SCIENTIFIC SUPPORT PLAN FOR A SUSTAINABLE DEVELOPMENT POLICY

Intermediary report - January 2003

SUSTAINABILITY ASSESSMENT OF TECHNOLOGIES AND MODES FOR TRANSPORT IN BELGIUM
CP-43

VITO - KULeuven

SPSD II

PART 1

SUSTAINABLE PRODUCTION AND CONSUMPTION PATTERNS

- GENERAL ISSUES
- AGRO-FOOD
- ENERGY
- TRANSPORT

This research project is realised within the framework of the Scientific support plan for a sustainable development policy (SPSD II)

Part I "Sustainable production and consumption patterns"

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(Contract CP/67/431)

Sustainability Assessment of technologies and modes in the transport sector in Belgium

Intermediary Scientific Report

*** CES/KUL**

Study performed for the SSTC

2002/IMS/R/

Vito

January 2003

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Scientific support plan for a sustainable development policy (SPSD II) Part I “Sustainable consumption and production patterns”

0 SUSTAINABILITY ASSESSMENT OF TECHNOLOGIES AND MODES IN THE TRANSPORT SECTOR IN BELGIUM

Intermediary scientific report based on the activities in 2002.

Acronym: SUSATRANS
Project duration: 3 years (2002-2004)
Partners: Vito and CES/KUL
Network nr. CP/67/431

1 INTRODUCTION

1.1 Context and summary

Within the last 30 years mobility demand has doubled. If policy remains unchanged, passenger transport may grow by about 40% in the period 2000-2020, growth may even reach 50% for goods transport. This growth will have an important impact on the environment and health. Objectives on greenhouse gases as derived from the Kyoto Protocol will be difficult to reach within transport. The dominant position of road transport and still decreasing share of railway and inland navigation, will result in a further increase of traffic jams and noise.

Within this project we carry out an integrated assessment of policy measures, aimed at a successful introduction of new technologies in the transport sector on the one hand and of a shift between modes on the other, all this in order to promote sustainable mobility. Besides the road traffic, motorcycles included, also technological developments regarding railway traffic and inland navigation will be studied.

1.2 Objectives

Gaining insight in appropriate policy measures to increase the introduction of new technologies in the transport sector, and to stimulate the shift from road transport to other modes.

Sub-objectives are:
- Performing a technological, social, economical and environmental evaluation of technologies and measures.

- Developing an integrated methodology to select the most sustainable technologies.
- Obtaining a better understanding of consumer behaviour with regard to new technologies.
- Updating and developing models to evaluate the impact of policy measures on mobility demand, emissions and external costs of transport.
- Delivering recommendations to national, regional and local policies related to mobility and environment. Not only at the end of the project but also while the project is going on.

1.3 Expected outcomes

The **major results** of this project are:
- Selection of a group of sustainable technologies and fuels within transport.
- Integrated methodology to select sustainable technologies for transport (multi criteria analysis and group decision making).
- Updated car choice model.
- Updated mobility, emission and external cost models for road transport (2020).
- New emission models to evaluate the technological evolution within railway traffic and inland shipping.
- New recommendations to regulators in the field of mobility and environment.

Some other results related to different subtasks:
- Extended sustainability information sheets for the selected technologies.
- List of stakeholders for the sustainability screening and the Technology Assessment (TA) studies.
- Three extensive Technology Assessment case studies.
- Uncertainty analyses on the modelling of emissions and environmental external cost from transport.
- A series of reports and publications that document and discuss the results of this study.

2 DETAILED DESCRIPTION OF THE SCIENTIFIC METHODOLOGY

2.1 Task A: Sustainability screening of individual new technologies

During the year 2002 the main focus of this task laid on the development of the methodology and the definition of criteria for the screening, and the creation of the list of technologies. A first evaluation exercise is performed by several decision makers and results are expected in the beginning of 2003.

The selection and definition of the criteria for the screening of individual new technologies was a long and intense process. Several meetings were needed not only to define the technologies that were going to be subjected to the screening, but of course also the criteria.

In the first stage a brainstorm with experts in all major fields of sustainable development was held in order to identify the major criteria. The criteria had to reflect the technological, social, economical and environmental aspects of the technologies. On the basis of this brainstorm a work document was created, that circulated among the different experts. Several meetings later a draft version was ready. This document was presented to the user committee in June 2002. They had the opportunity to give comments on the document, as well as two other external experts. Their comments were integrated as much as possible. Some of the comments however could not be integrated due to one of the following reasons:

- The comment was irrelevant for this study or;
- The comment was relevant, but it is not possible to integrate these in the sheet, because it actually is an research on its own.

These reasons led to the following general assumptions that apply to the evaluation:

- The evaluation of the technologies will only take place within a mode and not between modes. The shift between modes will be incorporated in a later phase of the study, the mobility demand scenarios.
- The evaluation of technologies consists of an evaluation of power trains and the according fuel, no brands of cars. Therefore criteria that are linked to a certain type of car like trunk space, volume of the car, crash tests etcetera are not taken into account. These aspects will come to its expression during the consumers' questionnaire and the passenger car choice model. For example for a passenger car, a middle class car with 1400 – 2000cc is considered.

Criteria are scored using quantitative and qualitative criteria. Since many people were concerned with the coherence of the qualitative scores, the rating of these was done by mutual agreement among the researchers. Sources of information about the scoring of the criteria for a certain technology will be kept on a separate sheet. This sheet would also contain interesting data about non regulated emissions if available.

Criteria concerning technology transfer were integrated in one of the four domains that were already defined. They reflect things like the availability of the technology, the education needed to operate the technology and the cost of the technology.

One criterion will be extremely difficult to score: the social basis. Scoring will be done on a very rough base and will only give an indication. Data will be extracted from literature and experience from experts. More detailed information for a selection of technologies, will be gathered in the Technology Assessment studies and the consumers' questionnaire.

The result was thus a sustainability information sheet that consisted of 40 criteria in total. However, it was not possible to evaluate all the identified technologies with these due to the time and resources. Therefore, it was decided that a pre-screening had to take place. The criteria for the pre-screening were derived from the European Vision [1] on renewable fuels/energy and experience from former Vito projects. Of course attention was paid to the fact that the criteria reflected the four domains which were defined earlier: society, economy, environment and technology.

The pre-screening is done on the basis of a multi criteria method called ARGUS (Achieving Grades by Using ordinal Scales only) [2,3]. To be able to do this we needed the input of several decision makers that are aware of sustainable mobility. The multi criteria exercise is performed in two rounds: one with experts from Vito and one with the experts from the users' committee. Each decision maker could define his/her preference structure values and importance to defined criteria. The individual rankings are then gathered by the means of a GDSS (Group Decision Support System) and from which a group ranking of the technologies is generated [4].

Out of this ranking the technologies for a more detailed sustainability screening are selected.

2.2 Task B: Penetration degree of technologies and modes

2.2.1 TREMOVE transport demand model

The existing TREMOVE transport activity model will be used to make a forecast of the penetration degree of vehicle technologies and modes. This model has been developed for the European Commission in the Auto-Oil program (1998-1999) by consortium DRI - K.U.Leuven [5]. The model is a partial equilibrium model representing all the transport markets (passenger and freight, all modes) and contains a crude representation of congestion.
The input of the model consists of demand functions for different means of transportation, resource costs of different means of transportation and initial stock of transport means.

The model output are transport activity figures (in pkm/tkm) for all modes and vehicle technologies, which will be delivered to Vito for emission calculation. First steps have been undertaken to gear the output of the mobility demand model and the emission models. Further analyses have to be performed to harmonise road types and vehicle categorisation for heavy duty trucks as well as vehicle stock for trains and inland shipping.

Task B has been divided in five subtasks. In 2002, the focus was mainly on subtask B2, the design of a new technology choice model.

2.2.2 Task B.2: Vehicle technology choice model

The TREMOVE model used for the Auto-Oil II project doesn't allow for alternative vehicle technologies being introduced. This means that a new technology choice model has to be designed. Research in 2002 has been mainly devoted to the development of a proper methodology; most results are expected by mid-2003 after the customer survey has been accomplished.

The technology choice model will be included in the bigger TREMOVE model. This defines the framework which we have to take into account during the design of the choice sub model.
The input TREMOVE expects from the choice submodel are market shares of technologies for all modes. For passenger cars, a distinction has to be made for shares in the small cars category at one hand and technology shares of medium and big cars at the other hand.

An important limitation of the TREMOVE model is the absence of a socio-demographic sub model. As a result, technology choice can be based on properties of the technology only. These properties are exogenous to the model.

Because of the importance of the private car market together with it's different technology choice process nature compared to most other modes (consumers vs. business), we decided to focus mainly on the private car technology choice problem and to apply a simplified methodology for the other modes.

2.2.2.1 Private cars

As a first step in designing a private car technology choice model, a literature review was conducted in 2002 (see results). This served as an input for the design of the new technology choice model for Belgium, as well as the questionnaire survey which will serve to calibrate the model parameters.

A first question to be addressed is which (exogenous) vehicle technology properties will be used as an input for the calculation of market shares.
As we want to calculate the market shares of technologies only, many parameters can already be omitted since they are not relevant for technology choice, such as brand, production country, colour of the car, etc.
We decided to put up a shortlist of technology properties which proved to have a significant influence on market shares in past research, based on the literature review (see results).

Next a customer's choice model has to be selected that allows for an accurate representation of the technology choice process as well as an efficient implementation in GAMS in which the TREMOVE model was implemented.
In the literature review, three different model types were found to be used for technology choice modelling in the past: multinomial logit (MNL), nested multinomial logit (NMNL) and mixed logit (ML). The models differ in the utility formula used to determine choice probabilities and the resulting market shares. The utility of a technology is a function of its properties. The choice probability of each technology is a function of its utility as well as the utility of the other technologies. The market shares are then calculated based on the choice probabilities of each technology. Figure 1 shows the general structure of a technology choice model.

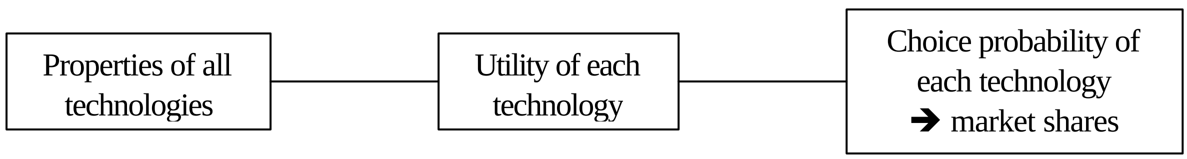

Figure 1: Structure of the technology choice model

The first model (MNL) has the major disadvantage that it doesn't allow for correlation of a customer's choice between technologies. However, in the technology choice process, we could expect such a correlation: e.g. when somebody has a stronger than average preference for

electrical battery powered cars, we could expect a similar preference for hybrid cars by the same person.
The NMNL does allow for such a correlation of a customer's choice. Literature confirms our expectation that this should lead to better modelling results.
The ML is a state-of-the-art model for customer's choice. It has however the disadvantage of lacking a closed formulation for the choice probabilities. Implementing a mixed logit model in TREMOVE would require a coding effort which is beyond the scope of this project.
As a result of the consideration formulated above, we decided to stick to a nested multinomial logit model.

Now that we have a list of exogenous technology properties as well as a model, we need to calibrate the parameters of the model. A survey will be carried out by a subcontractor in the first half of 2003 in order to accomplish this task.

For the survey, only a draft methodology has been fixed yet. It is our intention to make use of computer aided telephone interviews (CATI). The participants will get three fictional vehicles presented with different technologies and their respective technology properties. A table containing all this information will in advance be sent to them by post. Next they will be asked which of the three vehicles they would buy the most likely given that they have to buy a new car and that the three proposed cars differ in the presented properties only. As an alternative to the combination of CATI and postal, an internet oriented approach will be considered.
Technology properties will vary over (at least) three values in order to allow for estimation of second degree effects. A fractional design will be used to prepare a subset of orthogonal three-car tables. This subset will next be customized for each respondent, taking into account the car he/she is possessing at that moment. This will also determine if the response is used to calibrate the small car or the medium & big car technology choice model.
An important parameter in the design of the customer survey is the budget constraint. We decided to limit the number of technologies proposed in a choice set to three, and the number of sets to one for each customer in the survey. This should raise the response rate and minimise the cost per respondent. However, even then it may be difficult to get parameter estimations which are significant when the number of properties is too big (resulting in a too large fractional design). This may lead to the necessary omission of one or more properties.
The design of the customer survey will be fixed early 2003.

2.2.2.2 Other modes

For other modes, a simplified modelling will be used, based on financial costs only. This because of the assumption that most of these vehicles are company-owned, and companies tend to make their decision when buying new vehicles (trucks, buses, boats, trains) looking to financial properties only.

This requires a relatively small redesign to the TREMOVE model in comparison to the private car technology choice model.

The parameters of the model will be estimated based on further literature review combined with revealed preferences: base year statistics will provide evidence on the choice whether to buy e.g. a diesel train or a electric train. For some modes not having different technologies for the base years (e.g. buses: nearly all buses are diesel driven), data from literature will provide evidence on model parameter estimations.

2.2.3 Task B.1 and B.3-B.5

Research on these tasks in 2002 didn't progress sufficiently to allow for a methodology to be fixed.

2.3 Task D: Evaluation of total mobility

In 2002 the focus within this task laid on the definition of approaches and the setup of new relevant contacts, mainly within railway and inland shipping traffic (Task D.1).

Road emission model TEMAT. An action plan for updating and extending this model has been drawn up. Figures on vehicle stock and mobility data will be updated with statistical data for the years 1999 up to 2002. Evolution in fuel specification and emission factors for new vehicles will updated, looking to new (proposed) EC Directives and findings of ongoing EC research within the 6th Framework programme (Artemis and Decade). For alternative motor fuels, Vito's expertise will be integrated together with information via our international network contacts (IEA, ESTO, E^{n}R, COST 346, …). Special attention will also be paid to the evolution of CO_2 emission factors of vehicles.
Several workshops are planned to discuss possibilities to extend TEMAT and to define priorities. Experts within Vito as well as policy makers will be involved. Due to their impact on health, particulate emissions of petrol-fuelled vehicles and alternative motor fuels will be certainly integrated.

Emission model for railway traffic and inland navigation. We started to gather information on models available within Europe. For inland shipping the methodology set up within the Artemis project is not appropriate to evaluate technological evolution within ships [6]. In The Netherlands some models are available. The model of the University of Amsterdam is too aggregated to use for our defined technology scenarios [7]. Last year Vito has had the opportunity to perform two small studies on the impact of inland shipping. They clearly show the importance of taking into account technological evolution in ships (see 3.3).
For trains contacts have been made with rivm (NL) for their PRORIN model [8] and TRL (UK) for the model worked on within Artemis.
More analyses have to be carried out on existing models. When done, we will decide which approach will be used.

3 DETAILED DESCRIPTION OF THE INTERMEDIARY RESULTS, PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS

3.1 Task 1: Sustainability screening of individual new technologies

One of the first results of this task was a list with the different technologies per mode that would be taken into consideration during the evaluation. Table 2 gives an example of data included in the database[1].

A second result within this task is the choice of criteria for the pre-screening. Table 1 gives an overview of the criteria and how they cover the four domains regarding sustainability. Criteria 1, 2, 3, 5 and 7 were derived from the European Vision [1]. Criteria 4 and 6 were added in the light of previous experiences with transport studies within Vito[2].

Table 1: Criteria for the pre-screening

Technological criteria 1. Energy-efficiency (well – to – wheel)	Social-economic criteria 2. Continuity of energy supply 3. Availability of the fuel
Economic criteria 4. Additional cost of the technology/fuel according to diesel	Environmental criteria 5. Greenhouse gas emissions during production and users' phase 6. PM-emissions in the users' phase 7. Dependence of non-renewable resources

The third result is the scores of each of the technologies for road transport (freight and passenger) on these criteria[3]. A literature review has been performed by Pelkmans et al. [9].

[1] The full list of technologies be considered can be found in the annex.
[2] Definitions of the criteria for the prescreening as well as for the detailed evaluation can be found in the annex in Dutch.
[3] The scores of each technology against the criteria can be found in the annex.

Table 2: Example of the database for the list of technologies

				Area of application (Mode, category)						Level of innovation					
Fuel	Power train	Description	Options	Road: motorbikes	Road: passenger cars	Road: freight transport/ busses	Rail	Inland waterway	Remarks	Commercial	Marked introduction	Prototype phase	Research phase	Thoughts	Remarks
Diesel	Diesel engine	Classical technology	New developments for emission reduction (new diesel injection systems + after treatment)		**X**	**X**	**X**	**X**		**X**					Classical technology + space for product improvement (lowering of emissions)
	Hybrid	Diesel engine combined with battery + electro engine	Serial / parallel hybrid or combination		**X**	**X**	**X**				**X**				First marked introduction, phase of technology innovation not completed yet.

The result from this pre-screening is a ranking of different technologies for freight and passenger transport, from which technologies are selected for the detailed sustainability evaluation. After the pre-screening, the detailed sustainability evaluation will take place.

Figure 2 shows the 40 defined criteria in a tree structure. The assumption in the final evaluation is that all four domains are equal to each other and thus have a equal weight in the end result. Scoring of the different technologies on these 40 criteria will be ready in April 2003. The result of this evaluation is a list of sustainable technologies from which three will be chosen for the technology assessment studies.

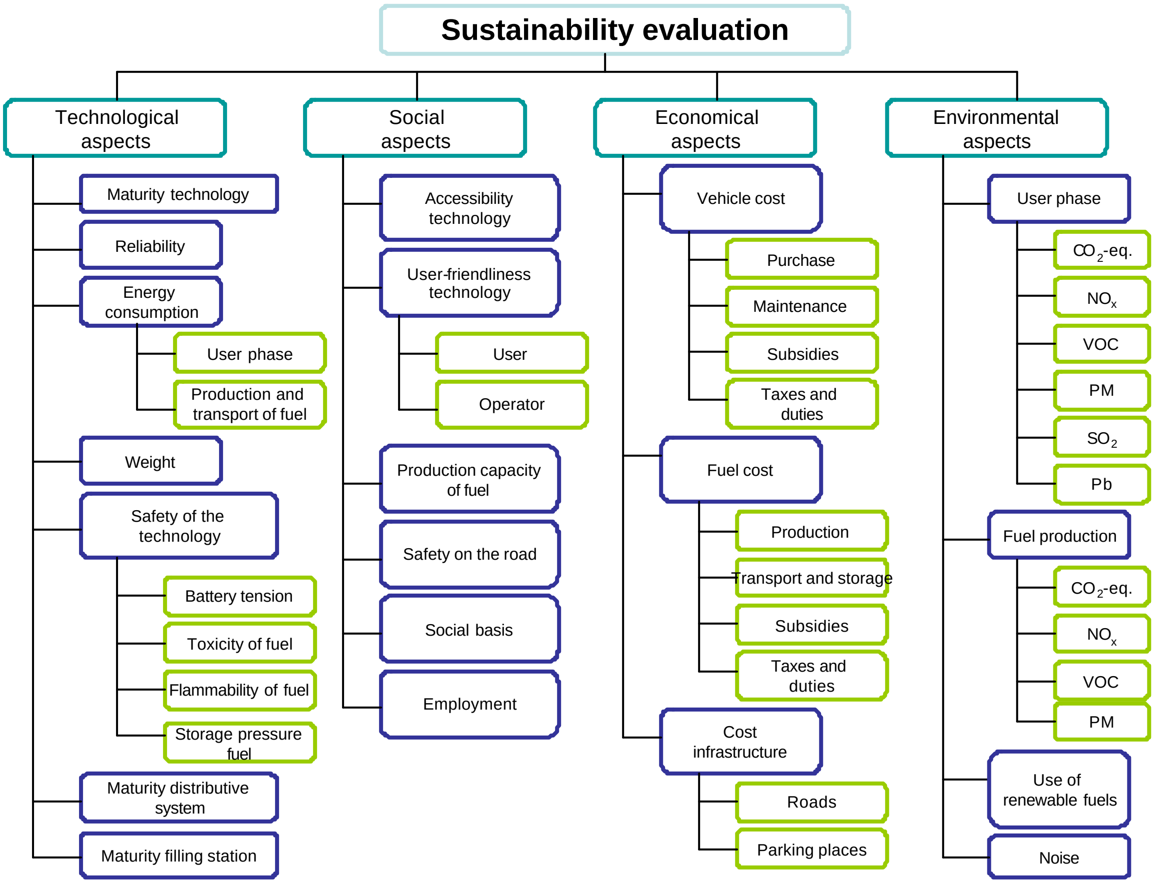

Figure 2: Criteria for the detailed sustainability evaluation

3.2 Task B: Penetration degree of technologies and modes

3.2.1 Task B.2: Vehicle technology choice model

Within this study focus lays at passenger cars (see methodology).

3.2.1.1 Literature review

1) California

Much research on private car technology choice has been done in California for the development of a micro simulation model of the vehicle market for the greater LA area.
Bunch et al. [10] conducted a pilot study and estimated a nested multinomial logit (NMNL) model based on stated preference (SP) data. They conducted a survey in three phases, resulting in 562 returned questionnaires (20% response rate). The technology attributes included were determined earlier by Golob et al. [11]. Three cumulative models are estimated. The first model (Table 3) only includes technology-specific variables, whereas subsequent models include socio-demographic variables as well. In the last model, segmentation variables based on anticipated next vehicle type are added. Five technology types were included in the model: gasoline, alternative fuel only, multiple-fuel (alternative fuel and gasoline), electric and hybrid.

Table 3: Nested Multinomial Logit model by Bunch et al. [10]

Variable	Coeff.	t-stat
Purchase price ($1000)	-0,134	-10,4
Fuel cost (cents/mile)	-0,190	16,4
Range (100 miles)	2,52	11,4
Range2 (100 miles)2	-0,408	-7,4
Emissions level (fraction of current)	-2,45	-7,0
Emissions level2 (fraction of current)2	0,855	2,7
Fuel availability (fraction of stations)	2,96	5,7
Fuel availability2 (fraction of stations)2	-1,63	-3,5
Alternative fuel (constant relative to gasoline veh.)	0,098	0,9
Multiple fuel (constant relative to gasoline veh.)	0,693	6,7
Electric vehicle (constant relative to gasoline veh.)	-0,024	-0,1
Hybrid electric (constant relative to gasoline veh.)	-0,257	-1,5
Electric: charge at work as well as home (dummy)	-0,126	-1,1

Electric: low performance (dummy)	-1,04	-6,2
Electric: low performance with hybrid (dummy)	0,544	2,3
Nonelectric vehicles (log-sum coefficient)	0,805	3,2

Some parameters in the model were found not to differ significantly from zero: alternative fuel, electric vehicle and the possibility to charge at work as well as at home for electric vehicles. The constant for hybrid electric is not significant at p=0,05.
Brownstone et al. [12] build a large multinomial logit (MNL) model based on new SP data. The same data have been reused by Brownstone and Train [13] to compare MNL with mixed logit (ML) models. In the survey, four technology types were included: gasoline, CNG, methanol and electric.

Table 4: Multinomial Logit Model by Brownstone et al.[13]

Variables	Estimate	Std. error
Price/ln(income)	-0,185	0,027
Range	0,350	0,027
Acceleration	-0,716	0,111
Top speed	0,261	0,080
Pollution	-0,444	0,100
Size	0,935	0,311
'Big enough'	0,143	0,076
Luggage space	0,501	0,188
Operating cost	-0,768	0,073
Station availability	0,413	0,097
Sports utility vehicle	0,820	0,144
Sports car	0,637	0,156
Station wagon	-1,437	0,065
Truck	-1,017	0,055
Van	-0,799	0,053
Constant for EV	-0,179	0,169
Commute < 5 x EV	0,198	0,082
College x EV	0,443	0,108
Constant for CNG	0,345	0,091
Constant for methanol	0,313	0,103
College x methanol	0,228	0,089

In Brownstone et al.[14], revealed preference (RP) data have been added to develop a joint joint mixed logit model.

<u>2) Europe</u>

In Europe, a technology choice model has been developed by Ramjerdi et al.[15] to estimate demand for clean fuel cars in Norway. Both MNL and NMNL models have been estimated.

Three fuel technologies were included: gasoline, electric and alternative fuel. Different models were estimated for the household's main car (Table 5) and the second car.

Table 5: NMNL model for HH main car by Ramjerdi et al. [15]

Variables	Estimation
Constant, electric car	-2,2030
Constant, alt fuel car	-1,0450
Electric car, refuelling range	0,0391
Gasoline car, emission	-0,2971
Gasoline car, HH without car	-1,6120
Gasoline car, age over 66	0,6355
Alt fuel car, refuelling range	0,0256
Gasoline, HH income	0,0015
Purchase price	-0,0115
Number of seats	-0,7337
Number of seats2	0,1597
Top speed	0,1112
Logsum (nonelectric vehicles)	0,6566

A study by COWI [16] on fiscal measures to reduce CO_2 emissions from new passenger cars includes a car choice model. This model consists of two sub models, one for the private car market and another to calculate the demand for company cars, and was estimated based on a Danish dataset.

The private car model is estimated for 24 types of car users, depending on the car buyer's family type and income class. The variables that were included:

- Price of the car (inclusive tax and VAT)
- Running cost (fuel and circulation tax)
- Size of the car (length)
- Luggage capacity
- Acceleration

The company car model has six "agents", depending on sector and whether the company manager or the employee decides which car to buy. The variables included in the model are:

- Cost of acquisition (Personal taxation rules)
- Running cost (Personal taxation rules
- Size of the car (length)
- Luggage capacity
- Acceleration
- Horse Power

The private/company split is modelled by a binary discrete choice model.

3.2.1.2 Technology properties

Based on literature review, we selected a shortlist of technology properties to be included in the choice model:

- Purchase cost
- Fuel cost
- Range
- Emissions level
- Fuel availability
- Performances (acceleration or top speed)
- Trunk space
- Technology class
- Size

The purchase and fuel costs properties are quite obvious. However, the maintenance cost didn't turn out to have a significant influence on market shares in past research.
The range of a vehicle is the distance that can be driven without refuelling. The emissions level and fuel availability parameters could be expressed as a percentage of today's car.
The performance parameter could be expressed in terms of acceleration (e.g. seconds to reach a given speed) or top speed (e.g. 140 km/h or less). Trunk space can be expressed as a percentage of a 'normal' car.
Technology class is a somewhat special property. We need to define a number of technology classes. This will allow us to estimate a technology specific term in the utility formula, as well as choice correlations between different classes of technologies. Currently we think of using the following technology class classification: electrical cars, gasoline cars, diesel cars and alternative fuelled cars.
The size property will only be included in the medium & big cars choice model, as in the small car model all cars are small and thus have the same size.

The range of the parameters, as well as the levels of each parameter needs to be defined taking into account the technologies that will have to be introduced in the model. A further constraint is imposed by the survey budget which is fixed and may require to skip one or more properties and/or to decrease the number of distinct technology classes included.

3.2.1.3 Nested logit tree structure

We decided not to fix a tree structure on beforehand. After the survey has been accomplished, parameter estimates for different tree structures will be made. The log-likelihood of each estimate will tell us which structure is the most fit for the technology choice problem. This will allow us to calculate the choice probabilities the most accurate possible and to gain correct insight in the choice correlations.

3.3 Task D: Evaluation of total mobility

Last year it became clear that one has to take into account technological evolution within ships when evaluating the environmental impact of modal shift scenario's. This will be illustrated in the following.

In our case study dealing with the transportation of large single items, the impact on emissions was evaluated when shifting from road transport to inland navigation. Both modes of transportation has been compared for the technologies mandatory in the years 1990, 2003 and 2007. Based on available statistics, both 70% loaded ships (MCR 75%) and 50% loaded ships (MCR 65%) were studied.
Unlike road transport, no European emission standards exist for inland ships. Recently, the Central Commission for Rhine Shipping (CCR) took an initiative to impose standards for new ships [17]. They are a mix of IMO's (International Maritime Organisation) limits for SO_x and NO_x, complemented with data from the European R47/68 standard for mobile tools (for CO, HC and PM). These new standards are mandatory in all states on the Rhine river and Belgium but not in the rest of Europe. CCR planned to impose the first phase in 2002 but this was later postponed to 2003. Phase 2 is tentatively planned somewhere between 2005 and 2007. These standards were integrated in our emissions calculations.

An overview of the technology scenarios being studied in this case study is given in Table 6. 1990 has to be seen as a baseline scenario. 2003 is the year in which phase 1 of the CCR emission standards for inland ships is introduced. Phase 2 should be enforced in 2007. For each scenario, Table 6 gives the mandatory engine technologies for new road freight vehicles and inland ships. As phase 2 of the CCR is not yet official, an alternative scenario for 2007, assuming phase 2 would not come into force, was also evaluated.

Table 6: Technology scenarios within the case study

Scenario	**Engine technology**	
	Heavy duty trucks	**Inland ships**
1990 reference	Pre-Euro 1	Technology 1990
2003 CCR-1	Euro 3	CCR-1
2007 CCR-2	Euro 4	CCR-2
2007 CCR-1	Euro 4	CCR-1

Emissions and external costs were estimated per kilo tonne transported over one kilometre (ktonne.km). This made it possible to compare different modes and to take into account loading factors. Road transport was compared to a 600 tonne ship and a 3000 tonne ship.

Compared to road transportation, long range transportation of large single items by inland shipping has a distinct advantage for fuel consumption, CO_2 and CO emissions. This advantage is less pronounced for HC emissions. For NO_x, PM and SO_2, emissions and impacts are generally lower for road transport.

The results for each of the four technology scenarios are plotted in Figure 3, distinguishing between the different pollutants. Only results for the 3000 tonne ship (14 km/h) compared to road transport (30 km/h) are shown here. Results are expressed as a gain in external environmental costs (in Euro per ktonne.km modal shift). Positive figures indicate an environmental advantage for the 3000 tonne ship, negative values indicate that emissions are lower for trucks.

Analysis of the gain in external environmental costs shows that the gain for inland shipping is most pronounced under the baseline scenario (1990). The environmental advantage for inland shipping decreases when comparing future engine technologies for both modes of transportation. Comparing the CCR 1 technology for ships with euro 4 trucks (scenario 2007 CCR-1) clearly shows an overall environmental advantage for trucks. Much better results were found for ships loaded for about 70 % (graphs not shown here). Gains could be up to 5 euro/ktonne.km under the baseline scenario and 1 euro/ktonne.km under the 2007 CCR-2 scenario. For 50 % loaded ships these gains were respectively 3.5 and 0.4 euro/ktonne.km.

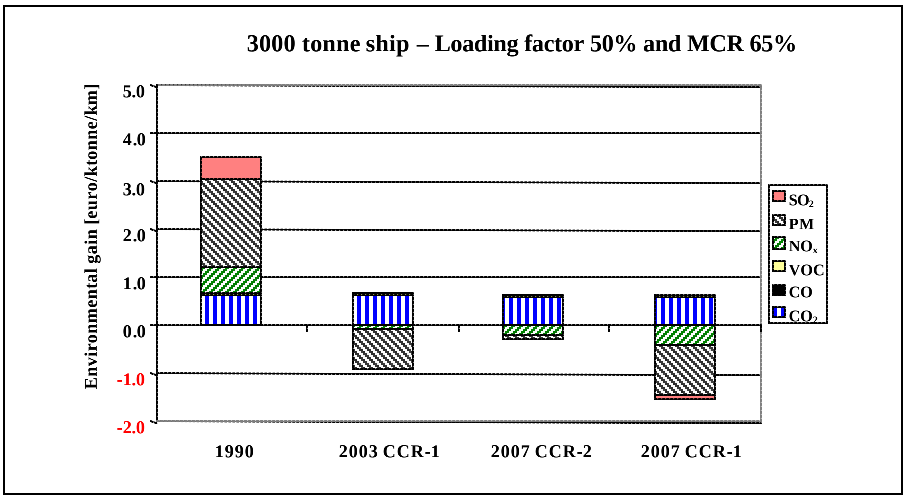

Figure 3: Gain in external environmental costs for a 3000 tonne vessel (loading factor 50%) under the 4 defined technology scenarios, in euro/ktonne.km (euro 2000)

The implementation of phase 2 of the CCR emission standards for inland ships is needed to preserve environmental advantages of inland shipping over road haulage. Although, one has to be aware that potential advantages in the future will be much lower than under the 1990 scenario. Lower emissions of CO_2 are the main benefit of inland ships in all scenarios. Conclusions therefore depend heavily on which monetary value is chosen to rate CO_2 emissions. In principle this analysis is about which impacts are more important: the global effects of CO_2 or the local and regional impacts of PM and NO_x [18].

4 FUTURE PROSPECTS AND FUTURE PLANNING

The first months of 2003 we will finish and complement extensive sustainability information sheets for the different selected technologies within the transportation modes road traffic, railway and inland navigation.

A survey to get input for the vehicle choice model related to the Belgian situation, will be carried out by mid 2003.

At the end of 2003 all tools (mobility demand, emissions, environmental external cost) will be fine-tuned and extended.

On overview of tasks to be done in 2003 and 2004 is given in Table 7.

Table 7: Adjusted timetable of work 2003-2004

Tasks	Year 2003	Year 2004
A. Sustainability screening individual technologies	Xxxxx	
B. Degree of penetration of technologies		
B1. Economical/social development	Xxxx	
B2. Questionnaire consumer's choice	Xxxxx	
B3. Fine tuning and extension tool	Xxxxxxxx	
B4. Policy assumptions	xxxxxxx	
B5. Modelling mobility demand	xxxxxxx	Xxxx
C. Technology Assessment		
C1. Case study technology 1	xxxxx	
C2. Case study technology 2	xxxxx	
C3. Case study technology 3	xxx	Xx
D. Evaluation of total mobility		
D1. Emissions (Air))		
- *Development tool rail, inland Navigation*	Xxxxxxx	
- *Fine-tuning TEMAT road transport*	Xxxxxx	
- *Baseline scenario*	Xxxx	
- *Policy scenarios + uncertainties*	xxxxxx	Xxxxx
D2. Impacts and external cost		
- *Fine-tuning and extension tool*	xxx	
- *Policy scenarios*	xxxxxx	Xxxxxx
- *Uncertainty analyses*	xx	Xx
D3. Internal cost of mobility	xxx	Xxxx
E. Policy measures		

E1. Policy advice	xxxxxxxxxxx	xxxxxxxxxxxxx
E2. Implementation path		xxxx
Reports	Xxxxxxxxxxxx	xxxxxxxxxxxx
User group (2 meetings/year)		
Meeting 3 en 5	30/06/03	30/06/04
Meeting 4 en 6	15/12/03	15/12/04

5 ANNEXES

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5.3 Detailed results

5.3.1 Task 1: Sustainability screening of individual new technologies

5.3.1.1 Technology database

				Toepassingsgebied (Modi, categorie)						Innovatieniveau					
		Omschrijving	Optie	Weg: tweewielers	Weg: personenwagens	Weg: vrachtwagens/bussen	Spoor	Binnenvaart	Opmerkingen	Commercieel	Marktintroductie	Prototypefase	Onderzoeksfase	Denkpiste	Opmerkingen
Diesel	Dieselmotor	Klassieke technologie	Verdere ontwikkelingen voor emissieverlaging (nieuwe dieselinspuitsystemen + nabehandeling)		X	X	X	X		X					klassieke technologie + ruimte voor productverbetering (vooral gericht op emissieverlaging)
	Hybride	Dieselmotor gecombineerd met batterij + elektromotor	Serieel / parallel hybride of combinatie		X	X	X				X				Eerste marktintroducties, fase van technologie-innovatie nog niet voltooid
Diesel + 5% biodiesel	Dieselmotor	Klassieke technologie	Verdere ontwikkelingen voor emissieverlaging (nieuwe dieselinspuitsystemen + nabehandeling)		X	X	X	X		X					klassieke technologie + ruimte voor productverbetering (vooral gericht op emissieverlaging)
	Hybride	Dieselmotor gecombineerd met batterij + elektromotor	Serieel / parallel hybride of combinatie		X	X	X				X				Eerste marktintroducties, fase van technologie-innovatie nog niet voltooid
Biodiesel / B20	Dieselmotor	Klassieke technologie (zeer beperkte aanpassingen)	Verdere ontwikkelingen voor emissieverlaging (nieuwe dieselinspuitsystemen + nabehandeling)		X	X	X	X		X					klassieke technologie + ruimte voor productverbetering (vooral gericht op emissieverlaging)
	Hybride	Dieselmotor gecombineerd met batterij + elektromotor	Serieel / parallel hybride of combinatie		X	X	X				X				Eerste marktintroducties, fase van technologie-innovatie nog niet voltooid
DME	Dieselmotor	Klassieke technologie (beperkte aanpassingen)	Verdere ontwikkelingen voor emissieverlaging (nieuwe dieselinspuitsystemen + nabehandeling)			X	X	X			X				eerste trials en prototypes
	Hybride	Dieselmotor gecombineerd met batterij + elektromotor	Serieel / parallel hybride of combinatie			X	X							X	Concept analoog aan diesel hybride

				Toepassingsgebied (Modi, categorie)						Innovatieniveau					
		Omschrijving	Optie	Weg: tweewielers	Weg: personenwagens	Weg: vrachtwagens/bussen	Spoor	Binnenvaart	Opmerkingen	Commercieel	Marktintroductie	Prototypefase	Onderzoeksfase	Denkpiste	Opmerkingen
Synthetische diesel	Dieselmotor	Klassieke technologie	Verdere ontwikkelingen voor emissieverlaging (nieuwe dieselinspuitsystemen + nabehandeling)		X	X	X	X		X					klassieke technologie + ruimte voor productverbetering (vooral gericht op emissieverlaging)
	Hybride	Dieselmotor gecombineerd met batterij + elektromotor	Serieel / parallel hybride of combinatie		X	X	X							X	Eerste marktintroducties, fase van technologie-innovatie nog niet voltooid
Benzine	Vonkontstekingsmotor	Klassieke technologie	+ lambdacontrole, OBD, catalysatoren, …	X	X					X					klassieke technologie + ruimte voor productverbetering (vooral gericht op emissieverlaging)
	Hybride	Benzinemotor gecombineerd met batterij + elektromotor	Serieel / parallel hybride of combinatie		X						X				Eerste marktintroducties, fase van technologie-innovatie nog niet voltooid
	Brandstofcel + EM	met reformer (benzine tot waterstof)			X	X						X			eerste trials, maar technologie nog niet bewezen
LPG	Vonkontstekingsmotor	Klassieke technologie (beperkte aanpassingen)	+ lambdacontrole, OBD, catalysatoren, …		X	X				X					klassieke technologie + ruimte voor productverbetering (vooral gericht op emissieverlaging)
	Hybride	LPG-motor gecombineerd met batterij + elektromotor	Serieel / parallel hybride of combinatie		X	X						X			Concept analoog aan benzine hybride
	Brandstofcel + EM	met reformer (LPG tot waterstof)			X	X								X	
Aardgas / biogas	Vonkontstekingsmotor	Klassieke technologie (beperkte aanpassingen)	+ lambdacontrole, OBD, catalysatoren, …		X	X				X	X				klassieke technologie + ruimte voor productverbetering (vooral gericht op emissieverlaging)
	Hybride	aardgasmotor gecombineerd met batterij + elektromotor	Serieel / parallel hybride of combinatie		X	X						X			Concept analoog aan benzine hybride
	Brandstofcel + EM	met reformer (aardgas tot waterstof)			X	X							X		reforming aardgas naar waterstof zal eerder gebeuren in stationaire opstellingen.

				Toepassingsgebied (Modi, categorie)						Innovatieniveau					
		Omschrijving	Optie	Weg: tweewielers	Weg: personenwagens	Weg: vrachtwagens/bussen	Spoor	Binnenvaart	Opmerkingen	Commercieel	Marktintroductie	Prototypefase	Onderzoeksfase	Denkpiste	Opmerkingen
Waterstof	Vonkontstekingsmotor	Gekende technologie met nieuw brandstofsysteem	brandstofsysteem = vernieuwend		X	X					X				eerste trials en prototypes
	Hybride	waterstofmotor gecombineerd met batterij + elektromotor	Serieel / parallel hybride of combinatie		X	X								X	Concept analoog aan benzine hybride
	Brandstofcel + EM	Direct bruikbaar in PEM-brandstofcel			X	X		X				X			eerste trials
Ethanol / E85	Vonkontstekingsmotor	Klassieke technologie (beperkte aanpassingen)			X	X				X	X				klassieke technologie (commercieel in een aantal landen) + ruimte voor productverbetering (vooral gericht op emissieverlaging)
	Hybride	ethanolmotor gecombineerd met batterij + elektromotor			X									X	Concept analoog aan benzine hybride
	Brandstofcel + EM	met reformer (ethanol tot waterstof)			X	X								X	
Methanol / M85	Vonkontstekingsmotor	Klassieke technologie (beperkte aanpassingen)			X					X	X				klassieke technologie (commercieel in een aantal landen) + ruimte voor productverbetering (vooral gericht op emissieverlaging)
	Hybride	methanolmotor gecombineerd met batterij + elektromotor			X									X	Concept analoog aan benzine hybride
	Brandstofcel + EM	met reformer (methanol tot waterstof)			X	X						X			nog in trial en prototype fase
Synthetische benzine	Vonkontstekingsmotor	Klassieke technologie	+ lambdacontrole, OBD, catalysatoren, …	X	X					X					klassieke technologie + ruimte voor productverbetering (vooral gericht op emissieverlaging)
	Hybride	Benzinemotor gecombineerd met batterij + elektromotor	Serieel / parallel hybride of combinatie		X									X	Eerste marktintroducties, fase van technologie-innovatie nog niet voltooid
	Brandstofcel + EM	met reformer (benzine tot waterstof)			X	X								X	eerste trials, maar technologie nog niet bewezen

				Toepassingsgebied (Modi, categorie)						Innovatieniveau					
		Omschrijving	Optie	Weg: tweewielers	Weg: personenwagens	Weg: vrachtwagens/bussen	Spoor	Binnenvaart	Opmerkingen	Commercieel	Marktintroductie	Prototypefase	Onderzoeksfase	Denkpiste	Opmerkingen
Batterijen	Elektromotor	Zuiver elektrisch voertuig, concept bestaat reeds lange tijd, batterijkeuze blijft evolueren			X	X			Vrachtwagens: stadsdistributie		X				Eerste marktintroducties, fase van technologie-innovatie nog niet voltooid
	Hybride	Combinatie batterijen / elektromotor + verbrandingsmotor			X	X			Vrachtwagens: stadsdistributie		X				Eerste marktintroducties, fase van technologie-innovatie nog niet voltooid
	Brandstofcel + EM	Batterijen dienen als buffer	Uitwerking reformers		X	X			Vrachtwagens: stadsdistributie			X			Marktintroducties zeer binnenkort, fase van technologie-innovatie nog niet voltooid

5.3.1.2 Scores for the prescreening

Passenger cars

		Continuïteit van de energievoorziening	Afhankelijkheid van niet-hernieuwbare grondstoffen	Potentieel	Meerkost	Primair energieverbruik (MJ/km)	PM-emissies (motor) tijdens gebruik (g/km)	Broeikasgas-emissies (g/km)
Diesel	Dieselmotor	< 50 jaar	100	groot	vergelijkbaar	2,20	0,04	166
Diesel	Hybride	< 50 jaar	100	groot	beperkt	1,85	0,02	140
Diesel + 5% biodiesel	Dieselmotor	< 50 jaar	95	groot	vergelijkbaar	2,25	0,04	161
Diesel + 5% biodiesel	Hybride	< 50 jaar	95	groot	beperkt	1,90	0,02	136
Biodiesel	Dieselmotor	Hernieuwbaar	0	klein	beperkt	3,33	0,02	59
Biodiesel	Hybride	Hernieuwbaar	0	klein	matig	2,81	0,01	50
Synthetische diesel uit aardgas	Dieselmotor	>= 50 jaar, maar < 100 jaar	100	groot	beperkt	3,41	0,02	198
Synthetische diesel uit aardgas	Hybride	>= 50 jaar, maar < 100 jaar	100	groot	matig	2,87	0,01	167
Benzine	Vonkontstekings motor IDI	< 50 jaar	100	groot	vergelijkbaar	2,83	0,0005	217
Benzine	Hybride, IDI	< 50 jaar	100	groot	beperkt	2,06	0,0005	159
Benzine	Vonkontstekings motor, DI	< 50 jaar	100	groot	vergelijkbaar	2,42	0,001	187
Benzine	Hybride, DI	< 50 jaar	100	groot	beperkt	1,91	0,001	148
Benzine	Brandstofcel + EM	< 50 jaar	100	groot	hoog	2,05	0	157
LPG	Vonkontstekings motor	< 50 jaar	100	matig	vergelijkbaar	2,73	0,0005	189
LPG	Hybride	< 50 jaar	100	matig	matig	1,99	0,0005	139
Aardgas	Vonkontstekings motor	>= 50 jaar, maar < 100 jaar	100	groot	beperkt	2,68	0,0005	162
Aardgas	Hybride	>= 50 jaar, maar < 100 jaar	100	groot	matig	2,06	0,0005	126
Biogas	Vonkontstekings motor	Hernieuwbaar	0	klein	beperkt	3,30	0,0005	23
Biogas	Hybride	Hernieuwbaar	0	klein	matig	2,55	0,0005	19
Waterstof uit aardgas	Vonkontstekings motor	>= 50 jaar, maar < 100 jaar	100	groot	matig	3,19	0	182
Waterstof uit aardgas	Hybride	>= 50 jaar, maar < 100 jaar	100	groot	hoog	2,34	0	134
Waterstof uit aardgas	Brandstofcel + EM	>= 50 jaar, maar < 100 jaar	100	groot	hoog	1,79	0	100
Waterstof uit elektrolyse (net)	Vonkontstekings motor	>= 100 jaar	95	groot	hoog	9,32	0	263
Waterstof uit elektrolyse (net)	Hybride	>= 100 jaar	95	groot	hoog	6,84	0	194
Waterstof uit elektrolyse (net)	Brandstofcel + EM	>= 100 jaar	95	groot	zeer hoog	5,46	0	152
Waterstof uit elektrolyse (lokaal	Vonkontstekings motor	Hernieuwbaar	0	klein	zeer hoog	3,35	0	3
Waterstof uit elektrolyse (lokaal	Hybride	Hernieuwbaar	0	klein	zeer hoog	2,46	0	3
Waterstof uit elektrolyse (lokaal	Brandstofcel + EM	Hernieuwbaar	0	klein	zeer hoog	1,88	0	0
Waterstof uit biomassa	Vonkontstekings motor	Hernieuwbaar	0	matig	hoog	3,84	0	46
Waterstof uit biomassa	Hybride	Hernieuwbaar	0	matig	hoog	2,82	0	35
Waterstof uit biomassa	Brandstofcel + EM	Hernieuwbaar	0	matig	zeer hoog	2,15	0	24
Bio-Ethanol	Vonkontstekings motor	Hernieuwbaar	0	klein	beperkt	6,22	0,0005	140
Bio-Ethanol	Hybride	Hernieuwbaar	0	klein	matig	4,54	0,0005	103
Bio-Ethanol	Brandstofcel + EM	Hernieuwbaar	0	klein	zeer hoog	4,28	0,0005	97
Methanol uit aardgas	Vonkontstekings motor	>= 50 jaar, maar < 100 jaar	100	groot	beperkt	3,98	0,0005	231

Freight transport - trucks

		Continuïteit van de energievoorziening	Afhankelijkheid van niet-hernieuwbar grondstoffen	Potentieel van de brandstof	Meerkost	Primair energieverbruik (MJ/km)	PM-emissies (motor) tijdens gebruik (g/km)	Broeikasgas-emissies (g/km)
Diesel	Dieselmotor	< 50 jaar	100	groot	vergelijkbaar	13,4	0,4	1001
Diesel	Hybride	< 50 jaar	100	groot	matig	13,4	0,3	1001
Diesel + 5% biodiesel	Dieselmotor	< 50 jaar	95	groot	vergelijkbaar	13,8	0,4	969
Diesel + 5% biodiesel	Hybride	< 50 jaar	95	groot	matig	13,8	0,3	969
Biodiesel	Dieselmotor	Hernieuwbaar	0	klein	beperkt	20,4	0,3	347
Biodiesel	Hybride	Hernieuwbaar	0	klein	matig	20,4	0,2	347
DME uit aardgas	Dieselmotor	>= 50 jaar, maar < 100 jaar	100	groot	matig	21,4	0,08	1210
DME uit aardgas	Hybride	>= 50 jaar, maar < 100 jaar	100	groot	hoog	21,4	0,05	1210
DME uit aardgas	Brandstofcel + EM	>= 50 jaar, maar < 100 jaar	100	groot	zeer hoog	21,8	0	1234
Synthetische diesel uit aardgas	Dieselmotor	>= 50 jaar, maar < 100 jaar	100	groot	beperkt	20,3	0,3	1180
Synthetische diesel uit aardgas	Hybride	>= 50 jaar, maar < 100 jaar	100	groot	matig	20,3	0,2	1180
Benzine	Brandstofcel + EM	< 50 jaar	100	groot	hoog	14,9	0	1119
LPG	Vonkontstekingsmotor	< 50 jaar	100	matig	beperkt	16,3	0,05	1115
LPG	Hybride	< 50 jaar	100	matig	matig	15,6	0,03	1064
Aardgas	Vonkontstekingsmotor	>= 50 jaar, maar < 100 jaar	100	groot	beperkt	18,3	0,05	1077
Aardgas	Hybride	>= 50 jaar, maar < 100 jaar	100	groot	matig	17,5	0,03	1029
Aardgas	Brandstofcel + EM	>= 50 jaar, maar < 100 jaar	100	groot	hoog	15,1	0	888
Biogas	Vonkontstekingsmotor	Hernieuwbaar	0	klein	beperkt	22,6	0,05	128
Biogas	Hybride	Hernieuwbaar	0	klein	matig	21,6	0,03	195
Biogas	Brandstofcel + EM	Hernieuwbaar	0	klein	hoog	18,6	0	169
Waterstof uit aardgas	Vonkontstekingsmotor	>= 50 jaar, maar < 100 jaar	100	groot	matig	22,6	0	1267
Waterstof uit aardgas	Hybride	>= 50 jaar, maar < 100 jaar	100	groot	hoog	21,5	0	1210
Waterstof uit aardgas	Brandstofcel + EM	>= 50 jaar, maar < 100 jaar	100	groot	hoog	14,1	0	795
Waterstof uit elektrolyse (net)	Vonkontstekingsmotor	>= 100 jaar	95	groot	hoog	65,9	0	1842
Waterstof uit elektrolyse (net)	Hybride	>= 100 jaar	95	groot	hoog	62,9	0	1758
Waterstof uit elektrolyse (net)	Brandstofcel + EM	>= 100 jaar	95	groot	zeer hoog	41,3	0	1155
Waterstof uit elektrolyse (lokaal	Vonkontstekingsmotor	Hernieuwbaar	0	klein	zeer hoog	23,7	0	3
Waterstof uit elektrolyse (lokaal	Hybride	Hernieuwbaar	0	klein	zeer hoog	22,6	0	3
Waterstof uit elektrolyse (lokaal	Brandstofcel + EM	Hernieuwbaar	0	klein	zeer hoog	14,8	0	3
Waterstof uit biomassa	Vonkontstekingsmotor	Hernieuwbaar	0	matig	hoog	27,1	0	336
Waterstof uit biomassa	Hybride	Hernieuwbaar	0	matig	hoog	25,9	0	321
Waterstof uit biomassa	Brandstofcel + EM	Hernieuwbaar	0	matig	zeer hoog	17,0	0	212
Ethanol	Dieselmotor met ignition starter	Hernieuwbaar	0	klein	beperkt	31,2	0,3	691
Ethanol	Brandstofcel + EM	Hernieuwbaar	0	klein	zeer hoog	31,2	0	691
Methanol uit aardgas	Brandstofcel + EM	>= 50 jaar, maar < 100 jaar	100	groot	hoog	18,6	0	1072
Synthetische benzine uit aardgas	Brandstofcel + EM	>= 50 jaar, maar < 100 jaar	100	groot	zeer hoog	22,5	0	1311
Batterijen (net)	Elektromotor	>= 100 jaar	95	groot	matig	26,2	0	732

5.3.1.3 Definitions of the criteria (Dutch)

Eerste screening

De eerste screening gebeurt aan de hand van 7 criteria die enerzijds de Europese visie[4] weergeven op deze problematiek, aangevuld met een criterium uit eigen ervaring dat belangrijk is, namelijk PM-emissies (volksgezondheid).

Criterium 1: Continuiteit van de energievoorziening
Hier wordt gemeten hoe we in de toekomst in een bepaalde brandstof kunnen blijven voorzien.

Hernieuwbare voorraad; Voorraad = 100 jaar; Voorraad = 50 jaar, maar < 100 jaar; Voorraad < 50 jaar

Criterium 2: Afhankelijkheid van niet-hernieuwbare grondstoffen
Hier meten we hoeveel % van de brandstof afomstig is van niet-hernieuwbare grondstoffen.

Eenheid: %

Criterium 3: De beschikbaarheid van de brandstof
De beschikbaarheid van de brandstof, m.a.w. in hoeverre kan deze brandstof voldoen aan de huidige jaarlijkse brandstofvraag.

Klein; Matig; Groot

Criterium 4: Meerkost van de brandstof
Dit criterium geeft weer hoeveel de productie van de beschouwde brandstof duurder is dan van een dieselvoertuig.

Zeer hoog; Hoog; Matig; Beperkt; Vergelijkbaar

Criterium 5: energie-efficiëntie (well – to – wheel; bron tot wiel)
Dit criterium meet hoeveel energie er effectief gebruikt wordt voor het voortbewegen van het voertuig (van de bron tot aan het wiel).

Eenheid: MJ/km

[4] Com(2001) 547 def. Mededeling van de Commissie aan het Europees Parlement, de Raad, Het economisch en sociaal comité en het comité van de regio's over alternatieve brandstoffen voor het wegvervoer en een pakket maatregelen ter bevordering van het gebruik van biobrandstoffen.

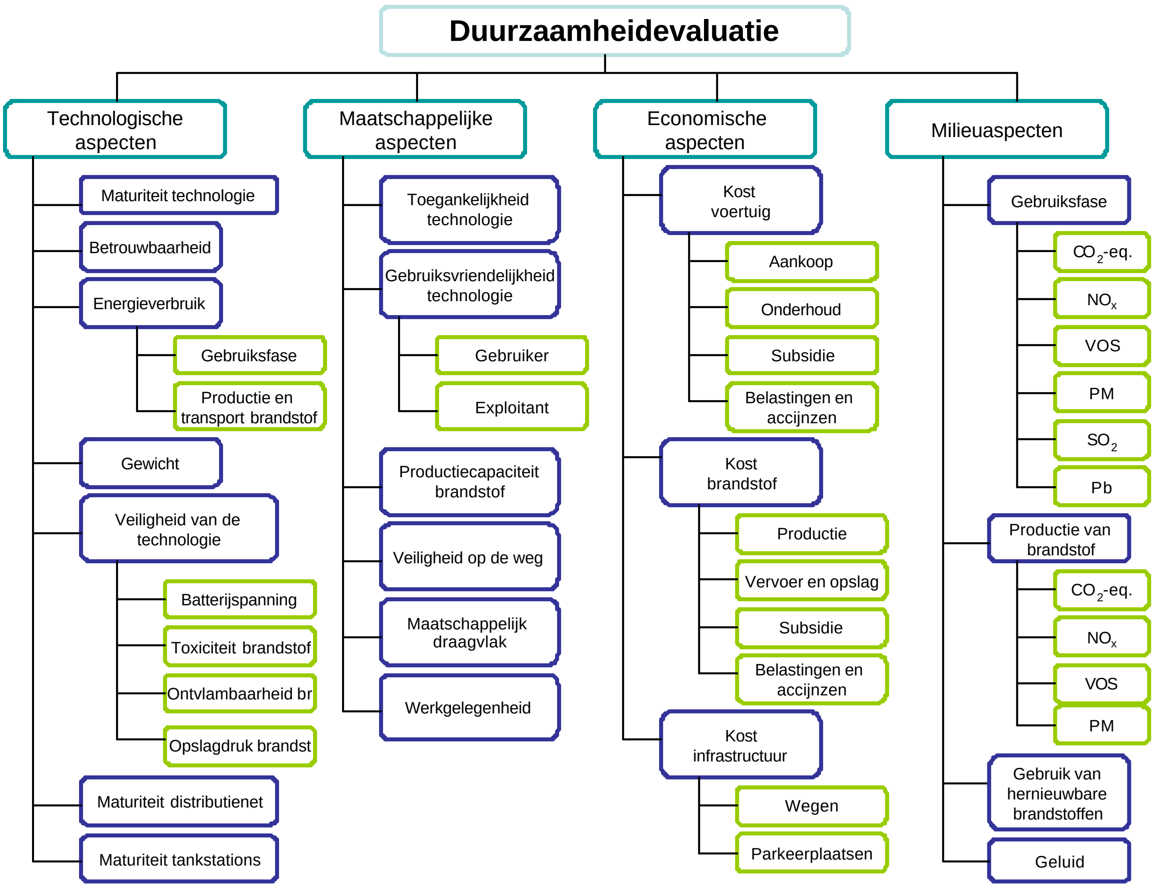
Criterium 6: PM-emissies in de gebruiksfase
Dit criterium geeft de massa aan fijn stof weer die gerelateerd is aan de emissies van de technologie.

Eenheid: g/km

Criterium 7: Broeikasgasemissies tijdens de productie- en gebruiksfase
Dit criterium geeft aan hoeveel broeikasgasemissies er tijdens de gehele levensfase (buiten de afvalbehandeling) van het voertuig geproduceerd worden.

Eenheid: CO_2-equivalenten/km

Detailevaluatie



Technologische aspecten

Criterium	Beschrijving	Meeteenheid
Maturiteit technologie	In welk ontwikkelingsstadium bevindt de technologie zich? Denkpiste: er bestaat slechts een vaag idee over de technologie en hoe dit zou moeten werken. Onderzoeksfase: het concept van de technologie wordt stilaan uitgewerkt en in de praktijk gebracht. Het is een fase met veel trial en error. Prototypefase: de technologie wordt volop getest, maar is nog niet beschikbaar om aan het grote publiek te verkopen. Nog vele mankementen moeten overwonnen worden. Eerste markintroductie: de technologie wordt voor het eerst ter beschikking gesteld van het grote publiek zodat ook zij ook deze technologie kunnen kopen. Er kunnen nog een aantal ongemakken aanzitten die er uit moeten gefilterd worden. Gecommercialiseerd: de technologie is reeds wijd verspreid en vertoont nog maar zelden gebreken.	
Bedrijfszekerheid	Hoeveel defecten treden er op tijdens de gebruiksfase?	Weinig; Matig; Hoog
Energieverbruik – gebruiksfase	Hoeveel energie verbruikt de technologie tijdens zijn gebruik: bijv. een auto tijdens het rijden.	MJ/vkm
Energieverbruik – productie en transport van de brandstof	Hoeveel primaire energie is er nodig om de brandstof waarop de technologie draait te produceren en deze te transporteren naar de plaats waar ze uiteindelijk door de technologie zal opgenomen worden? Hoeveel MJ is er nodig om de brandstof in mijn tank, met een energie-inhoud van 1000 MJ, te produceren en te transporteren naar het verdeelpunt?	%
Gewicht	Dit heeft wat te maken met de efficiëntie van de technologie. Namelijk wat is het bruttogewicht van de technologie in vergelijking met wat de technologie netto kan vervoeren bij maximale belading? Dit wordt opgesplitst naar goederen en personen.	Personen: Kg/persoon Goederen: Ton/Ton goederen
Batterijspanning	Wat is de spanning die op de batterij gezet wordt en waaraan de gebruiker wordt blootgesteld ? Hoog: > 50V, elektrische, hybride voertuigen en brandstofcellen Laag: voor conventionele voertuigen, < 50V	
Toxiciteit brandstof	Dit criterium meet de toxiciteit van de brandstof voor de mens en de natuur bij rechtstreeks contact. De brandstof zal al naargelang de toxiciteit ingedeeld worden in één van de 7 klassen, waarbij klasse 1 staat voor helemaal niet toxisch en klasse 7 voor uitermate toxisch. Deze klasse-indeling is gebaseerd op de Toxic Potential Indicator[5], zoals ontwikkeld door Fraunhofer, die een indicatie weergeeft van de toxiciteit van de stof voor mens en ecosysteem.	
Ontvlambaarheid brandstof	Hoe snel ontvlambaar is de brandstof? Deze evaluatie zal gebeuren aan de hand van gegevens over het vlampunt en de explosiegrens. Hoog: De brandstof is reeds ontvlambaar bij een lagere temperatuur als	

[5] Nissen, N.F., 2001, "Chapter 3.2: Das Schadstoffpotential oder Toxic Potential Indicator." In: *Entwicklung eines ökologischen Bewertungmodells zur Beurteilung elektronischer Systeme* Doctoral Dissertation. Technical University of Berlin. Of de website: www.pb.izm.fhg.de/ee/070_services/toolbox/

	kamertemperatuur. Matig: De brandstof is een vloeistof en slechts ontbrandbaar op kamertemperatuur mits de aanwezigeheid van vonken. Laag: Niet ontvlambaar op kamertemperatuur, de brandstof moet eerst op een bepaalde minimum temperatuur gebracht worden.
Opslagdruk brandstof	Op welke druk moet de brandstof opgeslagen worden om transporteerbaar te zijn. Hoge druk: deze brandstoffen worden vloeibaar gemaakt onder hoge druk omdat anders het volume te groot is om dit economisch te kunnen transporteren (bijvoorbeeld bij gassen). Vloeibaar gemaakt bij ~200 bar Voorbeeld: Waterstof, aardgas Beperkte druk: Vloeibaar gemaakt bij ~10 bar. Voorbeeld: LPG, DME Atmosferisch: Voorbeeld: diesel, benzine
Maturiteit brandstofdistributienet	Dit criterium meet in hoeverre het bestaande brandstofdistributienet voldoet om tegemoet te komen aan de eisen van de technologie. Een heel nieuw distributienet moet ontwikkeld worden; Een grote aanpassing aan het bestaande distributienet is nodig; Een substantiële aanpassing is nodig; Een kleine aanpassing aan het distrbutienet is nodig; Het huidige distributienet is voldoende.
Maturiteit beschikbare tankfaciliteiten	Dit criterium meet in hoeverre de bestaande tankfaciliteiten voldoen om tegemoet te komen aan de eisen van de technologie. Tankfaciliteiten bestaan niet; De tankfaciliteiten bestaan, maar zijn niet voldoende aanwezig; De bestaande tankfaciliteiten voldoen.

Maatschappelijke aspecten

Criterium	Beschrijving Meeteenheid
Toegankelijkheid technologie	Toegankelijkheid van de potentiële gebruikers tot de technologie (de kost wordt hier helemaal buiten beschouwing gelaten). Bij modi gaat het hier ook om het feit of zij makkelijk bereikbaar zijn voor iedereen, bijvoorbeeld oudere mensen die niet zo goed te been zijn. Voor een elite groep; Voor een minderheid; Voor een groot deel van de gebruikers; Voor het grootste deel van de gebruikers; Voor iedereen.
Gebruiksvriendelijkheid technologie voor de exploitant	Het gaat om de kennis die iemand nodig heeft om de technologie te kunnen onderhouden. Dit moet steeds vergeleken worden met de referentietechnologie per modus. Hogere opleiding vereist; Korte bijscholing vereist; Grondige zelfstudie vereist; Korte uitleg van verkoper/verdeler vereist; Geen opleiding of uitleg vereist.
Gebruiksvriendelijkheid technologie voor de gebruiker	Het gaat om de kennis die iemand nodig heeft om de technologie te gebruiken/besturen. Dit moet steeds vergeleken worden met de referentietechnologie per modus aangezien je om te kunnen autorijden, varen of treinbesturen toch altijd een opleiding moet gevolgd hebben. Het betreft hier dus bijkomende opleidingen.

Criterium	Beschrijving	Meeteenheid
	Hogere opleiding vereist; Korte bijscholoing vereist; Grondige zelfstudie vereist; Korte uitleg van verkoper/verdeler vereist; Geen opleiding of uitleg vereist.	
Productiecapaciteit brandstof	In feite gaat het hierover de beschikbaarheid van de brandstof. Is er voldoende aanwezig om de technologie te laten lopen of bestaat deze brandstof wel, maar kan ze niet in grote hoeveelheden geproduceerd worden omwille van productiebeperkingen en dergelijke. Dit heeft niets te maken met de beschikbaarheid volgens uitputting van "resources" uit het milieu.	
	Niet; Beperkt; Matig; Voldoende; Overvloedig.	
Veiligheid in het verkeer	Het betreft hier de veiligheid van de technologie ten opzichte van andere gebruikers. Wat is het risico op ongevallen ten opzichte van de referentietechnologie?	
	Sterk verhoogd; Verhoogd; Gelijk blijvend; Verlaagd; Sterk verlaagd	
Maatschappelijk draagvlak	Bestaat er een maatschappelijk draagvlak voor het introduceren van de technologie? Wordt de introductie voldoende gedragen door de bevolking? Zullen zij maw deze technologie effectief gebruiken?	
	Geen; Klein; Redelijk; Groot; Zeer groot.	
Werkgelegenheid	Zullen bij het op de markt brengen van de technologie, extra banen nodig zijn in België? Bijvoorbeeld extra personeel aan benzine stations om de brandstof te tanken, gespecialiseerde garages voor die bepaalde technologie.	
	Sterk dalend; Dalend; Gelijkblijvend; Stijgend; Sterk stijgend.	

Economische aspecten

Criterium	Beschrijving	Meeteenheid
Kost voertuig – aankoop	Hier gaat het om de aankoopprijs van de technologie, berekend op jaarbasis. De levensduur van de technologie wordt hier dus in rekening gebracht.	€/jaar
Kost voertuig – onderhoud	Het betreft hier de kosten voor het onderhoud van de technologie gedurende zijn levensloop, maar berekend per persoonkm voor voertuigen en tonkm voor goederenvervoer.	€/tonkm of €/pkm
Kost brandstof (productie)	Hoeveel kost het produceren van de brandstof van de technologie, bekeken voor personen en goederenvervoer.	€/tonkm of €/persoonkm
Kost brandstof (vervoer en opslag)	Hoeveel kost het vervoer tot de opslagplaats en de opslag van de brandstof?	€/tonkm of €/pkm
Kost brandstof – subsidies	De gelden die de gebruiker of exploitant krijgen van de overheid per jaar.	€/jaar
Kost brandstof – belastingen en accijnzen	De gelden die de gebruiker of de exploitant moeten betalen aan de overheid per jaar.	€/jaar

Kost infrastructuur – parkeerplaatsen	Hoeveel kost het jaarlijkse onderhoud en aanleg van parkeerplaatsen? (Er wordt eveneens gekeken naar wie dit betaalt.)	€/jaar
Kost infrastructuur - wegen	Hoeveel kost de infrastructuur jaarlijks aan onderhoud? Of Hoeveel kost een nieuwe aanleg van infrastructuur voor een bepaalde technologie? (Er wordt eveneens gekeken naar wie dit betaalt.)	€/jaar
Kost infrastructuur – subsidies	De gelden die de overheid betaalt voor de opbouw van de infrastructuur	€/jaar
Kost infrastructuur – belastingen en accijnzen	De gelden die de gebruiker moet betalen om gebruik te kunnen maken van de infrastructuur.	€/jaar

Milieuaspecten

Criterium	**Beschrijving**	**Meeteenheid**
CO_2-eq. in de gebruiksfase	Dit criterium geeft de CO_2, N_2O en CH_4-emissies weer van de verschillende technologieën tijdens het gebruik.	CO_2-equivalenten
NO_X-emissies in de gebruiksfase	Dit criterium geeft de NO_X-emissies weer van de technologie tijdens het gebruik.	g/km
VOS-emissies in de gebruiksfase	Dit criterium geeft de Vluchtige organische stoffen weer die de technologie uitstoot tijdens het gebruik.	g/km
PM –emissies in de gebruiksfase	Dit criterium geeft de massa aan fijn stof die direct gerelateerd kan worden met het gebruik van de beschouwde technologie of modus. Dit criterium is belangrijk voor de volksgezondheid.	g/km
SO_2-emissies	Dit criterium geeft de S-emissies weer van de technologie tijdens het gebruik.	g/km
Pb-emissies	Dit criterium geeft de Pb-emissies weer van de technologie tijdens het gebruik.	g/km
CO_2-eq. bij de productie van de brandstof	Dit criterium geeft de CO_2, N_2O en CH_4-emissies weer van de verschillende technologieën bij de brandstofproductie	CO_2-equivalenten
NO_x-emissies bij de productie van de brandstof	Dit criterium geeft de NO_X-emissies weer van de technologie bij de brandstofproductie	g/km
VOS-emissies bij de productie van de brandstof	Dit criterium geeft de Vluchtige organische stoffen weer die de technologie uitstoot bij de brandstofproductie	g/km
PM bij de productie van de brandstof	Dit criterium geeft de massa aan fijn stof die direct gerelateerd kan worden met de productie van de beschouwde technologie of modus. Dit criterium is belangrijk voor de volksgezondheid.	g/km
Aandeel van hernieuwbare brandstoffen	Dit heeft te maken met de aard van de brandstof waarop de technologie draait. Bijvoorbeeld een auto op diesel met bijmenging van biodiesel (5%), heeft een klein aandeel als hernieuwbare brandstof, waar bijvoorbeeld een auto op hout of zo een zeer groot aandeel hernieuwbare brandstof zou gebruiken.	

Criterium	Beschrijving	Meeteenheid
Geluid	Geen; Klein; Redelijk; Groot; Zeer groot Bij het gebruik van de technologie zal waarschijnlijk een min of meer hoorbaar geluid geproduceerd worden. Zeer luid; Luid; Redelijk hoorbaar; Weinig hoorbaar; Niet hoorbaar	