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SCIENCE FOR A SUSTAINABLE DEVELOPMENT

CLEVER

Clean Vehicle Research: LCA and policy measures

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FINAL REPORT PHASE 1

CLEVER

CLEAN VEHICLE RESEARCH: LCA AND POLICY MEASURES

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<u>**Promotors**</u>

Joeri Van Mierlo
Vrije Universiteit Brussel (VUB)
Department of Electrotechnical Engineering and Energy Technology (ETEC)
Research Group Transportation Technology

Leen Govaerts
Vlaamse Instelling voor Technologisch Onderzoek (VITO)

Cathy Macharis
Vrije Universiteit Brussel (VUB)
Department of Mathematics, Operational Research, Statistics and Information
Research Group Transport and Logistics (MOSI-T)

Walter Hecq
Université Libre de Bruxelles (ULB)
Centre d'Etudes Economiques et Sociales de l'Environnement (CEESE)

Bernard De Caevel
RDC-Environment

<u>**Researchers**</u>
Fayçal Boureima, Nele Sergeant, Vincent Wynen &
Maarten Messagie (VUB-ETEC)
Tobias Denys, Michiel Vanderschaegh (VITO)
Laurence Turcksin (VUB MOSI-T)
Marion Englert , Fanny Lecrombs, Frédéric Klopfert (ULB-CEESE)
Marc De Vos (RDC Environnement)

BELGIAN SCIENCE POLICY

Rue de la Science 8
Wetenschapsstraat 8
B-1000 Brussels
Belgium
Tel: +32 (0)2 238 34 11 – Fax: +32 (0)2 230 59 12
http://www.belspo.be

Contact person: Igor Struyf
+32 (0)2 238 35 07

PROJECT WEBSITES:

Public website: http://etec.vub.ac.be/CLEVER.htm
Intranet: http://etecmc10.vub.ac.be/clever/index.php

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Acronyms, abbreviations and units

BEV	Battery Electric Vehicle
CH_4	Methane
CLEVER	Clean Vehicle Research
CML	Centrum voor Milieukunde Leiden
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CT	Circulation Tax
DALY	Disability Adjusted Life Years
E85	Blend of petrol with 85 % ethanol
ELV	End-of-Life Vehicle
EU	European Union
EuroNCAP	European New Car Assessment Program
FCAI	Federal Chamber of Automotive Industry of Australia
FCEV	Fuel Cell Electric Vehicle
FISITA	International Federation of Automotive Engineering Societies
FU	Functional Unit
GHE	Greenhouse Emission
HC	Hydrocarbons
HEV	Hybrid Electric Vehicle
HP	Horsepower
ICE	Internal Combustion Engine
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organisation for Standardisation
LCA	Life Cycle Assessment
LCC	Life Cycle Cost
LCI	Life Cycle Inventory
LPG	Liquefied Petroleum Gas
N_2O	Dinitrogen Oxide
NGO	Non-governmental Organisation
NH_3	Ammonia
NiMH	Nickel Metal Hydride
NOx	Nitrogen Oxides
PM	Particulate Matter
PV	Present Value
SO_2	Sulphur Dioxide
SO_x	Sulphur Oxides
SUV	Sports Utility Vehicle
TIC	Techno-Institutional Complex
TTW	Tank-to-Wheel
VAT	Value Added Tax
VRT	Vehicle Registration Tax
WTT	Well-to-Tank
WTW	Well-to-Wheel

Executive summary

Objectives

How environmentally friendly are conventional and new vehicle technologies? How can their environmental effects be compared? How are they accepted by the general public and other users (enterprises, public administrations)? What are the barriers to their introduction on the market? What possible incentives and policy measures could be implemented to stimulate this market? This project intends to analyse and answer these different questions, with a focus on the passenger car market. The objectives of the project can be described as follows:

- Create an objective image of the environmental impact of vehicles with conventional and alternative fuels and/or drive trains;
- Investigate which price instruments and other policy measures are possible to realize a sustainable vehicle choice;
- Examine the external costs and verify which barriers exist for the introduction of clean vehicle technologies on the Belgian market;
- Analyse the global environmental performances of the Belgian car fleet;
- Formulate recommendations for the Belgian government to stimulate the purchase and use of clean vehicles.

Life Cycle Assessment

To compare the environmental impacts of vehicles with different conventional (diesel, petrol) and alternative fuels (Liquefied Petroleum Gas (LPG), Compressed Natural Gas (CNG), alcohols, bio-fuels, biogas, hydrogen) and/or drive trains (internal combustion engines and battery, hybrid and fuel cell electric vehicles), a Life Cycle Assessment (LCA) is performed, within a Belgian context.

Within the 'Clean Vehicle Research' (CLEVER) project an LCA methodology is being developed with per-model applicability instead of an average vehicle LCA. This will allow taking into account all the segments of the Belgian car market and producing LCA results per vehicle technology and category. Thus the authorities will be able to take the right measure for the right segment and the consumer will be provided with the detailed information required for his/her vehicle choice.
In order to have a global comparative view of the different vehicle technologies, conventional and alternative vehicles have been mutually compared on the basis of the same provided service to the user. This has been defined as the use of a passenger car in Belgium during 13,7 years and a lifetime driven distance of 230.500 km. The results include all the life cycle steps (production, use phase, recycling) of a vehicle in a Belgian context.

LCA results are always linked to impact calculation methods used in specific conditions. The results should be understood and interpreted in the context of the used calculation methods and assumptions. For each specific impact calculation method, only the pollutants involved in the method are taken into account with respect to the equivalence factor attributed to each pollutant.
The impact methods available in this report are [1,2]: the IPCC (Intergovernmental Panel on Climate Change) 2007 Greenhouse Effect (GHE), the human health impact from Impact 2002+ and the air acidification from 'Centrum voor Milieukunde Leiden' (CML). The other impact methods are presented in the scientific report: eutrophication, chemical toxicity indicators, depletion of the ozone layer, consumption of renewable and non-renewable energy, waste production and land use.

One of the most interesting conclusions of this analysis is that Battery Electric Vehicles (BEVs) always score better than all other vehicle technologies for the three considered impact categories. Only the sugar beet Ethanol 85 (E85) vehicle has a better score than the BEV when dealing with human health. This is due to the high capacity of sugar beets to extract heavy metals from the agricultural soil. However, the fate of these extracted heavy metals can change the score of the sugar E85 vehicle. In this approach it is assumed that the retained heavy metals are treated as hazardous waste. When a rye based ethanol instead

of the sugar beet one is used for the E85 vehicle, its impacts on human health and climate become higher than all the other assessed vehicles. This bad score is essentially due to the rye production which requires high amounts of fertilizers and pesticides on the one hand and several agricultural processes (fertilising, tillage, sowing, harvesting, drying…) on the other hand. It is important to mention that a less intensive and/or biologic production of the rye will allow a reduction of the impacts of the E85 vehicle. The impact of the rye based E85 on climate change is not only due to the carbon dioxide (CO_2) emissions. In fact, the use of the different nitrogen based fertilisers induces important dinitrogen oxide (N_2O) emissions and the global warming potential of N_2O is almost 300 times higher than the one of CO_2. Additionally, shifting from petrol to E85 has increased the fuel consumption by more than 39%. This is due to the relatively low LHV (lower heating value) of the bio-ethanol.
When dealing with the acidification, the Fuel Cell Electric Vehicle (FCEV) will have the worst score. This is due mainly to the platinum contained in the fuel cell. However the recovery of the platinum in the end-of-life fuel cell with a pyrometallurgical process will reduce the acidification impact of the FCEV by more than 68%. The FCEV will then have the second best score after the BEV. Like the BEV, the FCEV is a zero direct emission vehicle. Additionally, the hydrogen consumption per km is relatively low (0,0086 kg hydrogen/km). The rye-based E85 has a higher acidification impact because of the high emissions of ammonia (NH_3), sulphur oxides (SO_x) and N_2O during the rye production.
However, shifting from first to second generation bio-ethanol (wood ethanol) will reduce all the impacts of the E85 which will then score better than the gasoline car for all the three considered impact categories. This will be particularly interesting for human health and acidification for which the reduction potential is higher.
Thanks to the reduction of the gasoline consumption in hybrid vehicles compared to gasoline vehicles and the nickel recovery at end-of-life, the hybrid vehicle is always scoring better than all the Internal Combustion Engine (ICE) vehicles assessed in this analysis. As the production of Liquefied Petroleum Gas (LPG) emits less nitrogen oxides (NO_x), SO_x and particle matter (PM), as a consequence the impacts of an LPG vehicle on human health and air acidification are lower than for diesel and petrol cars.

Life Cycle Cost Assessment

To compare the cost-efficiency of different vehicle technologies, the **Life Cycle Cost** (LCC) methodology has been chosen. From a user perspective, the LCC is often a crucial factor. Financial factors such as the purchase price and operating cost turned out to be decisional purchase factors [3]. Moreover, it has been found that the environmental friendliness of the car is not taken into consideration at the purchase of a new car. The LCC consists of the vehicle financial costs (purchase price, governmental support, registration tax), fuel operational costs and non fuel operational costs (yearly taxation, insurance, technical control, battery, tyres and maintenance).
With the help of an LCC model, the cost-efficiency of different vehicle technologies can be compared, market opportunities discovered and necessary fiscal support identified. The purchase of an environmentally friendly car may become a rational economic decision if these cars provide lower or equal private consumer costs compared to conventional diesel and petrol cars. Secondly, by comparing the external costs (environmental, congestion and accident costs) with the LCC calculations, it can be identified whether the current Belgian fiscal system is promoting the purchase and use of environmentally friendly vehicles.

The following fiscal strengths and distortions have been identified. Private consumer costs of LPG cars are lower compared to their petroleum equivalents thanks to the exemption of excises on these fuels (strength 1). Nevertheless, these cars are still confronted with an additional circulation tax which causes a heavy yearly tax burden (distortion 1). Electric cars and cars with blends of bio-ethanol seem to be less cost-efficient for the end-users. Reasons for the high costs of electric cars are the high purchase costs and high battery costs. This cost is for the old Peugeot 106, for newer cars this cost can be lower due to newer battery technologies, such as Lithium batteries, which have a longer life expectancy. Bio-ethanol cars are, on the other hand, faced with high fuel costs due to a combination of a high ex-refinery price, a higher energy consumption and high excises on bio-fuels (distortion 2). The attractiveness of hybrid vehicles mainly depends on their financial costs as their low fuel consumption makes it a very cost-efficient car for the end users. The governmental support for low CO_2 emitting vehicles is in this respect a great effort to increase their attractiveness for the larger public (strength 2). Diesel cars are very cost-efficient for the end user thanks to their lower fuel consumption (-20 to -30%) and excises (-50%) relative to their petroleum counterparts. Diesel cars are however not attractive for the society as they pay less taxes while they are more polluting in terms of PM than petrol cars (distortion 3). As a result of this lower taxation, there is an increasing number of diesel cars in the Belgian car park with an increasing impact on the environment. Diesel cars, standard equipped with a PM-filter, are however not a cost-efficient option as it is more expensive than the diesel version without filter.

Price elasticities

The proposed policy measures will only be effective if they induce the right behavioural responses. That is why **price elasticities** needs to be taken into account. The aim is to get insights in the impact of various policy measures on the purchase behaviour and usage of cars by households.

In a first part, several factors affecting price sensitivity have been identified. In a second part, a literature review of price elasticities has been performed. An overview of disaggregated elasticities has been performed with respect to several price components. Finally, a scheme for the evaluation of policy measures has been presented, based on [4]. In this scheme, the travellers' attitudes are linked to the price elasticities with the aim of obtaining a view on the effectiveness of policy proposals.

Belgian consumers are on average more sensitive for their vehicle expenses than for their public transport expenses. Household income has the largest impact on fuel consumption, followed by fuel prices. This means that fuel prices should rise faster than income to keep fuel consumption at a constant rate. Increasing fuel prices are found to have a larger effect on fuel consumption than on vehicle traffic as the rapid behavioural responses such as changes in driving speed or style, or modifying to the least energy-inefficient trips will affect fuel consumption more than traffic. As a result, fuel taxes will be more effective in reducing fuel consumption than in reducing road congestion. Moreover, they are found to affect vehicle trips and kilometres more than parking charges. Fuel taxes alone are however not politically attractive. That is why [5] advises to introduce fuel-efficiency regulations too as it would promote technological improvements whilst evoking vehicle-mix shifts towards more fuel-efficient vehicles. Such a system will on the other hand hardly affect safety, congestion and noise. From these perspectives, it may be desirable to make the tax system more variable. Time-based pricing is found to produce the greatest overall benefits, followed by distance-based (kilometre) charging, congestion pricing and cordon pricing**.** Kilometre charging based on real traffic emissions will have a larger impact on fuel consumption and emissions compared to kilometre charges based on measured emissions from drive cycles.

External Costs

An external cost, also known as a negative externality, arises when the social or economic activities of one group of persons provide damage to another group and when that damage is not fully accounted, or compensated for, by the first group.
The "ExternE" methodology for the calculation of external costs of transportation is updated and adapted for its use in a Belgian context. Attention is paid to the best methods and their updating, in order to quantify the external effects associated with new vehicle technologies. Thanks to the knowledge of the externalities, the environmental cost can be integrated into the LCC analysis of new vehicles. This approach allows a complete comparison with conventional vehicles, based on a full-cost approach.
A sample of 53 cars, covering a wide range of car sizes, fuel type or propulsion system is considered and analysed. The pollutants taken into account are mainly PM_{10}, NO_x, CO_2, CH_4, N_2O, SO_2 and noise. The contribution of the car fleet to the pollutant concentration in the ambient atmosphere is assessed through dispersion modelling.
Diesel cars without particulate filter are associated with the highest total external cost, reaching c€ 23.6/v.km for a SUV in the most realistic scenario. Diesel vehicles equipped with particulate filters have the second highest total external cost (up to c€ 15.19/v.km for an SUV), though they are much closer to those of the petrol, LPG, CNG, Flexifuel and Biofuel engines (c€ 9.98/v.km to c€ 13.21/v.km). At the opposite, electric cars generate the lowest impacts (c€ 4.81/km). Hybrid car also prove to have lower external costs than any other technology for vehicles of same weight. This assessment does not allow direct comparison of Flexifuel and Biofuel vehicles as the emissions have been measured according to different homologation procedures.

Globally, external costs are proportional to the weight of the vehicle for a given motorisation system and are thus highly correlated with the car size.
The study also clearly shows the predominance of PM_{10} related impacts in the total societal costs. More specifically, non-exhaust PM appeared to be the main cost driver. At the current stage of knowledge however, non-exhaust PM_{10} emissions and their specific impacts on health and building damage are surrounded by a great deal of uncertainty.

Social barriers

The main barriers impeding the development of alternative vehicles in Belgium as well as their relative importance have been identified. This objective is approached through the consultation of the different groups of stakeholders. Barriers can be grouped into the following categories: economic, technical, psychological, legislative, political, institutional, environmental/societal, market, supply and demand barriers.
While economic barriers appear to be very important[1], results have shown that other aspects also have a significant impact on consumer behaviour about alternative cars, sometimes more important than economic aspects. More specifically, results have shown that psychological barriers have a significant impact on consumer behaviour about cars. Economic, market and supply barriers appear to be the most important categories of barriers to the purchase/use of alternative vehicles in general when considering "conscious" motivations of people. However, while the barrier "lack of confidence in safety" (psychological barrier) is not highly quoted when asking people to evaluate its importance, it appears that this barrier does influence their purchase intentions.

Interviews of fleet managers have highlighted that it is the combination of several barriers (supply, economic, technical and market) that make alternative vehicles particularly unattractive for introducing them in vehicle fleets (except hybrid, for which the main barrier is economic). Also, some previously bad experiences (technical problems) with some types of vehicles (like electric, CNG and LPG vehicles) imply a lack of confidence in those vehicles. The shortage of supply (and the number of suppliers) creates sometimes the impossibility for companies to buy or to lease alternative vehicles. The lack of supply of alternative vehicles in leasing companies and also the inexistence of alternatives for intervention vehicles or vans limit greatly the development of alternative vehicles in some vehicle fleets. In this last case, barriers not only originate from the companies but also from the supply-side of the market.

An important barrier which prevents car manufacturers from developing alternative vehicles is related to the fact that they expect no (or not enough) demand for those vehicles, as they are not competitive with conventional vehicles for several reasons: economic, technical and psychological. Also, the lack of fuel availability (e.g. CNG or bio-fuel) is a major brake for car manufacturers to develop and commercialise alternative vehicles.
Some supply-side stakeholders mentioned also that there are too many possible alternatives and too many uncertainties about the sustainability of the different options. Their current strategy is rather to focus on the improvement of conventional fossil fuel cars -diesel in particular- in terms of efficiency and reduction of emissions.

Currently, the market is "stuck" because supply-side stakeholders expect no demand and demand-side stakeholders wait for supply development. This implies a need for policy intervention to release this locking mechanism. However, there is also a lack of policy measures to promote alternative vehicles.

Policy measures

The CLEVER project will allow investigating possible **policies towards a more sustainable car choice**. Implementation pathways for a consistent policy for the promotion of cleaner vehicles are being developed. These possible policies are price policies, regulatory policy, etc. The investigated policy

[1] This is in line with the results from the survey of task 3.2 of the CLEVER project which show that the first selection criteria of a new car are based on rational factors, economic factors in particular (most important car attributes according to the "spontaneous" answers of the respondents).

instruments not only focus on individual vehicle-buying behaviour but also on policies towards companies and public authorities. The pathways will be developed based on the analysis of the environmental impact, the barriers for the purchase and use of cleaner vehicles.
An inventory of measures for the support of environmentally friendly vehicles was made based on a literature study of different national and international sources. Main obstacle in the analysis of policy instruments is the lacking information on the impact of the different instruments.
Following conclusions are made from the inventory. A mix of policies which integrates carrots (incentives), sticks (disincentives) and regulations works best. This includes a mix of target audiences: steer industry and final consumers, both public and private. For private consumers, tax systems based on environmental performance are getting more and more common. No mandatory systems towards private fleet consumers exist today, voluntary systems are in place and the market starts offering green products. Company car taxation seems the appropriate instrument to influence that market. For public consumers, mandatory targets for clean vehicles seem to have an effect on the overall market and are a suitable instrument to open the market.

The second phase in the policy research is to seek stakeholder support for redesigning the policy pathways adapted to the Belgian situation. For this purpose, stakeholder round tables were organised to discuss the effectiveness and feasibility of policy measures. The conclusion of the stakeholder consultation process is that for the introduction of cleaner vehicles each of the actors has his responsibility and that cooperation is extremely important to support the market introduction of these vehicles. Individual actors will have to take the positions of all actors in the field into account to create a win-win situation for the whole market, based on a long term vision. Anyhow, immediate and strong choices are needed to be able to draw up a development strategy, as a stable market is necessary. For example, there has to be a standardization of the alternative fuels and these should be stimulated with lower excise duties.
Further, almost all stakeholders agree on the fact that the current tax system (based on fiscal horsepower (HP)) is outdated. It is also clear that a comprehensive mobility policy is needed, with a coherent mix of measures and valuable alternatives.
To define clean vehicles and clean fuels, stakeholders realize that a well-to-wheel approach is necessary and as such the Ecoscore may be a good indicator. However, a lot of stakeholders would stick to well known standards like (the combination of) CO_2-emissions and the Euro emission standard.

1. Introduction

1.1 Context

A substantial increase and modifications of transport in the European Union are expected in the coming decades. In a period when environmental issues on a local, regional and global scale are becoming very important, the relationship between transport and the environment needs to be clarified. The finite nature of oil resources and the associated political and economic effects presently lead to the need to assess alternative energy sources and to reduce dependency on imported oil. In addition to these energy aspects, there are important environmental, safety and economy related (e.g. congestion) reasons for changing our transport systems. Transport is the cause of large quantities of pollutants in the atmosphere, and these have direct and indirect effects on environmental receptors (people, materials, agriculture, ecosystems and climate, etc.) [6,7,8,9].

In order to make transportation more sustainable, different possible options are available [10,11,12,13]: controlling the need for motorised travel, land use planning, making travel safer (driving behaviour), encouraging modal shifts (walking, cycling, public transport) and technical innovation. Among these options, technical innovation of vehicles plays a key positive role, as mentioned by The Centre for Sustainable Transportation: "chiefly through widespread adaptation of vehicle types that are already marketed and through their further improvement" [14].

New technologies are being applied to conventional petrol and diesel vehicles (improved engines, On-Board Diagnostic system, etc.) to meet more and more challenging emissions directives. Drive systems, such as fuel-cell powered and hybrid or battery-driven electric vehicles are attractive alternatives. Also, several alternative fuels (LPG, natural gas, bio-diesel, bio-ethanol, biogas, hydrogen) are being considered as potential fuel choices for the future.

The environmental impact and road safety of automotive technologies over their different life cycle phases are changing. Also the End-of-Life Vehicle (ELV) treatment is expected to evolve strongly due to the related EU ELV directive entering into effect [15].

How environmentally friendly are these conventional and new vehicle technologies? How can their environmental effects be compared? How are they accepted by the general public and other users (enterprises, public administrations)? What are the barriers to their introduction on the market? What possible incentives and policy measures could be implemented to stimulate this market?

1.2 Objectives

In this context, the CLEVER project intends to analyse and answer these different questions. The objectives of the project can be described as follows:

- Create an objective image of the environmental impact of vehicles with conventional and alternative fuels and/or drive trains;
- Investigate which price instruments and other policy measures are possible to realize a sustainable vehicle choice;
- Examine the external costs and verify which barriers exist for the introduction of clean vehicle technologies on the Belgian market;
- Analyse the global environmental performances of the Belgian car fleet;
- Formulate recommendations for the Belgian government to stimulate the purchase and use of clean vehicles.

The focus of CLEVER is the passenger car market. In all analyses, a qualitative reflection will be done to possible extrapolation to heavy duty vehicles, with buses as a special case because of their capability to be an early adopter of new technologies.

1.3 Methodology

To achieve these objectives, a multidisciplinary approach has been proposed, in which the different tasks are performed by the different partners.

On the basis of a literature review, a preliminary **“state-of-the-art”** has been carried out on different topics, more specifically on vehicle technologies, existing environmental vehicle assessments, policy measures and consumer behaviour for the purchase of cars.

To compare the environmental impacts of vehicles with different conventional (diesel, petrol) and alternative fuels (LPG, CNG, alcohols, bio-fuels, biogas, hydrogen) and/or drive trains (internal combustion engines and battery, hybrid and fuel cell electric vehicles), a **Life Cycle Assessment (LCA)** is performed, within a Belgian context. LCA studies the environmental aspects and potential impacts of a product throughout its life from raw material acquisition through production, use and disposal and presents the advantage of being standardized (ISO 14040 & 14062) [16]. Next to the well-to-wheel emissions (related to fuel production, transportation and fuel use in the vehicle), which is assessed in the Ecoscore methodology, the LCA also includes cradle-to-grave emissions (related directly and indirectly to vehicle production and end-of-life processing of the vehicle). The final aim is to develop a methodology with a per-model applicability. A detailed description of the different tasks of the LCA approach (software selection, inventory and data collection, classification and characterisation, sensitivity and probability analysis, scientific validation of the Ecoscore approach) is described further in chapter 2.

To compare the cost-efficiency of different vehicle technologies, the **Life Cycle Cost** (LCC) methodology has been chosen. From a user perspective, the LCC is often a crucial factor. Life cycle costs are all the anticipated costs associated with a car throughout its life and include all user expenses to own and use vehicles. The LCC consists of the vehicle financial costs (purchase price, governmental support, registration tax), fuel operational costs and non fuel operational costs (yearly taxation, insurance, technical control, battery, tyres and maintenance). The used method within the LCC analysis is the net present value method as one has to accurately combine the initial expenses related to the purchase of the car with the future expenses related to the use of the car. A further description of the methodology and results of this task are described in chapter 3.

The proposed policy measures will only be effective if they induce the right behavioural responses. That is why **price elasticities** need to be taken into account (chapter 4). Based on the different market segments, the decision factors for car purchase and the price elasticities, a car purchase and usage model will be developed. The aim of this model is to get insights in the impact of various policy measures on the purchase behaviour and usage of cars by households. With this model and on the basis of fleet data, the budget neutrality of the proposed policy measures can be analyzed.

The different tasks are supported with inputs of state-of-the-art **external cost** factors. The “ExternE” methodology for the calculation of external costs of transportation is updated and adapted for its use in a Belgian context. Attention will be paid to the best methods and their updating, in order to quantify the external effects associated with new vehicle technologies. Thanks to the knowledge of the externalities, the environmental cost can be integrated into the life cycle cost analysis of new vehicles. This approach will allow a complete comparison with conventional vehicles, based on a full-cost approach (chapter 5).

The main barriers impeding the development of alternative vehicles (with alternative fuels and propulsion systems) in Belgium as well as their relative importance have been identified. This objective is approached through the consultation of the different groups of stakeholders. Barriers can be grouped into the following categories: economic, technical, psychological, legislative, political, institutional, environmental/societal, market, supply and demand barriers. Strong relationships exist between the different barriers; in fact, they are integrated into an aggregation of complex causal connections. The second original objective is to derive a systemic scheme representing the inter-relations between barriers. This allows for a more global view on the barriers, which is essential for drawing effective policy measures (chapter 6).

Price instruments are suitable to integrate the environmental performance of vehicles in this purchase decision. The CLEVER project will allow to investigate possible **policies towards a more sustainable car choice** (chapter 7). Implementation pathways for a consistent policy for the promotion of cleaner vehicles are being developed. These possible policies are price policies (road pricing, fiscal measures, modulated vehicle taxation, parking prices, subsidies...), regulatory policy, etc. The investigated policy instruments not only focus on individual vehicle-buying behaviour but also on policies towards companies and public authorities. The pathways will be developed based on the analysis of the environmental impact, the barriers for the purchase and use of cleaner vehicles. This is done in parallel with the international review of policy measures and related research and consultation of the different target groups in Belgium.

The **road emission model** from VITO will be used to assess the global environmental performance of the whole **Belgian vehicle fleet**. The Ecoscore model will be applied to the different vehicle categories (defined by fuel, age, engine size, vehicle weight, etc.) of the road emission model to result in a combined Ecoscore-emissions-road model. This will allow to generate an indicator of the global environmental performance of the fleet and make projections how this will evolve in time in different **scenario's**. The **projections** will be done for the mid term timeframe (2015) and the long term timeframe (2030). Three scenarios will be calculated.

Finally an overall assessment will be carried out on the basis of the results of the LCA, LCC, external costs, social barriers and fleet analysis. The influence of fiscal and other policy measures will be assessed. The integration of the results will be done by a **multi-criteria analysis**. Recommendations for stimulating the purchase and use of clean vehicles will be formulated.

Figure 1 gives an overview of the different tasks of the CLEVER project and the interactions between these tasks.

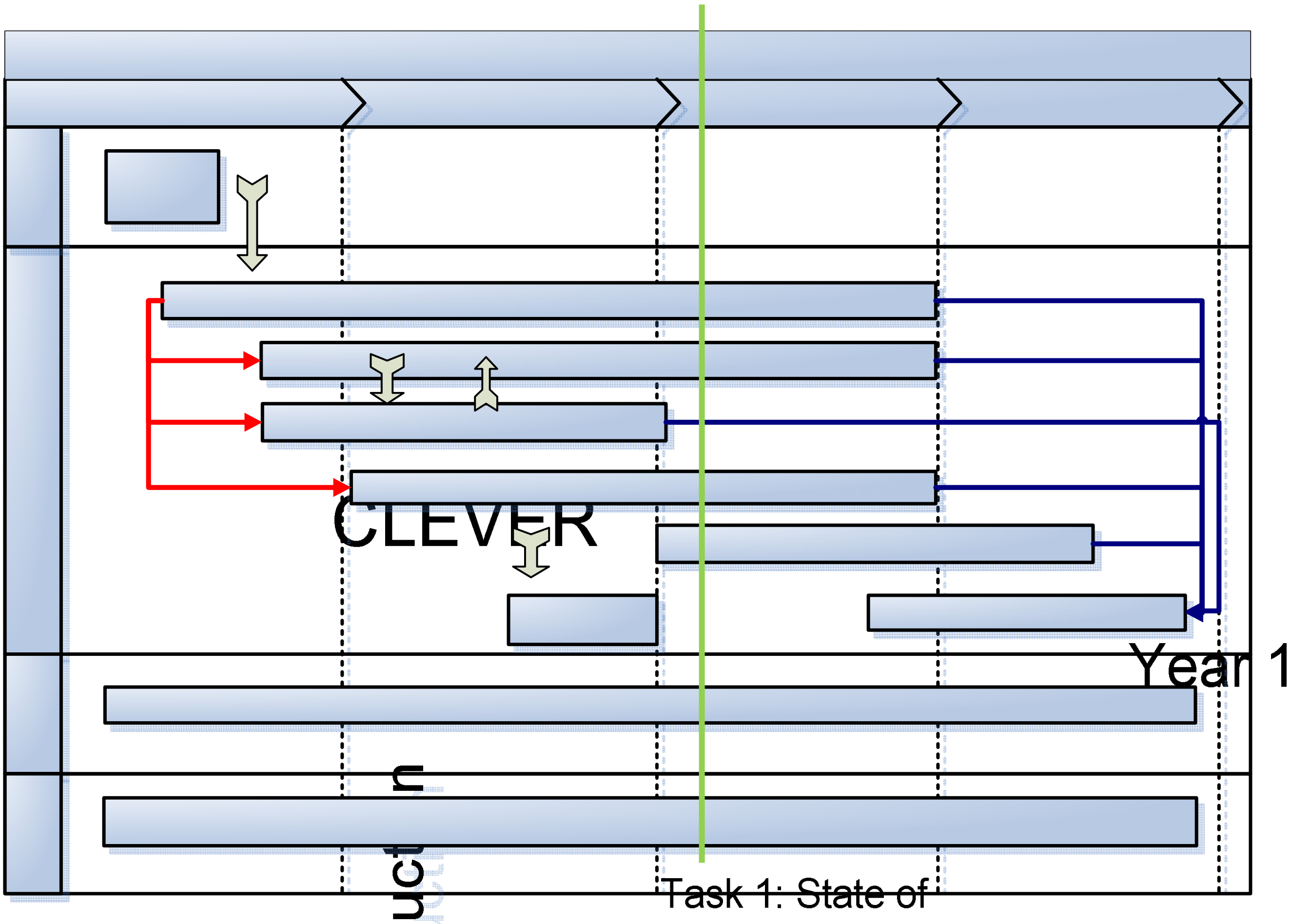

Figure 1: Timeline with the different tasks and interactions of the CLEVER project.

2. Life Cycle Assessment

2.1 Segmentation

In contrast to several other vehicle LCA studies, the CLEVER project is developing an LCA methodology with per-model applicability instead of an average vehicle LCA. This methodology will allow taking into account all the segments of the Belgian car market and producing LCA results per vehicle technology and category. Thus the authorities will be able to take the right measure for the right segment and the consumer will be provided with the detailed information required for his/her vehicle choice.
Several vehicle classification systems already exist, but each of them has some insufficiencies. The main issue is the choice of the segmentation parameters. According to the systems, different parameters are used. For example, The FCAI (Federal Chamber of Automotive Industry of Australia) uses the displacement [17], while the EuroNCAP (European New Car Assessment Program) uses the vehicle's length [18]. The FISITA (International Federation of Automotive Engineering Societies) system seems to be the most exhaustive since it takes into account the displacement, the power and the weight [19]. The assessment of all those systems reveals that none of them exactly correspond to the Belgian market segments.
After several meetings and discussions, the CLEVER team decided to develop a new classification system based on the existing Ecoscore [20] and the FEBIAC [21] systems. The classification criteria come from the Ecoscore database[2]. The innovation of this proposal is the split-up of some vehicle categories of the Ecoscore database into two others, e.g. the 'small car' category in the Ecoscore database is split-up into 'city car' and 'supermini'. Indeed the cars of these two categories present large differences in terms of emissions. Those vehicles could serve as common examples for the whole CLEVER project. The following vehicle segments are then used: city car, supermini, small family car, family car, small monovolume, monovolume, exclusive car, sports car and SUV.

2.2 Data analysis

The modelling parameters of the life cycle of the different vehicles are extracted from the Ecoscore database. A data analysis was performed to extract these parameters from the raw data available in the Ecoscore database [24]. Since the Belgian fleet includes a large variety of cars, the modelling parameters are not fixed values but ranges. In the model, all the possible variations of these parameters are taken into account, resulting in a variation of the considered impacts. When including the frequencies of these values, one can match a triangular or uniform distribution with the real distribution of the values. Figure 2 and Figure 3 give an example of this approach for a Euro 4 family car using petrol.
There are strong correlations between fuel consumption and vehicle weight, carbon dioxide and sulphur dioxide. These parameters can be described as a linear function of fuel consumption, multiplied with an 'error' distribution, expressing the difference between the linear equation and the real distribution of the parameter. For the other emissions (HC, NO_x, CO, PM, CH_4 and N_2O), no satisfying correlation with fuel consumption was found. These emissions are modelled as a triangular or a uniform distribution, matching the reality as closely as possible.
The chosen distributions have an important impact on the overall result, preliminary conclusions of the data analysis are therefore interesting to discuss.
Fuel consumption, weight, CO_2 and SO_2 are highly dependent of the chosen segment. On the other side, the Euro standard does not influence these parameters. Impacts of manufacturing and well-to-tank emissions do not change by introducing newer Euro standards. Tank-to-wheel (TTW) emissions of CO_2 and SO_2 will also not change by introducing newer euro standards. On the other hand it is noticeable that the Euro standard influences highly the other regulated TTW emissions. The higher the Euro standard, the lower HC, NO_x, CO, PM, CH_4 and N_2O emissions are.
Next to the homologation emissions provided in the Ecoscore database, heavy metals and non-exhaust emissions have been included in the LCA model. On the one hand, the heavy metals, expressed in milligram per kg of burned fuel, are gathered from the CORINAIR project [22]. On the other hand, the particulate matter (PM) emissions produced by the abrasion of the tires and the brakes are collected from the CORINAIR project as well and included in the LCA model. Consequently, both tailpipe and non-tailpipe emissions and their effect on the environment are taken into account in this model.

[2] The database can be consulted on www.ecoscore.be.

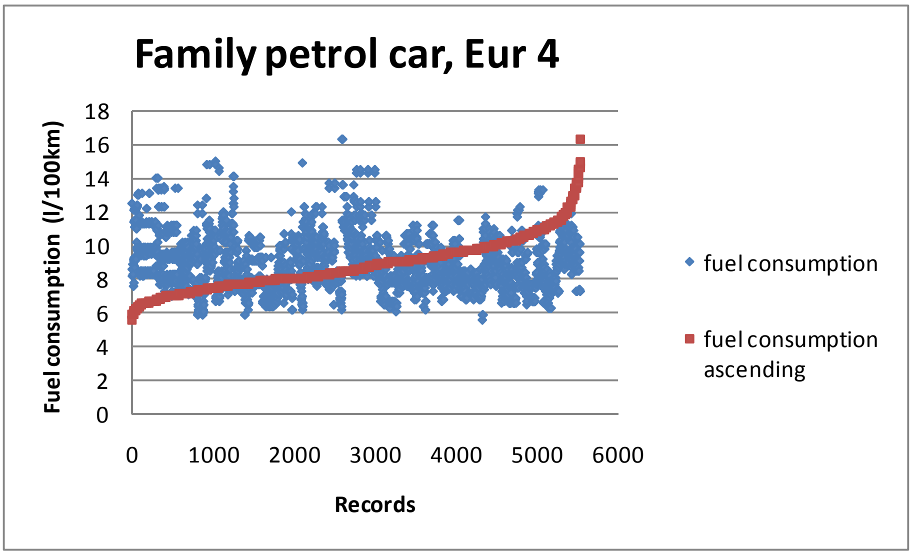

Figure 2: Range of the fuel consumption of the family petrol Euro 4 car.

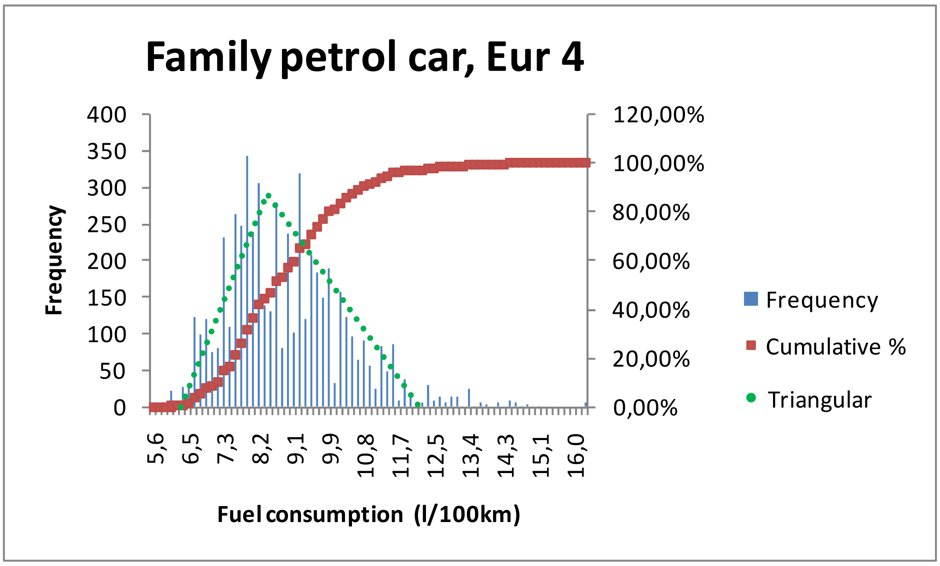

Figure 3: Distribution of the fuel consumption of the family petrol Euro 4 car.

To compare the environmental impact of the different vehicle technologies, a Functional Unit (FU) has been defined. It corresponds to the use of a passenger car in Belgium during 13,7 years and a lifetime driven distance of 230.500 km. As a car can have a lifetime driven distance shorter or longer than the F.U., the actual lifetime driven distance has been modelled with a normal distribution covering about 50.000 km to more than 400.000 km with an average corresponding to the F.U. The multiplication of the manufacturing step of a vehicle by the quotient of the F.U. over the effectively driven distance will allow taking into account the number of time a vehicle will need to be produced to correspond to the F.U. When calculating the LCA results, a driven distance is chosen randomly between the minimum and the maximum of the normal distribution of the effectively driven distance.

2.3 Range based modelling system

The different vehicle technologies are modelled in one single LCA tree (Figure 4). For each specific vehicle technology, the fuel consumption, the weight and the different emissions are written as statistical distributions. The data analysis methodology has allowed attributing to each range of data the most relevant distribution. A preliminary calculation has shown that the fuel consumption is the most important parameter of the model and it has almost a perfect correlation with the greenhouse effect which is one of the most important impact categories in LCA of vehicles. So it has been decided to write the distribution of all the other parameters (weight and emissions) in function of the distribution of the fuel consumption. As a consequence, when running the LCA model, all the parameters will vary in function of the variation of the fuel consumption instead of varying independently. This will create a dynamic model in which every change in one part of the model will influence the other parts allowing a permanent and automatic sensitivity analysis.

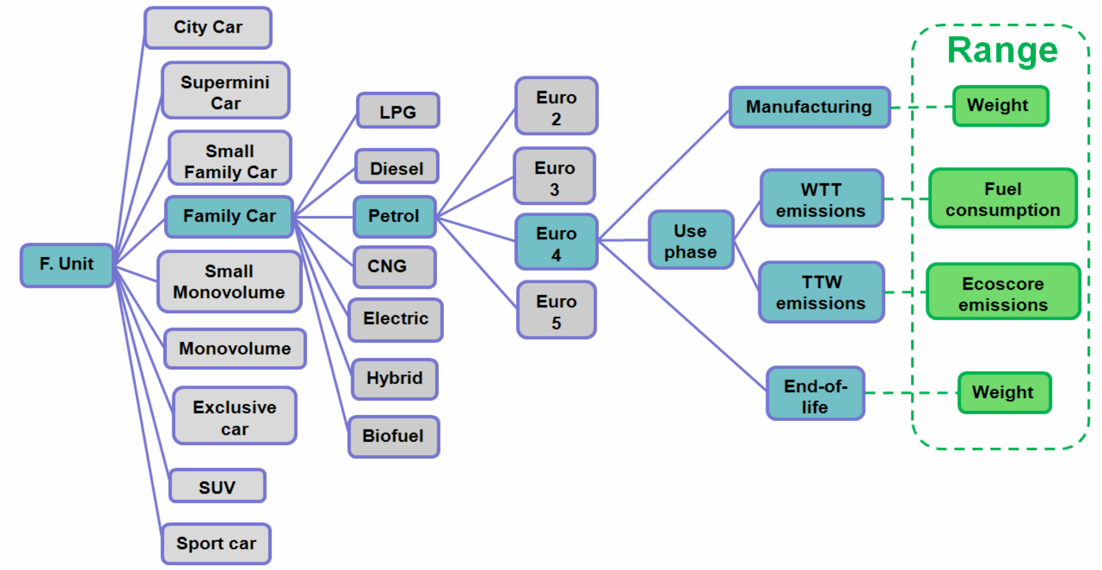

Figure 4: Range-based modelling system used in CLEVER.

2.4 LCI

The life cycle inventory of the CLEVER project has covered all the life cycle phases of conventional and alternative vehicles. It includes the production and use of fuels, the extraction of raw materials, the assembly, the use phase and the end-of-life. New materials, fuels and substances have been added to the last version of the LCI report[3]:

- The material breakdown of FCEV including the fuel cell and the hydrogen tank has been gathered from [23]. The hydrogen production has been updated with the steam reforming of natural gas inventory data [24].
- LPG and CNG production assumptions have been gathered from the CONCAWE project [25] and used in the Ecoinvent database [26] to calculate their LCI data.
- The LCI data of the lithium ion battery have been completed with the detailed production data of the electrolyte (lithium hexafluorophosphate) [27].
- Direct emissions and fuel consumption of flexi-fuel vehicles have been gathered from the BIOSES project [27].

Detailed LCI data of vehicles and fuels are available in the LCI report written by the ETEC department.

2.5 Impact calculation methods

Absolute environmental impacts do not exist. LCA results are always linked to impact calculation methods used in specific conditions. The results should be understand and interpreted in the context of the used calculation methods and assumptions. The results which are presented here are produced with three calculation methods:

- The IPCC 2007 Greenhouse Effect (GHE) over 100 years [1];
- The human health impact from the Impact 2002+ method [2] (Table 1);
- The air acidification method from CML (Table 2).

[3] See report of WP2.3 : 'Inventory and data collection', written by VUB-ETEC.

For each specific impact calculation method, only the pollutants involved in the method are taken into account with respect to the equivalence factor attributed to each pollutant.

Table 1: Impact 2002+- impact on human health calculation method [1].

Damage category	Human health	Unit
Carcinogens	2,8E-06	DALY / kg C_2H_3Cl eq
Non-carcinogens	2,8E-06	DALY / kg C_2H_3Cl eq
Respiratory inorganics	7E-04	DALY / kg $PM_{2.5}$ eq
Ionizing radiation	2,1E-10	DALY / Bq C-14 eq
Ozone layer depletion	1,05E-03	DALY / kg CFC-11 eq
Respiratory organics	2,13E-06	DALY / kg C2H4 eq

DALY (Disability Adjusted Life Year)

Table 2: CML air acidification calculation method [1].

Included pollutants	Air acidification	Unit
Ammonia	1,6	kg SO_2 eq / kg
Nitric oxide	0,76	kg SO_2 eq / kg
Nitrogen dioxide	0,5	kg SO_2 eq / kg
Nitrogen oxides	0,5	kg SO_2 eq / kg
Sulphur dioxide	1,2	kg SO_2 eq / kg
Sulphur oxides	1,2	kg SO_2 eq / kg

Next to these three impact categories, ozone layer depletion, land use, consumption of renewable and non-renewable resources, etc. are calculated for the vehicle technologies and will be available in the LCA WP2 report.

2.6 Results

In order to have a global comparative view of the different vehicle technologies, conventional and alternative vehicles have been mutually compared on the basis of the same provided service to the end user. The results include all the life cycle steps of a vehicle used and treated at its end-of-life in a Belgian context. One of the most interesting conclusions of this analysis is that BEVs always score better than all other vehicle technologies (Figure 5) for the three considered impact categories. Only the sugar beet E85 vehicle has a better score than the BEV when dealing with human health. This is due to the high capacity of sugar beets to extract heavy metals from the agricultural soil. However, the fate of these extracted heavy metals can change the score of the sugar E85 vehicle. In this approach it is assumed that the retained heavy metals are treated as hazardous waste. When a rye based ethanol instead of the sugar beet one is used for the E85 vehicle, its impacts on human health and climate (GHE) become higher than all the other assessed vehicles. This bad score is essentially due to the rye production which requires high amounts of fertilizers and pesticides on the one hand and several agricultural processes (fertilising, tillage, sowing, harvesting, drying...) on the other hand. It is important to mention that a less intensive and/or biologic production of the rye will allow a reduction of the impacts of the E85 vehicle. The impact of the rye based E85 on climate change is not only due to the CO_2 emissions. In fact, the use of the different nitrogen based fertilisers induces important N_2O emissions and the global warming potential of N_2O is almost 300 times higher than the one of CO_2. Additionally, shifting from petrol to E85 has increased the fuel consumption by more than 39%. This is due to the relatively low LHV (lower heating value) of the bio-ethanol.

When dealing with the acidification, the FCEV (H_2 produced from steam methane reforming) will have the worst score. This is due mainly to the platinum contained in the fuel cell. However the recovery of the platinum in the end-of-life fuel cell with a pyrometallurgical process will reduce the acidification impact

of the FCEV by more than 68%. The FCEV will then have the second best score after the BEV. Like the BEV, the FCEV is a zero direct emission vehicle. Additionally, the hydrogen consumption per km is relatively low (0,0086 kg hydrogen/km). The rye-based E85 has a higher acidification impact because of the high emissions of ammonia (NH_3), sulphur oxides and N_2O during the rye production.
However, shifting from first to second generation bio-ethanol (wood ethanol) will reduce all the impacts of the E85 which will then score better than the gasoline car for all the three considered impact categories. This will be particularly interesting for human health and acidification for which the reduction potential is higher.
Thanks to the reduction of the gasoline consumption in hybrid vehicles compared to gasoline vehicles and the nickel recovery at end-of-life, the hybrid vehicle is always scoring better than all the ICE vehicles assessed in this analysis. As the production of LPG emits less NO_x, SO_x and PM, as a consequence the impacts of an LPG vehicle on human health and air acidification are lower than for diesel and petrol cars.

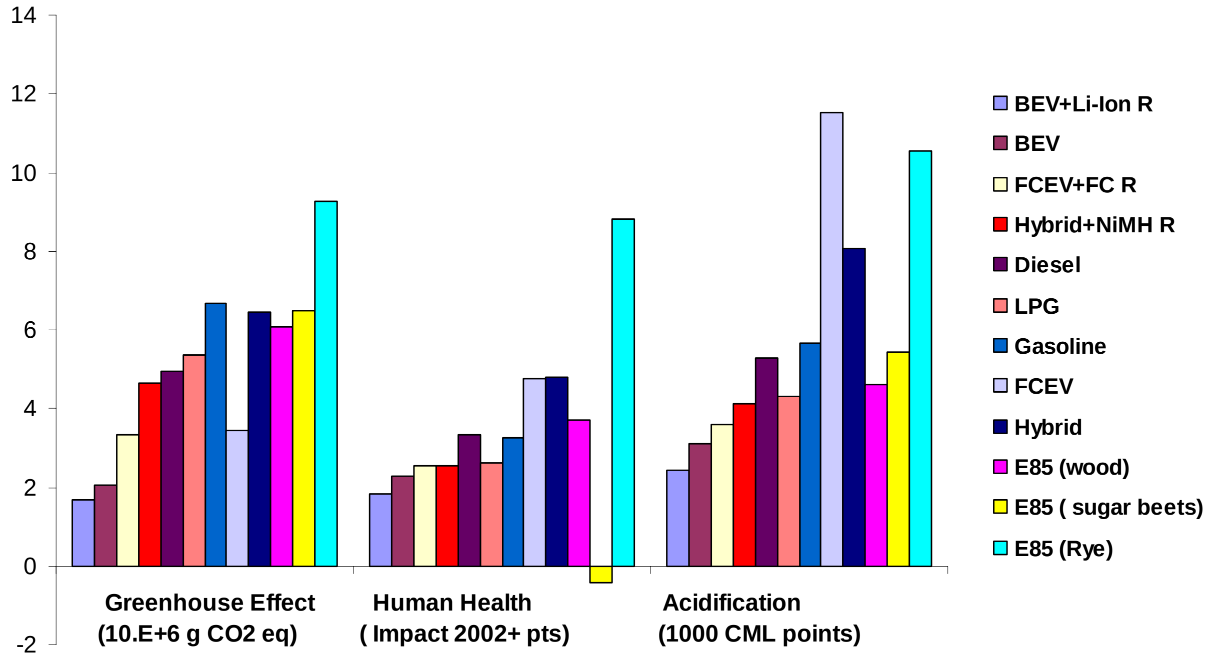

Figure 5: Comparative LCA results of conventional and alternative vehicles from the family car segment (R= Recycling; FC = Fuel Cell).

In order to have a clear comprehension of these results, the different vehicle technologies have been compared to each other at all the life cycle steps. Thanks to this comparison, the main impact sources in terms of materials, components and life cycle steps are determined. In Figure 6, one can notice that the use phase is the main cause of the impact on human health for the E85, petrol, diesel and LPG vehicles. For the FCEV, the BEV and the HEV, respectively the fuel, the lithium ion battery and the NiMH have a significant contribution to the overall impact. However their end-of-life treatment with a pyrometallurgical process will balance their impact.

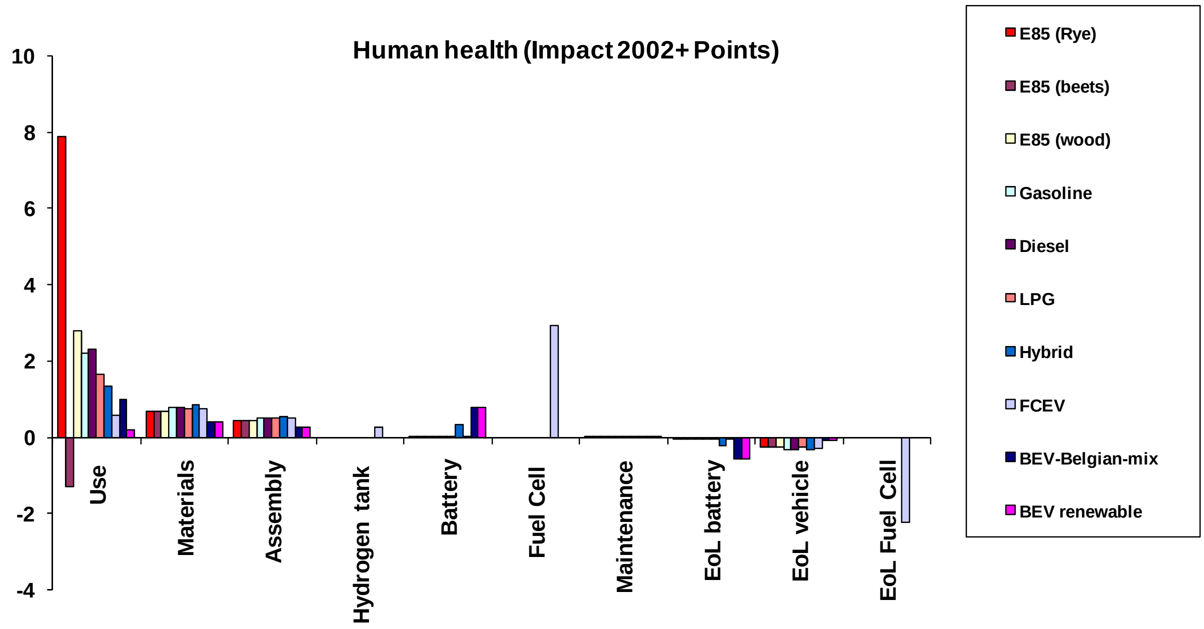

Figure 6: Comparison of the contribution of the different life cycle phases of conventional and alternative vehicles to the impact on human health.

2.7 Sensitivity analysis

In a classic LCA, average values are used during the modeling of the life cycle of the product system. To perform a sensitivity analysis in such a model, the parameters should be changed manually for the introduction of each specific new value. As a range-based modeling system has been used in this study, all the possible values of each parameter are included in the model with respect to their distribution type. The results can be expressed both in terms of average values as well as in terms of ranges of values. Thanks to this approach, a permanent and automatic sensitivity analysis is performed at each impact calculation. In addition, the modeler is free to choose the number of iterations during the sensitivity analysis.

The influence of Euro emission standards on NO_x and PM emissions of diesel cars has been assessed in Figure 7 and Figure 8. One can notice that the lower the emission standard, the higher the NO_x emission. However, the borderline between Euro 4 and 5 vehicles is not that clear. In the Euro standard the maximum NO_x emissions remain the same. For the PM emissions of diesel cars, one can notice that Euro 2 and Euro 5 cars have fixed PM emissions, which are default values in the Ecoscore database. So when assessing an impact caused by PM, the extension of the LCA model to these specific two emission standards will not allow producing extra information. However, the PM emissions are sensitive to Euro 3 and 4 vehicles and Figure 8 shows that the Euro 4 cars are always better than the Euro 3 ones.

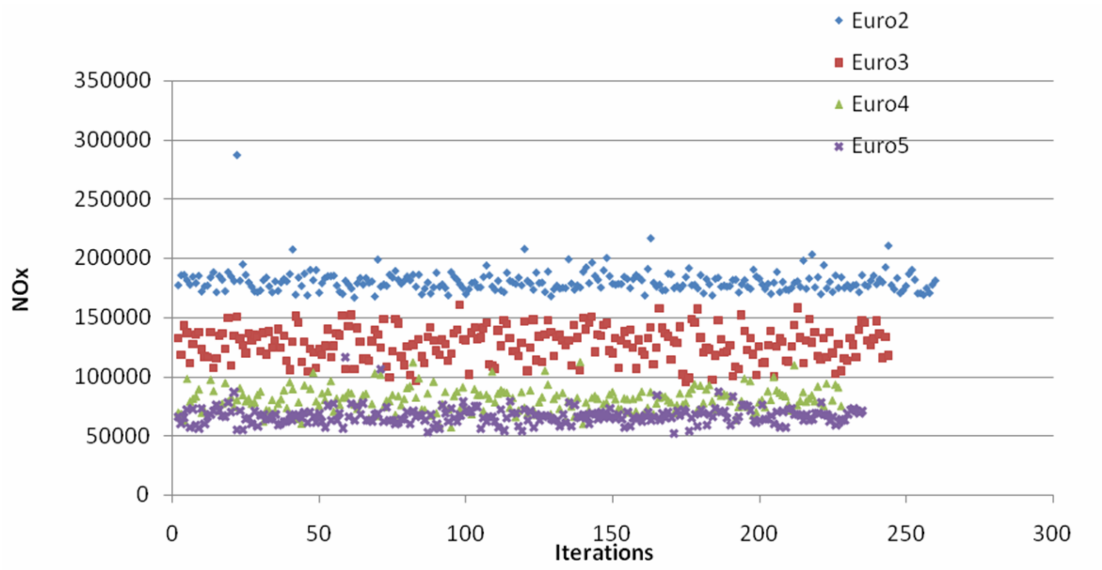

Figure 7: Influence of the Euro emission standards on the NOx emissions of diesel family cars.

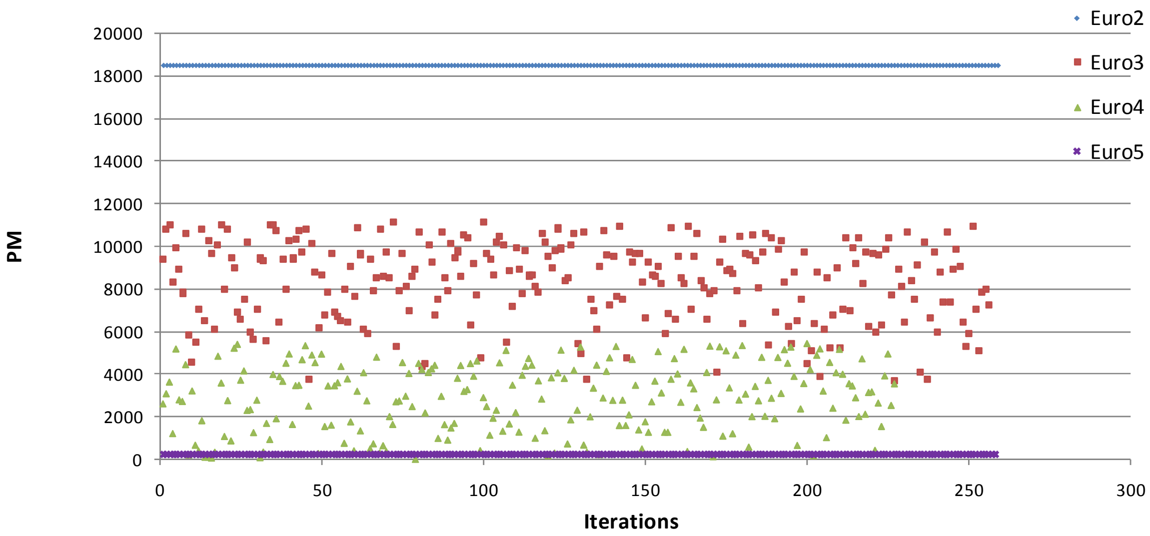

Figure 8: Influence of the Euro emission standards on the PM emissions of diesel family cars.

The same exercise on a gasoline car reveals that the limits between the different Euro standards are not that clear, especially for Euro 4 and 5 which are completely mixed for the NO_x emissions (Figure 9). However, Euro 4 and 5 emit nearly always less NO_x than Euro 2 and 3 cars.

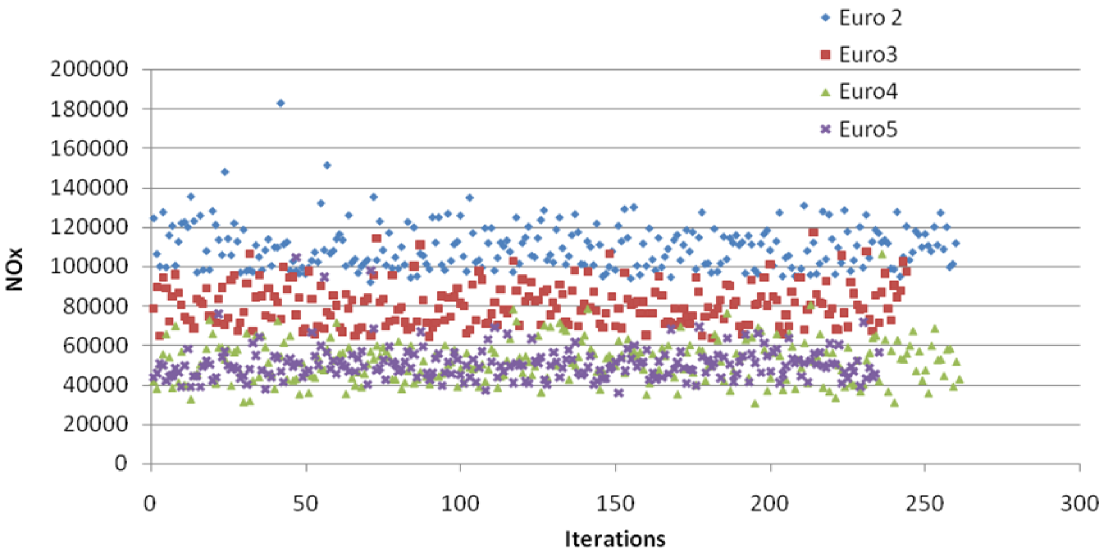

Figure 9: Influence of the Euro emission standards on the NO_x emissions of gasoline family cars.

2.8 Further work in second phase of the project

During the second phase of the CLEVER project, the LCA will be focused on the sensitivity and probability analysis on the one hand and on the estimation of the optimal time of car replacement on the other hand. The sensitivity analysis will cover the composition of the electricity in terms of type of feedstock, the introduction of innovative materials, e.g. composite, and the use of different blends of bio-fuels.
The optimal time of vehicle replacement will be assessed by comparing the production and the use of an extra car at a given period of a vehicle lifetime and its prolonged use.

3. Life Cycle Cost Assessment

3.1 Introduction from literature review

The state-of-the-art on car purchase behaviour [3] revealed that financial factors such as the purchase price and operating cost turned out to be decisional purchase factors. Based on these factors, consumers will select a couple of alternatives. Their final choice will depend on the evaluation of the intrinsic characteristics of the car (e.g. design, performance, comfort) and personal, cultural, social and household characteristics. Moreover, it has been found that the environmental friendliness of the car is not taken into consideration at the purchase of a new car. Consumers do not want to give up other car attributes for the environmental benefit. Their willingness to pay for a more environmental friendly car depends on the price and vehicle characteristics to be fully competitive with conventional cars. These results have been tested by means of two inquiries. The first inquiry was presented face-to-face on the European Motor show in Brussels (17-25 January 2008). This inquiry was continued online through a web-based survey (March-September 2008). It was confirmed that there is indeed a heightened environmental concern, but which is still of minor importance compared to other car attributes such as reliability, purchase price, fuel consumption, comfort, space and size. Regarding these findings, it is first of all interesting to have a look at the actual cost of different vehicle technologies within the current Belgian fiscal system. With help of a life cycle cost model, the cost-efficiency of different vehicle technologies can be compared, market opportunities discovered and necessary fiscal support identified. The purchase of an environmentally friendly car may become a rational economic decision if these cars provide lower or equal private consumer costs compared to conventional diesel and petrol cars. Secondly, by comparing the external costs (environmental, congestion and accident costs) with the life cycle cost calculations, it can be identified whether the current Belgian fiscal system is promoting the purchase and use of environmentally friendly vehicles.

3.2 Methodology

The Life Cycle Cost (LCC) methodology has been chosen to determine and quantify the cost of each vehicle technology. Life cycle costs are all the anticipated costs associated with a car throughout its life and include all the user expenses to own and use vehicles [28]. A vehicle lifetime of 7 years has been assumed, with an annual vehicle mileage of 15.000 kilometres. Only the first owner is considered in the analysis, and not the total vehicle lifespan which is 13.7 years [29]. The LCC for the end-user, or the so-called private consumer costs consist of vehicle financial costs, fuel operational costs and non fuel operational costs. Vehicle financial costs include the purchase price minus governmental supports, opportunity and depreciation costs. Fuel operational costs include the production costs, excises and VAT on the fuel. Non fuel operational costs comprise the yearly taxation, insurance, technical control, tyres and maintenance. In order to accurately combine the initial expenses related to the purchase of the car with the future expenses associated with the use of the car, the net present value method has been used. A real discount rate has been applied to calculate the discounted Present Value (PV) of one-time future costs (battery replacements, etc.) and recurring future costs (maintenance costs etc.). The discounting of external costs is the subject of considerable debate. With a higher discount rate, more importance is given to the near-present, while a discount rate of 0% gives an equal importance to the external effects of today and tomorrow [30]. Discount rates for external costs typically range from 0% to 5%, with 1% and 3% as most frequently used values. Sensitivity analysis has been performed to test the robustness of the outcomes at discount rates of 1%, 3% and 5%. This analysis showed that the different discount rates had no major impact on the outcomes of the external cost calculation. The life cycle costs and the external costs are calculated in three steps. First, every stream of periodic costs is analyzed. Second, the present value is calculated and finally, this present value is divided by the vehicle lifetime (for yearly costs), or by the vehicle mileage driven during the vehicle lifetime (for costs/km). This enables comparing different vehicle segments (supermini, small city car, small family car, big family car, small monovolume, monovolume, exclusive car, sports car and SUV), fuels (petrol, diesel, LPG, CNG and bio-ethanol) and drive train technologies (internal combustion engine, hybrid electric and battery electric vehicles).

The LCC calculations are based upon the current fiscal system in Belgium. The Belgian fiscal system consists of taxes related to the purchase, ownership and use of the car. Purchase taxes comprise a VAT of 21%, a Vehicle Registration Tax (VRT) with a reduction of 298 € for LPG and CNG vehicles and a governmental support for vehicles with low CO_2 emissions and for diesel vehicles, standard equipped with a PM-filter. Vehicles with CO_2 levels between 105 and 115 g/km receive a reduction of 3% of their purchase price, with a maximum amount of 810 € (indexed amount in 2008). Vehicles with CO_2 levels lower than 105 g/km receive a reduction of 15%, with a maximum amount of 4350 € (indexed amount in 2008). A reduction of 200 € can be obtained when purchasing a diesel vehicle, standard equipped with a PM-filter and with a CO_2 level lower than 130 g/km and a PM level lower than 5 mg/km. This reduction does not apply to diesel vehicles, retrofitted with a particulate filter. In 2008, the Belgian government could offer those reductions to no more than 43.626 cars, which is a small amount compared to the 535.947 newly registered cars in that year. The largest reduction of 15% was granted to 9.637 cars, wheras the reduction of 3% applied to 18.175 cars. 15.815 diesel cars with PM-filter were given a reduction of 200 € [31]. Ownership taxes include an annual Circulation Tax (CT), and an additional CT for LPG and CNG vehicles. Finally, user taxes refer to the VAT and excises on fuels. LPG, CNG and BEV are currently exempted from excises.

3.3 Results

A life cycle cost model was first of all developed to compare the cost-efficiency of different vehicle technologies. By adding an environmental score (Ecoscore) to each individual car, a classification has been made according to the cost-efficiency and environmental performance. “Stars”, characterized by cars with a high environmental performance (Ecoscore > 70) and a high cost-effectiveness (< 0,50 €/km), are mainly represented by supermini’s, small city cars and environmentally friendly versions (LPG, HEV) of larger cars. Cars in this segment will be able to support the transition towards a more environmentally friendly fleet. “Cash cows”, defined by a low environmental performance (Ecoscore < 70) but a great cost-efficiency (< 0,50 €/km), consist mainly of diesel cars. These cash cows can become stars when putting efforts to make these cars more environmentally friendly such as the standard equipment of a PM-filter. Exclusive cars, sports cars and SUVs, characterized by a poor environmental performance (Ecoscore < 70) and a very low cost-efficiency (> 0,50 €/km), find themselves in the “Top Gear” segment. Although environmentally friendly technologies (hybridisation, LPG etc.) of these cars could increase their environmental performance, the question remains if there is room for expensive exclusive cars (> 0,50 €/km) which are environmentally friendly (Ecoscore > 70). The more expensive cars are mainly more heavy vehicles and hence consume more fuel. This results in a reduction of the Ecoscore. Secondly, by comparing the taxes with the external costs (environmental, accident and congestion costs), it was investigated whether the Belgian fiscal system stimulates the purchase and use of environmentally friendly vehicles. The following fiscal strengths and distortions have been identified. Private consumer costs of LPG cars are lower compared to their petroleum equivalents thanks to the exemption of excises on these fuels (strength 1). Nevertheless, these cars are still confronted with an additional circulation tax which causes a heavy yearly tax burden (distortion 1). Electric cars and cars with blends of bio-ethanol seem not so cost-efficient for the end-users. Reasons for the high costs of electric cars are the high financial costs and high battery costs. Bio-ethanol cars are, on the other hand, faced with high fuel costs due to a combination of a high ex-refinery price, a higher energy consumption and high excises on bio-fuels (distortion 2). The attractiveness of hybrid vehicles mainly depends on their financial costs as their low fuel consumption makes it a very cost-efficient car for the end users. The governmental support for low CO_2 emitting vehicles is in this respect a great effort to increase their attractiveness for the larger public (strength 2). Diesel cars are very cost efficient for the end user thanks to their lower fuel consumption (-20 to 30%) and excises (-50%) relative to their petroleum counterparts. Diesel cars are however not attractive for the society as they pay less taxes whilst they are more polluting in terms of PM than petrol cars (distortion 3). As a result of this lower taxation, there is an increasing number of diesel cars in the Belgian car park with an increasing impact on the environment. Diesel cars, standard equipped with a PM-filter, are however not a cost-efficient option as it is more expensive than the diesel version without filter. The governmental support appears here not effective in making these cars attractive for potential car purchasers (distortion 4). New policy measures should be introduced tackling the main distortions of the Belgian fiscal system meanwhile encouraging the cost-efficiency of environmentally friendly vehicles. As such, this may on the long term evoke a shift in the composition of the Belgian car fleet towards a more environmental whole as it will become a rational decision to purchase an environmentally friendly car.

3.4 Further work in second phase of the project

The life cycle cost analysis will be applied for measuring the impact of policy measures on the cost-efficiency of environmentally friendly vehicles. New policy measures will however only be effective if they induce the right behavioural changes. That is why price elasticities and travelers' attitudes (see chapter 4) should be taken into account when measuring the shift in the composition of the Belgian car fleet towards a more environmentally friendly whole.

4. Price elasticities

4.1 Introduction from literature review

By means of a face-to-face survey on the European Motor show in Brussels (17-25 January 2008) and a web-based survey (March-September 2008) (see also section 3.1), it was also investigated whether policy measures can be an effective instrument in promoting the purchase and use of environmentally friendly vehicles. A kilometre charge or an extra pollution tax were ranked as the most effective policy measures by the respondents. Before introducing such policy measures, one needs to have a look at the travelers’ attitudes, as well as at the price elasticities as these will give an insight in the effectiveness and appropiateness of the policy measure.

4.2 Methodology

In a first part, several factors affecting price sensitivity have been identified such as type of price change, characteristics of the pricing policy, type of trip and traveller, quality and price of alternative routes and destinations, scale and scope of pricing and time period. In a second part, a literature review of price elasticities has been performed. The price elasticity of travel demand measures the reactivity of a change in price on travel demand, both measured in percentage changes. An overview of dissagregated elasticities has been performed with respect to several price components such as vehicle operational costs, parking costs, fuel costs, toll fees, emission charges, travel time costs, vehicle price and income, commute trips and financial incentives and their resulting changes in travel demand ranging from changes in travel modes, destination, travel routes, departure times and trip patterns to changes of residence and employment location [32]. Finally, a scheme for the evaluation of policy measures has been presented, based on [4]. In this scheme, the travellers’ attitudes are linked to the price elasticities with the aim of getting an insight in the effectiveness of policy proposals.

4.3 Results

Belgian consumers are on average more sensitive for their vehicle expenses than for their public transport expenses. Household income has the largest impact on fuel consumption, followed by fuel prices. This means that fuel prices should rise faster than income to keep fuel consumption at a constant rate. Increasing fuel prices are found to have a larger effect on fuel consumption than on vehicle traffic as the rapid behavioural responses such as changes in driving speed or style, or modifying to the least energy-inefficient trips will affect fuel consumption more than traffic. As a result, fuel taxes will be more effective in reducing fuel consumption than in reducing road congestion. Moreover, they are found to affect vehicle trips and kilometres more than parking charges. Fuel taxes alone are however not politically attractive. That is why [5] advise to introduce fuel-efficiency regulations too as it would promote technological improvements whilst evoking vehicle-mix shifts towards more fuel-efficient vehicles. Such a system will on the other hand hardly affect safety, congestion and noise. From these perspectives, it may be desirable to make the tax system more variable. Time-based pricing is found to produce the greatest overall benefits, followed by distance-based (kilometre) charging, congestion pricing and cordon pricing**.** Kilometre charging based on real traffic emissions will have a larger impact on fuel consumption and emissions compared to kilometre charges based on measured emissions from drive cycles. Kilometre charges are seen as a very effective tool as it makes it possible to differentiate according to energy-use, emissions, noise, road safety, driving style and congestion. As a result, people will switch to more fuel-efficient vehicles, rather than reducing their total amount of vehicle mileage or vehicle trips. These findings are in line with the results obtained from the face-to-face and web-based surveys. The surveys also revealed that an extra pollution tax, based on the environmental performance of cars, would be effective in discouraging the use of fuel-inefficient cars. Out of the price elasticity review, it appears that policy measures affecting purchase prices and fixed costs would indeed evoke a shift in the composition of the stock towards the most fuel-efficient car, but with a limited effect on the overall stock. Finally, a scheme for the evaluation of policy measures has been presented, in which the travellers’ attitudes are linked to the price elasticities in order to get an insight in the effectiveness of policy proposals. Congestion pricing or road pricing will be effective if travellers have a favourable attitude towards the policy measure and if the elasticity is high indicating that they will probably not travel by road as they have other travel options. Road financing schemes will be effective when travellers have favourable attitudes and when the elasticity is low indicating that people support the purpose of the policy measure and that they are still travelling by road.

4.4 Further work in the second phase of the project

Based on the different market segments, the decision factors for car purchase and the price elasticities, a car purchase and usage model will be developed. The aim of this model is to get insights in the impact of various policy measures on the purchase behaviour and usage of cars by households. With this model and on the basis of fleet data, the budget neutrality of the proposed policy measures can be analyzed.

5. External Costs

5.1 Introduction

An external cost, also known as a negative externality, arises when the social or economic activities of one group of persons provide damage to another group and when that damage is not fully accounted, or compensated for, by the first group. In order to take the external costs of transport into consideration within the transport costs, the European Commission has supported the development and application of a framework for assessing external costs of energy use, by continued funding of the ExternE project. The purpose of this project is to provide a general framework for assessing impacts that are expressed in different physical units into a common unit – the monetary value. The ExternE project aims at covering all relevant (*i.e.* not negligible) external effects.
Within the scope of this project, the impact pathway methodology has been used and constantly improved. It relies on a four step bottom-up approach, that can be summarized as follows: (i) emissions identification and characterisation; (ii) ambient air pollutant concentration by dispersion modelling; (iii) impact assessment in physical units; (iv) monetisation of these physical impacts.

5.2 Methodology

The ExternE methodology aims at covering all relevant (*i.e.* not negligible from the monetary viewpoint) external effects. In this logic, the impacts to consider are related to health (mainly particulate matter and ozone), building damages (particulate matter and SO_2), global warming (greenhouse gases) and amenity losses from noise. The pollutants to take into account are therefore limited to exhaust PM_{10}, NO_x, CO_2, CH_4, N_2O, SO_2, non-exhaust PM_{10} and noise. HC and CO emissions are not taken into account, as their low emission levels do not produce significant direct health impact. Although HC are known to be one of the ozone precursors and do therefore have indirect impacts on health, the complexity of this matter did not allow us to integrate such models in our assessment.

Definition of the emission sources and characterisation of air emissions have been performed by ETEC-VUB (W.P. 2.3). A sample of 53 cars, covering a wide range of car sizes, fuel type or propulsion system is considered and analysed for the pollutants listed above.

The contribution of the car fleet to the pollutant concentration in the ambient atmosphere is assessed through dispersion modelling. This task was done using a statistical dispersion model based on daily concentration measurements and taking both economic and meteorological variables into account [33] (FAVREL, 2001). The dispersion model allowed us to create new emission-immission relationships characterising the global car fleet. These emission-immission relationships have been used to calculate the increase in immission caused per kilometer driven, for each car of the fleet sample ($\mu g/m^3$.km). This modelling applies within the geographical zone of the Brussels Capital Region and for TTW emissions only. WTT emissions' contribution to local air immission levels could not be assessed. Indeed, these emissions occur higher up, in locations often separated from where the TTW emissions take place, and therefore require the development of specific dispersion models.

5.3 Results

Health costs represent between 40% and 45% of the external costs of all vehicles. These costs are mainly related to the emission of particulate matter and, but also to ozone, a secondary pollutant produced by other emissions such as NO_2 and VOC.

Health costs are mainly related to particulate matter. The largest contribution to these costs comes from mortality due to airborne particulate matter (54.8% of the total PM health costs). The second most important contribution arises from chronic bronchitis due to particulate matter (22% of the total health costs). These observations are in line with the ExternE predictions.
Globally, societal health costs related to PM range from € 1.93 10^{-2}/v.km for a supermini petrol vehicle to € 12.12 10^{-2}/v.km for a diesel monovolume. Diesel engines generate the highest costs (from € 4.10 10^{-}

^{2}/v.km to 12.12 10^{-2}/v.km). The use of particulate filters allows reducing these costs approximately by a factor two.

Ozone health costs are mainly due to an increase in chronic mortality and in cough days for children (56% and 24% of the total ozone health costs, respectively). Diesel cars cause the greatest ozone health impacts (from € 1.78 10^{-3} /v.km for a SmallMV car to € 2.84 10^{-3}/v.km for a monovolume equipped with a particulate filter). Following our model, particulate filters have a slight negative impact on ozone health costs of diesel cars, as their presence increases NO_2 emissions, an important ozone precursor.
Petrol, LPG and CNG cars of the same vehicle size segmentation induce very similar ozone impacts, which are considerably lower, between 5 and 10 times less than ozone impacts caused by equivalent diesel cars. Hybrid technology induces significantly lower ozone related health impacts for large vehicles (€ 1.74 10^{-4}/v.km for an Exclusive Hybrid against € 2.70 10^{-4}/v.km for an Exclusive Petrol or LPG). Electric cars have no direct ozone related health impacts. Keeping in mind the uncertainties surrounding ozone modelling, all these results should be regarded as approximations.

Building degradation costs are caused by acid rain (SO_2) and soiling from PM. Our assessment shows that this impact is negligible. The highest value calculated is € 3.06 10^{-5}/v.km for a sports car.

Building soiling is a result of PM emissions. Only diesel cars are responsible for direct exhaust PM emissions. When equipped with a particulate filter, the soiling costs range between € 2.56 10^{-3}/v.km to € 1.28 10^{-2}/v.km. These values are approximately 10 times lower than the corresponding vehicles without filter. For other engine types, exhaust PM emissions are negligible.
However, all cars emit non-exhaust particulate matter as a result of tyre, brake and road wearing. Although there is a lack scientific studies on these emissions, this assessment shows that they are far from being negligible, with a contribution to building soiling costs in the range between € 1.48 10^{-2}/v.km to € 5.30 10^{-2}/v.km. These values are about 4 times more important than the exhaust PM emissions of diesel car with filters.

From the **global warming** perspective, N_2O and CH_4 contributions to total climate change costs are small to negligible (~1%) in comparison to CO_2 impacts. However, for vehicles running on CNG, CH_4 WTW emissions account for 10% of the total emissions. Except for electric cars, WTT contribution to the climate change costs range from 7% to 14% of the total costs for all vehicles. The highest ratios of 14% are all related to the CNG engines. This comes from the important CH4 emissions in the WTT phase of CNG preparation.
In the case of electric vehicles, 100% of the greenhouse gas emissions occur during the WTT phase and come from CO_2 releases associated with electricity production. Overall, CO_2 TTW contribution to global warming marginal costs is by far the most pre-eminent.
Taking the car segmentation view angle, we can observe that the WTW climate change costs tend to increase with the car size, from c€ 1.01/km for the superminis to € 2.93 10^{-2}/v.km for sport car.
The 10 cars with the highest climate change costs (above € 2.00 10^{-2}/v.km) are all sports, SUVs or exclusive vehicles. The lowest climate change costs are by far the electric cars (below € 0.45 10^{-2}/v.km), followed by supermini vehicles with different motorisation systems (petrol, LPG, hybrid or diesel).
Costs discussed here have been obtained using the €90/t CO_2 eq scenario.

Noise impacts are only dependent on noise emissions. The data provided by ETEC shows that they are not linked to car size, fuel type or propulsion system. Therefore noise costs cannot be analysed through these criteria – however, electric cars are known to be the quietest and therefore the proxy used to value their noise emission should be reviewed and reduced. Noise costs related to urban day time emissions range from € 3.02 10^{-3}/v.km (68dB emission level) to € 1.52 10^{-2}/v.km (75dB emission level) whereas noise costs related to urban night time emissions range from € 5.52 10^{-3}/v.km (68dB) to € 2.78 10^{-2}/v.km (75dB). Similar noise costs have been also derived for emissions occurring in rural areas. A weighted situation, representing the average kilometres driven in Belgium has been calculated using the national mileage split factor between rural and urban kilometres.

Considering **the total external costs** for the most realistic scenario (greenhouse gas emissions valued at €90/t CO_2 eq; noise emission valued as urban day time emissions; 50% of PM_{10} non-exhaust emissions added to the exhaust PM_{10} emissions), health impacts arising from PM_{10} are the main cost driver (**40% to 45%**), followed by the building soiling impacts (**30% to 35%**). PM_{10} are thus the main cost driver, accounting in total for 70% to 80% of the total societal cost. For diesel cars without filter, this proportion even reaches 90%. The second main cost driver is climate change impacts, with **15% to 25%** of the total average external cost, followed by noise costs (**5% to 10%**) and health impacts arising from ozone related health impacts (1%). Building damage related to rain acidification is negligible.

Diesel cars without particulate filter are associated with the highest total external cost, reaching c€ 23.6/v.km for a SUV in the most realistic scenario. Diesel vehicles equipped with particulate filters have the second highest total external cost (up to c€ 15.19/v.km for an SUV), though they are much closer to those of the petrol, LPG, CNG, Flexifuel and Biofuel engines (c€ 9.98/v.km to c€ 13.21/v.km). At the opposite, electric cars generate the lowest impacts (c€ 4.81/km). Hybrid car also prove to have lower external costs than any other technology for vehicles of same weight. This assessment does not allow direct comparison of Flexifuel and Biofuel vehicles as the emissions have been measured according to different homologation procedures.
Globally, external costs are proportional to the weight of the vehicle for a given motorisation system and are thus highly correlated with the car size.

The study also clearly shows the predominance of PM related impacts in the total societal costs. More specifically, non-exhaust PM could be the main cost driver. At the current stage of knowledge, however, non-exhaust PM emissions and their specific impacts on health and building damage are surrounded by a great margin of uncertainty. Further scientific evidence in these matters should be taken into consideration in future similar studies. The effects of re-suspended particles, especially in densely populated areas, should also be included in such analyses.

Other ways of refining the results may be: (i) to enlarge the area covered by the dispersion model - this can be done either through developing new models (for other cities, for the countryside, or on a national scale) or by applying an updated benefit-transfer method to the present results; (ii) to improve integration of TTW emissions in the overall assessment - this also implies developing long-range/high altitude dispersion models; (iii) to include more impact categories in the overall assessment, particularly impacts on ecosystem degradation.

This study demonstrates that the implementation of impact pathway methodology for assessing external costs of air pollution remains a delicate exercise, given the number of uncertainties and unknown features surrounding the mechanisms associated with the impact of pollution by vehicles. The results of this study should therefore be considered with great caution.

6. Social barriers

6.1 Introduction

Main barriers to the development of alternative vehicles in Belgium have been identified through the consultation of different groups of stakeholders, and a systemic diagram with the interrelations between barriers (and possible levers to overcome those barriers) has been derived. It has to be noted that in the report, a distinction has been made between barriers that prevent the development of alternative vehicles in general and those that more specifically apply to certain technologies or fuels. Here, only barriers in general are presented.

6.2 Methodology

The first step consisted of performing a literature review on barriers to the development of alternative vehicles. A series of barriers have been pre-identified and classified by category with a typology inspired by literature[4]. Those referred studies generally identify barriers in an independent way, in such a manner that they are all considered in a same level, without taking interrelations into account.
The literature review helped to draw up the questionnaires for the consultation of the stakeholders, which is the second and main step of the report. As all the stakeholders are not confronted with the same barriers or will perceive differently the importance of barriers, they have been classified in the different groups listed below: Demand-side stakeholders (individual consumers, fleet managers), Supply-side stakeholders and "Experts" (universities and research centres, NGO's and associations, and politicians).
For the individual consumer's group, a survey was carried out at the Brussels Motor Show in January 2008. For the supply-side stakeholders and the experts, a more detailed questionnaire was drawn up. In those cases, smaller samples of stakeholders (about 20 for each group, with various contributions) were met to answer the questionnaire directly and to allow for an in-depth interview-discussion. For the companies and administrations with a fleet of vehicles, a sample of 14 fleet managers was sounded out by phone. The majority of them were from public institutions, from Brussels in particular. The data and information collected from the stakeholders' consultation have been treated trough statistical and/or qualitative analysis.
In a third and last step, a systemic diagram representing the interrelations between barriers expressed by the different stakeholders has been derived from a transversal analysis of the results. This analysis has been complemented by elements of the literature about the "technological lock-in" concept.

6.3 Results

Barriers to the purchase and use of alternative vehicles for the individual consumer

The survey at the Brussels Motor Show has highlighted several types of barriers to the purchase and use of alternative vehicles from the individual consumer's point of view: economic (high price…), supply (short supply of vehicles and fuel…), market (lack of development…), technical (technical immaturity and limited range…), etc. While economic barriers appear to be very important[5], results have shown that other aspects have also a significant impact on consumer behaviour about alternative cars, sometimes more important than economic aspects. Non-economic factors are potentially stronger than economic ones. More specifically, results have shown that psychological barriers have a significant impact on consumer behaviour about cars. Economic, market and supply barriers appear to be the most important categories of barriers to the purchase/use of alternative vehicles in general when considering "conscious" motivations of people. However, while the barrier "lack of confidence in safety" (psychological barrier) is not highly

[4] See the report of the task 4.2 for definitions and examples.
[5] This is in line with the results from the survey of the WP 3.2 of the CLEVER project, which show that the first selection criteria of a new car are based on rational factors, economic factors in particular (most important car attributes according to the "spontaneous" answers of the respondents).

quoted when asking people to evaluate its importance, it appears that this barrier does influence their purchase intentions.
About the importance of barriers mentioned by the respondents, it came out that barriers related to the short supply (of vehicles and fuel) are of course a major brake to the purchase/use of alternative vehicles. Market barriers appear also to be important; this group includes the lack of development of the market, the competition with low emission conventional cars and the lack of information. Statistical analyses have revealed the presence of an interaction between barriers.
This implies that measures aiming at overcoming the barrier “lack of information” will have a positive effect on the reduction of the perception of other barriers. However, while the lack of information is a very important barrier, overcoming it would not always guarantee a better development of the alternative.
Finally, the survey has also revealed the presence of doubts and scepticism about the environmental advantages of those vehicles; in particular, the “true ecologists” prefer not to have a car and use other ways of transportation (bike, public transport, car-sharing...) rather than owning a private car, even cleaner than the average. So, if even the “green people” are not supporting alternative cleaner cars, it is difficult to find a market segment for this category of vehicles.

Barriers to the introduction of alternative vehicles in vehicle fleets

Interviews of fleet managers have highlighted that it is the combination of several barriers (supply, economic, technical and market) that make alternative vehicles particularly unattractive for introducing them in vehicle fleets (except hybrid, for which the main barrier is economic). Also, some previously bad experiences (technical problems) with some types of vehicles (like electric, CNG and LPG vehicles) imply a lack of confidence in those vehicles. The short supply (and the short number of suppliers) creates sometimes the impossibility for companies to buy or to lease alternative vehicles. The lack of supply of alternative vehicles in leasing companies and also the inexistence of alternative for intervention vehicles or vans limit greatly the development of alternative vehicles in some vehicle fleets. In this last case, barriers don’t come from the companies but from the supply-side of the market.

Barriers to the supply of alternative vehicles

An important barrier which prevents vehicle makers from developing alternative vehicles in their supply is related to the fact that they expect no (or not enough) demand for those vehicles, as they are not competitive with conventional vehicles for several reasons: economic, technical and psychological (consumers are used to conventional cars), and because of the actual trend of the characteristics of the demand (more and more requirements of the consumers for more comforts and options at an acceptable cost). Also, the lack of fuel availability (e.g. CNG or bio-fuel) is a major brake for vehicle makers to develop and commercialise alternative vehicles.
Some supply-side stakeholders mentioned also that there are too many possible alternatives and too many uncertainties about the sustainability of the different options. Their current strategy is rather to focus on the improvement of conventional fossil fuel cars -diesel in particular- in terms of efficiency and reduction of emissions.
Given the current context, alternative vehicles would not spontaneously emerge from the market but need an impulse trough policy intervention. The lack of coherent, clear and harmonised policy measures to promote alternative vehicles is thus a major barrier to their introduction. Moreover, there are a lot of uncertainties about the evolution of future legislation. This lack of clear, global and long-run defined policy scheme prevents the industry from defining a strategy[6]. In the same line, there is a lack of clear policy for the introduction and the promotion of alternative fuel: policy measures should ensure alternative fuel distribution. More generally, policy makers have to promote alternative vehicles/fuels and take a clear position.

[6] The need for a stable framework for the car industry has also comes out from the stakeholders consultations lead by VITO in the context of WP 5.2 of the CLEVER project.

Barriers at society level

Currently, the market is "stuck" because supply-side stakeholders expect no demand and demand-side stakeholders wait for supply development. This implies a need for policy intervention to release this locking mechanism. However, there is a lack of policy measures to promote alternative vehicles. Interviews of "experts" have brought several types of barriers "upstream", and also gave some reasons why there is a lack of policy and supportive measures for alternative vehicles. On the one hand, according to some NGOs and politicians, there would be a lobbying from the automobile industry and oil companies against some environmental measures. On the other hand, we noticed trough the interviews a kind of lobbying from environmental NGOs against many alternative vehicles. Also and importantly, it appears from the interviews that alternative and clean vehicles do not constitute a political priority for green politicians. Like environmental NGOs, green politicians would rather act for a more structural change of the society: reduction of the use of cars, promotion of the use of bikes etc., because alternative technologies are still bad for the environment (environmental barrier) and make agents think that we don't have to change our habits of consumption. This lack of social support for alternative vehicles from green activists and green politicians (that would rather orientate their policies for a reduction of the number of cars) is in line with the result from the survey at the Motor show, where it has been noticed that "true ecologists" prefer not to have a car than buying a vehicle, even a cleaner one.

Technological lock-in and interrelation between barriers

The consultation of the different groups of stakeholders typically illustrates a technological locked-in situation. Some evolutionary economists have studied and described the characteristics and the consequences of the technological lock-in process. This description appears to correspond to the barriers to alternative vehicles mentioned by the stakeholders, which brings a theoretical framework to our conclusions.

It is necessary to better depict the context wherein alternative vehicles have to develop in order to identify the potential triggers that could help to overcome the barriers preventing their wider diffusion ("lock-out" situation). Alternative vehicles do not come up and operate in a "virgin" environment. Indeed, conventional cars with internal combustion engines working with fossil fuels have been used for decades. This implies that alternative vehicles must compete with this old and well-developed pre-existing technology for which the linked technologies, economic sectors, institutions, infrastructures etc. are well established.

The automobile market belongs to the "fossil fuel energy system", which can be considered as a "Techno-Institutional Complex" (TIC)[7]. In the case of the automobile system, it is composed of the following interconnected elements: cars, refuelling infrastructures, garages, firms, lobbies, culture (e.g. automobile sport), shaped mentalities (symbolic of the car and representation of what should be a car), etc. So, all these components of the system are related to fossil fuel vehicles; we speak about a "locked-in" situation (inertia) when the technological system follows a trajectory which is difficult and costly to change (path-dependent process).

Technological lock-in emerges from a path-dependent process with increasing returns to scale, improving efficiency, and narrowing relationships between the different stakeholders that become interdependent. In this context and due to increasing returns to adoption, the technology which has gained an initial lead will gradually exclude other competitors (as its advantages intensify with development). Four types of increasing returns identified by the lock-in literature can be mentioned: "scale economies", "learning economies", "adaptive expectations" and "network externalities". The network starts with the development of firms and infrastructures resulting from the production, the distribution and the services linked to the technology/fuel (roads, refuelling infrastructures, garages…). Then, other relations between firms or industry are created (for example, the plastic industry uses by-products from oil refineries). So,

[7] Note that the description of the energy system and the lock-in process that we made here are based on [35] and [36].

strong relations and interdependencies between firms and industries emerge. Development of the network goes together with development of various lobbies.

Also, beside the decreasing costs mentioned, the building of the system also implies a decrease of the "social cost" because of a "use effect" (habits) to the technology. Indeed, agents adopt "routine" behaviour in their purchase decision to avoid mental effort and to ensure satisfaction (no uncertainties). So, it results that agents are "locked-in" in routine consumption patterns, which have often been observed in the energy field (and can explain non-rational behaviour and non-efficient decision). Routine behaviour can also expand to firms and institutions.
The lock-in process implies that society at large is "stuck" in a specific technology because of past choices, as it has reached a point where economic and social costs are low enough because of network externalities[8]. The entire society is designed in accordance with the general use of fossil fuel technology, with strong links between the different components of the system and reinforcing lock-in effects. The lock-in situation, the interrelations and causality relations between barriers have been presented in a systemic diagram in the third part of the report of the task 4.2 (chapter 3.2). This systemic diagram is derived from a transversal analysis of the results from the stakeholder's consultation and from elements of the literature about the lock-in process.

[8] It has to be mentioned that those externalities can eventually lead to a lock-in in a non-efficient technology. However, the consideration whether internal combustion engines working with fossil fuel were (at the beginning of their development) the most-efficient choice is beyond the scope of this study.

7. Policy measures

Policy supporting cleaner vehicles is being introduced on several policy levels, some examples: European legislation on cleaner vehicles for public fleets; European legislation for reducing CO_2-consumption of passenger cars; European ongoing legislative process for fiscal measures based on CO_2-emissions; federal support on vehicles with particulate filters and low CO_2-emissions, regional discussions on greener car taxation, local measures for environmental zoning. In this multi-level policy context, the analysis of effective measures supporting the market introduction of cleaner vehicles is extremely important to come to a consistent and efficient policy mix. The objective of the policy analysis is to investigate the effectiveness of different policy instruments in steering the market towards the purchase and use of more environmentally friendly vehicles and to seek for stakeholder support for the introduction of such measures in the Belgian context.

An inventory of measures for the support of environmentally friendly vehicles was made based on a literature study of different national and international sources. The emphasis lies on measures initiated in Europe, but also international measures were included into the inventory if relevant. Main obstacle in the analysis of policy instruments is the lacking information on the impact of the different instruments. Even if vehicle sales data are available, several instruments are put in place simultaneously which makes it harder to distinguish market trends and the impact of specific instruments. Post-evaluation of the implementation of policy instruments is no common practice by the responsible authorities.

Following conclusions are made from the inventory. A mix of policies which integrates carrots (incentives), sticks (disincentives) and regulations works best. This includes a mix of target audiences: steer industry and final consumers, both public and private. For private consumers, tax systems based on environmental performance are getting more and more common. No mandatory systems towards private fleet consumers exist today, voluntary systems are in place and the market starts offering green products. Company car taxation seems the appropriate instrument to influence that market. For public consumers, mandatory targets for clean vehicles seem to have an effect on the overall market and are a suitable instrument to open the market.
Monitoring and impact assessment results from different policy measures implemented are lacking most of the time. However, this is essential in the evaluation of how the market reacts on the different measures. Policy towards cleaner vehicles is dynamic so governments should be aware of the impact and redefine the measures whenever necessary.
A similar assessment of policy measures was made in the Ecoscore project in 2004. The main evolution in 3 years time is that classic car taxation paid for ownership of a car are decreasing in favour of more place and time based road charges also depending on environmental performance of vehicles. Classic subsidy programmes are abolished because they are not in line with EU legislation on subsidies or because of the higher management costs of the system.

Policy pathways for the implementation of policy instruments for the support of purchase and use of clean vehicles in Belgium are designed based on the assessment of existing policy measures and the results of the research on barriers, life cycle costs and LCA. Selected measures were withheld to develop the policy pathways:

- Green car taxation
- Road pricing (‘kilometre charge’)
- Congestion charge
- Subsidies
- Green public fleets
- Availability of green vehicles and fuels
- User (dis)advantages (parking and restricted zones)

The second phase in the policy research is to seek stakeholder support for redesigning the policy pathways adapted to the Belgian situation. For this purpose, stakeholder round tables were organised to discuss the effectiveness and feasibility of policy measures. Four round tables were organised with each 10 to 15 participants of different stakeholders in the field of cleaner vehicles: policy makers, industry, NGO’s, experts, other. The round tables were prepared by means of a discussion paper distributed in advance to the participants. The discussion started by a confronting policy decision followed by the elements relevant to the impact and feasibility of specific policy measures. The round tables were concluded by a written questionnaire for scoring the policy instruments on impact, feasibility and priority.

The conclusion of the stakeholder consultation process is that for the introduction of cleaner vehicles each of the actors has his responsibility and that cooperation is extremely important to support the market introduction of these vehicles. Individual actors will have to take the positions of all actors in the field into account to create a win-win situation for the whole market, based on a long term vision. Anyhow, immediate and strong choices are needed to be able to draw up a development strategy, as a stable market is necessary. For example: there has to be a standardization of the alternative fuels and these should be stimulated with lower excise duties.
Further, almost all stakeholders agree on the fact that the current tax system (based on fiscal HP) is outdated. It is also clear that a comprehensive mobility policy is needed, with a coherent mix of measures and valuable alternatives.

To define clean vehicles and clean fuels, stakeholders realize that a well-to-wheel approach is necessary and as such the Ecoscore may be a good indicator. However, a lot of stakeholders would stick to well known standards like (the combination of) CO_2-emissions and the Euro emission standard.
Of course there are also different opinions between stakeholders. From the viewpoint to modulate on running costs, some (like traditional car manufacturers) would like to abolish the registration tax, others consider it as a powerful tool to steer the purchase behaviour. Anyway, this tax should depend on the environmental impact of the car, as also the annual circulation tax should do. In general, kilometre charge is seen as a very effective measure, but somewhat harder to apply, so this may be a measure for the longer term and on a European scale. There is much less support for a congestion charge and only progressive voices like the idea of environmental city zones with limited access. It is clear however that such user (dis)advantages will only have a significant effect in combination with a coherent policy mix.

Older cars may be made cleaner by granting subsidies for diesel filters or alternative fuel systems. Policy makers like the idea of subsidies because they have a direct effect, but there is less consensus about a scrapping fee to promote newer and cleaner cars.
For most stakeholders it is obvious that green public fleet quota should be mandatory – and in practice this is almost realized. In the future there also can be quota for private fleets.

7.1 Further work in second phase of the project

Policy scenarios will be drawn up in a next stage, but from these stakeholder meetings we can already make some proposals for a realistic short-term scenario and for a more progressive scenario on the longer term. A very realistic scenario could contain a definition of clean cars defined on the basis of a combination of CO_2-emissions and Euro emission standards, a registration tax and circulation tax based on the environmental impact, advantages for Euro 5/6 cars, lower excise duties for the (standardized!) clean fuels, subsidies for retrofitting older cars with clean technologies and mandatory public green fleet quota.
The progressive scenario goes further and could work with the Ecoscore to define clean cars, the replacement of the registration and circulation tax by an intelligent kilometre charge, quota for cleaner public fleets and environmental city zones with restricted access.

The results of the stakeholder consultation process will be integrated in the building of the policy scenarios. The impact of the policy scenarios will be analysed by means of the e-motion fleet model. For this purpose, the e-motion model will be extended with the Ecoscore indicator which allows to analyse the impact on the integrated environmental performance of the Belgian vehicle fleet.

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