an increase of gasoline prices by 12%, it would mean double the increase for diesel prices. As a result, although the results have the same direction as the results in the high oil scenario as regards the penetration of alternative technologies, they strongly favour gasoline as compared to diesel.

The **carbon tax 100** scenario assumes a carbon content tax equivalent to 100 euros per ton of CO_2. At that level of carbon tax the results would be comparable to that of the high oil price scenario, with the exception that gasoline has an advantage over both diesel and fuel cells. The other two alternative options, electric and –mainly hybrid- would also benefit.

The three scenarios on **subsidy** for **electric**, **hybrid** and **fuel cells** correspond to a decrease of the purchase cost of each alternative technology by 2000 euros. This would decrease the price differential of these technologies compared to conventional technologies and accelerate their introduction. For electric, although its share is increased, this is not enough for the difference in costs to be covered. For hybrid and fuel cells, penetration is accelerated and each of the two can become an important technology by 2020. Subsidies would not have any significant impact on total transport demand, but would further marginally reduce CO_2 emissions (except in the case of fuel cells).

The **zero emissions** scenario assumes the prohibition of conventional technologies in urban areas. This would favour hybrid vehicles in the medium term and all alternative technologies, in a proportional way, in the longer term. The main losers would be the light gasoline (and in the longer term, the light diesel) cars, since their predominantly urban role would be played by alternative technologies. This scenario also leads to a reduction in CO_2 emissions, though lower than in the case of *high oil* or *carbon tax 100*, where restrictions are applied to the whole fleet.

In order to test the case of industry selecting winning technologies and concentrating solely on them, a number of scenarios where one or more of the alternative technologies is abandoned were investigated. The rationale behind those scenarios is that manufacturers will not be willing to concentrate on all five paths (2 conventional and 3 alternatives) but will instead concentrate only on a limited number (2 to 4). In all cases of concentrating in only 4 paths, the projected share of the technology that is abandoned is expected to be divided proportionally between the 4 paths. That is to say, none of the alternatives is in fact blocking the development of the other alternatives or the demand for them, although abandoning one of them could help establish the critical mass for either or both of them. In **no electric**, no significant impacts on the penetration of the other alternatives, since the projected share of electric was too small to make a difference. In **no hybrid**, conventional technologies would still monopolise the market in 2010, since no alternative options would be sufficiently attractive. By 2020, the lost projected share of hybrid would again be divided proportionally among the remaining options. **No fuel cells**, would have no impact until the end of the 2010's.

If fuel cells are the only alternative technology to be developed (**no el or hyb**), the market will again be monopolised by conventional technologies until fuel cells improve significantly. But fuel cells will have then an important share of new registrations, higher than in baseline but still lower than in the *high oil* or *subsidy fuel cells* scenarios. But the situation in terms of CO_2 emissions would be worse, since the hybrids that they would replace would emit less.

The case of none of the alternative technologies being attractive enough (or manufacturers deciding to abandon all of them and concentrate on conventional technologies) is tested in **no new** scenario. Gasoline and diesel would share the market between them, and the main impact would be the worsening of the CO_2 emissions outlook. Instead of being significantly reduced, emission levels would remain at year 2000 levels. The 2 variants of *no new*, are a combination with the oil price scenarios. If oil prices are high (**no new, high oil**), demand slows down and emissions demonstrate a small improvement. But in the case of low oil prices (**no new, low oil**), both transport demand and CO_2 emissions increase dramatically.

Table 2-1: Overview of scenarios

Scenario	**Assumption**	**Technology penetration medium term**	**Technology penetration long term**
Baseline	Normal trends in demand, prices, technologies and policies	Diesel: increase Electric: <1% Hybrid: 10% Fuel cells: none	Diesel: stabilize Electric: 5% Hybrid: 25% Fuel cells: 10%
High oil	Oil price +7 $/bboe	Minimal impact	More alternative technologies Diesel preferred to gasoline
Low oil	Oil price -7 $/bboe	Delay in alternative technologies Gasoline is favoured	More conventional, mainly gasoline
Carbon tax 50	Fuel price +50 euro/tCO_2	Favours gasoline to diesel	Small acceleration of alternative technologies
Carbon tax 100	Fuel price +100 euro/tCO_2	Favours gasoline to diesel Small acceleration of alternative technologies	Unfavourable for fuel cells; Accelerates hybrid and electric
Subsidy electric	Electric vehicle price –2000 €	Minimal	Doubles penetration of electric
Subsidy hybrid	Hybrid vehicle price –2000 €	Accelerates hybrid	Hybrid becomes the main technology
Subsidy fuel cells	Fuel cell vehicle price –2000 €	Accelerates fuel cells	Fuel cells become established tech
Zero emissions	Only electric, fuel cells and hybrid in urban areas	Hybrid takes share of light gasoline	More alternative technologies
no electric	No electric car registrations (technology is abandoned)	Minimal	Minimal (lost share divided among all technologies)
no hybrid	No hybrid car registrations (technology is abandoned)	Market concentrated on conventional technologies	Lost share divided among all technologies: increase in electric and fuel cells
no fuel cells	No fuel cell car registrations (technology is abandoned)	None	Proportional distribution of lost share between gasoline, diesel, hybrid
no el or hyb	No electric nor hybrid	Proportional distribution of lost share between gasoline and diesel	Fuel cells become established tech
no new	No electric, hybrid of fuel cell	Proportional distribution of lost share between gasoline and diesel	Proportional distribution of lost share between gasoline and diesel
no new, high oil	Combination of no new with high oil scenario	Diesel gets most of lost share	Diesel gets most of lost share
no new, low oil	Combination of no new with low oil scenario	Gasoline gets most of lost share	Gasoline gets most of lost share

Table 2-2: Overview of scenarios (continued)

scenario	**Transport demand**	**CO_2 emissions[2]**
baseline	+26% in 2010 +33% in 2020	+ 3% in 2010 -13% in 2020
high oil	Slight slow-down of growth +18% in 2010 +24% in 2020	Small decrease in medium term, improvement (-22%) by 2020
low oil	Acceleration of growth +43% in 2010 +53% in 2020	+18% in 2010, balanced by technological progress in the long term
carbon tax 50	Slight slow-down of growth +22% in 2010 +28% in 2020	Slight improvement in the long term
carbon tax 100	Slight slow-down of growth, equivalent to high oil +18% in 2010 +24% in 2020	Improvement in the long term
subsidy electric	Minimal impact	Slight improvement in the long term
subsidy hybrid	Minimal impact	Slight improvement in the long term
subsidy fuel cells	Minimal impact	Minimal improvement in the long term
zero emissions	Minimal impact	Improvement in the long term
no electric	Minimal impact	Slightly worsening in the long term
no hybrid	Minimal impact	Worsening in the long term
no fuel cells	Minimal impact	Slightly worsening in the long term
no el or hyb	Minimal impact	Worsening in the long term
no new	Minimal impact	Worsening in the long term (remaining at 2000 levels)
no new, high oil	Slight slow-down of growth +19% in 2010 +29% in 2020	Worsening in the long term
no new, low oil	Acceleration of growth +44% in 2010 +56% in 2020	Large increase in the short and long term

[2] Including indirect emissions of electricity generation for electric cars, according to the projected energy mix for electricity generation (from POLES model)

3 Baseline scenario

The baseline scenario corresponds to the projections of the IPTS transport technologies model[3] concerning the potential share of each passenger car technology until year 2020. These projections were based on the outlook of the possible development of each technology, expressed in future trends in fuel economy and purchase cost for a typical passenger car, obtained through specific sectoral studies. Fuel economy and purchase cost correspond to a typical car with a specific engine power, price and fuel efficiency.

The average engine power used as a reference value for each technology for year 2000 is assumed to be:

Light gasoline	55 kW
Large gasoline	110 kW
Light diesel	70 kW
Large diesel	140 kW
Electric	80 kW
Fuel cells	80 kW
Hybrid	80 kW

The projections for the average car price for each technology, expressed in constant values, is given in Table 3-1. The average purchase cost of the reference car for all technologies is expected to fall in constant terms, a trend that has been evident in the last 20 years. As regards the conventional technologies, the decrease in diesel car price is expected to be larger than that of gasoline car prices. If differences in engine power and performance are also taken into account, the competition between the two technologies is expected to become even stronger in the future. The prices of electric and hybrid cars are expected to start becoming competitive between 2005 and 2010, while the outlook for fuel cells in more pessimistic, predicting competitive prices after 2015. As regards fuel economy, all three alternative technologies are expected to demonstrate a significant advantage compared to conventional technologies, although the fuel economy of electric vehicles will actually depend on the energy mix of electricity production (Table 3-2). Fuel prices may also have an impact on the potential of each technology. According to the projections of the POLES model that are used as input in the IPTS transport technologies model, the average price of electricity in the EU is expected to fall, mainly as a result of the increase of natural gas in electricity generation. On the other hand, diesel and gasoline are expected to become marginally more expensive (Table 3-3). However, differences at national level do exist, and therefore the potential of each technology can differ in each country.

Since the outlook for each technology is a result of surveys of research activities and car manufacturer published predictions, it can assumed that these figures represent a rather optimistic case for the development of each technology. It is rather unlikely that such low prices and fuel consumption levels will be achieved for all technologies, especially for the ones entailing a high degree of uncertainty in research activities. However, such projections - and the model results that can be derived from them- can still provide an indication of the potential of each technology and allow the investigation of policy measures that can be implemented in order to influence the dynamics of the car market.

[3] IPTS (2003), "Dynamics of the introduction of new passenger car technologies: The IPTS transport technologies model", Institute for Prospective Technological Studies, EUR , March 2003.

Table 3-1: Projections of average purchase cost of typical car in EU, constant prices, € (2000)

Year	**2000**	**2005**	**2010**	**2015**	**2020**
Light gasoline	16,047	15,548	15,070	14,553	14,055
Large gasoline	27,240	26,418	25,630	24,869	24,140
Light diesel	19,590	16,279	15,580	15,055	14,550
Large diesel	36,692	28,995	27,600	26,347	25,160
Electric	n/a	36,437	28,840	25,790	23,064
Fuel cells	n/a	n/a	43,760	32,245	24,800
Hybrid	n/a	25,688	23,740	20,867	18,424

Table 3-2: Projections of average fuel economy for new cars of each technology in EU

Year	**2000**	**2005**	**2010**	**2015**	**2020**
Light gasoline	7.3	6.9	6.6	6.3	6.1
Large gasoline	9.8	9.1	8.4	8.2	8.1
Light diesel	6.8	6.1	5.4	5.0	4.6
Large diesel	7.2	6.5	6.0	5.8	5.5
Electric	n/a	21.3	20.7	17.8	15.5
Fuel cells	n/a	n/a	4.1	3.2	3.1
Hybrid	n/a	4.7	4.3	4.0	3.9

Note: fuel economy expressed in kWh/100km for electric vehicles, diesel l/100km for diesel cars, gasoline l/100km for gasoline, hybrid and fuel cells

Table 3-3: Projections of average fuel price in EU-15, constant prices, €/toe (2000)

Year	2000	2005	2010	2015	2020
Gasoline	1492	1368	1426	1468	1507
Diesel	866	777	819	849	877
Electricity	1,732	1,736	1,736	1,656	1,583

Source: POLES model

According to the model's baseline projections, car ownership levels in the EU-15 are expected to continue increasing but, especially after 2015, will probably reach saturation at values between 600 and 650 cars per 1000 inhabitants (Figure 3-1). As a result, and in combination with the demographic and technological trends, annual new car registrations are expected to stabilise around 15 million for EU-15. The number of cars removed from the stock (scrapped or exported as used cars outside the EU-15) is expected to rise to almost 14 million per year, as a result of the 10-15 year lag compared with the increase of car ownership in the 1990's. The total number of passenger cars in circulation in EU-15 will rise to almost 220 millions by year 2020, an increase of 23% compared to year 2000.

As regards the penetration of new vehicle technologies, the model results suggest that only hybrid vehicles have the potential for a wide scale introduction by 2010 (Figure 3-2). Electric vehicles show a limited potential, concentrated mainly in some niche markets (urban areas in countries with cheap electricity), while fuel cells may capture a significant part of the market only by the end of the 2010's. Another trend that can be identified is that of the shift from gasoline to diesel. The expected improvements in diesel technology could provide significant cost savings and comparable performance with gasoline technology. A gradual replacement of gasoline cars with either diesel or hybrid (mainly gasoline-electric hybrids) is therefore expected in the medium term (2010-2015). In the longer term, conventional ICEs and hybrids may gradually lose their share to fuel cells (probably using hydrogen from reformed gasoline, natural gas or methanol), depending on the progress made in the development of fuel cell technologies.

Figure 3-1: Projected car ownership per capita in EU-15

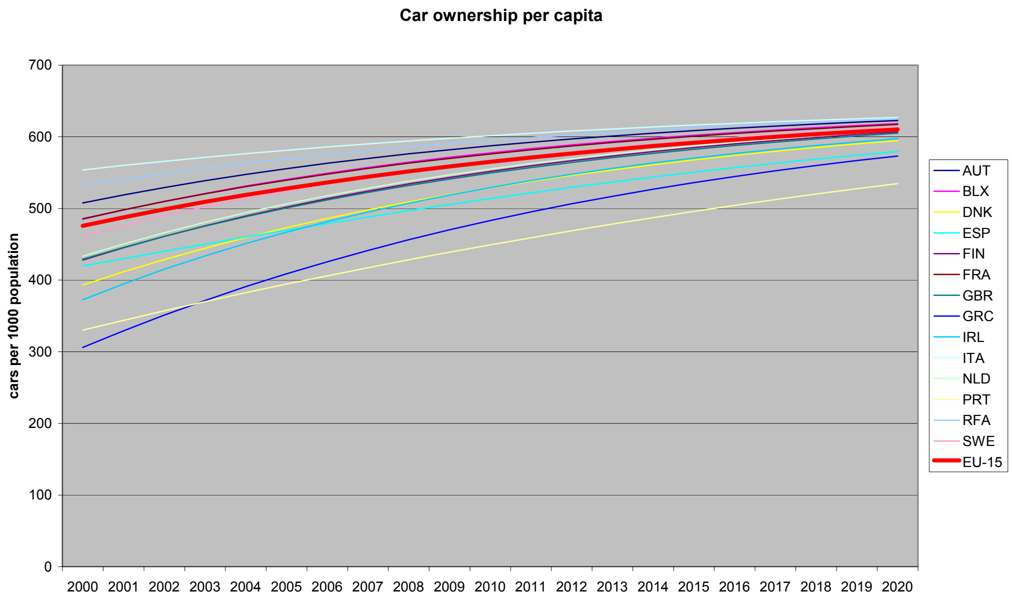
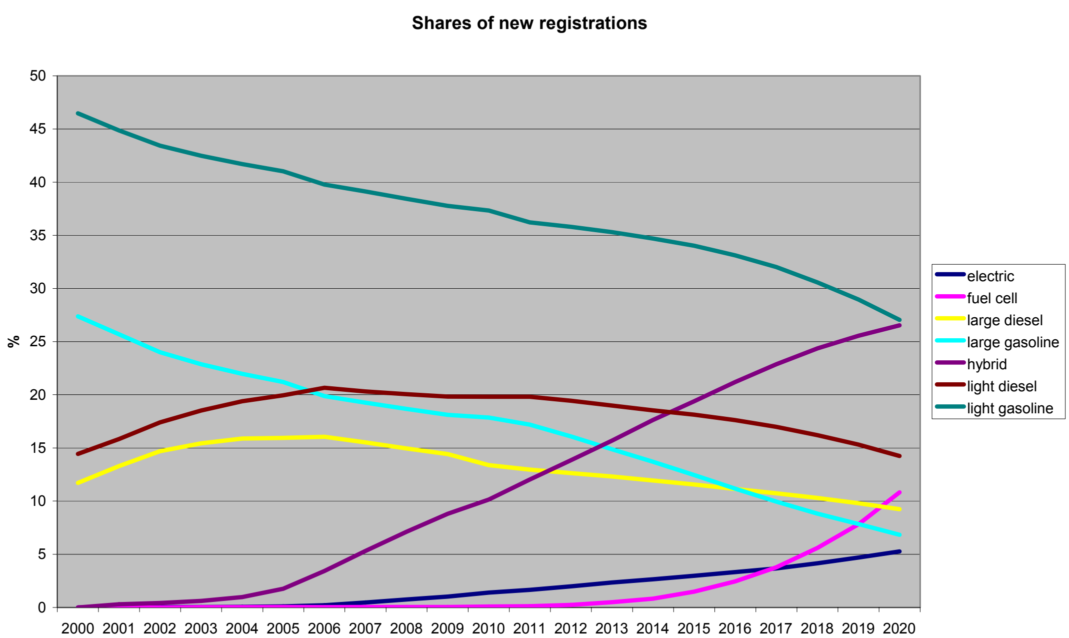


Figure 3-2: Projected share of new registrations for each technology



The size of the potential market for each technology at EU level suggests that it may take some years before alternative technologies reach the critical mass that will make them attractive options for car manufacturers (Table 3-4). At country level, large differences can be observed as a result of the differences in fuel costs. Countries where electricity is cheap (mainly the ones with a significant share of nuclear power in electricity generation) demonstrate a high potential for electric vehicles. Of course, the picture is only partial, since the demand at the global market is the main decisive factor for the strategy of the car manufacturers. Nevertheless, the European market is still an important part of the world market and strong demand for one of the alternative technologies may persuade manufacturers to invest in it.

Table 3-4: Potential market for each technology (projected number of new registrations)

	2000	**2005**	**2010**	**2015**	**2020**
Light gasoline	7.1 M	6.0 M	5.7 M	5.1 M	4.0 M
Large gasoline	4.2 M	3.1 M	2.7 M	1.9 M	1.0 M
Light diesel	2.2 M	2.9 M	3.0 M	2.7 M	2.1 M
Large diesel	1.8 M	2.3 M	2.0 M	1.7 M	1.4 M
Electric	n/a	15,000	200,000	450,000	750,000
Fuel cells	n/a	n/a	13,000	225,000	1.6 M
Hybrid	n/a	250,000	1.5 M	3 M	4 M

Table 3-5: Potential market and market share for alternative technologies in EU member states in year 2020

	Electric		Fuel cells		Hybrid	
	number	share	number	share	number	share
Austria (AUT)	<1000	0%	53,000	16%	70,000	21%
Belgium and Luxembourg (BLX)	40,000	8%	75,000	13%	140,000	26%
Denmark (DNK)	<1000	1%	70,000	38%	50,000	28%
Finland (FIN)	19,000	12%	25,000	16%	42,000	27%
France (FRA)	100,000	4%	460,000	18%	600,000	24%
Germany (RFA)	100,000	3%	300,000	8%	800,000	23%
Greece (GRC)	3,000	1%	12,500	5%	80,000	31%
Ireland (IRL)	3,000	2%	30,000	22%	30,000	21%
Italy (ITA)	60,000	3%	30,000	2%	550,000	31%
Netherlands (NLD)	73,000	10%	100,000	14%	200,000	27%
Portugal (PRT)	1,500	0%	25,000	8%	100,000	32%
Spain (ESP)	10,000	1%	60,000	7%	240,000	26%
Sweden (SWE)	64,000	21%	43,000	14%	84,000	28%
United Kingdom (GBR)	300,000	10%	300,000	11%	1,000,000	30%

Average car use is expected to stabilise around 14000 kms per car per year by 2020. However, notable differences among member states can be seen, due to the different lifestyles, geography, urbanisation and urban sprawl levels, and differences in statistics. Most of the expected changes in the driving factors can lead to increases in the average distance driven, but a certain saturation level for each country is expected to be reached in the next 15-20 years. As regards the total number of kms driven in each country, both the number of cars and the average distance are expected to rise and, as a result, total car use may increase by about 33% between 2000 and 2020. This projection implies that the overall increase in passenger transport demand that is expected in the next 20 years is most probably going to be covered by other modes (notably air transport for long distances), since car passenger transport will have reached saturation levels. This is highlighted in the projections for transport intensity that corresponds to passenger car transport. The ratio of kms driven to GDP is expected to continue rising until around 2005, but will tend to fall afterwards, since the growth in GDP will not be accompanied by a comparable growth in car passenger transport (Figure 3-3).

Total fuel consumption and CO_2 emissions are expected to follow a similar trend, reaching a maximum around year 2005 and starting to fall afterwards. This is the result of the expected fuel economy of passenger cars improving faster than the rate of growth of total car use. An important part of the improvement of fuel economy is expected to come from the introduction of hybrids and, later on, fuel cells but -even without these alternatives- the evolution of gasoline and diesel ICEs according to the EURO standards and the ACEA agreement should be enough to prevent CO_2 emissions from rising further. Fuel economy in Europe is expected to improve, but differences will still exist between member states due to the differences in user choices. The improvement of the average fuel economy for the whole car stock is expected to be even larger, since the majority of the cars that entered into circulation in the 1980's and 1990's will have been replaced in the next 10 years by much more fuel efficient cars.

The average age of cars in circulation is expected to rise slightly in the next 20 years, from 7.4 to 8.3 years. This is mainly the result of demographics in Europe (age distribution of car owners) and the saturation in car ownership levels (total demand). The effects of improved car technology on the length of a car's life (either technical or economic) seem to become marginal, and the average age of car scrapping (or removal from circulation in general) is stable. However, in both average age indicators, significant differences exist among member states. These differences are mainly the result of the different socio-economic conditions, car costs, disposable income and (new and used) car market operation in each country.

Figure 3-3: Projected passenger car transport intensity for EU member states

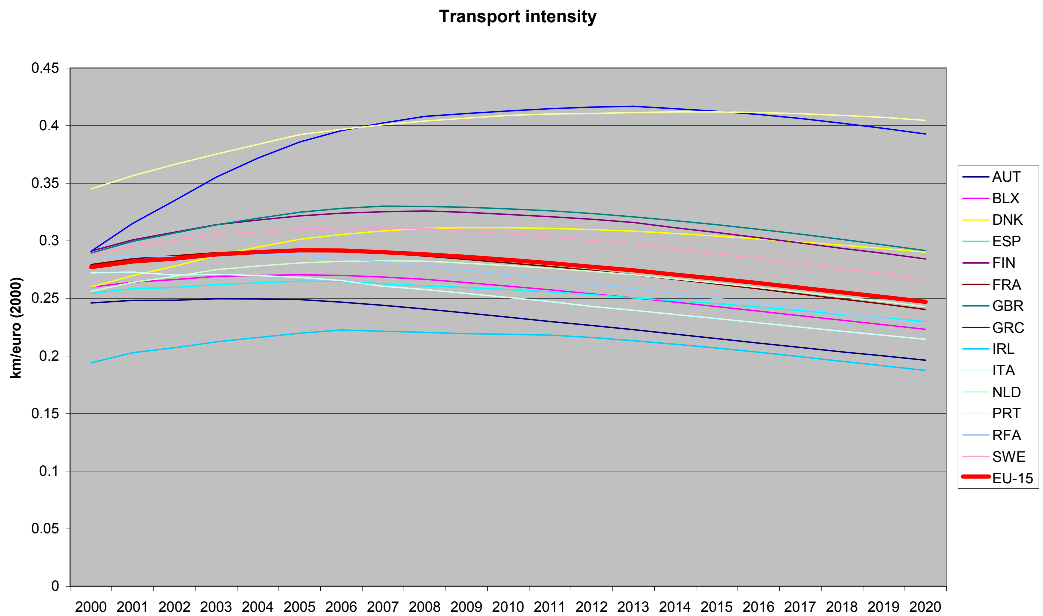
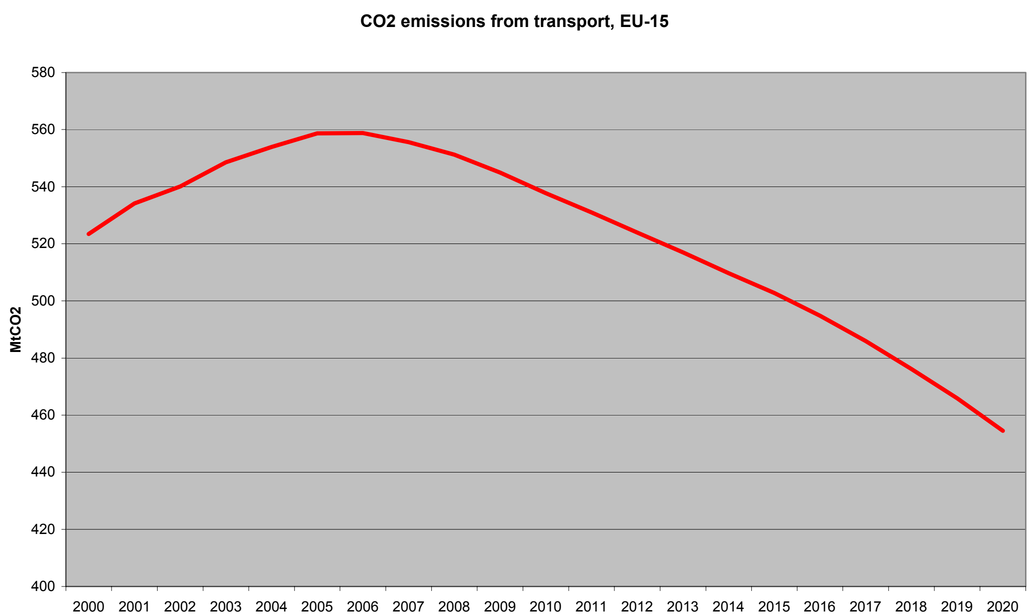


Figure 3-4: Projected CO_2 emissions from car passenger transport



4 Oil price and fuel tax scenarios

Two scenarios corresponding to higher and lower oil prices were investigated. These scenarios describe a potential development in external conditions, but could also result in the case of changing the taxation levels of oil based products (gasoline and diesel).

The change of oil price levels is applied to the fuel prices predicted by the POLES model during the whole period of the simulation. As a reference, the change of price is assumed to be equal to 28%. For example, if the price predicted by POLES was 25 US$ per barrel, in the high oil scenario it would be increased to 32 US$ and in the low oil scenario it would be decreased to 18 US$.

A change in oil prices would have a minimal impact in the medium term (up to 2010) as regards the introduction of alternative technologies. None of them would be mature enough (i.e. have competing costs) by then to benefit and increase their share (or to lose their share in the case of low oil prices).

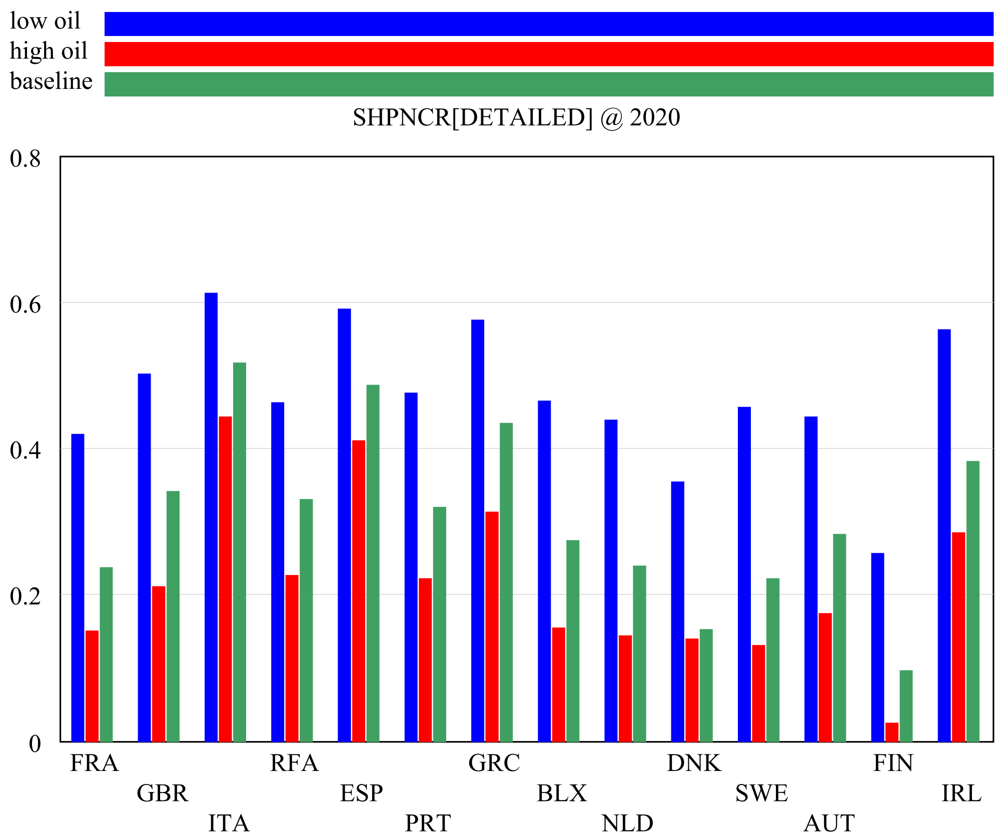
Table 4-1: Projected shares of new registrations for each technology in oil price scenarios, EU-15

		2000	2005	2010	2015	2020
Light gasoline	low oil	46.5%	42.9%	41.2%	39.6%	36.9%
	high oil	46.5%	40.1%	34.9%	29.6%	19.7%
	baseline	46.5%	41.0%	37.3%	34.0%	27.0%
Large gasoline	low oil	27.4%	22.8%	21.0%	17.1%	12.1%
	high oil	27.4%	20.4%	15.8%	9.8%	4.2%
	baseline	27.4%	21.2%	17.9%	12.4%	6.8%
Light diesel	low oil	14.4%	18.5%	18.0%	17.2%	16.1%
	high oil	14.4%	20.5%	20.3%	17.2%	11.9%
	baseline	14.4%	19.9%	19.8%	18.1%	14.2%
Large diesel	low oil	11.7%	14.3%	11.9%	10.4%	9.0%
	high oil	11.7%	16.8%	14.1%	11.8%	8.4%
	baseline	11.7%	15.9%	13.4%	11.6%	9.2%
Electric	low oil	0.0%	0.1%	0.5%	0.7%	0.8%
	high oil	0.0%	0.1%	2.9%	6.8%	10.6%
	baseline	0.0%	0.1%	1.4%	3.0%	5.3%
Fuel cells	low oil	0.0%	0.0%	0.1%	0.3%	1.6%
	high oil	0.0%	0.0%	0.2%	3.8%	21.0%
	baseline	0.0%	0.0%	0.1%	1.5%	10.8%
Hybrid	low oil	0.0%	1.4%	7.3%	14.6%	23.4%
	high oil	0.0%	2.0%	11.7%	21.0%	24.2%
	baseline	0.0%	1.8%	10.1%	19.4%	26.5%

In the longer term, an increase in the price of oil would benefit the alternative technologies, since their difference from the conventional technologies in terms of variable cost would become smaller. As regards the conventional technologies, higher oil prices would reinforce the shift from gasoline to diesel, as fuel economy becomes a decisive factor. A higher oil price would also slow down growth in transport demand. The slower growth in demand, combined with the shift towards alternatives and more efficient vehicles, would also lead to further reductions in CO_2 emissions.

The long tem impacts of low oil prices would, naturally, lead to the opposite direction in terms of the share of the market that alternative technologies can capture. The introduction of alternative technologies would be delayed and gasoline would remain the most attractive option. Transport demand would increase, though still slower than GDP growth (saturation levels of demand for passenger car transport will have probably been already reached). CO_2 emissions would increase significantly by 2010 and in the long term brought down to the levels of 2000 as a result of improved technology in gasoline cars.

Figure 4-1: Share of gasoline cars in new registrations in EU member states in 2020, oil price scenarios (100%=1)



The projected share of each technology and the impact that a change in fuel prices or taxes would have differ significantly among the EU member states (Figure 4-1). In all cases, however, the direction of the impacts would be the same for all countries. The average fuel economy and annual fuel consumption per car in the EU-15 are also expected to react to the change in fuel prices (Figure 4-2). High oil prices would lead consumers to chose more fuel efficient technologies (or smaller cars), while low prices would make fuel efficiency a less important parameter.

Figure 4-2: Annual fuel consumption per car in EU-15, oil price scenarios

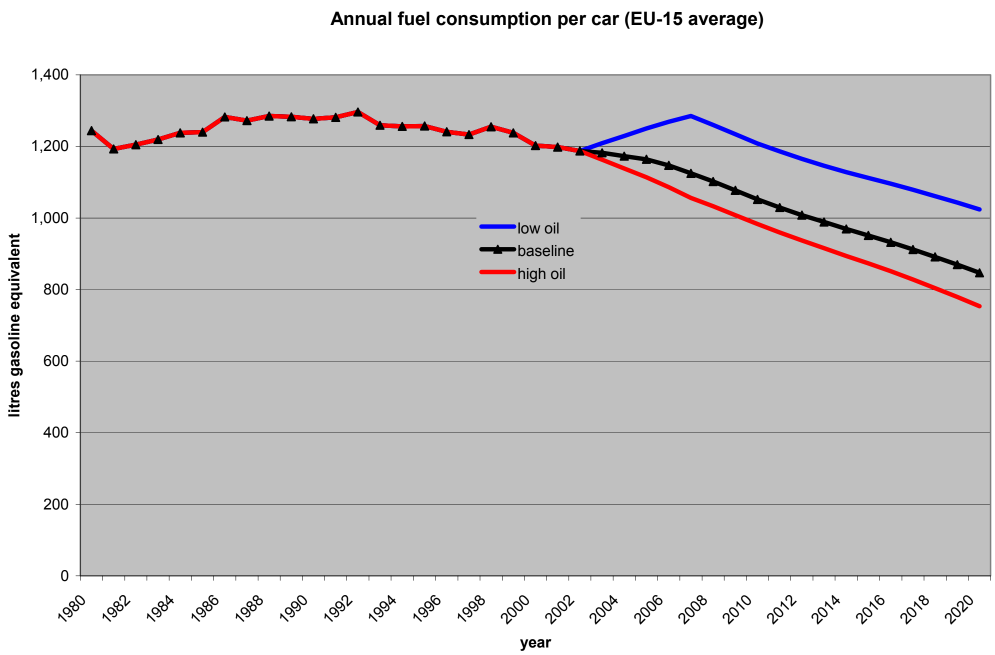


Figure 4-3: Total emissions from car passenger transport in EU member states in 2020, oil price scenarios (Mt CO_2)

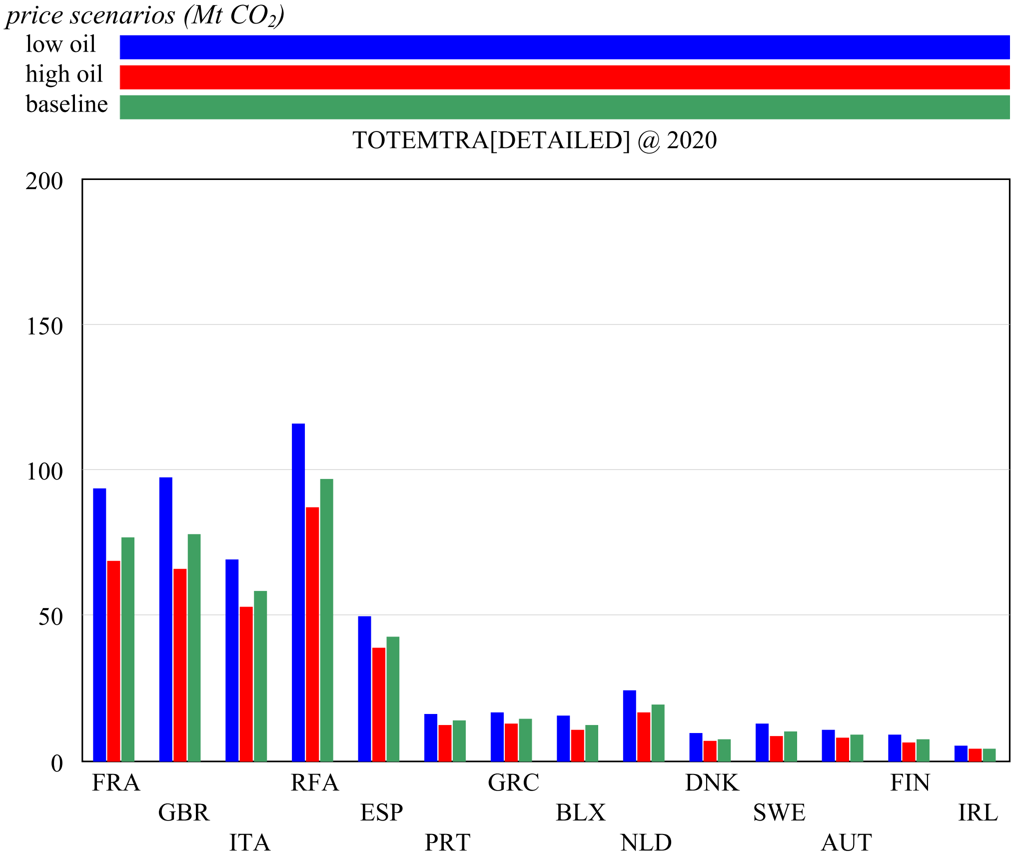


Table 4-2: Summary of main indicators for oil price scenarios (EU-15)

		2000	2005	2010	2015	2020
Share of gasoline cars in new registrations, EU-15 (percent)	low oil	74	66	62	57	49
	high oil	74	61	51	39	24
	baseline	74	62	55	46	34
Share of diesel cars in new registrations, EU-15 (percent)	low oil	26	33	30	28	25
	high oil	26	37	34	29	20
	baseline	26	36	33	30	23
Average of km driven per car per year, EU-15	low oil	12,760	14,536	15,640	15,797	15,804
	high oil	12,760	12,964	12,887	12,925	12,807
	baseline	12,760	13,549	13,719	13,802	13,713
Total of km driven per year, EU-15	low oil	2.262 M	2.832 M	3.241 M	3.391 M	3.460 M
	high oil	2.262 M	2.525 M	2.671 M	2.775 M	2.804 M
	baseline	2.262 M	2.639 M	2.843 M	2.963 M	3.002 M
Transport intensity of passenger cars (km driven per € of GDP), EU-15	low oil	0.28	0.31	0.32	0.31	0.28
	high oil	0.28	0.28	0.27	0.25	0.23
	baseline	0.28	0.29	0.28	0.27	0.25
Average fuel economy of new gasoline cars, EU-15 (l/100km)	low oil	8.2	7.7	7.2	6.9	6.6
	high oil	8.2	7.7	7.1	6.8	6.4
	baseline	8.2	7.7	7.2	6.8	6.5
Average CO2 emissions of new gasoline cars, EU-15 (gCO2/km)	low oil	199	186	173	167	160
	high oil	199	185	172	164	155
	baseline	199	185	173	165	157
Total fossil fuel consumption for passenger car transport, EU-15 (ktoe)	low oil	177,713	203,113	208,800	199,159	186,974
	high oil	177,713	180,921	169,833	156,280	137,452
	baseline	177,713	189,173	181,798	170,258	154,511
Total CO2 emissions of passenger car transport, EU-15 (MtCO2)	low oil	523	600	617	588	552
	high oil	523	534	503	463	406
	baseline	523	559	538	504	457
Average fuel efficiency of passenger cars in circulation (l/100km gasoline equivalent)	low oil	9.4	8.6	7.8	7.1	6.5
	high oil	9.4	8.6	7.7	6.8	5.9
	baseline	9.4	8.6	7.7	6.9	6.2
Average annual fuel consumption of passenger cars in circulation (l/car gasoline equivalent)	low oil	1,202	1,250	1,208	1,112	1,024
	high oil	1,202	1,114	983	873	753
	baseline	1,202	1,164	1,052	951	846
Average CO2 emissions of passenger cars in circulation (gCO2/km)	low oil	231	212	190	173	160
	high oil	231	212	188	167	145
	baseline	231	212	189	170	152

5 Carbon tax scenarios

The carbon tax scenarios are different from the oil price increase or fuel tax increase in the sense that a tax proportional to the carbon content of each fuel is applied. In the **carbon tax 50** scenario, the carbon content related tax that is imposed is the equivalent of 50 euros per ton of CO_2, while in the **carbon tax 100** scenario it is the equivalent of 100 euros per ton of CO_2.
The main difference from the high oil price scenario (that also corresponds to imposing a fuel tax) is that carbon tax affects gasoline and diesel in a different manner. Diesel has a higher carbon content and is cheaper than gasoline. So while this carbon tax would mean an increase of gasoline prices by 12%, it would mean double the increase for diesel prices. As a result, although the results have the same direction as the results in the high oil scenario as regards the penetration of alternative technologies, they strongly favour gasoline as compared to diesel.

At higher levels of carbon tax, electric and –mainly- hybrid cars would be especially favoured, since they would exploit their advantage in terms of CO_2 emissions (for electric, as a result of the change of the energy mix in electricity generation).

Table 5-1: Projected shares of new registrations for each technology in carbon tax scenarios, EU-15

		2000	2005	2010	2015	2020
Light gasoline	carbon tax 100	46.5%	41.9%	38.6%	34.5%	25.9%
	carbon tax 50	46.5%	41.5%	38.1%	34.3%	26.6%
	baseline	46.5%	41.0%	37.3%	34.0%	27.0%
Large gasoline	carbon tax 100	27.4%	22.6%	20.0%	13.6%	7.9%
	carbon tax 50	27.4%	22.0%	19.1%	13.2%	7.4%
	baseline	27.4%	21.2%	17.9%	12.4%	6.8%
Light diesel	carbon tax 100	14.4%	17.3%	14.0%	11.6%	8.4%
	carbon tax 50	14.4%	18.5%	16.7%	14.6%	10.8%
	baseline	14.4%	19.9%	19.8%	18.1%	14.2%
Large diesel	carbon tax 100	11.7%	15.7%	10.9%	8.7%	6.8%
	carbon tax 50	11.7%	15.8%	12.1%	10.1%	7.9%
	baseline	11.7%	15.9%	13.4%	11.6%	9.2%
Electric	carbon tax 100	0.0%	0.1%	2.9%	6.6%	11.6%
	carbon tax 50	0.0%	0.1%	2.0%	4.5%	8.3%
	baseline	0.0%	0.1%	1.4%	3.0%	5.3%
Fuel cells	carbon tax 100	0.0%	0.0%	0.1%	1.3%	9.9%
	carbon tax 50	0.0%	0.0%	0.1%	1.4%	10.5%
	baseline	0.0%	0.0%	0.1%	1.5%	10.8%
Hybrid	carbon tax 100	0.0%	2.4%	13.5%	23.7%	29.5%
	carbon tax 50	0.0%	2.1%	11.9%	21.8%	28.4%
	baseline	0.0%	1.8%	10.1%	19.4%	26.5%

Figure 5-1: Share of diesel cars in new registrations in EU member states in 2020, carbon tax scenarios (100%=1)

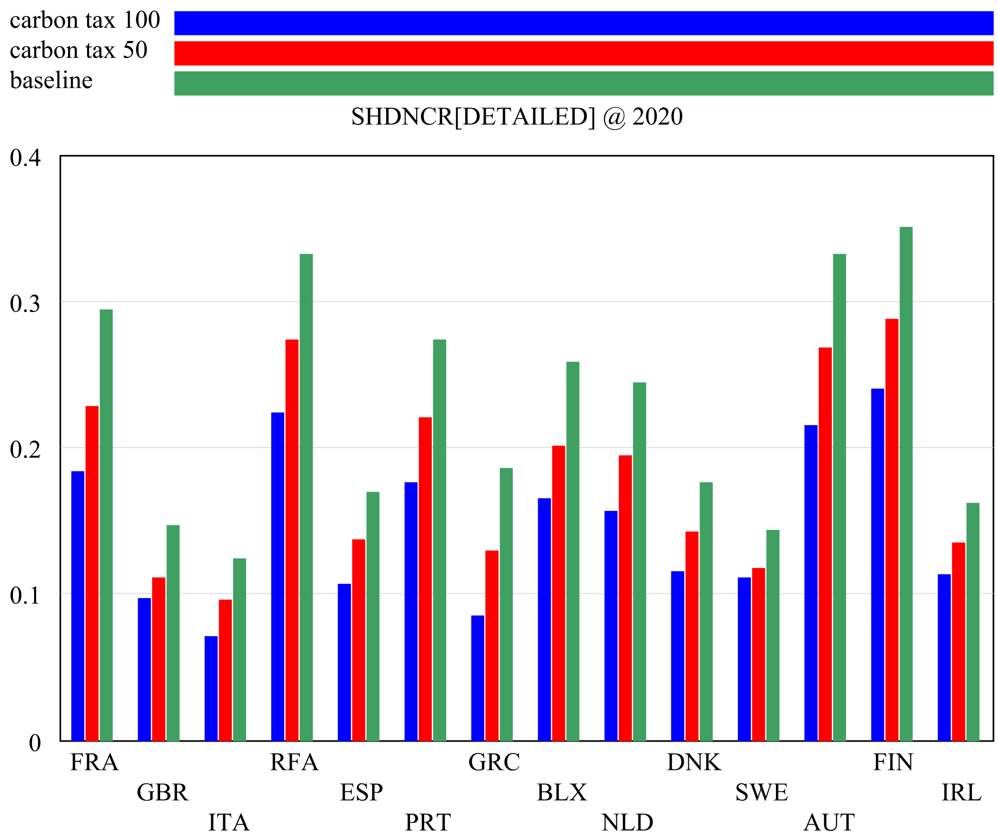


Figure 5-2: Influence of carbon tax on potential market share for each technology in year 2020

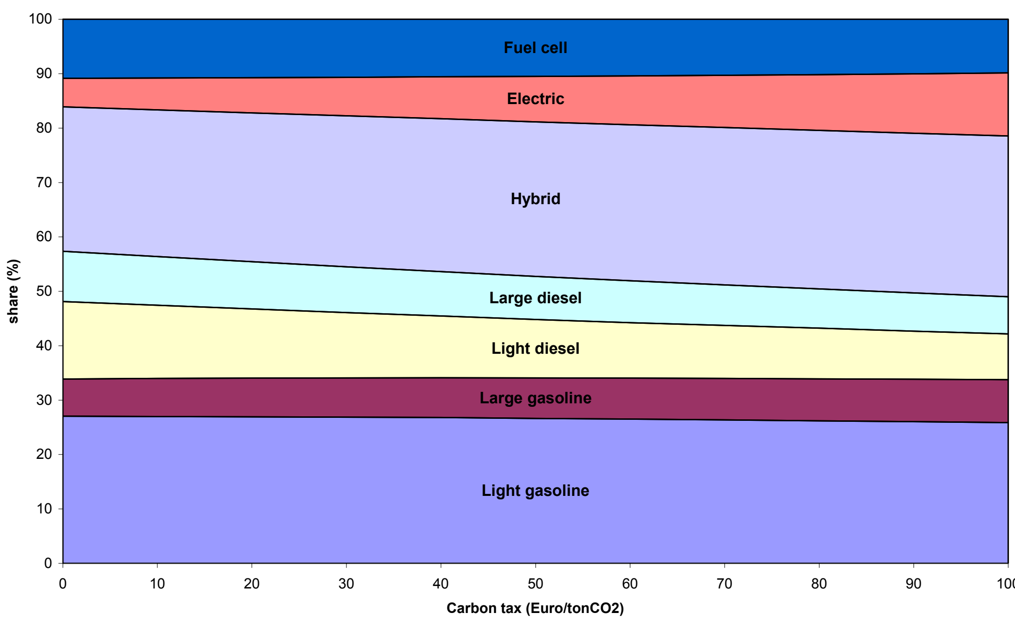


Figure 5-3: Annual fuel consumption per car in EU-15, carbon tax scenarios

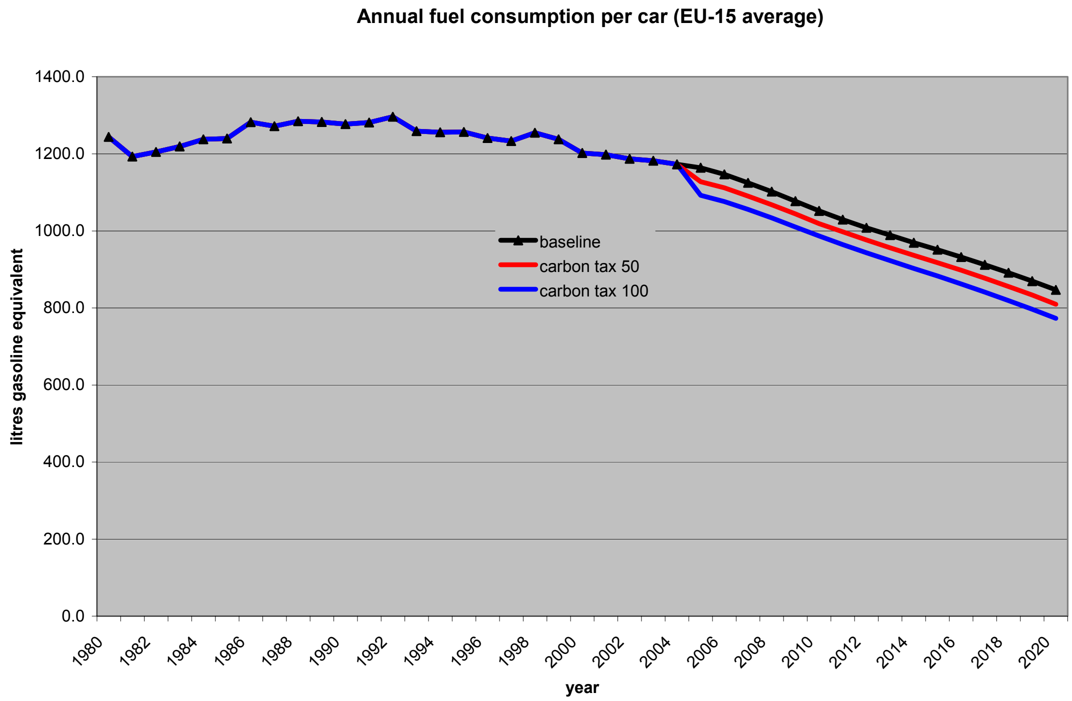


Figure 5-4: *Total emissions from car passenger transport in EU member states in 2020, carbon tax scenarios (Mt CO_2)*

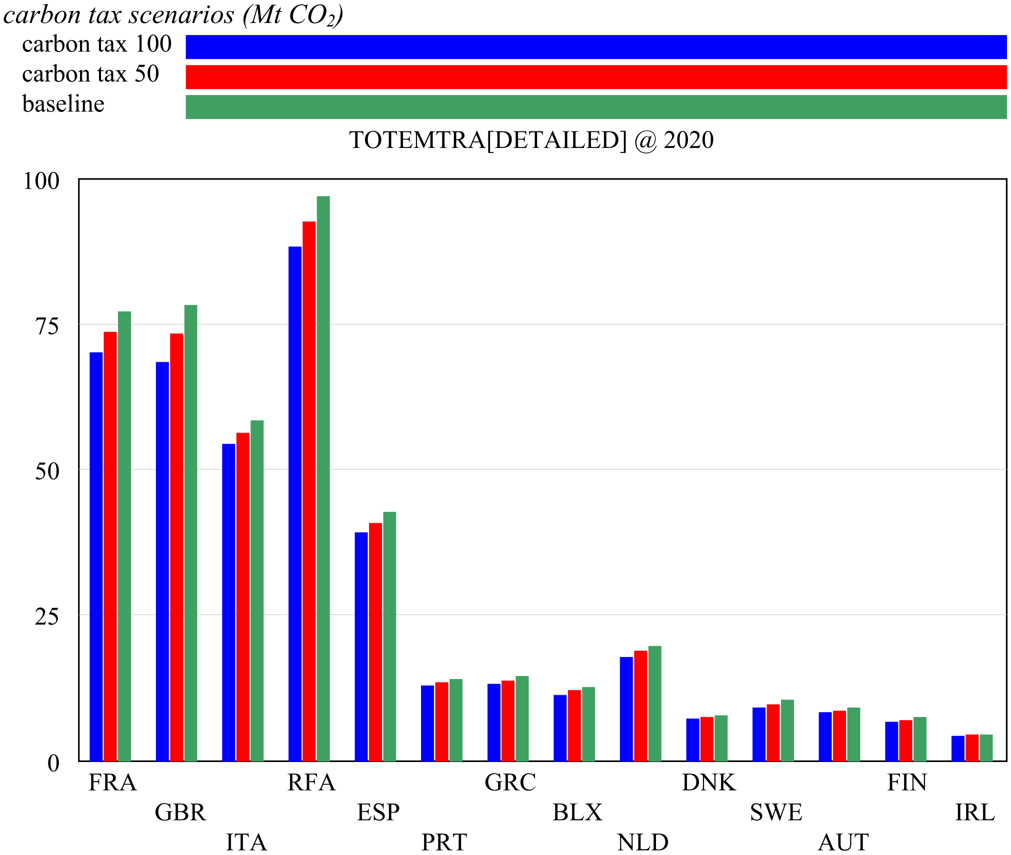


Table 5-2: Summary of main indicators for carbon tax scenarios (EU-15)

		2000	2005	2010	2015	2020
Share of gasoline cars in new registrations, EU-15 (percent)	carbon tax 100	74	64	59	48	34
	carbon tax 50	74	63	57	48	34
	baseline	74	62	55	46	34
Share of diesel cars in new registrations, EU-15 (percent)	carbon tax 100	26	33	25	20	15
	carbon tax 50	26	34	29	25	19
	baseline	26	36	33	30	23
Average of km driven per car per year, EU-15	carbon tax 100	12,760	12,705	12,861	12,920	12,805
	carbon tax 50	12,760	13,127	13,288	13,357	13,250
	baseline	12,760	13,549	13,719	13,802	13,713
Total of km driven per year, EU-15	carbon tax 100	2.262 M	2.475 M	2.665 M	2.774 M	2.803 M
	carbon tax 50	2.262 M	2.557 M	2.754 M	2.867 M	2.901 M
	baseline	2.262 M	2.639 M	2.843 M	2.963 M	3.002 M
Transport intensity of passenger cars (km driven per € of GDP), EU-15	carbon tax 100	0.28	0.27	0.27	0.25	0.23
	carbon tax 50	0.28	0.28	0.27	0.26	0.24
	baseline	0.28	0.29	0.28	0.27	0.25
Average fuel economy of new gasoline cars, EU-15 (l/100km)	carbon tax 100	8.2	7.7	7.2	6.8	6.6
	carbon tax 50	8.2	7.7	7.2	6.8	6.5
	baseline	8.2	7.7	7.2	6.8	6.5
Average CO2 emissions of new gasoline cars, EU-15 (gCO2/km)	carbon tax 100	199	186	174	165	159
	carbon tax 50	199	186	173	165	158
	baseline	199	185	173	165	157
Total fossil fuel consumption for passenger car transport, EU-15 (ktoe)	carbon tax 100	177,713	177,398	170,464	158,069	141,062
	carbon tax 50	177,713	183,287	176,175	164,269	147,808
	baseline	177,713	189,173	181,798	170,258	154,511
Total CO2 emissions of passenger car transport, EU-15 (MtCO2)	carbon tax 100	523	524	503	466	415
	carbon tax 50	523	541	521	485	436
	baseline	523	559	538	504	457
Average fuel efficiency of passenger cars in circulation (l/100km gasoline equivalent)	carbon tax 100	9.4	8.6	7.7	6.9	6.1
	carbon tax 50	9.4	8.6	7.7	6.9	6.2
	baseline	9.4	8.6	7.7	6.9	6.2
Average annual fuel consumption of passenger cars in circulation (l/car gasoline equivalent)	carbon tax 100	1,202	1,092	987	883	773
	carbon tax 50	1,202	1,128	1,019	918	810
	baseline	1,202	1,164	1,052	951	847
Average CO2 emissions of passenger cars in circulation (gCO2/km)	carbon tax 100	231	212	189	168	148
	carbon tax 50	231	212	189	169	150
	baseline	231	212	189	170	152

6 Subsidy scenarios

The three scenarios on **subsidy** for **electric**, **hybrid** and **fuel cells** correspond to a decrease of the purchase cost of each alternative technology by 2000 euros. This would decrease the price differential of these technologies compared to conventional technologies and accelerate their introduction. For electric, although its share is increased, this is not enough for the difference in costs to be covered. For hybrid and fuel cells, penetration is accelerated and each of the two can become an important technology by 2020. The average cost per km would rise, but it would not have only a marginal impact on total transport demand. Emissions of CO_2 can be reduced in the long term, depending on the rate of replacement of older vehicles with alternative technologies and the carbon efficiency of each technology.

Table 6-1: Projected shares of new registrations for each technology in subsidy scenarios, EU-15

		2000	2005	2010	2015	2020
Light gasoline	subsidy hybrid	46.5%	40.8%	36.0%	31.0%	21.5%
	subsidy fuel cells	46.5%	41.0%	37.3%	33.8%	25.4%
	subsidy electric	46.5%	41.0%	37.2%	33.5%	25.8%
	baseline	46.5%	41.0%	37.3%	34.0%	27.0%
Large gasoline	subsidy hybrid	27.4%	21.0%	16.6%	10.7%	6.8%
	subsidy fuel cells	27.4%	21.2%	17.9%	12.3%	6.0%
	subsidy electric	27.4%	21.2%	17.7%	12.2%	6.6%
	baseline	27.4%	21.2%	17.9%	12.4%	6.8%
Light diesel	subsidy hybrid	14.4%	19.7%	18.5%	15.9%	12.3%
	subsidy fuel cells	14.4%	19.9%	19.8%	17.9%	13.0%
	subsidy electric	14.4%	19.9%	19.7%	17.7%	13.5%
	baseline	14.4%	19.9%	19.8%	18.1%	14.2%
Large diesel	subsidy hybrid	11.7%	15.7%	12.3%	10.2%	8.9%
	subsidy fuel cells	11.7%	15.9%	13.4%	11.4%	8.3%
	subsidy electric	11.7%	15.9%	13.3%	11.4%	9.2%
	baseline	11.7%	15.9%	13.4%	11.6%	9.2%
Electric	subsidy hybrid	0.0%	0.1%	1.2%	2.4%	5.0%
	subsidy fuel cells	0.0%	0.1%	1.4%	2.8%	4.7%
	subsidy electric	0.0%	0.1%	2.0%	4.9%	9.4%
	baseline	0.0%	0.1%	1.4%	3.0%	5.3%
Fuel cells	subsidy hybrid	0.0%	0.0%	0.0%	1.1%	10.1%
	subsidy fuel cells	0.0%	0.0%	0.1%	2.6%	18.1%
	subsidy electric	0.0%	0.0%	0.1%	1.3%	10.0%
	baseline	0.0%	0.0%	0.1%	1.5%	10.8%
Hybrid	subsidy hybrid	0.0%	2.6%	15.3%	28.7%	35.3%
	subsidy fuel cells	0.0%	1.8%	10.1%	19.2%	24.4%
	subsidy electric	0.0%	1.7%	10.0%	19.0%	25.5%
	baseline	0.0%	1.8%	10.1%	19.4%	26.5%

Table 6-2: Total annual cost of subsidies per country (million €)

		2005	2010	2015	2020
France	subsidy hybrid	117	789	1438	1709
	subsidy fuel cells	0	4	254	1349
	subsidy electric	4	96	232	371
United Kingdom	subsidy hybrid	185	1163	2030	2360
	subsidy fuel cells	2	7	101	1202
	subsidy electric	8	150	446	1065
Italy	subsidy hybrid	102	586	1114	1424
	subsidy fuel cells	3	9	31	134
	subsidy electric	7	63	120	198
Germany	subsidy hybrid	139	840	1750	2266
	subsidy fuel cells	1	6	162	1112
	subsidy electric	6	98	243	425
Spain	subsidy hybrid	41	257	487	661
	subsidy fuel cells	1	5	36	228
	subsidy electric	3	22	37	53
Portugal	subsidy hybrid	17	109	205	253
	subsidy fuel cells	0	0	8	98
	subsidy electric	0	2	3	6
Greece	subsidy hybrid	15	90	179	192
	subsidy fuel cells	0	0	1	60
	subsidy electric	0	4	9	21
Belgium and Luxembourg	subsidy hybrid	26	171	317	384
	subsidy fuel cells	0	1	32	256
	subsidy electric	2	37	88	142
Netherlands	subsidy hybrid	40	269	450	519
	subsidy fuel cells	0	0	47	309
	subsidy electric	2	50	110	235
Denmark	subsidy hybrid	17	104	134	136
	subsidy fuel cells	0	1	52	160
	subsidy electric	0	1	2	2
Sweden	subsidy hybrid	20	131	196	207
	subsidy fuel cells	0	1	18	139
	subsidy electric	2	60	124	185
Austria	subsidy hybrid	13	80	164	204
	subsidy fuel cells	0	1	28	166
	subsidy electric	0	6	11	15
Finland	subsidy hybrid	11	67	106	108
	subsidy fuel cells	0	0	12	82
	subsidy electric	0	14	37	61
Ireland	subsidy hybrid	5	39	71	89
	subsidy fuel cells	0	1	15	89
	subsidy electric	0	3	6	9

Figure 6-1: Share of electric cars in new registrations in EU member states in 2020, subsidy scenarios (100%=1)

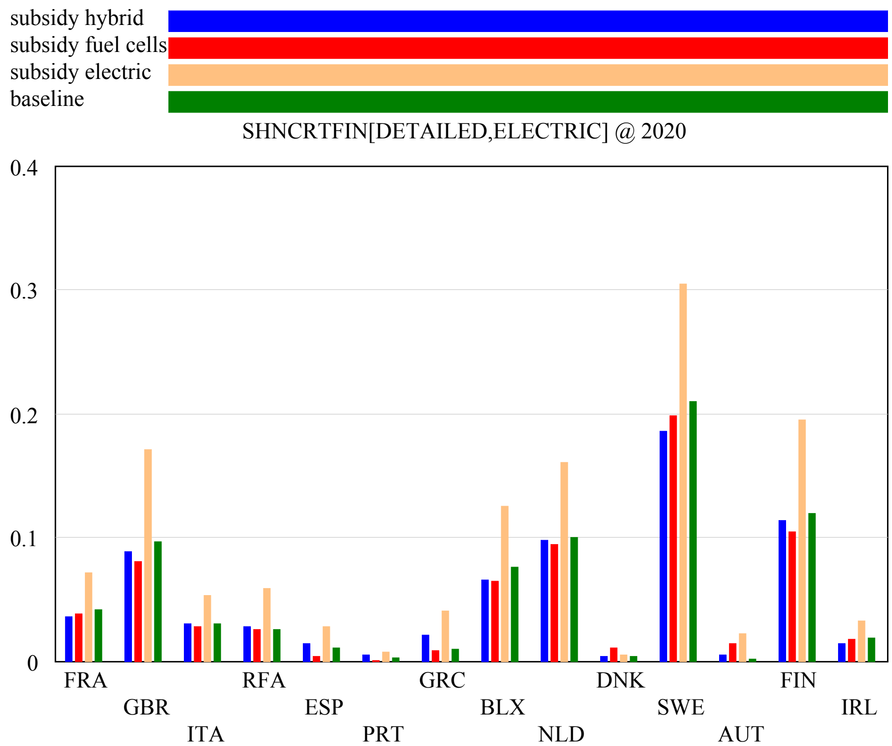


Figure 6-2: Share of fuel cells in new registrations in EU member states in 2020, subsidy scenarios (100%=1)

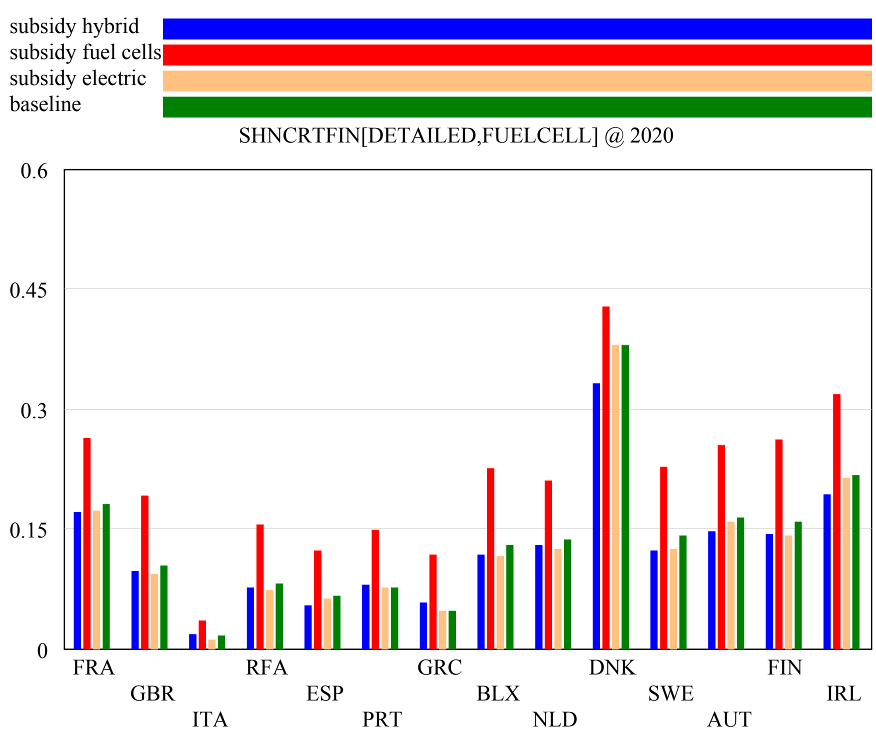


Figure 6-3: Share of hybrid cars in new registrations in EU member states in 2020, subsidy scenarios (100%=1)

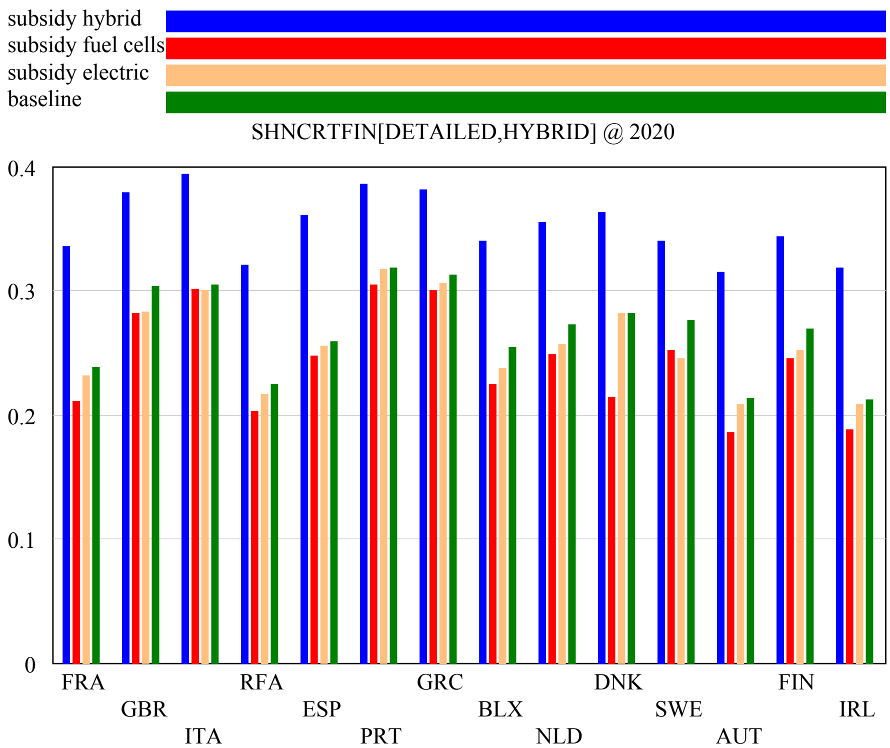


Figure 6-4: Total emissions from car passenger transport in EU member states in 2020, subsidy scenarios (Mt CO_2)

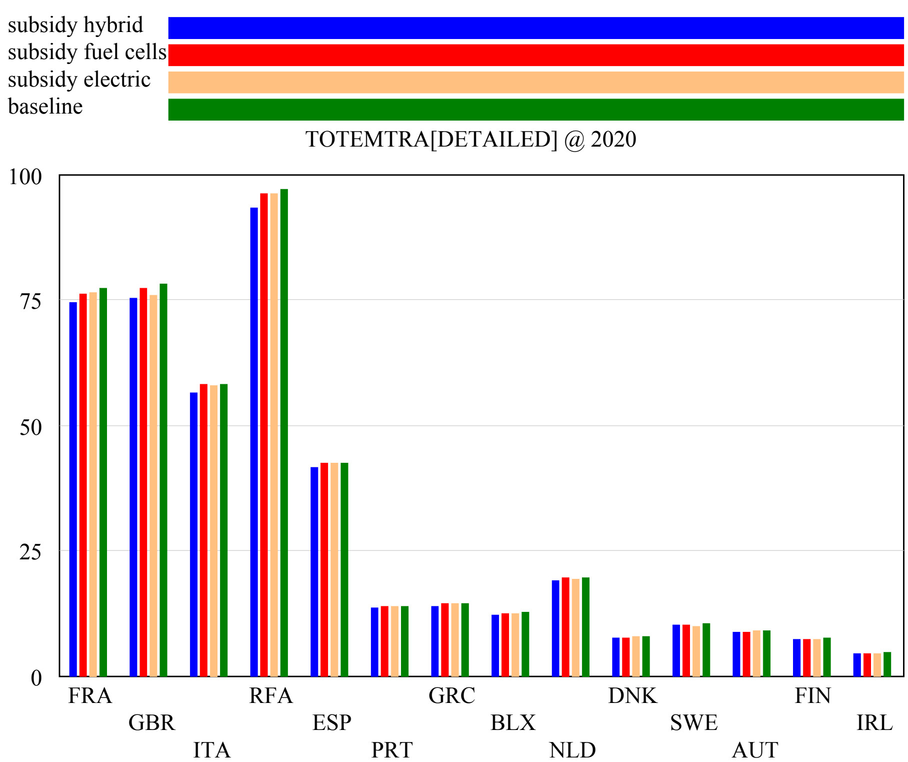


Table 6-3: Summary of main indicators for subsidy scenarios (EU-15)

		2000	2005	2010	2015	2020
Share of gasoline cars in new registrations, EU-15 (percent)	subsidy hybrid	74	62	53	42	28
	subsidy fuel cells	74	62	55	46	31
	subsidy electric	74	62	55	46	32
	baseline	74	62	55	46	34
Share of diesel cars in new registrations, EU-15 (percent)	subsidy hybrid	26	35	31	26	21
	subsidy fuel cells	26	36	33	29	21
	subsidy electric	26	36	33	29	23
	baseline	26	36	33	30	23
Average of km driven per car per year, EU-15	subsidy hybrid	12,760	13,548	13,691	13,722	13,600
	subsidy fuel cells	12,760	13,549	13,719	13,799	13,688
	subsidy electric	12,760	13,549	13,715	13,783	13,668
	baseline	12,760	13,549	13,719	13,802	13,713
Total of km driven per year, EU-15	subsidy hybrid	2.262 M	2.639 M	2.837 M	2.946 M	2.977 M
	subsidy fuel cells	2.262 M	2.639 M	2.843 M	2.962 M	2.996 M
	subsidy electric	2.262 M	2.639 M	2.842 M	2.959 M	2.992 M
	baseline	2.262 M	2.639 M	2.843 M	2.963 M	3.002 M
Transport intensity of passenger cars (km driven per € of GDP), EU-15	subsidy hybrid	0.28	0.29	0.28	0.27	0.24
	subsidy fuel cells	0.28	0.29	0.28	0.27	0.25
	subsidy electric	0.28	0.29	0.28	0.27	0.25
	baseline	0.28	0.29	0.28	0.27	0.25
Average fuel economy of new gasoline cars, EU-15 (l/100km)	subsidy hybrid	8.2	7.7	7.1	6.8	6.6
	subsidy fuel cells	8.2	7.7	7.2	6.8	6.5
	subsidy electric	8.2	7.7	7.2	6.8	6.5
	baseline	8.2	7.7	7.2	6.8	6.5
Average CO2 emissions of new gasoline cars, EU-15 (gCO2/km)	subsidy hybrid	199	185	173	164	159
	subsidy fuel cells	199	185	173	165	156
	subsidy electric	199	185	173	165	157
	baseline	199	185	173	165	157
Total fossil fuel consumption for passenger car transport, EU-15 (ktoe)	subsidy hybrid	177,713	189,114	180,521	166,653	149,677
	subsidy fuel cells	177,713	189,173	181,796	170,103	153,189
	subsidy electric	177,713	189,171	181,651	169,527	152,653
	baseline	177,713	189,173	181,798	170,258	154,511
Total CO2 emissions of passenger car transport, EU-15 (MtCO2)	subsidy hybrid	523	559	534	493	442
	subsidy fuel cells	523	559	538	504	453
	subsidy electric	523	559	538	502	451
	baseline	523	559	538	504	457
Average fuel efficiency of passenger cars in circulation (l/100km gasoline equivalent)	subsidy hybrid	9.4	8.6	7.7	6.8	6.1
	subsidy fuel cells	9.4	8.6	7.7	6.9	6.2
	subsidy electric	9.4	8.6	7.7	6.9	6.2
	baseline	9.4	8.6	7.7	6.9	6.2
Average annual fuel consumption of passenger cars in circulation (l/car gasoline equivalent)	subsidy hybrid	1,202	1,164	1,044	931	820
	subsidy fuel cells	1,202	1,164	1,052	950	839
	subsidy electric	1,202	1,164	1,051	947	836
	baseline	1,202	1,164	1,052	951	847
Average CO2 emissions of passenger cars in circulation (gCO2/km)	subsidy hybrid	231	212	188	167	148
	subsidy fuel cells	231	212	189	170	151
	subsidy electric	231	212	189	170	151
	baseline	231	212	189	170	152

7 Emission limits scenario

The **zero emissions** scenario assumes the prohibition of conventional technologies in urban areas. This would favour hybrid vehicles in the medium term and all alternative technologies, in a proportional way, in the longer term. The main losers would be the light gasoline (and in the longer term, the light diesel) cars, since their predominantly urban role would be played by alternative technologies. This scenario also leads to a reduction in CO_2 emissions, though lower than in the case of *high oil* or *carbon tax 100*, where restrictions are applied to the whole fleet.

Figure 7-1: Total emissions from car passenger transport in EU member states in 2020, emission limits scenario (Mt CO_2)

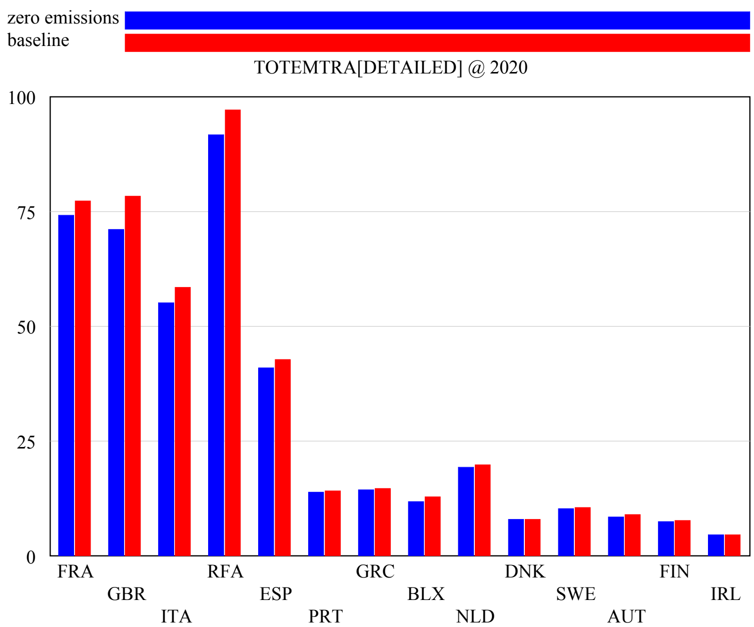


Table 7-1: Projected shares of new registrations for each technology in zero emissions scenario, EU-15

		2000	2005	2010	2015	2020
Light gasoline	zero emissions	46.5%	32.3%	26.0%	22.0%	16.8%
	baseline	46.5%	41.0%	37.3%	34.0%	27.0%
Large gasoline	zero emissions	27.4%	23.7%	18.4%	13.0%	7.0%
	baseline	27.4%	21.2%	17.9%	12.4%	6.8%
Light diesel	zero emissions	14.4%	19.1%	16.0%	13.6%	10.9%
	baseline	14.4%	19.9%	19.8%	18.1%	14.2%
Large diesel	zero emissions	11.7%	20.6%	16.0%	13.1%	9.7%
	baseline	11.7%	15.9%	13.4%	11.6%	9.2%
Electric	zero emissions	0.0%	0.5%	4.8%	7.3%	9.3%
	baseline	0.0%	0.1%	1.4%	3.0%	5.3%
Fuel cells	zero emissions	0.0%	0.2%	0.9%	4.6%	15.1%
	baseline	0.0%	0.0%	0.1%	1.5%	10.8%
Hybrid	zero emissions	0.0%	3.6%	17.9%	26.4%	31.1%
	baseline	0.0%	1.8%	10.1%	19.4%	26.5%

Table 7-2: Summary of main indicators for emission limits scenario (EU-15)

		2000	2005	2010	2015	2020
Share of gasoline cars in new registrations, EU-15 (percent)	zero emissions	74	56	44	35	24
	baseline	74	62	55	46	34
Share of diesel cars in new registrations, EU-15 (percent)	zero emissions	26	40	32	27	21
	baseline	26	36	33	30	23
Average of km driven per car per year, EU-15	zero emissions	12,760	13,559	13,709	13,711	13,541
	baseline	12,760	13,549	13,719	13,802	13,713
Total of km driven per year, EU-15	zero emissions	2.262 M	2.641 M	2.841 M	2.943 M	2.964 M
	baseline	2.262 M	2.639 M	2.843 M	2.963 M	3.002 M
Transport intensity of passenger cars (km driven per € of GDP), EU-15	zero emissions	0.28	0.29	0.28	0.27	0.24
	baseline	0.28	0.29	0.28	0.27	0.25
Average fuel economy of new gasoline cars, EU-15 (l/100km)	zero emissions	8.2	7.8	7.2	6.9	6.6
	baseline	8.2	7.7	7.2	6.8	6.5
Average CO2 emissions of new gasoline cars, EU-15 (gCO2/km)	zero emissions	199	189	175	167	159
	baseline	199	185	173	165	157
Total fossil fuel consumption for passenger car transport, EU-15 (ktoe)	zero emissions	177,713	189,426	180,620	165,386	146,692
	baseline	177,713	189,173	181,798	170,258	154,511
Total CO2 emissions of passenger car transport, EU-15 (MtCO2)	zero emissions	523	560	535	490	434
	baseline	523	559	538	504	457
Average fuel efficiency of passenger cars in circulation (l/100km gasoline equivalent)	zero emissions	9.4	8.6	7.7	6.8	6.0
	baseline	9.4	8.6	7.7	6.9	6.2
Average annual fuel consumption of passenger cars in circulation (l/car gasoline equivalent)	zero emissions	1,202	1,166	1,045	924	804
	baseline	1,202	1,164	1,052	951	847
Average CO2 emissions of passenger cars in circulation (gCO2/km)	zero emissions	231	212	188	166	146
	baseline	231	212	189	170	152

8 Technology focus scenarios

The results of the baseline and the alternative scenarios suggest that the situation concerning the potential of the alternative technologies in the long term depends on many parameters and entails a high degree of uncertainty. An important question that the scenario analysis raises is whether, given this uncertainty, car manufacturers will be willing to assume the risks and make the investments necessary in order to develop and market the alternative technologies. A hypothesis that should be investigated is the case of the industry not willing to disperse its research and marketing activities and, instead, concentrating on the technologies that have a high market potential. The rationale behind this hypothesis is that the car market is currently dominated by one technology (internal combustion engine) with two variants (diesel and gasoline) and that increasing the spectrum of technologies that a manufacturer should be able to offer would not be a feasible option. Under this hypothesis, car manufacturers would decide to invest in a technology only if the potential market for it would be large enough to justify the additional investment needed, i.e. manufacturers would select the winning technologies and would abandon the laggards.

In order to test the case of industry selecting winning technologies and concentrating solely on them, a number of scenarios where one or more of the alternative technologies is abandoned were investigated. In the first stage, the scenarios that were tested assumed that the market would be willing to invest in 4 technologies at the same time, thus having room for the 2 conventional ICE technologies and two promising alternative technologies. According to the model results, in all cases of concentrating in only 4 paths, the projected share of the technology that is abandoned is expected to be divided proportionally between the 4 paths. That is to say, none of the alternatives is in fact blocking the development of the other alternatives or the demand for them, although abandoning one of them could help establish the critical mass for either or both of them.

In the **no electric** scenario, it is assumed that since the projected market share of electric vehicles is small, manufacturers will decide that it is not worth investing in the technology. The advances predicted for this technology would not be realised, and electric cars with competing price and performance would not become available. In that case, electric cars would not be an option and its projected market share would be captured by the remaining competing technologies. However, since the projected share of electric was too small to make a difference, no significant impacts on the penetration of the other alternatives would be observed.

In **no hybrid**, conventional technologies would still monopolise the market in 2010, since no alternative options would be sufficiently attractive. By 2020, the lost projected share of hybrid would again be divided proportionally among the remaining options. From the car manufacturer point of view, not developing hybrid vehicles would mean that their market would remain, at least for the medium term, the same as their current market. The question that arises is whether car manufacturers, given such a situation, would be willing to take the risks involved in developing hybrids (or evolving ICEs into hybrids). A similar question is raised in the **no fuel cells** scenario. Not investing in fuel cells would have no impact until the end of the 2010's. The potential of fuel cells afterwards depends on the (highly uncertain) advances in fuel cell technology in the long term. In the optimistic case, fuel cell cars are the best long-term option, but the question is whether the industry is willing to start investing in a technology today.

If fuel cells are the only alternative technology to be developed (**no el or hyb**), the market will again be monopolised by conventional technologies until fuel cells improve significantly. But fuel cells will have then an important share of new registrations, higher than in baseline but still lower than in the *high oil* or *subsidy fuel cells* scenarios. But the situation in terms of CO_2 emissions would be worse, since the hybrids that they would replace would emit less.

Table 8-1: Projected shares of new registrations for each technology in technology focus scenarios, EU-15

		2000	2005	2010	2015	2020
Light gasoline	no new	46.5%	41.5%	40.3%	40.4%	39.3%
	no el or hyb	46.5%	41.5%	40.2%	39.5%	34.8%
	no fuel cells	46.5%	41.0%	37.3%	34.4%	29.5%
	no hybrid	46.5%	41.5%	39.7%	38.4%	32.7%
	no electric	46.5%	41.1%	37.6%	34.7%	28.3%
	baseline	46.5%	41.0%	37.3%	34.0%	27.0%
Large gasoline	no new	27.4%	21.7%	20.8%	18.6%	16.7%
	no el or hyb	27.4%	21.7%	20.7%	17.7%	12.3%
	no fuel cells	27.4%	21.2%	17.9%	12.7%	8.0%
	no hybrid	27.4%	21.6%	20.2%	16.6%	10.9%
	no electric	27.4%	21.2%	18.2%	13.0%	7.2%
	baseline	27.4%	21.2%	17.9%	12.4%	6.8%
Light diesel	no new	14.4%	20.4%	22.8%	24.5%	26.5%
	no el or hyb	14.4%	20.4%	22.7%	23.6%	22.0%
	no fuel cells	14.4%	20.0%	19.8%	18.5%	16.7%
	no hybrid	14.4%	20.4%	22.2%	22.5%	19.9%
	no electric	14.4%	20.0%	20.1%	18.8%	15.5%
	baseline	14.4%	19.9%	19.8%	18.1%	14.2%
Large diesel	no new	11.7%	16.4%	16.2%	16.6%	17.6%
	no el or hyb	11.7%	16.4%	16.1%	15.7%	13.6%
	no fuel cells	11.7%	15.9%	13.4%	11.7%	10.3%
	no hybrid	11.7%	16.4%	15.6%	14.8%	12.9%
	no electric	11.7%	16.0%	13.6%	11.7%	9.5%
	baseline	11.7%	15.9%	13.4%	11.6%	9.2%
Electric	no new	0.0%	0.0%	0.0%	0.0%	0.0%
	no el or hyb	0.0%	0.0%	0.0%	0.0%	0.0%
	no fuel cells	0.0%	0.1%	1.4%	3.1%	6.9%
	no hybrid	0.0%	0.1%	2.0%	4.6%	8.1%
	no electric	0.0%	0.0%	0.0%	0.0%	0.0%
	baseline	0.0%	0.1%	1.4%	3.0%	5.3%
Fuel cells	no new	0.0%	0.0%	0.0%	0.0%	0.0%
	no el or hyb	0.0%	0.0%	0.3%	3.6%	17.3%
	no fuel cells	0.0%	0.0%	0.0%	0.0%	0.0%
	no hybrid	0.0%	0.0%	0.2%	2.9%	15.5%
	no electric	0.0%	0.0%	0.1%	1.9%	12.0%
	baseline	0.0%	0.0%	0.1%	1.5%	10.8%
Hybrid	no new	0.0%	0.0%	0.0%	0.0%	0.0%
	no el or hyb	0.0%	0.0%	0.0%	0.0%	0.0%
	no fuel cells	0.0%	1.8%	10.1%	19.7%	28.7%
	no hybrid	0.0%	0.0%	0.0%	0.0%	0.0%
	no electric	0.0%	1.8%	10.3%	20.0%	27.6%
	baseline	0.0%	1.8%	10.1%	19.4%	26.5%

Figure 8-1: Projected sales of alternative technologies in EU-15, year 2020, technology focus scenarios (cars)

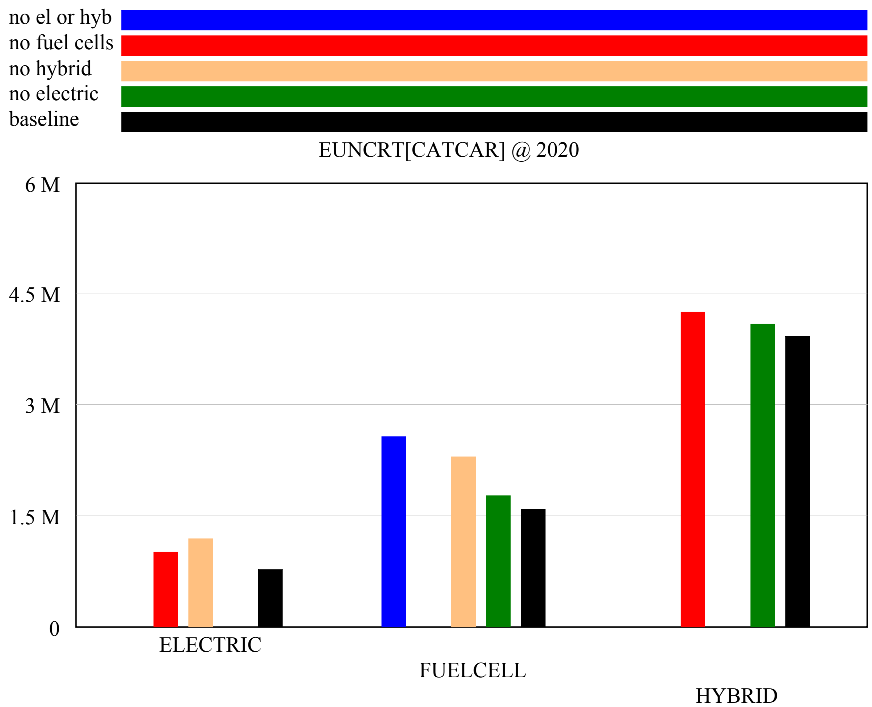


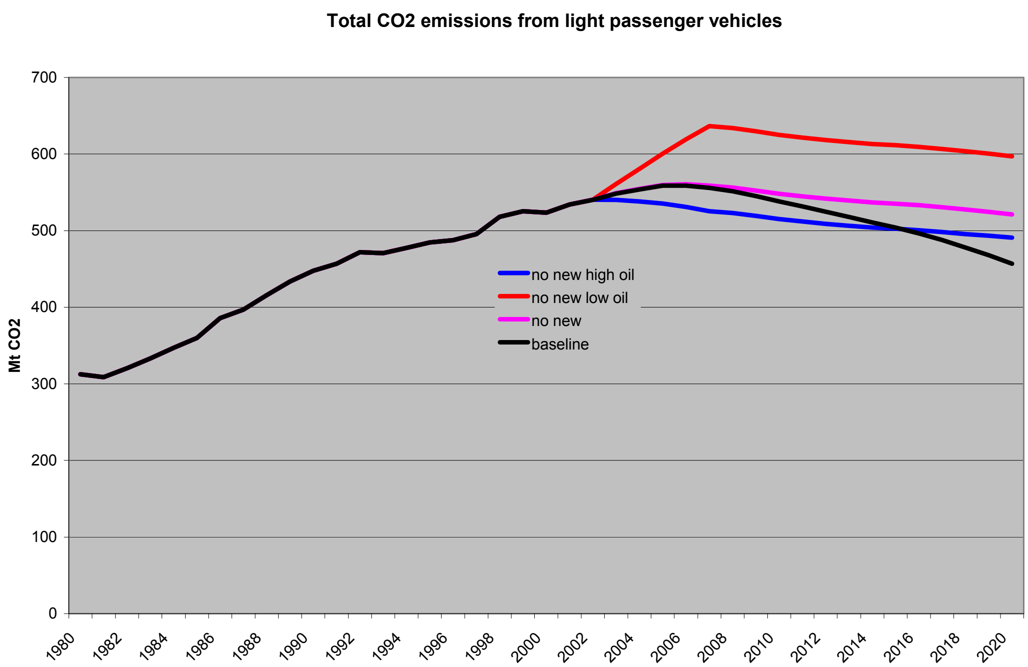
Table 8-2: Summary of main indicators for technology focus scenarios (EU-15)

		2000	2005	2010	2015	2020
Share of gasoline cars in new registrations, EU-15 (percent)	no new	74	63	61	59	56
	no el or hyb	74	63	61	57	47
	no fuel cells	74	62	55	47	38
	no hybrid	74	63	60	55	44
	no electric	74	62	56	48	35
	baseline	74	62	55	46	34
Share of diesel cars in new registrations, EU-15 (percent)	no new	26	37	39	41	44
	no el or hyb	26	37	39	39	36
	no fuel cells	26	36	33	30	27
	no hybrid	26	37	38	37	33
	no electric	26	36	34	31	25
	baseline	26	36	33	30	23
Average of km driven per car per year, EU-15	no new	12,760	13,557	13,792	14,029	14,180
	no el or hyb	12,760	13,557	13,790	14,011	14,063
	no fuel cells	12,760	13,550	13,719	13,805	13,741
	no hybrid	12,760	13,556	13,773	13,945	13,938
	no electric	12,760	13,550	13,731	13,839	13,778
	baseline	12,760	13,549	13,719	13,802	13,713
Total of km driven per year, EU-15	no new	2.262 M	2.641 M	2.858 M	3.012 M	3.104 M
	no el or hyb	2.262 M	2.641 M	2.858 M	3.008 M	3.079 M
	no fuel cells	2.262 M	2.640 M	2.843 M	2.964 M	3.008 M
	no hybrid	2.262 M	2.641 M	2.854 M	2.994 M	3.051 M
	no electric	2.262 M	2.640 M	2.846 M	2.971 M	3.016 M
	baseline	2.262 M	2.639 M	2.843 M	2.963 M	3.002 M

		2000	2005	2010	2015	2020
Transport intensity of passenger cars (km driven per € of GDP), EU-15	no new	0.28	0.29	0.28	0.27	0.26
	no el or hyb	0.28	0.29	0.28	0.27	0.25
	no fuel cells	0.28	0.29	0.28	0.27	0.25
	no hybrid	0.28	0.29	0.28	0.27	0.25
	no electric	0.28	0.29	0.28	0.27	0.25
	baseline	0.28	0.29	0.28	0.27	0.25
Average fuel economy of new gasoline cars, EU-15 (l/100km)	no new	8.2	7.7	7.2	7.0	6.8
	no el or hyb	8.2	7.7	7.2	6.9	6.7
	no fuel cells	8.2	7.7	7.2	6.8	6.5
	no hybrid	8.2	7.7	7.2	6.9	6.6
	no electric	8.2	7.7	7.2	6.8	6.5
	baseline	8.2	7.7	7.2	6.8	6.5
Average CO2 emissions of new gasoline cars, EU-15 (gCO2/km)	no new	199	186	174	168	164
	no el or hyb	199	186	174	168	161
	no fuel cells	199	185	173	165	158
	no hybrid	199	186	174	167	160
	no electric	199	185	173	165	158
	baseline	199	185	173	165	157
Total fossil fuel consumption for passenger car transport, EU-15 (ktoe)	no new	177,713	189,481	185,054	180,431	175,463
	no el or hyb	177,713	189,504	185,052	179,621	169,935
	no fuel cells	177,713	189,152	181,780	170,442	156,258
	no hybrid	177,713	189,472	184,415	177,128	164,833
	no electric	177,713	189,203	182,240	171,741	157,260
	baseline	177,713	189,173	181,798	170,258	154,511
Total CO2 emissions of passenger car transport, EU-15 (MtCO2)	no new	523	560	548	535	521
	no el or hyb	523	560	548	533	504
	no fuel cells	523	559	538	505	462
	no hybrid	523	560	546	525	489
	no electric	523	559	539	509	465
	baseline	523	559	538	504	457
Average fuel efficiency of passenger cars in circulation (l/100km gasoline equivalent)	no new	9.4	8.6	7.8	7.2	6.8
	no el or hyb	9.4	8.6	7.8	7.2	6.7
	no fuel cells	9.4	8.6	7.7	6.9	6.3
	no hybrid	9.4	8.6	7.8	7.1	6.5
	no electric	9.4	8.6	7.7	7.0	6.3
	baseline	9.4	8.6	7.7	6.9	6.2
Average annual fuel consumption of passenger cars in circulation (l/car gasoline equivalent)	no new	1,202	1,166	1,071	1,008	961
	no el or hyb	1,202	1,166	1,071	1,003	931
	no fuel cells	1,202	1,164	1,052	952	856
	no hybrid	1,202	1,166	1,067	990	903
	no electric	1,202	1,165	1,054	960	862
	baseline	1,202	1,164	1,052	951	847
Average CO2 emissions of passenger cars in circulation (gCO2/km)	no new	231	212	192	178	168
	no el or hyb	231	212	192	177	164
	no fuel cells	231	212	189	170	154
	no hybrid	231	212	191	175	160
	no electric	231	212	190	171	154
	baseline	231	212	189	170	152

The case of none of the alternative technologies being attractive enough (or manufacturers deciding to abandon all of them and concentrate on conventional technologies) is tested in **no new** scenario. Gasoline and diesel would share the market between them, and the main impact would be the worsening of the CO_2 emissions outlook. Instead of being significantly reduced, emission levels would remain at year 2000 levels. The 2 variants of *no new*, are a combination with the oil price scenarios. If oil prices are high (**no new, high oil**), demand slows down and emissions demonstrate a small improvement. But in the case of low oil prices (**no new, low oil**), both transport demand and CO_2 emissions increase dramatically.

Figure 8-2: Total CO_2 emissions from car passenger transport in EU-15, impact of oil prices without alternative technologies



9 Sensitivity analysis

The sensitivity analysis of the results of the model confirms the suggestion that the variables that influences the potential of alternative technologies the most are the ones related to their cost. In the baseline scenario, the purchase costs and the fuel economy of each type of vehicle were assumed to have the values predicted by experts in the sector. These values, however, probably correspond to a rather optimistic case, since they reflect the technical potential of each technology, assuming that this will be realised independently of external conditions. These predictions have obviously a very high degree of uncertainty, especially as far as the emerging alternative technologies are concerned.

In order to investigate the influence of higher or lower values than the ones predicted by the experts, the sensitivity tests included the case of both car purchase costs and fuel efficiency values varying within a margin of +10% to –10% for all 7 groups of technologies covered by the model. The changes in prices and efficiency values can be changed simultaneously during the sensitivity analysis, and the relative change of the cost of one technology can therefore be higher than 20% compared to one or more of the other technologies (e.g. the cost of fuel cell car is increased by 10%, its fuel efficiency is decreased by 10%, while the respective values for the other technologies go into the opposite direction).

According to the results of the sensitivity analysis, gasoline and –in most case- diesel, will probably remain the mainstream technologies for passenger cars at least until year 2020. Even if their future technological advances have been overestimated by 20% compared to the advance in alternative technologies, conventional ICEs will continue to control around 60% of the market (Figure 9-1-Figure 9-4).

The situation for the alternative technologies is entirely different. In the case of the future costs being 20% higher (in relative terms) than the ones used as input for the model, the share of none of the three alternative technologies can be expected to become important.

In the opposite case, if their future technological advance has been underestimated, alternative technologies can evidently capture a larger market share. However, given the fact that the prices used in the model are already optimistic, this is probably not the case. An exception would be a subsidy for a specific technology, in which case its relative cost compared to the other technologies would fall (e.g. as in the case of the subsidy scenarios).

The results of the sensitivity analysis also highlight the uncertainty as regards the potential of each technology and reinforce the argument that car manufacturers might not be willing to commit themselves in long-term investments in alternative technologies given this picture. If the risk associated with each technology is taken into account, the potential for hybrid cars in the medium term makes investing in hybrid cars a viable option for car manufacturers (Figure 9-5). In addition, hybrid cars entail a much lower technical risk, at least if it is assumed that they will be an evolution of gasoline ICE cars. On the other hand, electric cars show a high degree of uncertainty and a very small potential market share (Figure 9-6). It is doubtful, therefore, whether car manufacturers will be willing to invest in this technology if no additional stimuli are given. The case for fuel cells is even more uncertain (Figure 9-7). Depending on the technology advances, they may become a mainstream technology or they may remain completely outside the market.

Figure 9-1: Sensitivity analysis of the impact of costs on the share of light gasoline cars in the EU-15

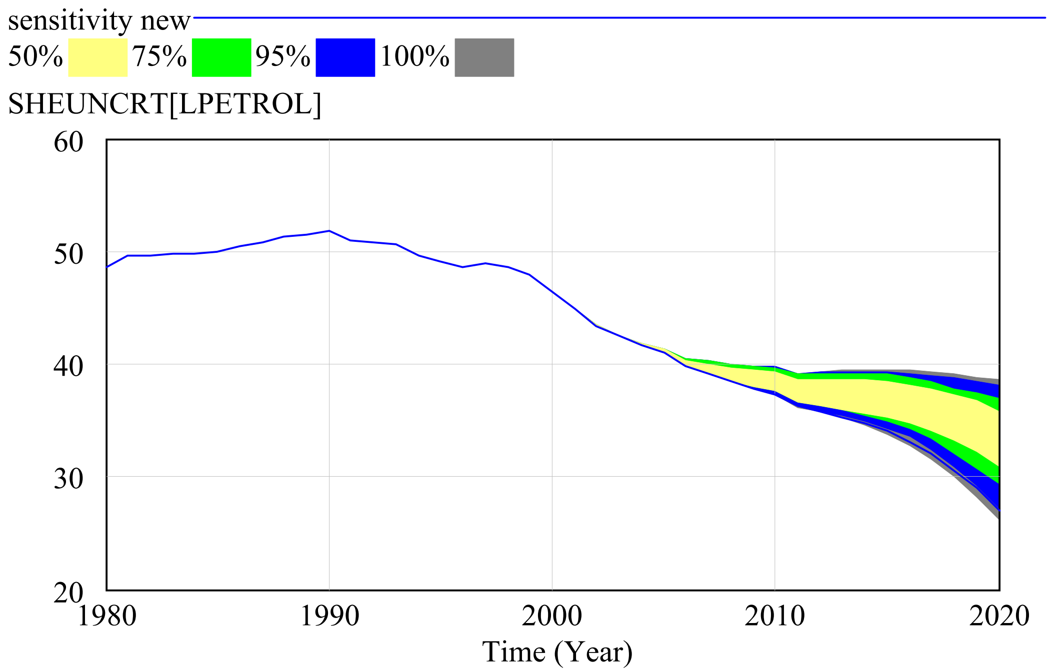


Figure 9-2: Sensitivity analysis of the impact of costs on the share of large gasoline cars in the EU-15

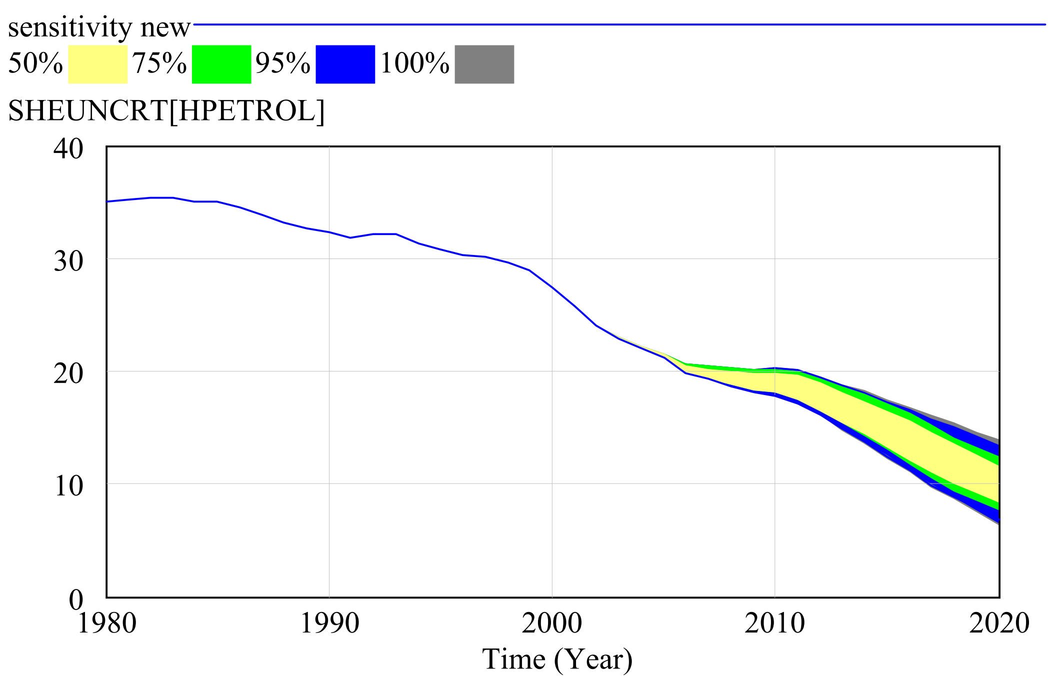


Figure 9-3: Sensitivity analysis of the impact of costs on the share of light diesel cars in the EU-15

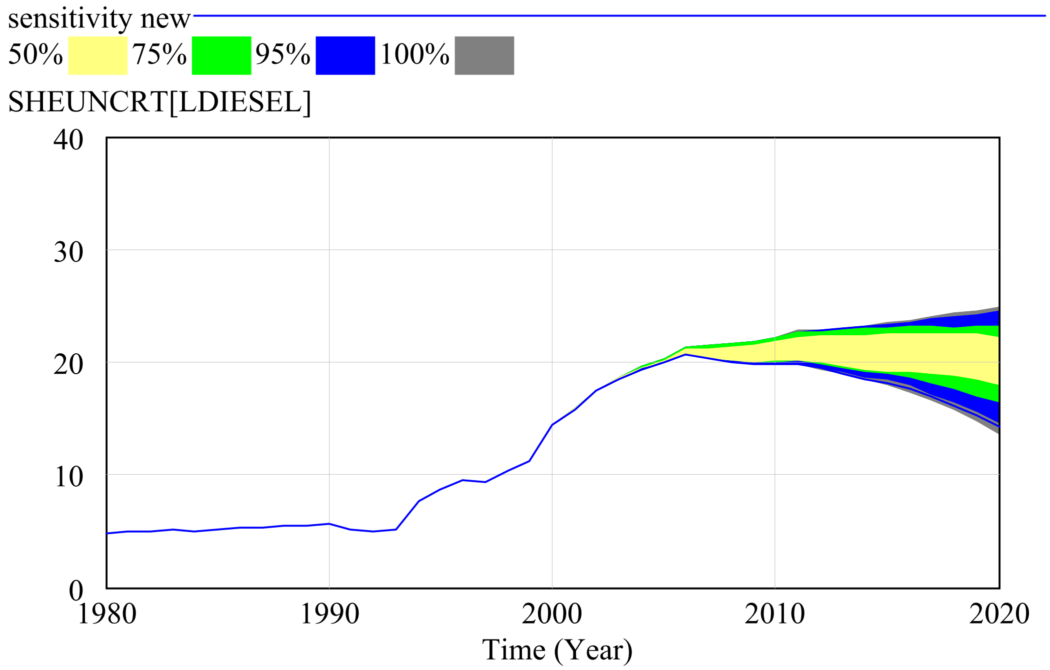


Figure 9-4: Sensitivity analysis of the impact of costs on the share of large diesel cars in the EU-15

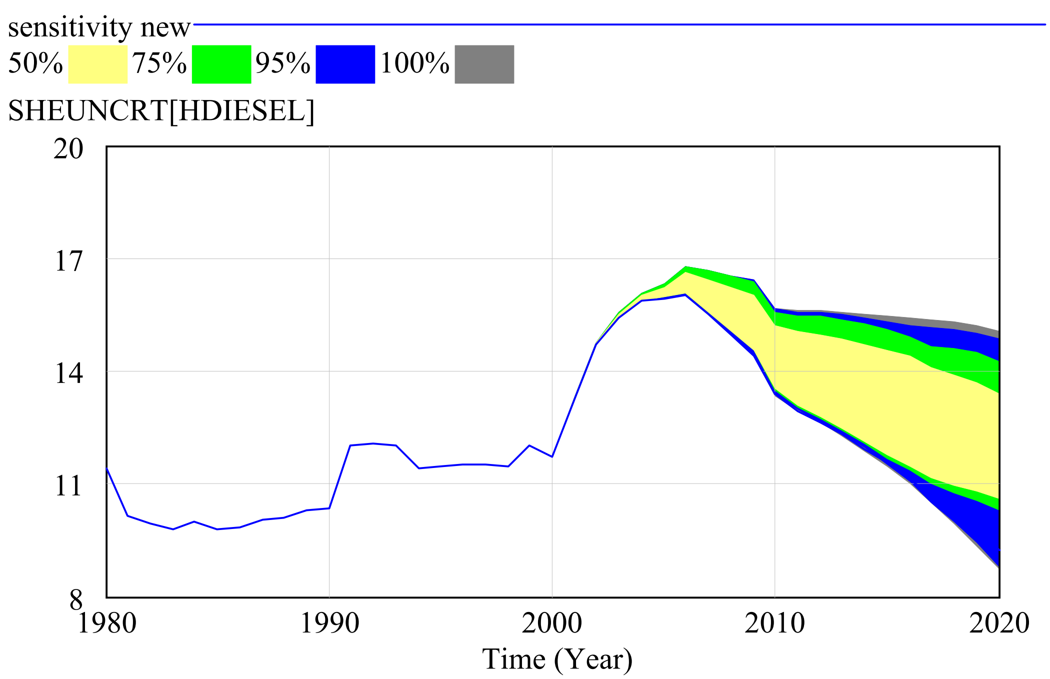


Figure 9-5: Sensitivity analysis of the impact of costs on the share of hybrid cars in the EU-15

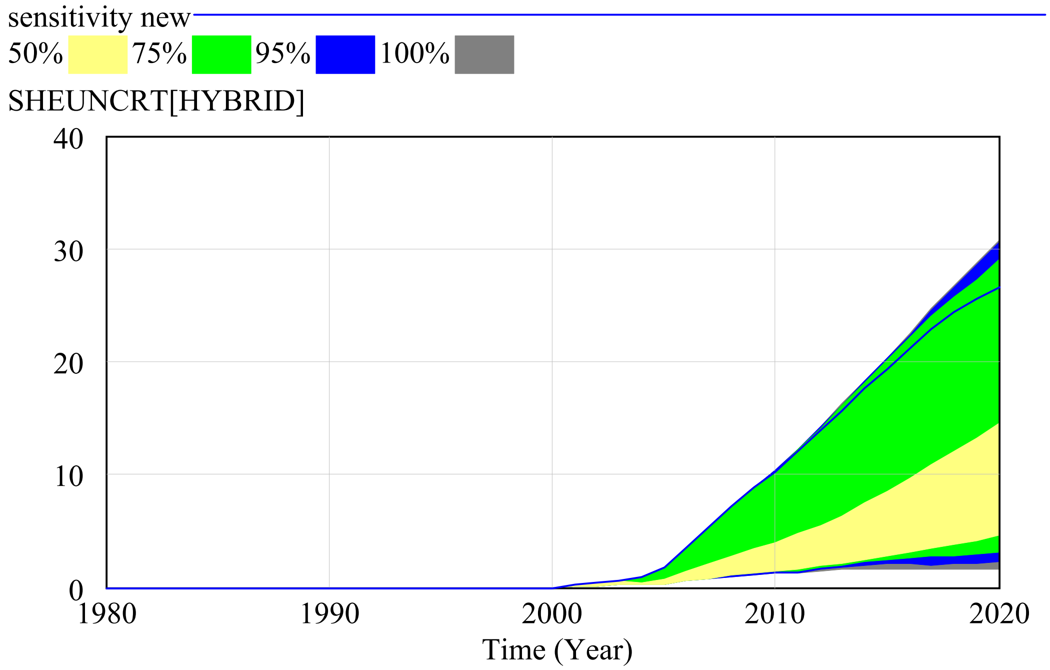


Figure 9-6: Sensitivity analysis of the impact of costs on the share of electric cars in the EU-15

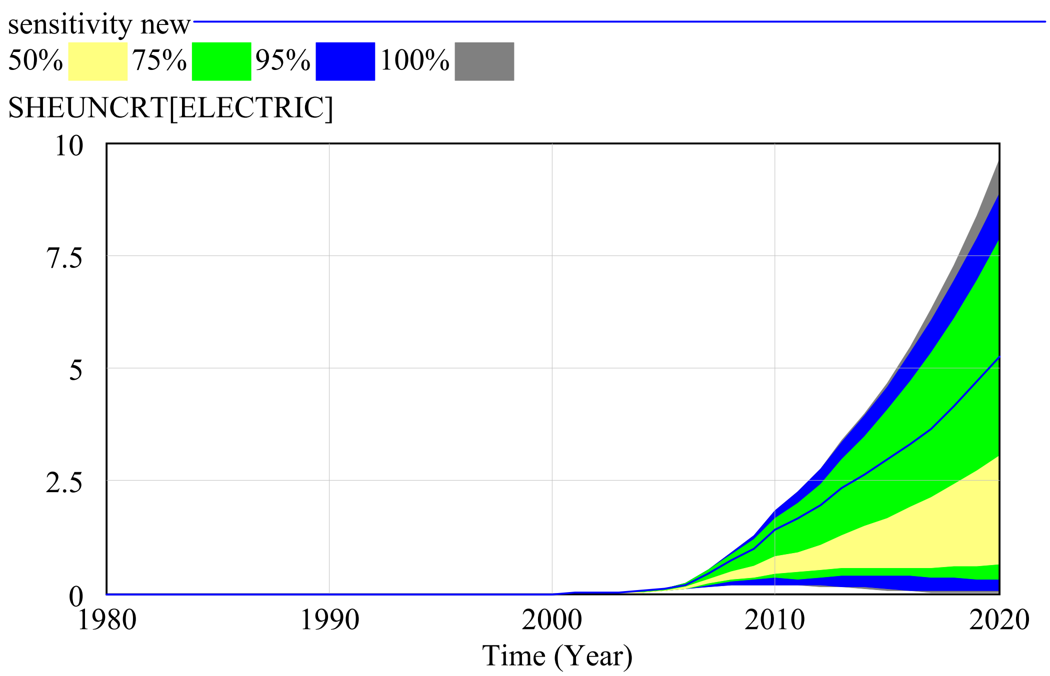
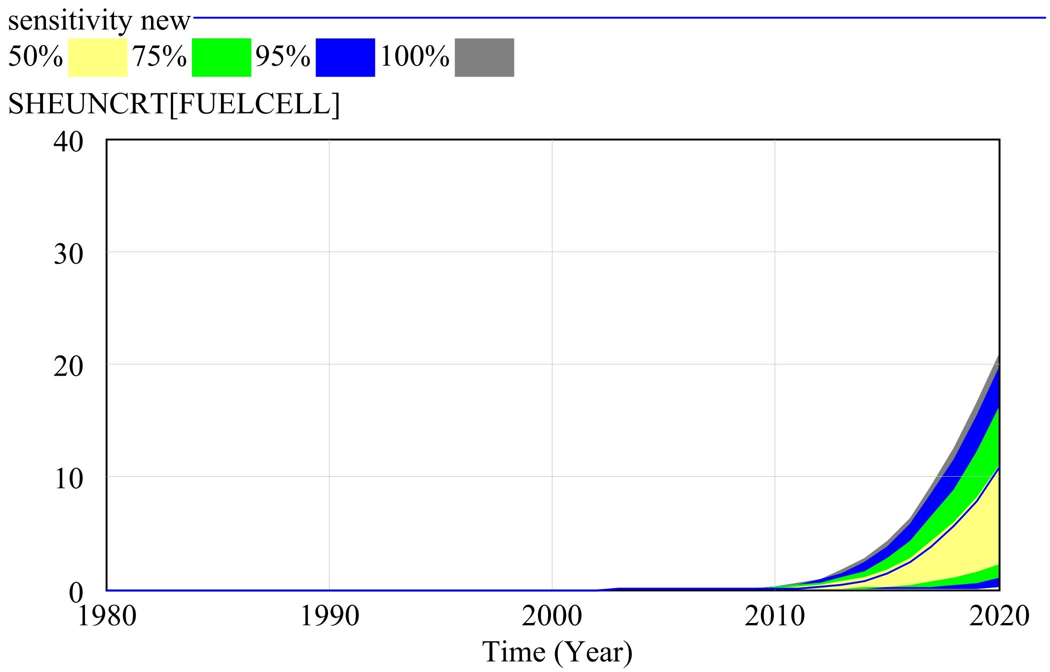


Figure 9-7: Sensitivity analysis of the impact of costs on the share of fuel cell cars in the EU-15



10 Conclusions

The scenarios described in this report investigated some issues of policy relevance concerning the introduction of alternative technologies in passenger cars. The analysis that was carried out identified a number of uncertainty factors that influence the potential of the various technologies in the sector and quantified their impact in the year 2020 horizon. Apart from the outlook of each technology in terms of market share, the scenarios also provided estimates concerning the development of certain policy relevant indicators, such as fuel consumption and CO_2 emissions in the EU and each member state.

The main conclusion from the scenario analysis is that although alternative technologies are promising from the technical point of view, their market potential is questionable if no measures to support them are taken. Most scenarios describe a situation of the market being dominated by conventional internal combustion engines at least until 2010. The gradual shift from gasoline to diesel is expected to continue in the meanwhile and, under certain conditions, an evolution from conventional ICEs to hybrid vehicles (probably ICE- electric) can be expected afterwards. Electric vehicles can be expected to capture a limited market only, while the share of fuel cells can become significant in the longer term.

It is rather questionable, however, whether the optimistic path of technological development can be followed for each alternative. The high degree of uncertainty concerning their future costs, the intense competition with conventional technologies, and the large long-term investments normally necessary in order to realise the technological breakthroughs needed may prevent car manufacturers from committing themselves into bringing the alternative technologies to the market. On the other hand, the potential benefits in terms of fuel consumption and emissions may make it worthwhile for policy makers to provide stimuli for technological development or to implement suitable measures that would reduce the degree of uncertainty.

The scenarios analysed in this report can give some indication of the elements of a suitable policy mix that would support the introduction of alternative technologies in the passenger car sector. There are numerous financial or regulatory measures that could accelerate the introduction of alternative technologies, but the co-operation of car manufacturers is necessary in all cases. The main question, therefore, is to identify the policy measures that would decrease the uncertainty that car manufacturers face concerning the long term prospects of alternative vehicle technologies.

Annex: Willingness to pay for new technologies

Input received from VITO in the context of the ESTO Project 'TRENDS in Vehicle and Fuel Technologies', WP3: Scenarios for future trends.

Introduction

The economic and social acceptation of new technologies within road transport as reported in the following, is based on a three steps process:

- Literature review and individual expertise;
- Vito working group;
- Workshop with external experts.

First a questionnaire on the willingness to pay for new technologies was filled in by some individual scientists at Vito based on their expertise and literature review. An internal Vito working group was established to achieve a Vito compromise. Finally, a workshop was organized bringing together Vito and external experts. The experts involved scientific and academic people, people from administrations and the automotive world.

The following policy options could give important information for the ESTO study:

- Advanced introduction of environmentally friendly conventional vehicles
- Advanced introduction of environmentally friendly alternative vehicles
- Conversion of vehicles to more environmentally friendly alternatives
- Introduction of electric passenger cars.

The results for these four options are discussed below.

I. Environmentally friendly conventional vehicles

This policy option has to result in an enhanced market share of new petrol- and diesel-fuelled vehicles fulfilling more stringent emission values than the prevailing regulation.

Table 1 shows the willingness to buy a more environmentally friendly petrol- or diesel-fuelled vehicle when buying a new vehicle. The willingness is related to the additional costs one has to pay for the new conventional technology.

Table 1: Willingness to pay for a more environmentally friendly conventional vehicle.

Additional costs Purchase and use	Willingness to buy a more environmentally friendly vehicle [% of users]
- 5 %	95 – 98
0 %	70 – 85
2,5 %	12 – 22
5 %	3 – 6
10 to 20 %	~ 0

Assumptions related to above percentages of willingness to pay are:

- A new generation of technologies is available on the market and they are similar with regard to safety, space and exterior;

- Dissemination of information has to be effected, so drivers will know about the existence of these more environmentally friendly vehicles;
- In reality the additional costs could be higher than mentioned in Table 1. Higher willingness to pay values could then be achieved through compensation measures (financial).

Once a new technology leading to more environmentally friendly conventional vehicles than prescribed in applied emission legislation is available; it was assumed that 75% of the users opt for this new technology when they buy a new vehicle. A transition-period of two years was taken into account. Furthermore, it was presupposed that no surplus costs are involved with the new technology. Therefore, government has to draw up supporting measures (e.g. fiscal advantages).

Table 2 gives an overview of the percentages of new vehicles having new conventional technologies under a realistic implementation level.

Table 2: Percentage of new conventional vehicles fulfilling more stringent future emission regulation values.

Year	**Realistic** implementation	
	Euro 3 (2000)	Euro 4 (2005)
2000	99	1
2001	95	5
2002	87,5	12,5
2003	65	35
2004	25	75
2005	0	100
2006	0	100
2007	0	100
2008	0	100
2009	0	100
2010	0	100
2011	0	100
2012	0	100

II. Environmentally friendly alternative vehicles

This policy option has to result in an enhanced market share of new alternative vehicles, fulfilling more stringent emission values than the prevailing regulation. Alternatives been taken into account are:

- Hybrid vehicles having two drivelines: a combination of electric power and a conventional combustion engine;
- Vehicles driven on LPG and CNG (installation by the manufactures);
- Vehicles on bio-diesel.

Willingness to buy a more environmentally-friendly alternative vehicle when buying a new vehicle now (2000-2002) and in 2010-2012 is given in Table 3.

Table 3: Willingness to pay for a more environmentally friendly alternative vehicle.

Additional costs Purchase and use	Willingness to buy an alternative vehicle [% of users]	
	2000-2002	2010-2012
- 5 %	60 – 70	65 – 75
0 %	45 – 55	50 – 60
2,5 %	5 – 15	10 - 20
5 %	1 – 3	2 – 5
10 to 20 %	~ 0	~ 0

Assumptions related to above percentages of willingness to pay are:
- The availability of alternative vehicles in 2010/2012 will be considerably higher than in 2000/2002. Moreover these vehicles will have more or less similar properties as conventional vehicles with regard to safety, space and exterior;
- Within the period 2000-2012 people are more suspicious at alternative vehicles compared to conventional fuels. Willingness to pay is therefore 25 to 30 % lower than for conventional vehicles;
- Dissemination of information has to be effected, so drivers will know about the existence of these more environmentally-friendly alternative vehicles;
- In reality the additional costs could be higher than mentioned in Table 3. Higher willingness to pay values could then be achieved by government through compensation measures.

In the short term not all brands will have alternative vehicles in their spectrum. Furthermore, the willingness to opt for alternative vehicles is smaller than for conventional. Once alternative technologies are available without a additional cost, it was expected that about 55% of the users choose an alternative technology. This has to be seen within a time frame of 5 to 10 years.

III. Conversion of vehicles to more environmentally friendly alternatives

This policy option has to result in the conversion of petrol- and diesel-fuelled vehicles into alternative vehicles or be equipped with exhaust gas after treatment devices:
- Convert petrol-fuelled cars into gas vehicles (LPG or CNG);
- Equip petrol-fuelled cars with three-way catalyst or replace older types of catalysts;
- Convert diesel-fuelled cars with e.g. an oxidation catalyst or CRT trap (Continuous Regeneration Trap).

Table 4: Willingness to convert petrol- or diesel-fuelled vehicles to more environmental friendly vehicles.

Financial support	Willingness for conversion [% of users]
None	0 – 2
Yes	20 – 30

Assumptions related to above percentages of willingness to pay are:
- Dissemination of information has to be effected, so drivers will know about the possibilities for conversion and the financial incentives;
- The pay back time for conversion has to be at the most two years.

For passenger cars it was assumed that retrofit equipment is installed during the first two years after more stringent emission regulation (Euro 3 and Euro 4) come into force for new vehicles. It was expected that about 20% of cars eligible for conversion to more environmentally friendly vehicles would be converted. Furthermore, vehicles were believed to be converted only once in a lifetime and to be driven at least three years after conversion. Types of conversion related to emission directives are given in Table 5.

Table 5: Overview of implementation period and types of conversion expressed according to the European emission directives for new vehicles.

Emission directive	Phase 1 (2001-2002)	Phase 2 (2005-2006)
Euro 0 Diesel Petrol & LPG	 Euro 1 Open-loop catalyst	 - -
Euro 1	Euro 3	Euro 4
Euro 2	Euro 3	Euro 4
Euro 3	-	Euro 4
Euro 4	-	-

IV. Electric passenger cars

This policy option has to result in an enhanced market share of electric passenger cars. As the radius of action of electric vehicles is rather limited compared to conventional vehicles, the field of application will be generally within the urban area. The radius of action could be increased by the lithium battery and fuel cell vehicles. These developments could play an important role after the year 2010.

Table 6: Willingness to buy an electric vehicle when buying a new vehicle.

Additional costs Purchase and use	Willingness to buy an electric vehicle [% of users]		
	Nowadays	Within 5 years	Within 10 years
0 %	~ 5	5 – 10	10 – 15
About 5 %	0 – 5	4 – 8	5 – 10
10 to 20 %	~ 0	0 – 2	3 – 5

Assumptions related to above percentages of willingness to pay are:

- There will be more electric vehicles available on the market in 2010/2012 compared to 2000/2002 and their radius of action will have increased;
- Dissemination of information has to be effected, so drivers will know about the availability of electric vehicles. Moreover, necessary infrastructure has to be provided for;
- In reality the additional costs could be higher than mentioned in Table 6. Higher willingness to pay values could then be achieved by government through compensation measures.

Within a timeframe until 2010 it was expected that only small petrol-fuelled passenger cars (city traffic) would be replaced by electric cars. The willingness to buy an electric car will rise in the coming 10 years from about none nowadays to about 5%, taking into account the hypothesis that the surplus cost will be 5 to 10%.

Table 7 shows the percentages electric passenger cars within the group of new bought cars for the period 2001-2012, together with the fraction of mileage driven by electric cars compared to the total mobility demand of the car fleet.

Table 7: Percentage electric cars and their fraction of mileage driven.

Year	Percentage electric cars in new cars [%]	Mobility fraction of electric cars within the total mobility of cars [%]
2001	0,3	0,02
2002	0,9	0,07
2003	1,3	0,14
2004	1,5	0,22
2005	2,0	0,32
2006	2,3	0,44
2007	3,0	0,60
2008	3,8	0,80
2009	4,3	1,02
2010	4,6	1,25
2011	5,2	1,50
2012	5,4	1,75

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