COMPARISON OF DIFFERENT PROPULSION SYSTEMS IN PRIVATE TRANSPORT IN TERMS OF ENERGY SAVING AND REDUCTION OF GREENHOUSE GASES

Study for the Bavarian State Ministry for Country Development and Environmental Questions

Summary

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0 SUMMARY

It is the goal of the present study to assess the reduction potential of greenhouse gas emissions from the passenger car sector through advanced conventional and alternative propulsion systems and fuels in Germany. Climate changing gas is in particular carbon dioxide (CO_2), but also methane (CH_4) and nitrous oxide (N_2O). The climate relevance is expressed in terms of equivalent CO_2 emissions.

The following propulsion system/ fuel combinations are analyzed:

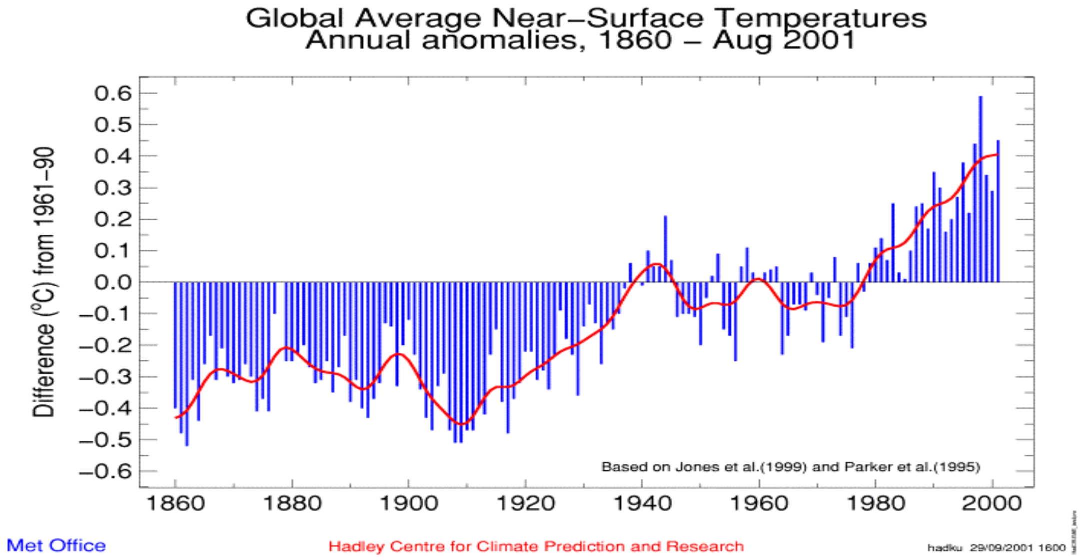
- Gasoline – internal combustion engine
- Gasoline – fuel cell
- Diesel – internal combustion engine
- Ethanol – internal combustion engine
- Ethanol – fuel cell
- Methanol – internal combustion engine
- Methanol – fuel cell
- Natural gas – internal combustion engine
- Hydrogen – internal combustion engine
- Hydrogen – fuel cell
- Battery electric

The fuel consumption during vehicle operation is assessed (“Tank-to-Wheel”) as well as the greenhouse gas emissions over the entire fuel production and supply chain (“Well-to-Tank”, including production, transport and distribution). From these data, the greenhouse gas emissions per kilometer driven are being deduced (“Well-to-Wheel”). In addition, an analysis is being made of the greenhouse gas emissions during the production of the vehicle, which are subsequently added to the “Well-to-Wheel” emissions.

0.1 Climate change

There is no more scientific doubt that the global climate and the chemical composition of the earth's atmosphere are progressively changing (see Figure 0-1). As an example, the global average temperature has risen by almost one degree Celsius over the last 100 years, with half this temperature increase having occurred during the last 20 years. In addition, the accelerated change of other climate parameters such as wind speed (air pressure), sudden and intense precipitation or extraordinary drought are grounds for worry. It has to be noted that the increase of an average value goes along with a disproportionate increase of extreme values – which are the cause for large damages (storms/ hurricanes, floods etc.).

Figure 0-1: Development of the global average temperature between 1860 and August 2001



Mainly human activities are identified as the cause for these developments, even though it is not yet definitely clear in how far natural processes interfere with the anthropogenic effects.

The latest calculations of the world's most renowned scientists working on behalf of the World Meteorological Society and the United Nations show that a continuation of current trends will cause the global average temperature to increase by another 1.5-6°C until the end of this century, this being accompanied by other climate parameters changing drastically and by severe economic consequences.

International politics and parts of the industry increasingly become aware of these threats and take them seriously. In Rio de Janeiro in 1992, the first so-called "Earth Summit" took place. During this event, the UNFCCC – United Nations Framework Convention on Climate Change was signed.

Main elements of the Climate Convention were on the one hand an immediate decision (which, nonetheless, was not binding by international law) to bring carbon dioxide emissions back to 1990 levels by the year 2000. And on the other hand, the establishment of a Climate Secretariat under the auspices of the United Nations, which was given the task to organize follow-up climate conferences that should decide upon necessary further measures.

The highlight of international climate politics is the formulation and the acceptance of the Kyoto Protocol. It was decided that the industrialized nations have to reduce the emissions of the six most important greenhouse gases by an average of 5.2% compared to 1990 levels until the end of the first contract period 2008 – 2012. Given the historic responsibility of the industrialized nations, the developing countries have no binding reduction goals.

During the two climate conferences in Bonn, Germany, and Marrakech, Morocco, in 2001 the parties have agreed on the main modalities for the implementation of the Kyoto Protocol. Based on this, an increasing number of countries signals to be willing to ratify the Protocol, which will probably allow the Protocol to come into force next year even without the ratification by the present government of the USA.[1]

Main instruments in the ratification of the Kyoto Protocol are economic mechanisms such as the international trade of emission certificates or the financial support for the transfer of modern energy technologies into developing countries.

Even if the Kyoto Protocol is criticized and valued rather low in the public because of the blurring of the original goals it has to be emphasized that this is the first time in human history that a global environmental treaty accepts the problems of climate change and that common political measures are considered necessary.

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[1] Status December 2002: 100 countries have ratified the Kyoto Protocol (55 are required). Developed country ratifications account for 43.7% of 1990 CO_2 emissions. The Russia Federation's 17.4% will be essential for achieving the required 55% for the Protocol to enter into force. The Russian Parliament is expected to act within the next several months.

0.2 Availability of fossil energy resources

The future availability of fossil energies is by no means as certain as public perception will have it.

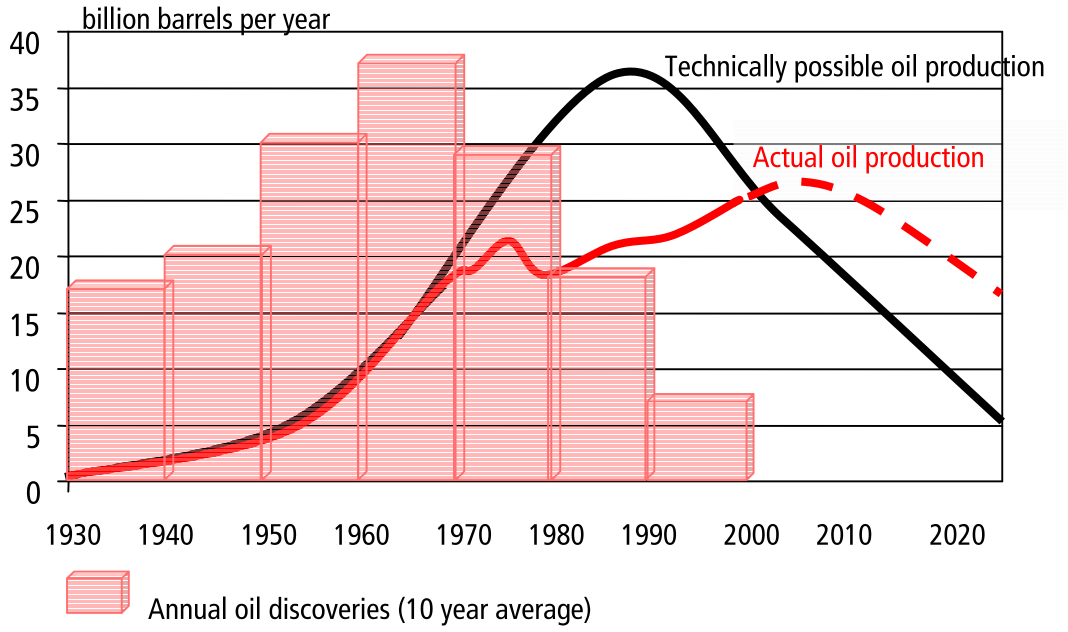
The question deciding about structural changes is not "How long will the reserves last?", but "When will production start to decrease?". The decisive point in time is when oil production cannot be increased any more, but when geological, technical and economic reasons cause oil production to decrease steadily. The change from generally increasing to generally decreasing production indicates the point in time, when the undoubted finiteness of fossil energies is reflected on the markets. This is the "end of cheap oil" if demand is not decreasing by the same amount.

This will lead to a broad and sustained change in investment decisions, away from oil towards possible alternatives in energy supply. The global production peak is the main indicator for the coming structural changes.

Figure 0-2: Oil discoveries and oil production

Within 5-10 years half the global oil will have been consumed

At that point, global oil production will start to decline



Globally, we are on the peak of oil consumption and of our dependency on oil. Three years ago, the oil prices increased considerably in connection with an increased market power of the OPEC members, which reduced oil production causing a supply shortage as demand continued to increase.

The peak of oil discoveries in the 1960ies is necessarily followed by the peak of oil production (see Figure 0-2).

World-wide, consumption is higher than discoveries for about 20 years now and the oil reserves are shrinking.

The fact that the reserves reported publicly are more or less constant during the last decade in spite of high consumption cannot be explained by new discoveries, but by a reevaluation of well-known fields being in production for a long time already.

The many mergers of big oil companies mark the necessary market restructuring in order to reduce overcapacities.

It is more than probable that the current situation of rather stable, low oil prices will not last long. As soon as the world economy recovers and the demand for oil increases oil prices will rise and slow down economic growth.

Oil will not be scarce from one day to the other. After reaching the peak, production will go down slowly but steadily. It is unclear whether this phase has already begun or whether we are still some years away from this point. The answer depends on the possibilities of production increases in the Middle East. Unfortunately, reliable information on this is very scarce.

0.3 Renewable energy potentials for vehicle fuels

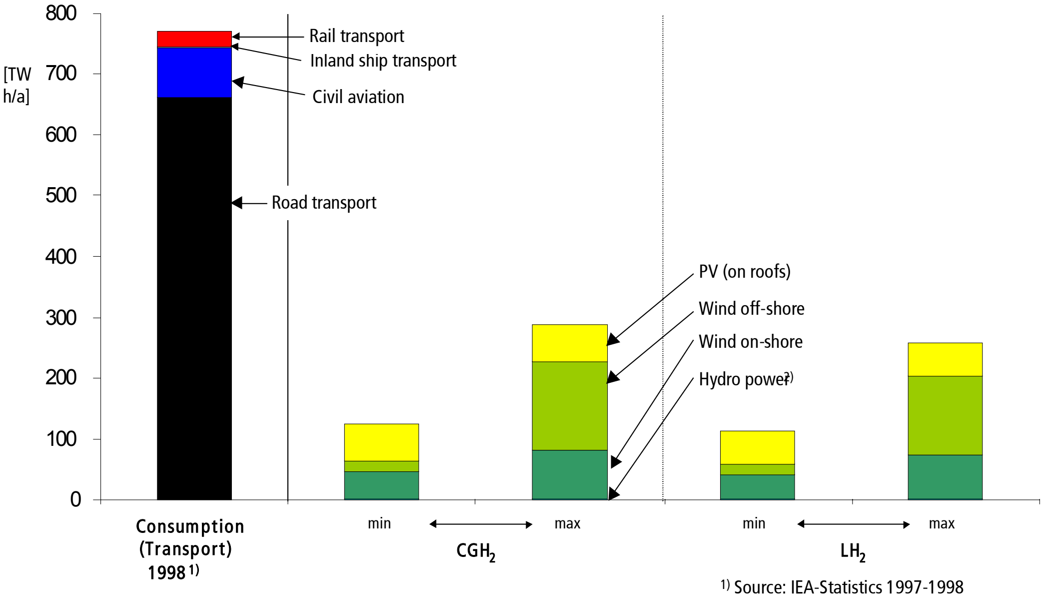
Here, the available potentials of renewable energies for the production vehicle fuels are discussed. Figure 0-3 shows the result of the potential assessment for Germany.

Assuming that half of the renewable electric potential in Germany can be made available to transport 9 – 22% of today’s vehicle fuel consumption could be substituted by compressed gaseous hydrogen, or 8 – 20% by liquid hydrogen produced via electrolysis from renewable electricity.

Under the same assumptions, 29 – 60% of the European Union road vehicle consumption (1998 levels) could be substituted by compressed gaseous hydrogen; for liquid hydrogen, the numbers would be 27 – 54%.

Solar energy in Northern Africa is a further potential renewable energy source, which might be available to Europe. There, solarthermal power plants will supply cheaper electric power than photovoltaics within the foreseeable future.

Figure 0-3: Technical Potentials of hydrogen production via electrlysis using electricity from renewable sources in Germany



[1] Source: IEA-Statistics 1997-1998
[2] Additional potential

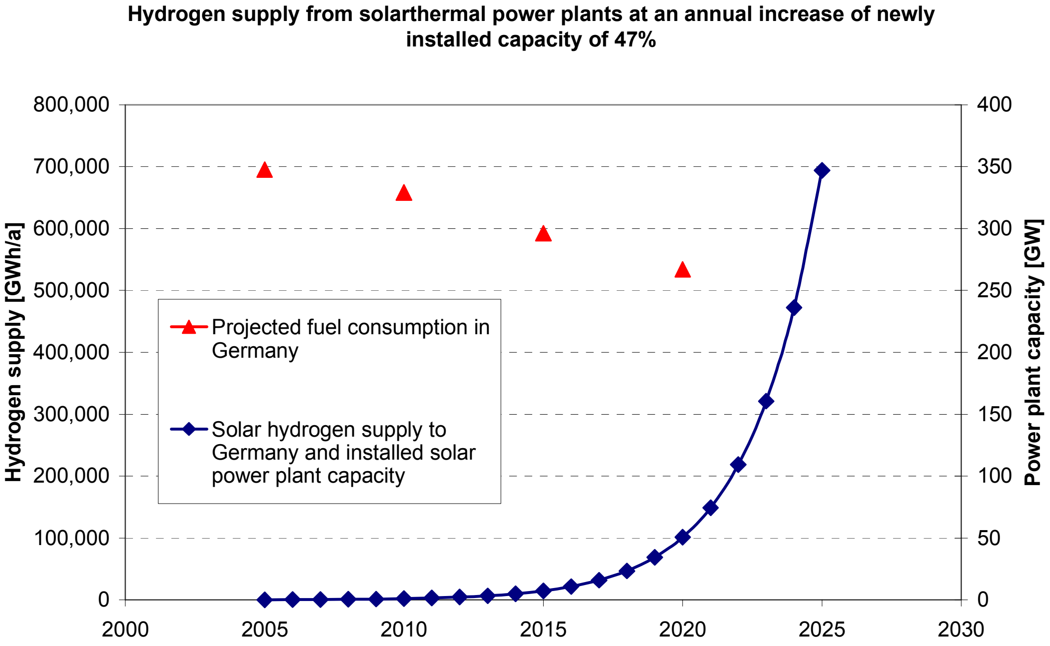
The potential estimate results in an electric power of around 11,000 GW and an electricity production potential of about 39,000 TWh per year. This would allow for a hydrogen supply to Germany of around 19,500 TWh_{H2}. This is equivalent to 36 times the fuel demand for road vehicles projected for the year 2020 by the German Mineral Oil Association. Assuming that 10% of the potential would be used for transport fuels this amounts to 1,950 TWh_{LH2}/yr. This is equivalent to 3.6 times the fuel demand in Germany in 2020 or more than 50% of EU fuel consumption in 1998.

Assuming further that fuel cell passenger cars will consume on average 0.3 kWh/km of hydrogen (equivalent to a 3.0 l/100 km diesel car) and that they will travel 12,000 km per year on average, the aforementioned amount of hydrogen would be sufficient to supply 2.5 times the passenger car fleet of Europe, i.e. some 200 million passenger cars.

In addition to the question of the pure quantitative potential, the second important question is to the possible speed of building up the necessary production capacities. Wind power development in Germany over the last decade will serve as an example here.

Assuming the first solarthermal power plant to be commissioned in 2005 and assuming further that the newly installed capacity will increase by 47% annually (as was the case for wind power in Germany between 1990 and 2000) some 17% of the projected fuel demand in Germany could be supplied by hydrogen from solarthermal power plants in 2020. A 100% supply would be possible five years later (see Figure 0-4). In this rough analysis the fact that fuel cell cars are significantly more efficient that conventional cars has not even been taken into account. A 100% supply could therefore be possible a few years earlier.

Figure 0-4: Possible development of solarthermal power plant installation; projection of transport fuel demand in Germany for the years 2005, 2010, 2015 and 2020 by the German Mineral Oil Association

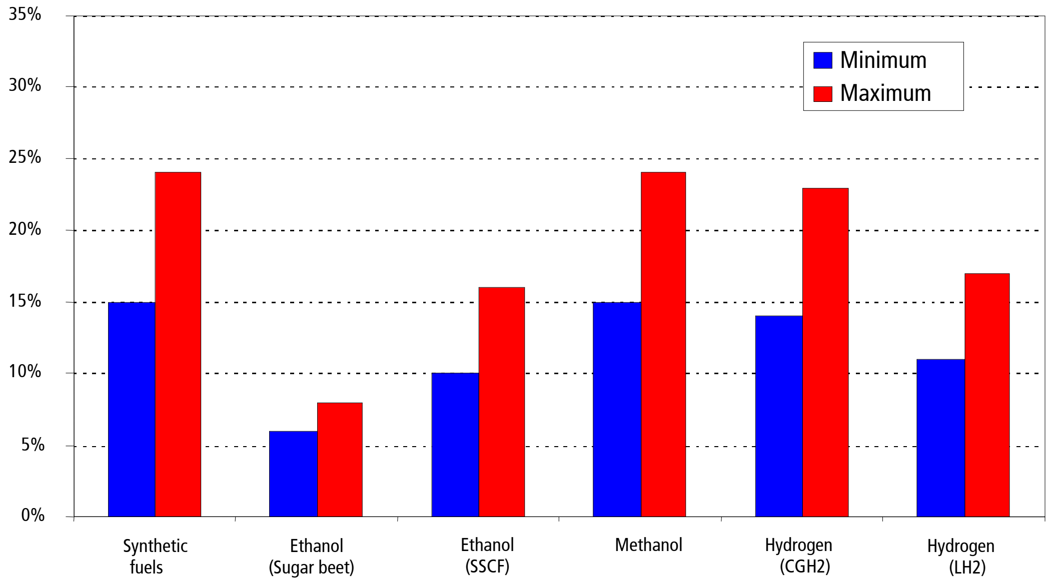


This assessment shows that it is possible to supply 100% of the transport fuels from renewable energies by 2025 provided that the corresponding political choices are made.

Biofuels such as ethanol (or plant oils) can only be produced from biomass. A maximum of 16% of transport fuel demand could be covered by bio-ethanol in Germany (EU: 22%), assuming 1.5 million ha (EU: 7.2 million ha) of arable land to be available for energy crops.

Other transport fuels (synthetic hydrocarbons or "synfuels", methanol and hydrogen) can cover a maximum of 11 – 24% of fuel demand in Germany and 12 – 33% of fuel demand in the EU, respectively, on the basis of biomass (1998 levels). The values for the different fuels cannot be added (see Figure 0-5).

Figure 0-5: Bandwidth of realistic coverage of transport fuel demand by biomass derived fuels in Germany



It has to be noted that the potential is not necessarily available for transport fuel production entirely. Assuming that only half of the potential can be made available to the transport market, bio-ethanol could cover 3 – 8% of today's fuel demand in Germany or 3 – 11% in the EU. Hydrogen from biomass could cover 5 – 12% of today's fuel demand in German (EU: 6 – 15%).

Hydrogen cannot only be produced from biomass, but also by electrolysis from renewable electricity. Therefore, hydrogen fuel has the potential to substitute conventional fuels to 100% in the long term.

On the other hand, the production of methanol and ethanol from renewable energies is practically limited to using biomass. Even though the production of methanol from electricity and CO_2 extracted from ambient air has been demonstrated on laboratory scale, the feasibility of the process in real scale is doubtful and has still to be demonstrated. Therefore, the greenhouse gas emission reduction potentials of methanol and ethanol are limited.

0.4 Fuel supply

The following fuel supply pathways have been analyzed:

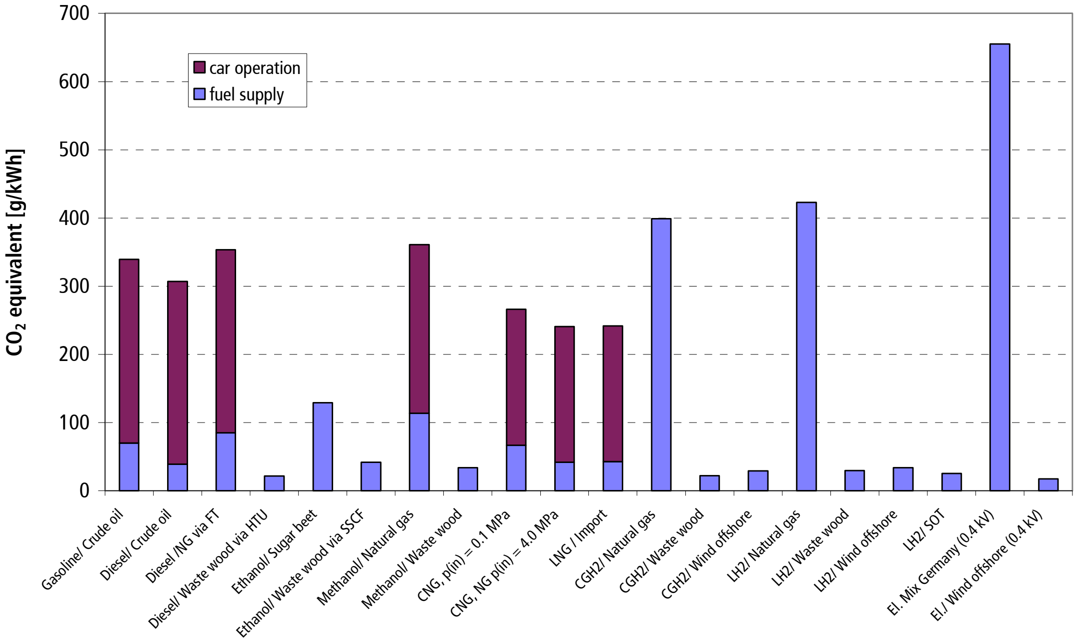
- Gasoline from crude oil
- Diesel from crude oil

- Diesel from natural gas via Fischer-Tropsch-Synthesis
- Diesel from waste wood via the HTU-Process
- Ethanol from sugar beet
- Ethanol from waste wood via the SSCF-Process
- Methanol from natural gas
- Methanol from waste wood
- Compressed natural gas (German natural gas mix; variant a „filling station connected to the high pressure natural gas grid", variant b „connection to low pressure gas grid")
- Liquid natural gas imported from Algeria
- Compressed gaseous hydrogen from natural gas via reforming at the filling station
- Compressed gaseous hydrogen from waste wood close to the filling station
- Compressed gaseous hydrogen via electrolysis at the filling station using electricity from off-shore wind power
- Liquid hydrogen from natural gas
- Liquid hydrogen from waste wood
- Liquid hydrogen via electrolysis using electricity from off-shore wind power
- Liquid hydrogen via electrolysis using electricity from solarthermal power plants in Northern Africa
- Electricity mix German (0.4 kV level).

More and other fuel supply pathways are possible. This selection has been made to span the entire width of possibilities of sensible pathways.

The following Figure 0-6 shows the greenhouse gas emissions of fuel supply and subsequent fuel consumption (combustion, of reforming to hydrogen in the car). The use of fuels derived from biomass is CO_2 neutral as the combustion liberates exactly the amount of CO_2 that has been extracted from the atmosphere during the growth of the plant by photosynthesis.

Figure 0-6: Greenhouse gas emissions (CO_2 equivalent) of fuel supply and use



Looking at the renewable fuels it is striking that ethanol produced from sugar beet has relatively high CO_2 equivalent emissions. This due to the high nitrous oxide emissions from growing sugar beet.

The greenhouse gas emissions of the renewable fuel supply pathways are around 10% of those of the conventional fossil pathways. Hydrogen from natural gas has 15 – 20% higher CO_2 equivalent emissions per unit of energy than gasoline. Combining this with the higher efficiency of the fuel cell car, this relationship is reversed. This shows that a sensible comparison can only be made combining fuel supply and fuel consumption in the car (see chapter 0.5).

0.5 Fuel consumption of passenger cars

The conventional power trains gasoline and diesel internal combustion engine after 100 years of development still have potentials to improve efficiency. In the present study, the ultimate reductions in fuel consumption of these power trains are assessed.

We start from best available technology today. For the alternative power trains, the consumption reduction potentials compared to the gasoline internal combustion engine are assessed. This allows to assess the fuel consumption ("Tank-to-Wheel") of all power trains analyzed here for the time frame of 2010 to 2020.

In reality, fuel consumption for various reasons is generally higher than using best available technology. The ratio of rated engine power to vehicle mass is a critical value influencing fuel consumption. With rising power to mass ratio, fuel consumption increases as the engine is operated in unfavorable power and RPM regimes.

According to the association of European automotive manufacturers (ACEA) the average CO_2 emissions of newly sold passenger cars have been reduced from 186 g/km to 169 g/km between 1995 and 2000. The share of diesel passenger cars increased from 22% to 35.8%. At the same time, the average car mass increased by 7.9%, the average engine displacement increased by 3.8%, and the average engine power increased by 14.3%. Depending on the assumptions concerning air drag and rolling resistance, the average car mass of 1118 kg (gasoline) and 1308 kg (diesel) average car efficiencies are 13.4 – 14.7% for gasoline cars and 16.8 – 17.7% for diesel cars. This means that the average cars sold are one third less efficient than best available technology, which is 21% efficiency for gasoline cars and 24% for diesel cars.

This means that considering best available technology does not give a correct view of reality. The most important "enemy" of state-of-the-art efficiency are customer demands concerning comfort, resulting in high vehicle masses, and concerning vehicle performance resulting in increasingly oversized engines. Both tendencies increase fuel consumption.

Therefore, the present study assumes that in the future, just as today, the average cars sold will have a 40% to 50% higher fuel consumption as the "best" car. Consequently, an additional reduction potential is to sell cars that better adapted to realistic drive patterns. This is equivalent to a reduction of engine power relative to vehicle mass.

The trend continues to be towards more powerful engines, larger engine displacement and heavier cars.

It has to be noted here that the fuel consumptions discussed do not include auxiliaries such as air conditioning, multi-media equipment etc. This auxiliary consumption is on the rise.

Table 0-1: Fuel consumption of conventional power trains in four vehicle categories

Today	"Lupo" class		"Golf" class		"5er" class		"Van" class	
	median	+/- band width	median	+/- band width	median	+/- band width	median	+/- band width
	[kWh/km]		[kWh/km]		[kWh/km]		[kWh/km]	
Gasoline ICE	0.515	0.084	0.752	0.216	0.955	0.277	0.955	0.260
Diesel ICE	0.370	0.070	0.570	0.130	0.715	0.175	0.715	0.085

Table 0-2 and Table 0-3 give an overview possible future fuel consumption reductions as an average of all passenger cars sold. A reduction of average car mass has not been assumed.

Table 0-2: Future improvement of conventional power trains compared to today and fuel consumption advantages of alternative power trains compared to gasoline internal combustion engine cars

2010-2020	Future advances over today				Advantage over gasoline ICE 2010/20			
	from	to	average	+/- band width	from	to	average	+/- band width
Gasoline ICE	25.6%	36.3%	30.9%	5.3%				
Gasoline FC					0%	20%	10%	10%
Diesel ICE	8%	20%	14%	6%				
EtOH-FC					17%	33%	25%	8%
MeOH-FC					18%	35%	26.5%	8.5%
CNG/LNG ICE					0%	0%	0%	0%
LH_2 ICE					0%	0%	0%	0%
LH_2/CGH_2 FC					34%	45%	39.5%	5.5%
Battery					63%	63%	63%	0%

Table 0-3: Future fuel consumption of the different power trains

2010-2020	"Lupo" class		"Golf" class		"5er" class		"Van" class	
	median	+/- band width	median	+/- band width	median	+/- band width	median	+/- band width
	[kWh/km]		[kWh/km]		[kWh/km]		[kWh/km]	
Gasoline ICE	0.356	0.064	0.520	0.154	0.659	0.198	0.659	0.186
Gasoline FC	0.320	0.068	0.468	0.148	0.593	0.190	0.593	0.180
Diesel ICE	0.318	0.064	0.490	0.117	0.615	0.156	0.615	0.085
EtOH-FC	0.267	0.056	0.390	0.123	0.495	0.158	0.495	0.149
MeOH-FC	0.261	0.056	0.382	0.122	0.485	0.156	0.485	0.148
CNG/LNG ICE	0.356	0.064	0.520	0.154	0.659	0.198	0.659	0.186
LH_2 ICE	0.356	0.064	0.520	0.154	0.659	0.198	0.659	0.186
LH_2/CGH_2 FC	0.215	0.043	0.314	0.098	0.399	0.125	0.399	0.118
Battery	0.132	0.024	0.192	0.057	0.244	0.073	0.244	0.069

A further reduction of fuel consumption can be realized by reducing vehicle mass. An aluminum bodywork reduced the vehicle weight by 11 – 13% compared to a steel bodywork. Using composite fiber materials for the bodywork reduces car weight by up to 17%.

Using all lightweight potentials in the entire car by means of an optimum materials mix including magnesium, aluminum and composite materials allows to reduce car weight by 30 – 35%.

This allows to realize the following fuel consumption reductions, both in gasoline internal combustion engine cars and in hydrogen fuel cell cars:

Table 0-4: Reduction of fuel consumption through reduced vehicle masses

[kWh/km]	"Lupo" class	"Golf" class	"5er" class
Fuel consumption reduction through aluminum bodywork	0.020 ± 0.006	0.026 ± 0.08	0.034 ± 0.011

Fuel consumption reduction through composite materials bodywork	0.026 ± 0.08	0.035 ± 0.011	0.042 ± 0.013
Maximum fuel consumption reduction through optimum materials mix in the entire vehicle	0.048 ± 0.015	0.075 ± 0.023	0.112 ± 0.034

Ultra-lightweight vehicles, so-called Hypercars, are extensively discussed. Hypercars combine all innovative concepts for the reduction of fuel consumption.

While the rather conventional cars VW Lupo 3L, Audi A2 or Greenpeace Smile are an evolution of existing technology, Hypercars are revolutionary prototypes. In the fuel consumption values, though, both concepts have more or less met, at least if all potentials are realized in the conventional cars, and the engine power is adapted to the actual requirements. Fuel cell drive trains would allow both vehicle types to nearly half their consumption figures. It has to be noted, though, that neither Hypercars nor advanced conventional vehicles with lightweight bodies have reached the end of their respective development.

All fuel consumption values given are based on the official New European Driving Cycle (NEDC) , which is the legal basis for consumption figures published by the car manufacturers.

Even though the NEDC has various disadvantages which make it rather inadequate for the comparison of conventional and advanced propulsion concepts (hybrid concepts, all electric propulsion based on fuel cell or battery) it is the basis for most values and comparisons cited in literature, as it is the official cycle in Europe. For a comparison of different propulsion concepts based on the NEDC, the following aspects should be considered.

Driving cycles that better represent actual passenger car driving situations in Europe display the following tendencies:

- The fuel consumption reductions of fuel cell vehicles compared to internal combustion engine cars in real driving situations are smaller than using the NEDC (10-30% reduction using the HYZEM cycle compared to 30-45% reduction using the NEDC).
- The parts of the more realistic driving cycles MODEM and HYZEM which simulate urban driving result in high fuel consumption reductions of fuel cell cars similar to those resulting from the NEDC (40-50% fuel consumption reduction).

- Independent of the driving cycle used, hydrogen fuel cell cars display to highest fuel consumption reductions compared to conventional drives.
- Fuel cell drives in heavier cars lead to higher fuel consumption reductions than in lighter cars. This tendency is even more pronounced using the more realistic driving cycles MODEM and HYZEM than using the NEDC.

0.6 Greenhouse gas emissions per kilometer driven

The fuel consumption of the different propulsion system/ fuel combinations can directly be converted into CO_2 emissions per kilometer driven. This represents the emissions from car operation only („Tank-to-Wheel“).

The greenhouse gas emissions from the production and supply of the fuel („Well-to-Tank“) may then be combined with the former values to give the overall greenhouse gas emissions („Well-to-Wheel“).

The ACEA goal of 140 g/km until 2008, which is based in fuel combustion in the car only, seems to be achievable by measures in the propulsion system alone. For gasoline internal combustion engines the largest improvement is expected to be the direct injection technology, which requires sulfur free gasoline. Internal combustion engine propulsion systems in general have reduction potentials in the following areas: starter/ generator unit, 42 V electric system, optimized automatic transmission etc.

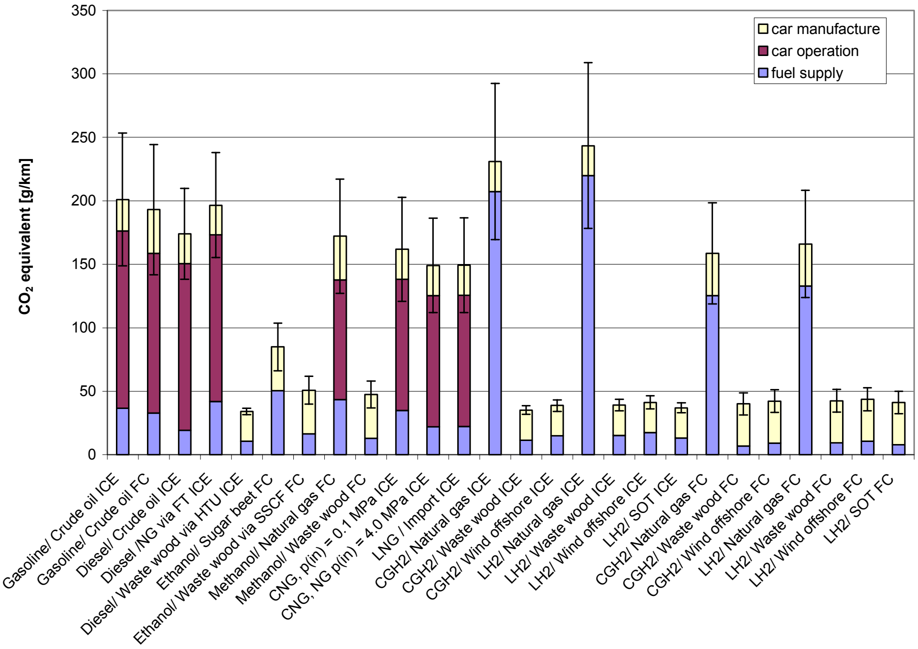
The goal of the European Union of 120 g/km until 2012 does not seem to be achievable by these measures alone. Additionally realizing all lightweight potentials would allow to achieve an ultimate 110 g/km. It has to be taken into account here that the trend towards heavier cars with stronger engines continues.

These assessments are based on the assumption that in the future, just as today, the average car sold has a 40% to 50% higher consumption than the "best" car. An additional potential for fuel consumption reduction is, therefore, to sell cars that are better adapted to the real requirements in traffic. This essentially means a reduction in engine power.

In addition it has to be noted that the consumption values discussed here do not include the consumption by auxiliary systems such as air conditioning, multimedia systems etc. The consumption caused by auxiliary systems is on the rise.

Figure 0-7 displays the greenhouse gas emissions of the entire fuel chain („Well-to-Wheel“). Additionally, the emissions from car manufacturing are included.

Figure 0-7: CO_2 equivalent emissions from car manufacturing, car operation as well as fuel production and supply in the "Golf" class of cars



The introduction of natural gas fuel would allow for a further reduction of CO_2 equivalent emissions of 22-29% compared to gasoline internal combustion engine cars or of 3-12% compared to diesel combustion engines, based on a per kilometer evaluation.

Drastic reductions of greenhouse gas emissions are possible by introducing fuels on the basis of renewable sources of energy. In combination with fuel cells, the emissions over the entire fuel chain („Well-to-Wheel“) can be reduced by over 90%. Including the emissions of car manufacture, reductions of around 75% can be achieved.

0.7 Introduction scenarios

Assessing the greenhouse gas emissions of a single vehicle represents the maximum emission reduction case. This is, therefore, equivalent to a scenario where all vehicles reach this value. As such a situation cannot be reached instantaneously, some scenarios for the market introduction of alternative propulsion system/ fuel combinations are presented here in comparison to the base case scenario, which is achieving the ACEA goal with conventional cars.

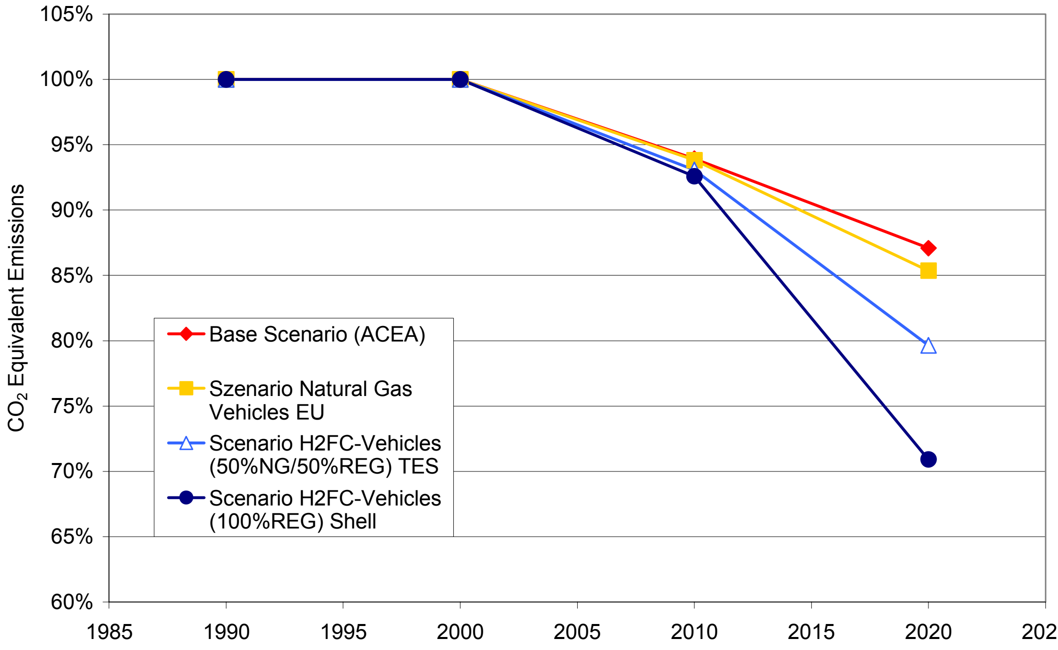
The German Federal Government has set the goal to achieve a 25% reduction of greenhouse gas emissions until 2005 compared to 1990. It is impossible to achieve this goal in the passenger car sector.

On the basis of the results presented by the Intergovernmental Panel on Climate Change further reduction goals of 40% reduction until 2025 and 80% reduction until 2050 are in discussion in Germany.

As other energy consuming sectors are much more advanced in CO_2 reductions than road transport a 20% reduction of greenhouse gas emissions from the passenger car sector is being proposed for the purpose of this study. This is in line with the goal of the European Union for a 20% substitution of conventional gasoline and diesel fuel by alternative fuels until 2020; this reduction, though, is in comparison to the year 2000.

The scenarios for the development of greenhouse gas emissions from the passenger car sector in Germany based on the ACEA goal and a further reduction to the minimum achievable level of 128 g/km in 2012 show that an emission reduction of 13% by 2020 compared to 1990 levels can be achieved (see Figure 0-8). Further reductions are possible to a minimum of 110 g/km in the average of all new cars sold seems to be achievable through weight reductions of the car.

Figure 0-8: Scenarios for the greenhouse gas emissions of the passenger car sector in Germany



The introduction of natural gas fuel would lead to further small reductions in greenhouse gas emissions. In addition to reductions in fuel consumption in both conventional and natural gas cars achieving the EU goal of 10% gasoline and diesel substitution by natural gas fuel in 2020 would reduce greenhouse gas emissions by 14.6%, or 1.7 percentage points more than the base case scenario (achieving the ACEA goal).

Introducing hydrogen fuel cell cars starting in 2007 in addition to tapping the fuel consumption reduction potentials in conventional cars and supplying 50% to 100% of the hydrogen from renewable sources of energy allows to reduce greenhouse gas emissions by 20-30% by 2020. Under ambitious but nonetheless realistic assumptions the entire fuel consumption of passenger cars in Germany could be substituted by renewable hydrogen by 2025.

No other propulsion system/ fuel combination has a higher emission reduction potential as the combination of hydrogen and fuel cells. Hydrogen internal combustion engines have a similar emission reduction potential as long as the hydrogen is 100% renewable. Fuel cell cars using renewable methanol or ethanol via an on-board reformer have a similar reduction potential. However, biomass is the only realistic renewable option for producing these fuels. The potential for substituting conventional gasoline and diesel by bioethanol is below 16% in Germany and below 22% in the European Union. The potential for substituting conventional fuels by bio-methanol is below 24% in Germany and below 33% in the EU. Renewable hydrogen, in contrast, can be produced from biomass as well as from renewable electricity (wind, hydro power, solar etc.).

Ultimately, greenhouse gas emissions can be entirely avoided by hydrogen fuel cell vehicles.

LBST
L-B-Systemtechnik

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L-B-Systemtechnik is strategy and technology consultant for sustainable energy and transport concepts supporting industry, politics and non-governmental organizations since 1982. In addition to multinational energy and automotive companies LBST's industrial clients also include innovative small and medium size enterprises.

With the perspective of a sustainable energy supply, hydrogen and fuel cells have been a major focus of LBST's work from the beginning. Detailed systematic studies and scenarios are being developed on infrastructures and costs of hydrogen and other alternative fuels, on well-to-wheel emission balances, on the state-of-the-art, perspectives and costs of technologies as well as on regulations, codes and standards. LBST coordinates large joint projects and has established and maintains major Internet presentations.

LBST supports industry, politics and non-governmental organizations

- in the identification of new products and services,
- in the development of strategies for the introduction of new products and concepts,
- with system studies,
- in finding new partners – networking,
- in the project management and coordination of projects,
- with strategic consultancy services.

Main fields of activities in the energy sector are renewable energies, improvement of energy efficiency, mitigation of negative greenhouse effects, the introduction of solar/ renewable hydrogen and fuel cells as well as resources of fossil energies. Main fields of activity in the transportation sector are improved railroad systems and interlinkage with road transport, alternative propulsion concepts for road vehicles and environmentally acceptable traffic concepts for metropolitan areas. In the overlap of these two areas, LBST works on clean fuels.

An interdisciplinary team of about 15 specialists works on scenarios and technology assessments, develops strategy papers and feasibility studies, initiates new projects, coordinates joint projects and provides strategic consultancy.

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