ENERGY AND ENVIRONMENT DEVELOPMENTS IN THE TRANSPORT SECTOR

Contribution for ENERGY 2030
2nd version [1]
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1. Scope and outline of the document

In this document we analyse the possible developments of energy use in the transport sector. We mainly focus on Belgium and analyse the period up to 2030. Section 2 presents the business as usual developments. Section 3 discusses the need to improve the fuel efficiency of cars. Section 4 deals with new technological developments. Security of supply is discussed in section 5 and section 6 concludes.

2. Business as usual developments

Modeling tool used

We rely on a recent study made with the TREMOVE II model for Belgium (TMLeuven, 2006). The TREMOVE model is a model covering the transport sector that has been used since a decade to study the environmental regulation of the European transport sector. For given growth rates of passenger and freight demand, it models the equilibrium on the transport markets. Passenger and freight transport can choose between different modes and different types of vehicles. This choice is a function of preferences, money costs and time costs. The stock of vehicles evolves over time in function of scrapping and the choice of new vehicles.
Different policies can affect the equilibrium. These can be taxation policies on motorfuels or car use but also regulation policies that limit emissions of cars and other transport means.

Assumptions for the business as usual scenario

The BAU scenario is based on a European forecast for passenger and freight transport that results from a moderate growth in energy prices and economic growth. In the BAU scenario there is moderate but continuous growth in the passenger transport sector. Most modal shares do not change a lot except for air traffic that grows quickly.

[1] I benefited from useful comments of W.D'haeseleer.

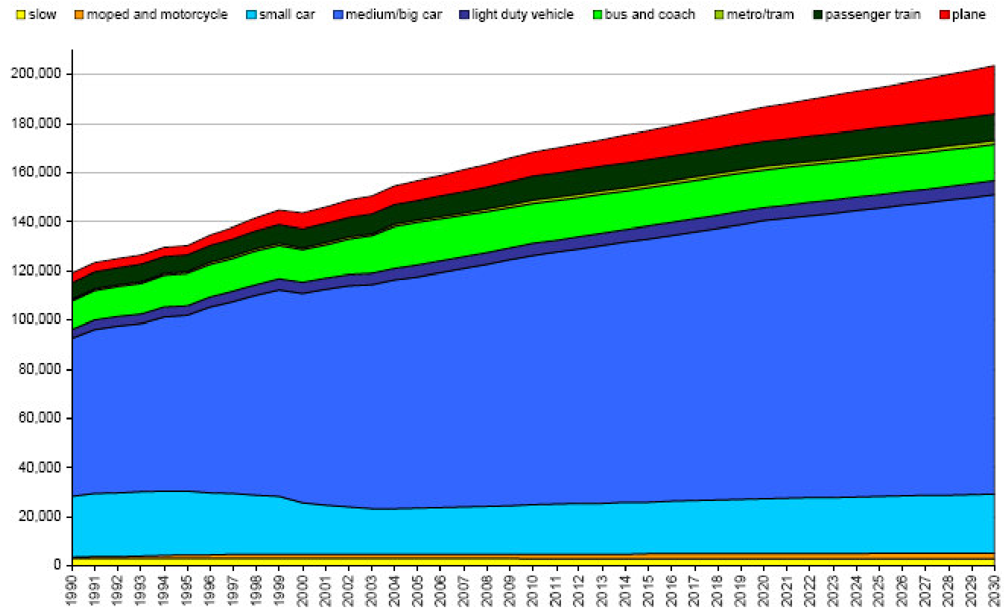

Fig 1 Growth in passengerkilometre (Million passenger kilometer) in the business as usual scenario (Source TMLeuven, 2006)

For freight transport, growth rates are higher and growth is mainly concentrated in the road mode.

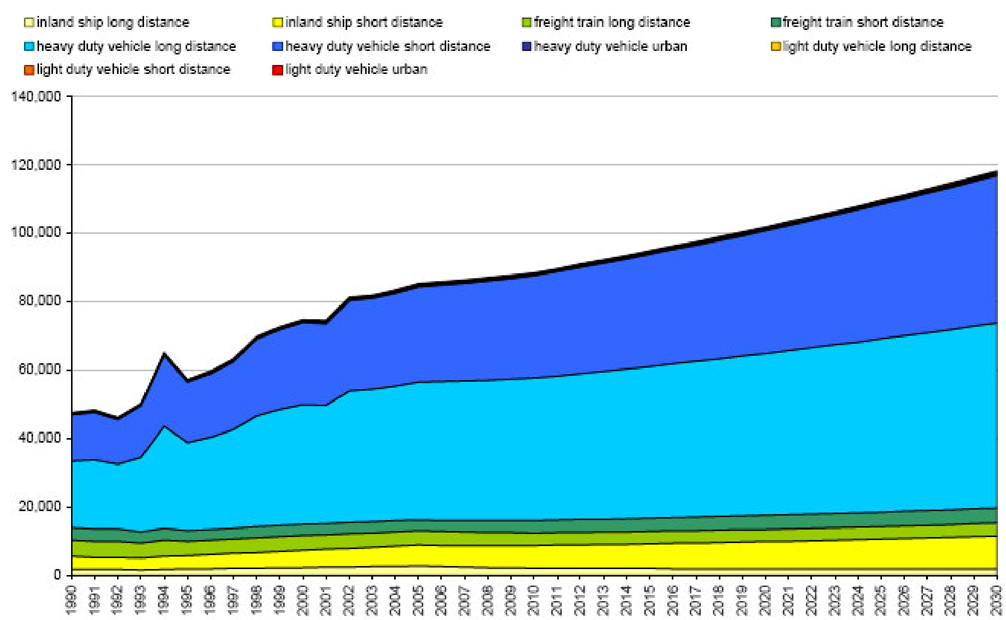

Figure 2 Growth in ton-kilometre (Million ton kilometer) in the business as usual scenario (Source TMLeuven, 2006)

Results

When one adds to these developments in the volume of transportation, the existing regulations on car emissions (including the coming EURO 5 standard), on truck emissions and on the quality of fuels, as well as current excise tax policies, one obtains the following results for the stock of cars by type of fuel. In Figure 3 we see that the major development ove the last 15 years has been the high penetration of diesel cars. This is expected to continue. New developments could be the penetration of hybrid cars (mainly diesel) and in the longer term Compressed Natural Gas.

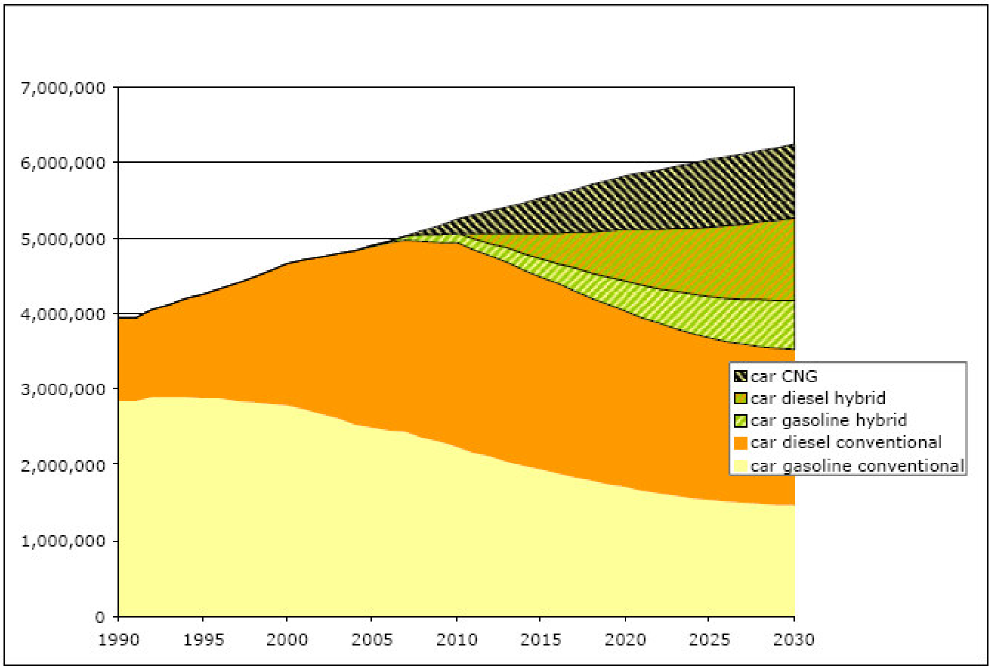

Figure 3 Evolution of car stock by type of fuel. (Source TMLeuven, 2006)

For freight transport, no important fuel shifts are foreseen.

In terms of emissions, one expects for the road sector a strong decrease in conventional emissions. In Figure 4, one sees that the NOX emissions decrease as a result of the regulations for new cars. Once the whole car fleet complies with the new regulations, the decrease levels off. So the more stringent standards more than compensate the growth in traffic volume. Similar results apply to the other conventional pollutants (NMVOC, CO, Particles,…). For the non road modes, there are fewer regulations so that overall, the share of the non road mode in total conventional emissions increases.

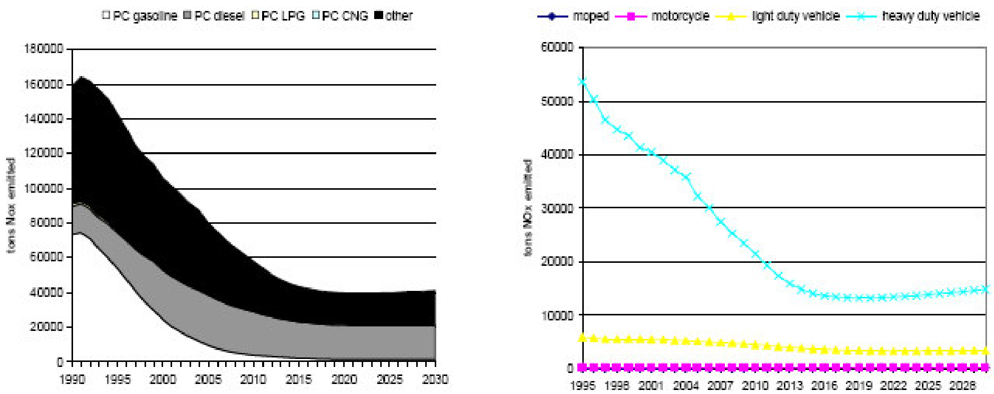

Figure 4 Growth in NOX emissions for road transport (Source TMLeuven, 2006)

The picture for CO2 emissions is different. One expects that carbon emissions will continue to grow. Cars and trucks may become somewhat more fuel efficient but this is insufficient to compensate the growth in transport volume.

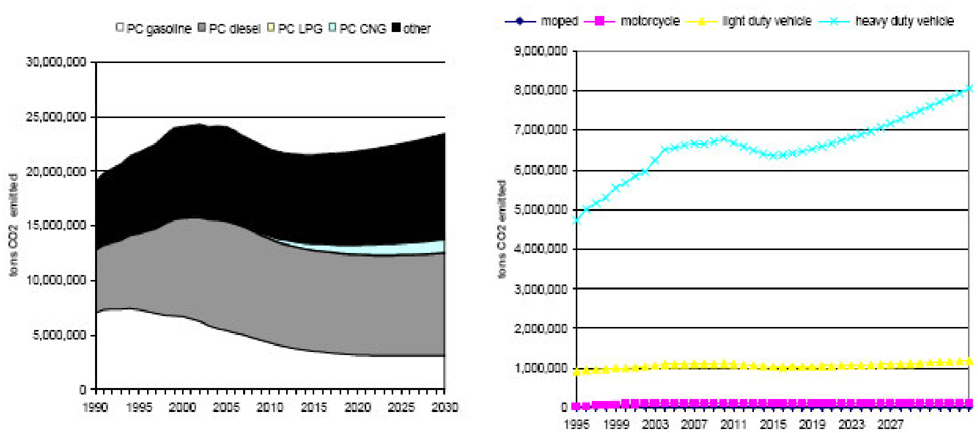

Figure 5 CO2 emissions from road transport (Source TMLeuven, 2006)

These developments are rather insensitive to fuel price increases. Fuel price increases will result in decreases in the overall volume and only to a small extent in substitution by other modes.

3. Is there a need for fuel efficiency efforts in the transport sector?

It is a popular belief that all sectors have to contribute to the reduction of GHG emissions. More specifically the transport sector is often targeted for its large and growing share (over 25% and rising) in overall CO_2 emissions. Private cars are a major source of CO_2 emissions in the transport sector and as a result policy makers are focusing heavily on their environmental record. In this section[2] we limit our attention to the CO_2 emissions of cars.

[2] This section is based on Knockaert & Proost (2005).

EU policy

The policy at the European Union level mainly focuses on a fuel efficiency standard--a limit on the fuel consumption per kilometre. For some years now the aimed target has been 120 g of CO_2 per vehicle per km; this is equivalent to approximately 5 litres of gasoline per 100 km and approx. 4.5 litres of diesel per 100 km. At the Belgian policy level subsidies have been introduced in order to motivate consumers to shift towards the most energy efficient vehicles. We think both policies are welfare reducing: they may reduce emissions of CO2 but at a very high cost compared to the reduction options available outside the transport sector.

When a fuel efficiency standard is imposed we can expect different effects: the type of cars, the number of cars, as well as the use of cars will change. Considering that car use is taxed in different ways (fuel taxes, registration taxes, etc.) and involves several external costs[3], the overall assessment of a fuel efficiency standard becomes rather complex and gives rise to many (mis)interpretations. We illustrate our reasoning with a very simple analysis that uses only one type of car.
The following assumptions allow simplifying and clarifying the analysis:

- there is only one car type with given specifications (e.g. size, driving performance);
- this car is used for a fixed number of years (the expected lifetime);
- the annual per car mileage is also fixed;
- there is perfect competition in the supply of fuel and cars, resulting in producers' prices being equal to the marginal cost;
- consumers act rationally in trading off fixed and variable costs of car use, i.e. they minimize the total costs of car use.
- When a fuel efficiency standard is imposed, the car manufacturers are able to adapt their cars (make lighter cars, more efficient engines) such that the additional manufacturing costs are compensated by the saving in fuel costs for the users. The result is that the user cost per vehicle for a given distance per year does not change

As car type we select a medium size gasoline car. In Table 1 we specify the data for this car—both for the reference case (without a fuel efficiency standard) and for the case where a fuel efficiency standard is imposed (right column). We specify the technical parameters (lifetime, fuel consumption) and the economic parameters (fuel prices, vehicle costs, interest rate) necessary to compute the annual user cost of the two vehicles. The user cost is the price paid by the car driver.

[3] An external cost exists when the action of one economic agent (here a car driver) negatively affects the well-being of other members of society without their consent. Typical examples of external costs of car use are air pollution, noise, accidents and congestion.

	Reference	*with Standard*
Fuel consumption per 100 km	6.5 litre ($160g\ CO_2$)	5 litre ($120g\ CO_2$)
Expected vehicle lifetime[4]	10 year	Idem
Real interest rate	10 %	Idem
Annualised car purchase price	€2,441[5]	€2,773[6]
Annual mileage	18,000 km	Idem
Fuel price (excl. excise taxes) per litre[7]	€0.51	Idem
Excise taxes per litre	€0.72	Idem
Saved fuel costs (excl. excise taxes)		€138[8]
Saved fuel excise taxes		€194[9]
User cost per year	€3,880	€3,880

Table 1 Car properties with and without 5 l/100 km standard

As we are interested in the cost difference, we only analyse two cost categories that change--fuel costs and vehicle manufacturing costs--and do not consider insurance costs, registration taxes and maintenance costs.

In the reference case, the user cost amounts to €3,880 (sum of annual equivalent of the purchase price + fuel cost for 18,000 km).

In order to compute the annual user cost for the case where the standard is imposed, we know the saved fuel costs (including excise taxes) but not the change in car manufacturing costs. The cost of a car will go up (lightweight materials, more fuel efficient engine, etc.), but it is difficult to know by how much. We use the assumption that the increase in manufacturing cost will be equal to the saved user costs of fuel. This assumption is based on the idea that, in a competitive car market, if a car manufacturer could have offered the 5 litre/100 km car at a total user cost lower than the annual user cost of the reference car, he would already have done so and would have captured the whole market. Important in Table 1 is that in the end the reference car and the 5 litre/100 km car have the same annual user cost.

[4] Expected lifetime and interest rate are needed to allow for calculations on an annual base.

[5] Purchase cost of €15,000 × 0.16275 (annuity for 10 years and 10%).

[6] Given our assumption, the annual cost increase per car is computed so as to compensate exactly for the saved fuel costs for the consumer = {1.5 litre less per 100 km × €1.23 per litre × 18,000 km per year}.

[7] This is the maximum price for gasoline on May 10, 2005 (source: Belgian Oil Industry Federation). We split this price into 2 components: the first component excludes excise taxes + VAT (21 %); the second component excises taxes + VAT (21%) on excises.

[8] {1.5 litre less per 100 km × €0.51 per litre × 18,000 km per year}.

[9] {1.5 litre less per 100 km × €0.72 per litre × 18,000 km per year}.

Decisions on environmental policy options need to consider the full cost for society rather than only the user cost. The full cost or social cost will be different than the user cost. We are interested in the additional social costs of a more fuel efficient car. See Table 2. This equals:

- PLUS the increase in production cost of a more fuel efficient car (lightweight materials, more fuel efficient engine[10], etc.);
- MINUS saved fuel costs (excl. taxes), here €138;
- MINUS the saved congestion costs (though these are absent from this model given the assumption that the user cost per year and distance travelled are fixed);
- MINUS saved external costs[11] related to fuel consumption. This concerns the traditional forms of air pollution (SO_2, PM, NO_X, VOC, etc.) but these are virtually unrelated to fuel consumption for EURO IV cars. Moreover, there is a reduction in the external cost related to energy dependency[12];
- PLUS the increase in costs to collect taxes in sectors other than car use (marginal cost of public funds): the reduction in tax income (€194 per year) times the social cost to raise an equal tax amount in other sectors, mainly on the labour market (extra cost of 50%[13]). This results in a cost increase of €194 × 0.5 = €97 per year.

The social cost increase per car and per year resulting from an imposed reduction in fuel consumption from 6.5 to 5 litre per 100 km is here summarized in Table 2:

In Euro PER CAR AND PER YEAR	
Car Production cost increase	+332.0
Saved fuel costs (excl. excise taxes)	- 138.0
Saved external costs related to fuel consumption (excl.CO_2)	-13.5
Saved external costs related to mileage	0
Social cost of raising public funds on the labour market	+97.0
TOTAL SOCIAL COST (per car per year)	+277.5
Saved emissions of CO_2 per car per year[14]	0.614 ton
COST of fuel efficiency standard per saved ton of CO_2	452
Market price of tradable CO_2 permits per ton	5 - 30

Table 2 Total Social cost of a 5 litre/100km car

Thus in our example, the total social cost of a more fuel efficient car equals 277.5 Euro per car per year. This extra cost needs to be compared with the saved CO_2 emissions. Per year our more fuel efficient car would reduce emissions by 0.614 ton CO_2. The social cost of reducing emissions by one ton using this policy measure is then equal to this total social cost divided by the reduction in CO_2 emissions. It is here 452 Euro/ton and this is much higher than the current market price of CO_2 emissions. The current market price of CO_2 emission permits gives an idea about the abatement costs in the rest of the economy.

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[10] A more complete model would also include possible loss of comfort.

[11] This does not include climate damage, which will be considered later, since assessments of climate damage are rather speculative. Consequently, we prefer to calculate a marginal damage cost per ton of emission reduction in order to allow for a simple comparison with other possibilities for emission reduction, as well as for the marginal environmental damage.

[12] A reduction in the consumption of crude oil could imply two external benefits: a reduction of the price of imported oil (optimal oil-import tariff argument) and a reduction of the costs related to import interruptions; this is estimated to amount to €0.05 per litre. Given an overall annual reduction of 270 litres of fuel, this results in an external benefit of €13.5. This is the optimal tariff argument in international economics; for a review, see Newbery (2005).

[13] The cost of public funds (cost for society of collecting one Euro of taxes, including the Euro collected) depends of the type of taxes being increased. Assuming we increase labour taxes, this tax amounts to €2.5 per euro tax income and €1.1 per euro tax income when non-labour taxes are used (Kleven and Kreiner, 2003). These values are high because higher labour taxes create many economic efficiencies. The values cited are high because they account not only for the number of working hours but also for the labour participation rate. We here apply a rather conservative value of 1.5.

[14] We assume 2.274 kg CO_2 per litre gasoline.

The high cost of saving CO_2 emissions by imposing the use of more fuel efficient cars can be explained by the fuel excise taxes--already very high in the transport sector. In a competitive car market and for a given comfort category, manufacturers are expected to supply cars with a minimised annual user cost. Here the fuel cost (including excise taxes) is taken into account. The manufacturer will hence supply a car for which the cost increase of a further reduction of the fuel consumption by one unit is equal to the cost of the same unit of fuel (including taxes). When we now force the manufacturer to leave his optimised car design in order to supply a more fuel efficient car, the additional car production cost per saved litre of fuel will be at least equal to the consumer price. The actual increase depends on the cost of alternative technological implementations.

This analysis can be refined in different ways: one can include imperfect competition on the car market, feedback effects on the total transport volume etc. but these refinements will rather re-enforce our conclusion.

Policy at Belgian level

The Belgian government has announced several measures for the transport sector in the last years. The most important measures are probably the low prices and an extended supply of Public Transport services, subsidies for the purchase of the most fuel efficient cars and the taxation of less fuel efficient company cars.
We will focus here in detail on the second measure--the subsidy for very fuel efficient cars[15].
This subsidy amounts to 15% of the purchase cost for cars that emit less than 105 g CO_2 per kilometre and 3% for cars that emit less than 120 g CO_2 per kilometre. The social cost of a CO_2 reduction realised with these subsidies is larger than the welfare cost of a comparable CO_2 reduction obtained with a fuel efficiency standard.
This can easily be verified with an example. Imagine two car types: one car A receives no subsidy while the other car B will receive a subsidy. We assume car prices to be independent of the subsidy—an assumption which is actually quite strong for a market with monopolistic competition. Furthermore, we assume that the subsidy of 15% of the purchase price of car B is just enough to convince the former buyer of car A to switch to car B, their user costs being the same.
For this consumer, the following equality holds (on an annual basis):

$$\begin{aligned} & C_A && + [f_A \times (P+T) \times M] - [w \times q_A] \\ = \ & [0.85 \times C_B] && + [f_B \times (P+T) \times M] - [w \times q_B] \end{aligned}$$

with C the purchase cost, f the fuel consumption per kilometre, P the fuel cost excluding taxes, T the fuel taxes, M the annual mileage, w the willingness to pay for a unit of quality and q the quality level.
This means that the total user cost (annualised purchase cost plus fuel costs, which are here equal to the specific fuel consumption f per vehicle kilometre, times price times annual mileage) corrected for the difference in quality of the cars (willingness to pay for quality times the quality level) has to be the same for both types of cars.

[15] The Public Transport strategy is discussed in De Borger and Proost (2001), Proost and Van Dender (2001) and Mayeres and Proost (2005).

The overall social cost of switching from A to B can then be computed in a way similar to the calculation of the cost of a fuel efficiency standard. It is equal to:

- The additional manufacturing costs that are not compensated for by lower fuel costs (excluding excise taxes).
- The increase in costs to collect extra taxes to compensate for the lost excise taxes and for the extra subsidy.

The social cost per unit of CO_2 saved will in principle be larger with a subsidy than with a fuel efficiency standard, because there are now more costly public funds needed to pay the subsidies.

The authorities issued a CO_2 guide providing a list of car models that apply for the subsidy. Nearly all cars in the list are diesel fueled, which is deplorable since diesel cars have a rather bad record when it comes to conventional air pollution (non-CO_2) compared to gasoline cars (Mayeres and Proost, 2001). This may continue to hold even after the introduction of a particles filter.

The only car that receives the 15% subsidy and that is a real environmental improvement is the hybrid Toyota Prius. With a price of €27,000, this car is about €10,000 more expensive than a conventional gasoline car. The authorities pay about €4,000 of this cost increase through the 15% subsidy. This is not a cost-effective way to reduce environmental emissions.

4. What will new technologies bring us?

The technological standards for private cars put forward by the European Commission since 1990 have resulted in a considerable reduction of non GHG exhaust emissions of private cars. The environmental cost[16] of a EURO IV car[17] is less than half that of the EURO I car, both for diesel and gasoline technologies. The average external environmental cost (incl. GHG emissions) per vehicle kilometre of a new medium-sized gasoline car is now under €0.015. This resulted in a significant decrease of overall transport emissions.

Further improvements of the existing diesel and gasoline technologies target both CO_2 emissions related to fuel efficiency (e.g. hybrid technologies) as well as other pollutants like particulate matter (PM) and NO_X (e.g. evolution towards EURO V standard). One can also look beyond the conventional cars and fuels to identify the environmental potential of new technologies (e.g. fuel cell) and fuels (e.g. hydrogen).

The SUSATRANS project (De Vlieger *et al*, 2005) identified a broad range of new fuels and technologies and made an assessment of their environmental potential. Production and maintenance cost, fuel efficiency and environmental performance of the new technologies were identified. The resulting overall user cost increase (excl. taxes), as well as the expected reduction in environmental damage are provided in Figure 1 (both in Euro per vehicle kilometer and compared to a new gasoline car that complies with the EURO 5 standard).

[16] The environmental cost is computed as the sum over pollutants of emissions (g/vehicle km) times the environmental damage cost per kg of pollutant.

[17] A EURO IV car is a car that complies with the present EU emission regulations for non GHG emissions.

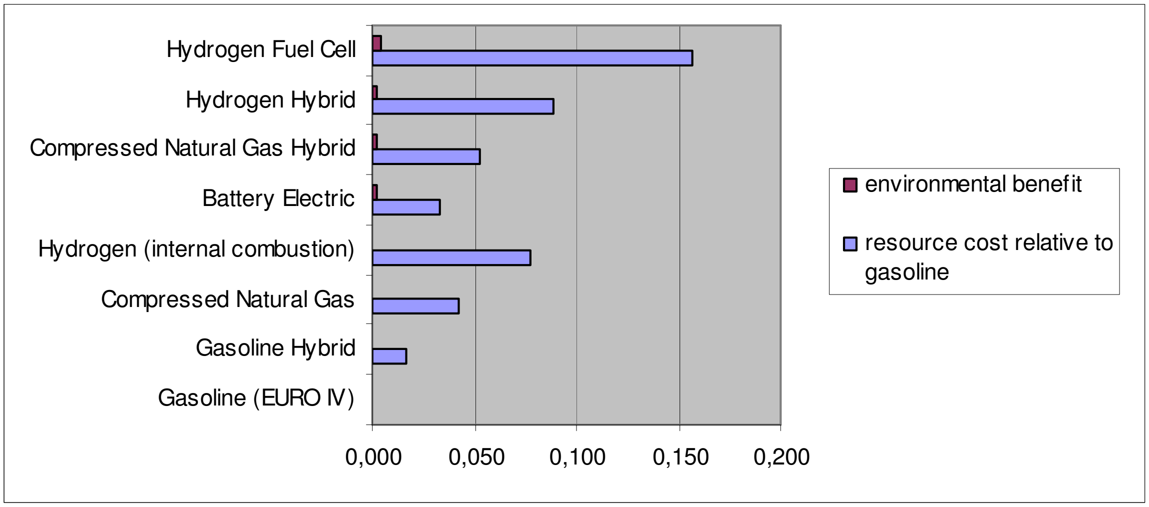

Figure 1: cost-benefit comparison of new technologies: extra resource costs and extra environmental benefit expected for different technologies in 2020 relative to a new gasoline car that complies with the EURO 5 standard

We observe a clear reduction in environmental cost of the new technologies. However, the reduction in damage is obviously smaller than the additional cost (excl. taxes). We should recall here that the existing EURO IV gasoline technology is already very clean; hence, the potential left for further improvements is limited.
If these new technologies were to be introduced, the overall impact on welfare could be expected to be negative: the environmental benefits are far lower than the resource cost increase.

5. *Vulnerability of oil supply*

Oil may become scarcer over the coming decades and there may be short term supply interruptions due to political or military reasons. What does this imply in terms of energy policy for the transport sector?
One can rely on 3 broad categories of instruments to address supply interruptions. The first one is emergency stockpiling of oil or refined products. The second one are import tariffs for oil and the third one are subsidies for development of alternatives. These 3 policies are already implemented to some degree. There is emergency stockpiling (3 months?), there are no import taxes but there are high consumption taxes for oil use in the transport sector and there is an important stimulus and R&D effort for the use of alternative fuels in the transport sector.
Compared to other sectors, the transport sector is subject to much higher consumption taxes than the other sectors. This implies that more efforts have been made than in other sectors to reduce the consumption of oil. So for the long term, the transport sector is probably prepared to bid much higher prices for oil use than the other sectors and will therefore also be the last to substitute away from oil if there are no technological breakthroughs.
When it comes to short term supply interruptions, it is first of all important to signal the scarcity of oil as transparently as possible to all consumers. This means using prices rather than rationing inside each country and also internationally when it comes

to manage the remaining supply and the emergency stockpiles. Secondly, there may be an interest to increase the short term flexibility of the oil consumers. In the transport sector this can be done by having public transport capacity available and bi-fuel cars. The public transport capacity is in Belgium rather well developed and there is certainly spare capacity. As for bi-fuel cars, the most important option available is probably a car that can also run on natural gas. This may be an interesting option to explore: what is the economic benefit of stimulating the use of natural gas in cars such that there is a distribution network and a car stock that can cope with oil supply interruptions?

In terms of R&D, there is a lot of interest in the production of biofuels as motorfuel and in the use of hydrogen. The use of biofuels in cars does not raise technical problems but may not be that interesting. Biofuels are difficult to produce in sufficient quantities locally and the environmental effects are not so positive. Hydrogen is a very long term option but only if there is a cheap way of producing hydrogen.

6. Conclusions

When present policies are continued, one expects a growth in the volumes of transportation. The growth in energy use will be somewhat lower than the growth in transport volume but CO2 emissions will not decrease. The emissions of conventional pollutants will decrease strongly due to the regulations on new cars.

Any extra effort to reduce CO2 emissions in the transport sector will be much more costly than in other sectors because the present excise taxes on motorfuels acts already as a very high CO2 tax.

In the immediate future there is no new car technology that offers better energy and environment performance at a reasonable cost.

The transport sector is strongly dependent on oil and is therefore vulnerable to oil supply shocks. Policies like the promotion of natural gas vehicles offers more perspectives to reduce vulnerability than a promotion of biofuel use.

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