1 INTRODUCTION

1.1 Objective of the study

The objective of the United Nations Framework Convention on Climate Change is to stabilize concentrations of greenhouse gases (GHG) in the atmosphere to a level that does not endanger the climate system. The first commitment period of the Kyoto protocol has to be seen as a start in the struggle against climate change. However, scientific research indicates that significant long term efforts will be necessary to avoid major damages from climate change.

According to the Protocol, negotiations are expected to start in 2005 towards new commitments for the period after 2008-2012.

On 12 October 2004, the Prime Minister declared: *"Like our neighbouring countries, the Government will elaborate realistic but ambitious objectives to reduce greenhouse gas emissions beyond 2012. To this end, account will be taken of scientifically founded objectives on which all stakeholders will be consulted"*.

This is the reason why the Federal Ministry for the Environment has asked VITO and ECONOTEC to undertake a study aimed at establishing a set of key assumptions specific for Belgium. These key assumptions would be the basis for the calculation of emission projections and assessment of emission reductions for the mid- and long-term (2020 and 2050) to be performed in the framework of a subsequent study. They should reflect the international framework and the specificity of the country, its regions and its specific sectors.

This report describes the key assumptions. It covers all Kyoto greenhouse gases (CO2, CH4, N2O, HFCs, PFCs, SF6), but the emphasis is put on CO2, which represented 85,5% of the total emissions in 2003.

The ultimate goal of the assumptions and the emission scenarios later to be calculated on their basis is to answer the following two questions:

- Which key factors of the world context could influence greenhouse gas emissions at the world/European/Belgian level and the efforts to reduce these emissions?
- What efforts could Belgium undertake to reduce its emissions and what would be their impact, with and without a European climate policy?

It should be stressed that the purpose of this document is not to calculate emission projections, nor to evaluate an emission reduction objective, but to establish assumptions to be used later in the calculation of emission projections.

As will be explained in section 2, assumptions are only meaningful if they are defined for plausible futures. This implies an internal consistency in the set of assumptions underlying each possible future. This is why the concept of **scenario** will be introduced. This term is used to reflect this consistency among assumptions, and may be interpreted as a synonym of "plausible future".

Note: emissions linked to international fuel bunkering (marine and aviation) are not taken into account in this study.

1.2 The global framework

Climate change is a global issue, and a national emission reduction effort only makes sense if it is part of a concerted action at world scale. Indeed, in a baseline scenario, the EU-25 emissions might represent only 8% of world emissions in 2050 (Criqui et al., 2003).

The EU can, and is probably in the best position to, play a major role in promoting international collaboration on climate change policies, in the framework of the UNFCCC. In the framework of this study, the Belgian situation should therefore be considered in the EU and UNFCCC climate policy frameworks.

The EU's target is that the global average temperature change should not exceed 2°C above pre-industrial levels[13]. When this target was set (in 1996), it was assumed that staying under this threshold corresponded to stabilising global atmospheric concentrations of **CO2 only** at or below 550 ppmv[14].

Since then, it has been recognised that stabilising the concentration **all Kyoto GHGs well below 550 ppmv** CO2-equivalent may be needed[15]. Several studies indicate that such a concentration corresponds to CO2 concentrations in the order of 450 ppmv for CO2[16].

This is in line with the most recent scientific findings, which indicate that the 2°C target is not likely to be met with greenhouse gas concentration levels above **450 ppmv** CO2-equivalent[17].

The issue at stake is considerable. Projected possible world GHG emission levels in 2050 differ by over a factor of 3[18]. The differences are to a large extent influenced by human decisions. Not only government policy decisions, but also private sector decisions and behaviours of individual citizens.

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[13] Decision of the European Council of June 1996, which has since been reaffirmed in recent Environment Council conclusions (20 December 2004 and 10 March 2005) and by the European Council (22-23 March 2005).

[14] "[…] the Council believes that global average temperatures should not exceed 2 degrees above preindustrial level and that therefore concentration levels lower than 550 ppmv CO2 should guide global limitation and reduction efforts. […]" (Council meeting, June 1996).

[15] Environment Council of the European Union, 10 March 2005.

[16] Eickhout et al. (2003) assumed that non-CO2 greenhouse gases will contribute 100 ppmv CO2-equivalents (based on the sum of their radiative forcing effect) (p. 12).

[17] See for instance European Commission (2005b), pp. 9-10, or the report of the Conference that was held in Exeter on 1-3 February 2005 (http://www.stabilisation2005.com/outcomes.html).

[18] The IPCC SRES scenarios (IPCC, 2000) span a wide range of values for world CO2 emissions in 2050: the lowest level is about a factor of 3 lower than the highest. However, this lowest level is still above the 1990 emissions. Given the recent scientific evidence just mentioned, it is likely that stronger emission reductions would be required to reach the 2°C target. New scenarios could be developed and presented in the 4th Assessment report of the IPCC to be issued on 2007.

1.3 Stakeholder consultation

A draft of this report has been submitted to a stakeholder consultation process, which took place as follows.

A list of stakeholders was established, including representatives of the Belgian society (business community, trade unions, consumer organisations, environmental NGOs, regional and federal administrations and experts). These stakeholders were informed about the consultation on the16th March and were invited to express their interest in taking part to the process.

One hundred persons answered positively. They received a draft of the report on 1st April, to prepare the meeting that was held on 15th April. The programme and the list of participants are given in annex 3.2.

During this meeting the study has been presented by the authors and discussed with the participants, in plenary session for the methodology and general assumptions, as well as in three parallel sessions, for 'Industry and Energy', 'Residential and Tertiary' and 'Transport'. Furthermore, written reactions have been received from a number of stakeholders.

The comments of the stakeholders are reflected in this report in three ways :

- In a certain number of cases, the report has been modified or enhanced to take account of remarks received from stakeholders. The way in which these remarks have been integrated is described in a dedicated section at the end of each of the main chapter or sub-chapters of the study: Methodology, General assumptions, Energy, Industry, Residential, Tertiary, Transport.

- The discussions held during the meeting have been summarized by rapporteurs, whose reports are provided in Annex 3.3.

- The written statements received from stakeholders are given in Annex 3.5.

Besides, the comments of the parallel sessions' respondents (also in their original language) are taken up in Annex 3.4.

1.4 Structure of the report

Section 2 defines the scope of the study, showing in particular the necessity to relate these assumptions to scenarios.

Section 3 presents the methodology used, which is based on an analysis of existing studies, mainly carried out abroad, at a national or an international level. This analysis has led to the selection, from the available literature, of four well-documented scenarios at the level of EU-15 which duly take into account global aspects.

On the basis of this information for EU-15 and of relevant studies for Belgium, **Section 4** describes the suggested assumptions for Belgium, general assumptions and assumptions by sector, as a function of the four scenarios.

2 SCOPE OF THE STUDY

The preparation of assumptions constitutes Phase I of a larger study comprising two phases, Phase II being devoted to the production of the actual projections. We will call this larger study the *overall prospective analysis*.

In order to better define the scope of Phase I, it is useful to consider more precisely the objective of this overall prospective analysis.

2.1 The overall prospective analysis

The long term future is highly uncertain and it cannot be predicted. It depends on numerous uncertain economic, technological, social and political developments taking place over a long period of time.

Taking into account the main elements of uncertainty is essential for strategic planning. It is common practice to address this issue by considering several contrasting *scenarios*, each of which representing one possible future development.

Actually, a prospective analysis generally has two components, which can be summarised by the answer to two questions:

- What possible futures can we expect?
- What should we do to influence them? (which strategy, i.e. set of policy actions, should be adopted?)

To answer those two questions, two types of scenarios can be developed:

- ***exploratory scenarios***, which are designed to show the outcome of a set of assumptions in the different fields (economic, social, policy,…) and which are useful for identifying the relevant issues. We will assume that this category also includes "business-as-usual", "reference" or "baseline" scenarios;
- ***normative scenarios*** (also called "targeted" scenarios), which are designed to identify strategic policy choices allowing to reach a desired objective. In the literature on climate change, such normative scenarios are sometimes referred to as "stabilisation" scenarios.

The construction of scenarios is typically a two-step procedure, exploratory scenarios serving as a basis for identifying the strategies required for the normative scenarios and allowing to evaluate the emission gap to be filled.

As defined here, exploratory scenarios generally include policy assumptions, but only as far as they are "exogenous" for, i.e. beyond the control of, the policy maker. In this framework, we consider that such assumptions are those related to policies outside the scope of climate change or to policies decided at a broad international level, like the EU or the UNFCCC.

In the choice of a strategy, an important criterion will be its *robustness*, i.e. its appropriateness for addressing not only one individual scenario, but the diversity of expected futures.

In order not beforehand to reduce the scope of the overall prospective analysis, we will translate the objective of the latter as follows:

- to explore the future emissions in Belgium through a set of "exploratory" scenarios representative of the range of possible outcomes, taking into account the impact of the relevant driving forces, as well as possible policy assumptions;
- to construct one or more normative scenarios, geared towards reaching a Belgian emission reduction objective (expressed in CO2-equivalents) based on relevant technologies and GHG emission reduction policy actions.

Note that in this document, which deals with Phase I of the study, we will only deal with **exploratory scenarios**.

According to Godet (1991, p. 15), scenarios are credible and useful only if they satisfy four conditions: **relevance**, **consistency**, **plausibility** and **transparency**.

Relevance means that the focus should be put on the right questions. From the hundreds of parameters that can influence the development of future emissions, it is important to identify the key driving forces. And these should not be limited to parameters that can be quantified, in order not to risk leaving out critical factors.

Consistency and **plausibility** imply constraints on the combinations of assumptions to be considered, by excluding unrealistic ones (e.g. high GDP growth with little external trade). This means in practice that assumptions should be defined in relation to specific scenarios. It is also important to have differentiated scenarios, in order to avoid leaving aside a large proportion of the possible future outcomes.

As to the **transparency**, it is essential for the involvement of the actors, represented by the stakeholders.

It should be kept in mind that the ultimate goal of scenarios and projections is not to know what the future will be, but to help making the right decisions now. Therefore, it is not necessary to project the long term future in all its detail. The adequate level of detail and accuracy is the one that is relevant for the policy decisions that are to be made now. This should be kept in mind when examining the quantified assumptions presented in this document.

The interest in taking a long term perspective lies precisely in the way this perspective might influence the decisions that have to be taken now. The term "decisions" is to be interpreted here in a broad sense, including not only Belgian government policy decisions, but also private sector decisions and behaviours of organisations and individual citizens in Belgium.

Investment decisions of the private sector and individual citizens will be influenced by their perceptions of the future economic and environmental contexts and the stability of these contexts, and hence by the signals sent not only by markets, but also by government policies, at the national and the international scales, e.g. about factors influencing future energy and carbon prices.

Particularly important in this respect are investment decisions on equipment with a long lifetime, such as electric power stations, heavy industry production capacities, buildings and transportation infrastructure.

2.2 Implications for the current assignment

An important implication of the required consistency among the assumptions is that these assumptions should be considered independently of each other, but rather that they should be defined for scenarios.

These scenarios are to be defined on the basis of:

- the identification of key driving forces of the future emissions;
- the analysis of existing studies;
- a consultation of stakeholders.

Using models for calculating the emissions or checking the internal consistency of these scenarios falls outside the scope of this assignment. Given the limited amount of time available for this assignment, the focus has been put on key variables.

The outputs of this Phase I assignment are:

- identification of a set of contrasting exploratory scenarios representative of the range of possible future outcomes;
- identification of key variables affecting the total GHG emission level in 2020 and 2050;
- a set of key assumptions for each of the scenarios.

2.3 Relationship between assumptions and models

As already mentioned, the assumptions prepared in this document are meant to be used in models for making projections. However, at this stage no prejudgement has yet been made about the type of projection model(s) that will be used.

Therefore, the terms “assumptions” or “hypotheses” are to be interpreted here in a broad sense, as quantitative or qualitative variables which can be either exogenous or endogenous[19], depending on the models used for calculating the scenarios.

Besides, it should be noted that in practice, the establishment of hypotheses is an iterative process, as the result of the model calculations may lead to revise some of the assumptions. Therefore, the hypotheses presented in this document have to be considered as an **initial set of assumptions**, open to later adjustments.

[19] In simple terms, an exogenous parameter of a model can be defined as an input to that model, while an endogenous variable is an output of it.

Note that the assumptions may include policy variables, to the extent that they are exogenous to the Belgian policy maker (in particular on international climate policy).

2.4 Distribution of greenhouse gas emissions

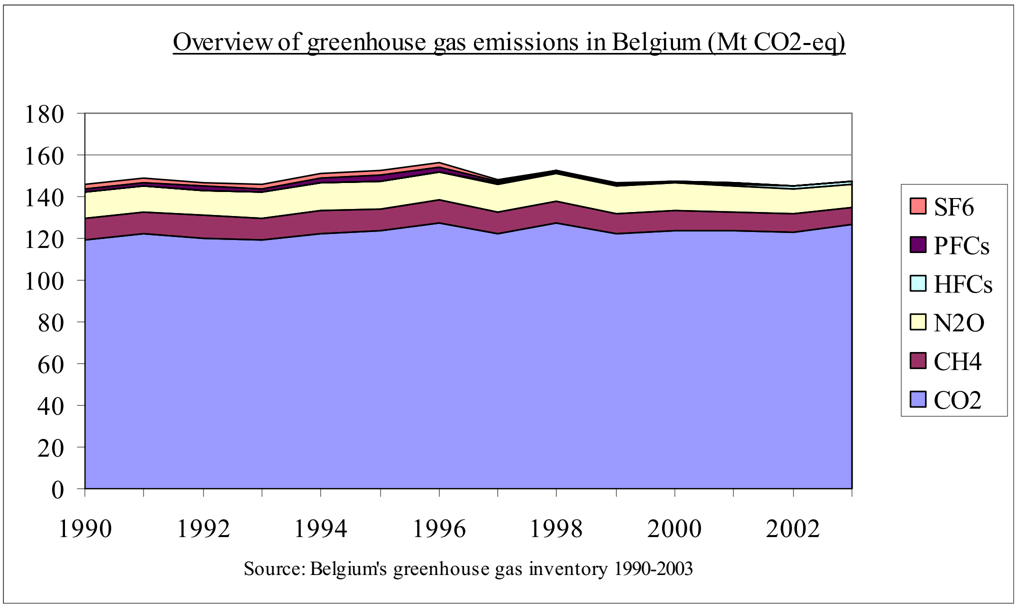
Below are given the distribution of the total greenhouse gas emissions in Belgium by type of gas and by emission source. The figures shown do not take into account Land Use and Forestry Changes (LUFC), which had a negative contribution of 3,4 Mt CO2-eq in 2003.

2.4.1 By type of gas

As mentioned above, all Kyoto greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6) are to be taken into account in the study. However, the relative importance of these gases in the total emissions in terms of CO2-equivalents differs considerably, as shown on the diagram below.

Therefore, the emphasis will be put first on CO2, then on N2O and CH4. These gases respectively represented 85,5%, 7,6% and 5,8% of the total emissions in 2003.

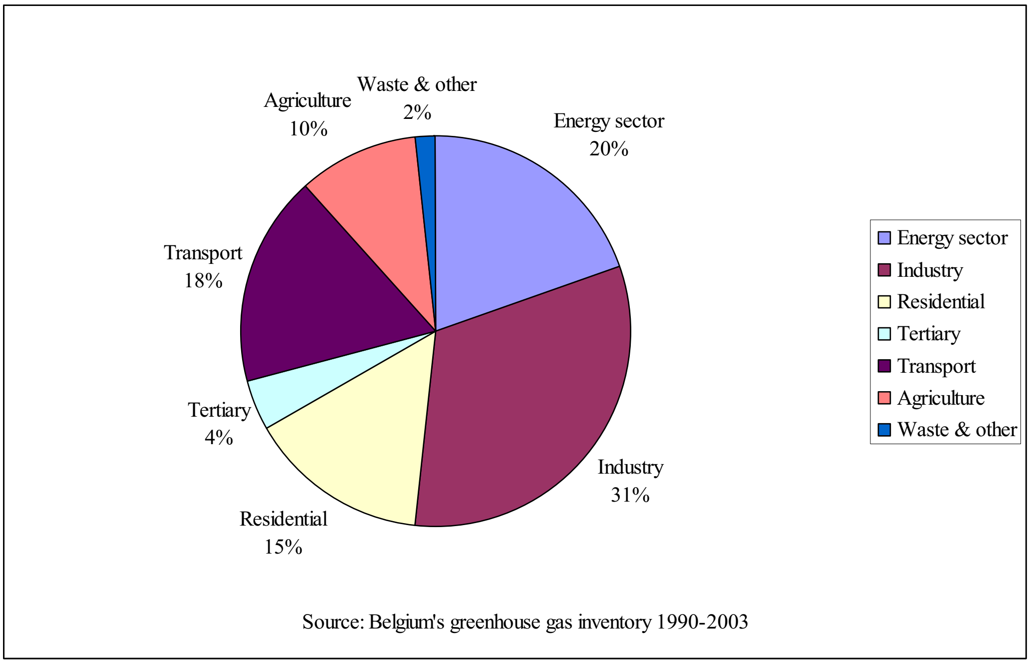
The contribution of fluor containing gases, HFCs, PFCs and SF6, which together represented only 1,1% of total emissions in 2003, is expected to increase, but should remain limited, especially in the long term.



2.4.2 By emission sector

The graph below shows the contributions by sector to the total emissions of Kyoto greenhouse gases in 2002[20].

CO2-equivalent emissions by sector in 2002 (%)



Note that for the final energy consumption sectors (industry, residential, tertiary, transport, agriculture), these emissions are the **direct emissions**, i.e. they do not take into account the indirect emissions produced by the electricity sector for generating the electricity they consume.

[20] Note that the same level of detail is not yet available for 2003.

3 METHODOLOGY

3.1 Introduction

The aim of the study is to prepare assumptions to be used in a subsequent study aimed at developing medium and long term emission projections.

In the long run, there is a wide range of possible futures, depending on the evolution of many uncertain factors, to a large extent influenced by human decisions. To reflect this range, different sets of assumptions are necessary. In order to ensure their internal consistency, these sets of assumptions are defined in terms of particular scenarios.

The construction of new consistent and plausible scenarios for the European and the international levels requires a sizeable amount of resources and lies beyond the scope of this assignment. On the other hand, existing studies, which often build on many years of previous experience, provide a considerable wealth of expertise as well as results that can readily be used for our purpose.

It is important to note that the driving forces of future emissions in Belgium are intimately linked to developments occurring at an international scale (economic development, international trade and finance, technological innovation, EU integration and harmonisation, other international policies and agreements, population migrations…). Therefore, assumptions for Belgium need to rely on assumptions, and hence on scenarios, at an international scale.

This section presents the insights gained from an analysis of existing studies carried out abroad, at a national or international level. It shows how this analysis has led us to select, from the literature, four existing scenarios that are both narratively described and to a significant extent quantified, at the level of EU-15 and duly taking account of global aspects. It then describes the main features of the selected scenarios for EU-15. These scenarios will be translated to the Belgian context in Section 4.

3.2 Insights from existing studies

Many existing studies on future emission projections are available. Given the limited time available, we have concentrated on the studies on long term scenarios, in our neighbour countries as well as at the level of the EU or at the global scale. We have also focused on the most recent studies.

The list of studies used as a basis for defining scenarios is given in Section 6.1.

3.2.1 Key parameters

In existing studies, the main driving forces determining future emissions were found to be:

- population growth
- evolution of GDP per capita
- structure of the economy (role of industry and of tertiary activities)
- technological change
- evolution of energy intensity
- evolution of fuel mix of final energy consumption
- evolution of fuel mix for electricity production (coal, gas, nuclear, renewables)
- delocalisation of energy intensive activities.

The main technological options considered are:

- energy end-use technologies
- renewables (+ electricity storage)
- nuclear power
- CO2 capture and storage
- hydrogen economy.

Remarks:

- In general, the existing studies consider that the availability of fossil fuel resources will not be an issue, although the cost of these resources will increase. Of concern, however, is the concentration of world oil and gas production in very few countries, which will increase the risks from the point of view of energy supply security.

- In general, the existing scenarios also assume gradual changes, without catastrophe or unexpected disruptions.

3.2.2 Types of scenarios

These studies for the long term future are generally based on either exploratory scenarios, normative scenarios or both categories of scenarios.

3.2.2.1 Baseline scenarios

A number of studies only consider one single exploratory scenario, which can be called "baseline scenario", "reference scenario", "business-as-usual scenario", "model scenario", "scénario tendanciel"…, against which required emission reduction efforts can be measured. This is the case of Criqui et al (2003), European Commission (2003a), ECN (2004), UBA (2005).

Criqui et al. (2003) deserves a special attention, as it is the study used as a basis by the Commission for its recent Communication to the Council (European Commission, 2005a) and Background paper (European Commission, 2005b).

It considers one **single baseline scenario** and **two alternative scenarios** ("emission profiles"), stabilising greenhouse concentrations at 550 and 650 ppm CO2-equivalent, respectively in 2100 and 2150.

The baseline scenario, called CPI (for Common POLES-IMAGE), is based on an existing 'POLES' reference scenario up to 2030 and extended to 2100 on the basis of the A1b and B2 IPCC SRES scenarios (see the definitions of the latter scenarios below), using the IMAGE 2.2 model. According to van Vuuren et al. (2003, Fig 3.2), the CPI-baseline should be regarded as a medium emission baseline. This scenario, without further action, leads to 935 ppm CO2-equivalent in 2100.

The alternative scenarios, which are called S550e and S650e (e for equivalent) are taken from Eickhout et al. (2003). Criqui et al. (2003) underlines that the S650e profile "is likely to overshoot the EU target" (of 2°C increase) (p. 11).

3.2.2.2 Differentiated exploratory scenarios

Given the considerable uncertainty on emissions in the long term, other studies consider more than one exploratory scenario, in order to better cover the range of possible futures. These scenarios can be widely diverging.

The main factors used for defining contrasting scenarios are those for which there is the largest uncertainty. These factors are generally qualitative, and broadly similar from one study to another.

Emission scenarios are often associated with some kind of "global futures" scenarios. As noted by the IPCC, global future scenarios do not specifically or uniquely consider GHG emissions; they are more general "stories" of possible future worlds. They "can complement the more quantitative emission scenario assessments, because they consider several dimensions that elude quantification, such as governance, social structures, and institutions, but which are nonetheless important to the success of mitigation (and adaptation) policies and, more generally, describe the nature of the future world" (IPCC, 2001).

This means that behind the usual quantified model assumptions, which can generally be considered as "proximate drivers" (population size and growth, economic volume and patterns; technological choice…), lie a number of "ultimate drivers", (values, desires and aspirations; structure of power; knowledge and understanding; human needs; long term ecological processes…), which are of a more qualitative nature[21].

The existing studies show that exploratory scenarios are mostly defined along one or two of the following **3 key uncertainty axes**:

1. *International cooperation, globalisation* versus *regionalisation*;
2. *Social and ecological values* (community values) versus *economic values/consumerism*;

[21] This classification was suggested by the Swedish Environment Institute (SEI) Global Scenario Group, quoted by IEA (2003).

3. Emphasis on *public responsibilities* (strong public institutions) versus *private responsibilities*.

Axis 1 is important for economic development (it influences external trade, technology transfer), international policies, EU institutions, migration patterns, security of energy supply (because of international trade and relations with energy producing countries), but also crucial for climate change policy.

Axes 2 and 3 represent the trade-off between "efficiency" (economic performance…) and "equity" (social and environmental performance). They are important for the level of distribution of revenues, the possibility of economic and social reforms, environmental policy, including climate change policy. They also influence economic growth and the rate of technological development.

Note that "IEA Energy to 2050" (IEA, 2003) considers two axes more focused on the IEA's specific perspective:

- technological change;
- attitudes and preferences with respect to the global environment.

While the second axis is similar to axis No. 2 above, technological change is actually linked to the three "key uncertainty axes". Therefore we have not considered it independently.

3.3 Description of the approach

In order to take into account the global scale and the international environment, we suggest a 3-step multi-scenario approach consisting in:

- starting from the IPCC families of **global scale** scenarios;
- using a translation of these global scenarios to the **EU-15** level based on existing studies;
- translating the EU-15 scenarios to the level of **Belgium**.

3.3.1 The global scale - IPCC SRES scenarios

In existing studies, scenarios are often defined with some link to one of the IPCC "SRES scenarios"[22], which worldwide constitute the major reference on global GHG emission scenarios.

The IPCC Special Report on Emission Scenarios (SRES), published in 2000, was prepared in particular for use as an input to the IPCC Third Assessment Report (2001) and is the result of an intense international collaborative effort.

It presents a large number of global scale "exploratory" scenarios (40 in total) on global GHG emissions for up to 2100, calculated with a variety of models. For each of these scenarios, emissions are provided at the level of 4 world regions, among which OECD.

[22] Special Report on Emission Scenarios (IPCC, 2000).

The large difference between scenarios is considered as representing the range of uncertainty.

These scenarios are grouped into 4 *families*, which can schematically be represented by dividing the future worlds along the 2 axes of economy-environment and globalisation-regionalisation :

A1: Economic emphasis with increased globalisation;
A2: Economic emphasis with increased regionalisation;
B1: Environmental and social emphasis with increased globalisation;
B2: Environmental and social emphasis with increased regionalisation.

Each family corresponds to a common narrative 'storyline'. For each storyline, one quantitative "marker" scenario was selected, which best reflected the scenario family, but which is not more or less likely than any other scenario of the family, only illustrative.

Note that **none of the scenarios include additional climate initiatives**. But the GHG emissions are affected by non-climate change policies designed for a wide range of other purposes.

3.3.2 The European scale – Four scenarios of Europe

In order to cover an adequate range of possible futures, we have decided to consider the four categories ("families") of global scenarios identified by IPCC SRES (A1, A2, B1 and B2) and the corresponding scenarios elaborated for EU-15 by the Dutch Centraal Planbureau (CPB) and RIVM[23].

In 2003, CPB has published "Four Scenarios of Europe" (CPB, 2003a), which can be considered as a detailed revision of the IPCC scenarios with focus on Europe and with more regional and sectoral disaggregation (Eickhout et al., 2004) and which has subsequently been enhanced for energy markets and climate change (CPB, 2004).

The main reasons for this choice are the following:

- These scenarios are based on the IPCC scenarios, major reference for global GHG emissions, and show a large span of possible futures.
- They focus on EU-15, while the IPCC scenarios only distinguish the broad OECD aggregate and more sectoral disaggregation.
- They focus on the period up to 2040 instead of up to 2100.
- They have been worked out in detail, and are to a large extent quantified, at the economic level (using a general equilibrium model of the world economy) and at the level of GHG emissions and their impacts.
- One of them takes into account a global level climate policy scenario.
- They are recent, hence take into account the latest scientific insights.

[23] Rijksinstituut voor Volksgezondheid & Milieu. Note that this institute has also actively contributed to the preparation of the IPCC SRES report.

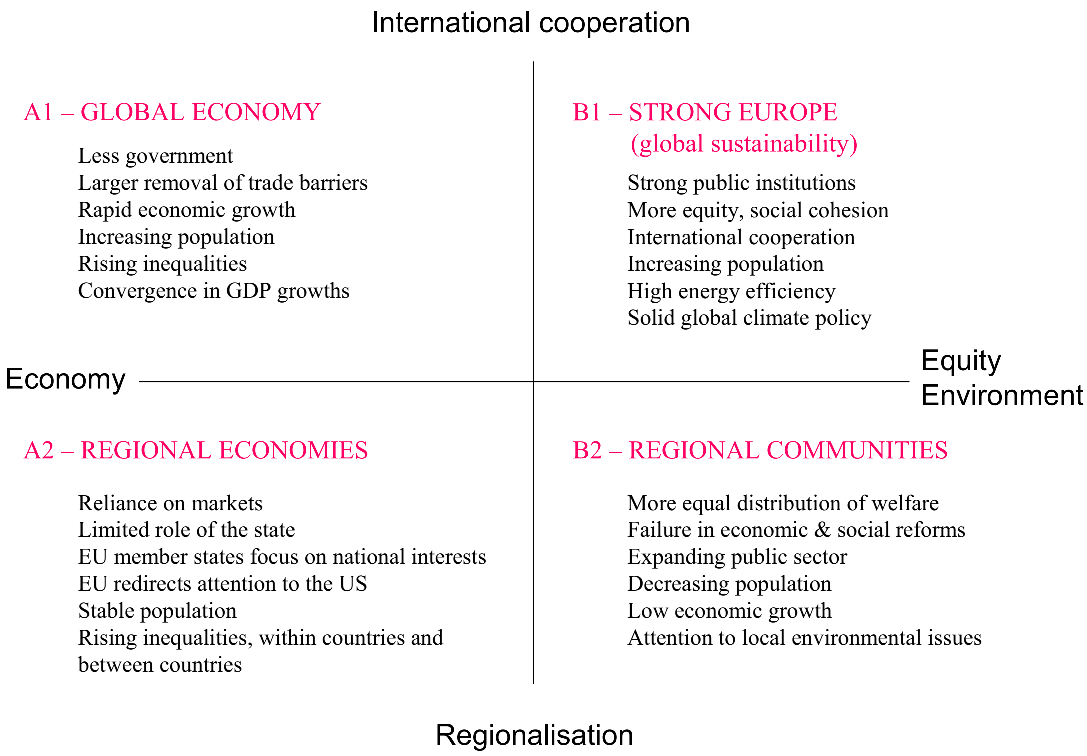
The collaboration between CPB and RIVM thus provides a comprehensive and consistent framework of quantitative as well as qualitative data, at the level of EU-15 and up to 2040.

Provided they are translated to the national context, these scenarios can be used as a basis for exploring strategic policies in a country like Belgium.

It should be stressed that for this they are to be considered as exogenous backgrounds that are outside the influence of the policy maker. Indeed, national policymakers only have a limited impact on international agreements and even less influence on policies in other countries (CPB 2003a, p. 208)[24]. All four are exploratory scenarios.

The four CPB-RIVM scenarios can be broadly defined along the following two key uncertainty axes, as schematically depicted on the figure below:

- *International cooperation* versus *Regionalisation*;
- *Equity and Environment* (public responsibilities) versus *Economy* (private responsibilities). This axis can also be interpreted as *Equity* versus *Efficiency*.



[24] This does not mean that national policy makers have no impact in the international decision making process. But that impact is far more important at a global scale than at the pure national level. Indeed, EU decision making not only applies to the EU emissions: given the leading role of the EU in this field, it may also significantly influence emissions in the other parts of the world.

For each scenario, a narrative storyline has been developed, on the basis of which a number of parameters have subsequently been quantified, using economic, energy and emission projection models.

GLOBAL ECONOMY (A1) puts the **emphasis on private initiatives and market-based solutions**. Trade barriers are removed, taxation is reduced under growing tax competition. Innovation and fierce competition spur labour productivity. Economic growth is high. But there is less income redistribution and income inequality grows (between the rich and the poor, the educated and not educated people). However, because of the international cooperation, there is a convergence in growth of country GDPs per capita. The problem of climate change intensifies. Energy security is not an issue, because of the good international relations and efficient organised markets believed to secure supply of energy.

In **REGIONAL ECONOMIES**[25] (A2), individual countries tend to focus on their national interests and to rely on market mechanisms. The role of governments is limited. Reforms of EU-decision making fail and further EU integration is difficult. The EU redirects attention to the US. Inequalities are rising, both within countries and between countries. Relations with oil and gas supply countries are more tense, leading to higher prices.

STRONG EUROPE (Global Sustainability) (B1) is characterised by strong public institutions, more equity and social cohesion. Successful reforms in the public sector help maintaining a stable and growing economy. There is broad international cooperation, in particular on climate change, for which a global climate policy is assumed which is consistent with the EU long term objective to keep the average global warming below 2°C. This latter assumption is a major difference with the IPCC scenarios, of which none considers a global climate policy.

This target is translated in emission profiles stabilising the Kyoto GHG concentration at 550 ppmv CO2-eq in 2100. Actually, as mentioned in section 1.2, the most recent scientific evidence suggests that lower concentrations are likely to be needed to reach this target.

The global climate policy is a stylised policy, based on a world cap-and-trade system with allocation of allowances on an equal per-capita basis[26]. The price of emission permits in 2040 is 450 $/t (116 $/t CO2). The total cost is a loss of 1,6% of GWP. For Europe, the GDP loss amounts to 2% (CPB, 2004).

In **REGIONAL COMMUNITIES** (B2), emphasis is also put on national sovereignty, but with more public intervention, leading to a more equal distribution of welfare. The public sector is expanding, but governments are unsuccessful in modernising welfare-state arrangements and the EU fails to reform her institutions. Environmental attention focuses on local (non-climate) issues. Economic growth is low.

All scenarios assume the continuation of existing EU policies, including the liberalisation of electricity and gas markets in the EU, the further improvement of energy technologies and stringent regulation of acid rain pollutants.

[25] Note that in the CPB (2003a) study, this scenario is called « Transatlantic Markets », a reference to the fact that in this scenario, the EU redirects its attention to the US.

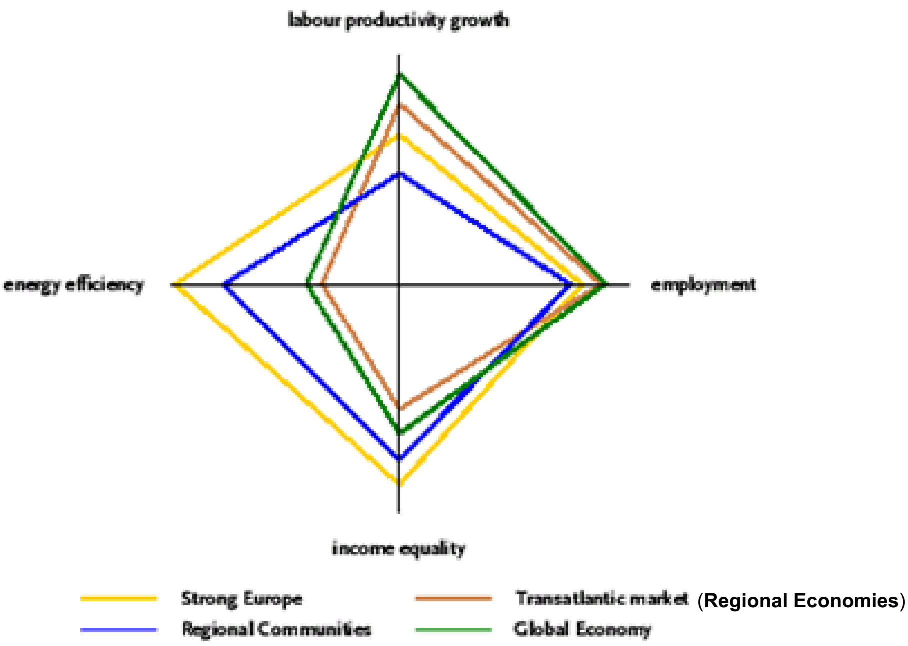
[26] From 2012 onwards, assigned amounts of the Kyoto protocol are assumed to converge and contract to an equal per capita basis in 2050.

It should be stressed that out of these four scenarios, STRONG EUROPE (Global Sustainability) is the only one compatible with a global climate policy. Indeed, such a policy makes a strong international cooperation imperative, as virtually all nations in the world have to agree on ambitious targets. This excludes REGIONAL ECONOMIES and REGIONAL COMMUNITIES. It also requires governments able to commit their countries and to enforce drastic policies, which excludes GLOBAL ECONOMY, all the more because this scenario has the highest baseline emissions.

A general trend is the continuation of the structural shift from manufacturing towards services in the total value added (the result of a higher income elasticity for services), which leads to a decrease in labour productivity growth. The shift is slightly more important for the "Regional economies" and for the "Global economy" scenarios.

A comparison of the four scenarios is given on the following diagram.

Comparing four dimensions of the scenarios



Source: CPB (2003a)

On this diagram, income equality is a ranking of the 4 scenarios. The remaining 3 indicators are quantified (see table below).

It is remarkable that on all four dimensions (labour productivity growth, employment, income equality and energy efficiency), GLOBAL ECONOMY is superior to REGIONAL ECONOMY and STRONG EUROPE (Global Sustainability) is superior to REGIONAL COMMUNITIES.

The diagram shows a trade-off between equity and efficiency, a higher income equality being gained at the expense of labour productivity. However, GLOBAL ECONOMY and STRONG EUROPE can be considered to lie on a higher equity-efficiency curve than REGIONAL ECONOMY and REGIONAL COMMUNITIES.

It is also interesting to note the correlation between income equality and energy efficiency.

The following table shows the main quantified characteristics of the 4 scenarios at the level of EU-15. These figures were obtained by CPB based on assumptions and the use of WorldScan, a world general equilibrium model (CPB 2003a, CPB 2003b). Note that these figures should not be considered as predictions, but rather as numerical illustrations of the scenarios.

Main quantified characteristics of the EU-15 economy in the four scenarios

	2000 or 1980-2000	Strong Europe	Regional Economies	Regional Communities	Global Economy
GDP growth (% per annum)	2,2%				
00-20		1,8%	2,3%	1,1%	2,7%
20-40		1,3%	1,6%	0,2%	2,3%
00-40		1,5%	1,9%	0,6%	2,4%
GDP per capita growth (% per annum)					
00-20		1,4%	2,1%	1,1%	2,3%
20-40		1,1%	1,7%	0,5%	2,1%
Population growth (% per annum)	0,3%				
00-20		0,4%	0,2%	0,0%	0,4%
20-40		0,2%	-0,1%	-0,3%	0,2%
00-40		0,3%	0,0%	-0,2%	0,3%
Labour participation rate (% of tot. popul.)	46,6%				
2020		44,3%	47,0%	44,7%	46,5%
2040		41,6%	45,2%	40,2%	45,8%
Share of 20-65 years (% of total population)	60,8%				
2020		57,5%	59,1%	60,2%	57,5%
2040		52,1%	53,1%	54,3%	52,1%
Employment growth (% per annum)	0,7%				
00-40		0,1%	0,1%	-0,5%	0,4%
Unemployment rate (% of labour force)	8,5%				
2020		7,1%	6,2%	8,4%	6,2%
2040		5,8%	3,9%	8,3%	3,9%
Labour productivity growth (% per annum)	1,5%				
00-20		1,6%	1,9%	1,2%	2,1%
20-40		1,4%	1,8%	1,0%	2,0%
00-40		1,5%	1,8%	1,1%	2,1%
World exports growth (% per annum)	5,6%				
00-40		4,5%	3,7%	2,4%	5,6%
Sector value added in 2040 (% of GDP)					
Agriculture and food	6,5%	4,2%	3,5%	4,7%	3,2%
Energy and raw materials	1,8%	0,9%	1,4%	1,5%	2,1%
Manufacturing	18,6%	13,3%	12,2%	12,4%	10,2%
Services	73,2%	81,7%	83,1%	81,3%	84,7%
Production growth					
Agriculture and food		1,7%	1,8%	1,1%	2,6%
Energy and raw materials		0,4%	1,9%	0,9%	3,4%
Chemicals and minerals		3,0%	3,5%	1,9%	5,1%
Capital goods (metal products)		2,0%	3,2%	0,8%	3,5%
Other manufacturing		2,1%	2,6%	1,2%	3,5%
Trade and transport		2,0%	3,1%	0,9%	3,1%
Business services		1,6%	2,1%	0,6%	2,4%
Other services		1,4%	1,7%	0,6%	2,2%
Energy prices : see below, section on energy prices					

Sources: CPB (2003a), CPB (2003b)

The following table gives the evolutions of energy consumption and energy-related CO2 emissions of the 4 scenarios for EU-15, as well as their component factors (GDP, evolution of energy and carbon intensities).

Emission characteristics of the CPB-RIVM scenarios for EU-15

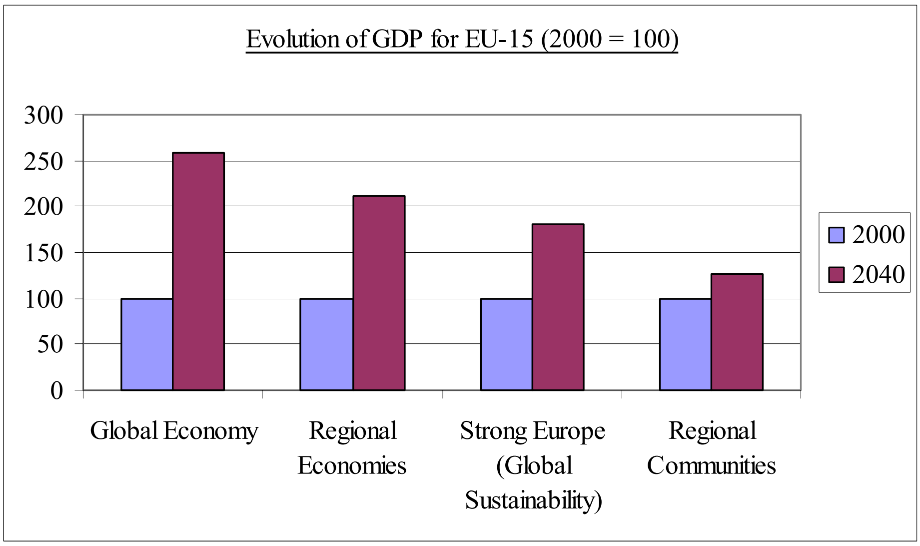
		2000-2040 (%/year)	2040/2000 ratio	2040 (index*)
GDP				
A1	Global economy	2,4%	2,58	203
A2	Regional economies	1,9%	2,12	167
B1	Strong Europe	1,5%	1,81	143
B2	Regional communities	0,6%	1,27	100
Energy intensity				
A1	Global economy	-1,2%	0,62	
A2	Regional economies	-1,0%	0,67	
B1	Strong Europe	-2,1%	0,43	
B2	Regional communities	-0,8%	0,73	
Carbon intensity				
A1	Global economy	-0,1%	0,96	
A2	Regional economies	-0,1%	0,96	
B1	Strong Europe	-0,6%	0,79	
B2	Regional communities	-0,5%	0,82	
Energy use				
A1	Global economy	1,3%	1,68	213
A2	Regional economies	0,9%	1,43	182
B1	Strong Europe	-0,6%	0,79	100
B2	Regional communities	-0,2%	0,92	117
Energy related CO2 emissions				
A1	Global economy	1,2%	1,61	272
A2	Regional economies	0,8%	1,36	230
B1	Strong Europe	-1,3%	0,59	100
B2	Regional communities	-0,7%	0,75	127

* Value of lowest scenario = 100 Source: CPB (2004)

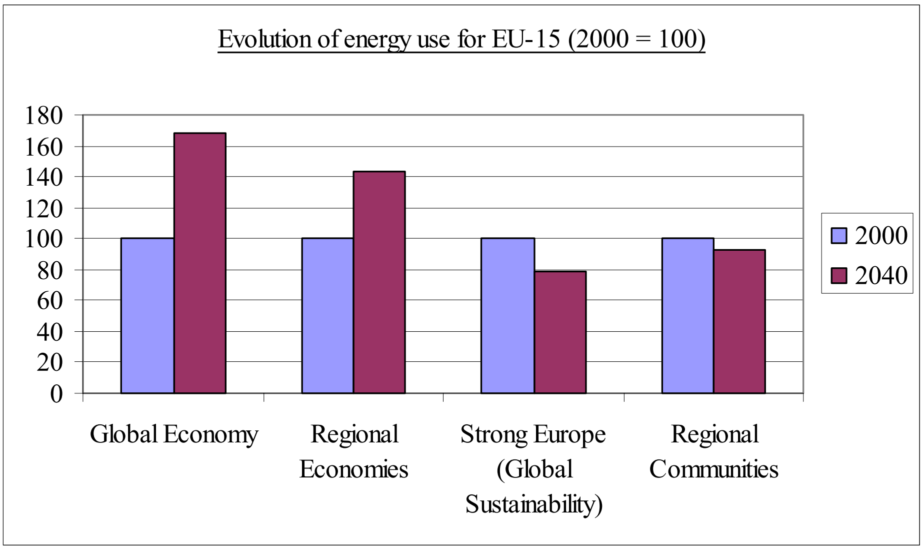
The index in the last column of the table shows the size of the spread between scenarios. It can be seen that between the extreme values in 2040, there is a factor 2 for the GDP, 2,1 for energy consumption and 2,7 for the CO2 emissions.

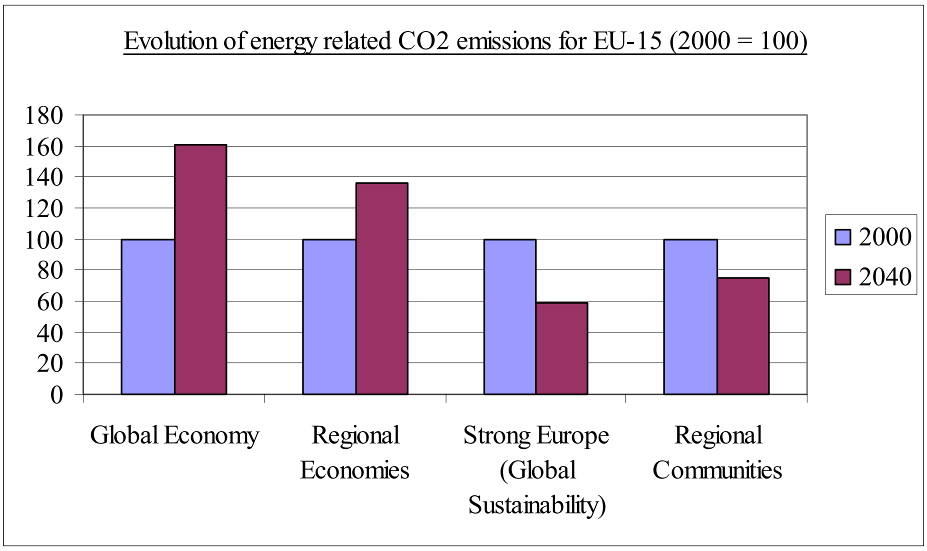
This spread between the four scenarios in 2040 is graphically illustrated on the three figures below, respectively for GDP, energy consumption and energy-related CO2 emissions.

It can be noticed that despite a significantly higher economic growth, STRONG EUROPE (Global Sustainability) has a lower energy consumption and lower CO2 emissions than REGIONAL COMMUNITIES. This is of course due to the climate policy, which induces a shift towards lower energy intensities and lower carbon energy sources.



In comparing the scenarios, it should be kept in mind that the GDP is an imperfect indicator of welfare, in particular as it does not fully take into account negative environmental externalities (it can even grow as a result of expenditures made to solve environmental problems).





3.3.3 Translating the four EU-15 scenarios to the Belgian context

In order to establish assumptions at the level of Belgium, we have translated each of the four scenarios for EU-15 to the Belgian context, taking into account the national specificities.

The detailed assumptions are presented in section 4.

Relationship to a BAU scenario

For the short to medium term, it is common practice to develop a business-as-usual (BAU) type of scenario, taking into account the best available information on the most likely future trends in the absence of new policies.

As our four scenarios are rather well differentiated, they differ from such a BAU scenario, which tends to have a more central position on the two axes described above (section 3.3.2).

As these two axes are qualitative, it is not possible to quantify the overall relationship between the two types of scenario, but from the narrative description of the CPB scenarios (CPB, 2003a), we consider that on the first figure of section 3.3.2, a business-as-usual scenario should lie somewhere below the horizontal axis, between scenarios A-2 (REGIONAL ECONOMIES) and B-2 (REGIONAL COMMUNITIES).

3.3.4 Limitations of the approach

Quantifying assumptions for the projection of long term future emissions is an ambitious undertaking. It is a necessary step for making projections, it has the advantage of providing clear pictures in support of the preparation of policies, but shouldn't be interpreted as an accurate representation of the future.

The assumptions provided in this document are not forecasts, for what will really happen is impossible to predict. They are merely illustrations of possible future developments, based on judgement and taking into account the best available knowledge.

These assumptions are based on a set of existing scenarios established at an international level. Although one might argue about the value of some of their underlying assumptions, these scenarios have been considered as a whole, in order to preserve the advantage of their internal consistency.

Translating these scenarios to the Belgian context has in turn required a number of additional assumptions, not covered by the CPB study. These assumptions remain imperfect and should be considered as initial hypotheses. In some cases, models would indeed be needed to check the consistency of some of them, but the use of models was beyond the scope of this assignment.

The heterogeneity of the energy consumption sectors has also made it difficult to harmonise the approaches used in establishing the assumptions for each.

For certain sectors, especially the residential, tertiary and transport, the (inter)national literature does not mention detailed key assumptions like they were listed initially (see annex 1). For these sectors it is important to show the main driving forces, certainly for the long term, and to mention tendencies in a qualitative way.

These limitations should be kept in mind when using the suggested assumptions and in interpreting the results of projections that are to be based upon them. In a number of cases, sensitivity analyses will be necessary.

4 DESCRIPTION OF THE ASSUMPTIONS FOR BELGIUM

On the basis of the characteristics for EU-15 of the four selected scenarios, which was presented in the previous section, this section presents suggested assumptions for Belgium, by sector and as a function of the four scenarios.

4.1 General assumptions

4.1.1 Population

Demographic assumptions have an impact on greenhouse gas emission scenarios. Projections by age group influence the evolution of the labour supply (ageing of the population), heated surface of school buildings, resting homes, changes in mobility...

The **UN 2002** revision of population projections up to 2050 provide medium, high and low values by country. It is to be noted that the high value for Belgium in 2050 is 20% higher than the low value, which represents a significant difference. The three variants (low, medium, high) share the same assumptions regarding mortality and international migration. They differ among themselves only with respect to the assumptions regarding fertility.

CPB (2003a) uses population projections from Eurostat (2000). The baseline projection is used for REGIONAL ECONOMIES, the high-population variant for GLOBAL ECONOMY and STRONG EUROPE, the low-population variant for REGIONAL COMMUNITIES. As the high and low population variants are extreme scenarios, the authors have reduced the Eurostat deviation between the baseline and the high and low variants by a third. Differences of population growth under the 4 CPB scenarios are caused by differences in migration policies.

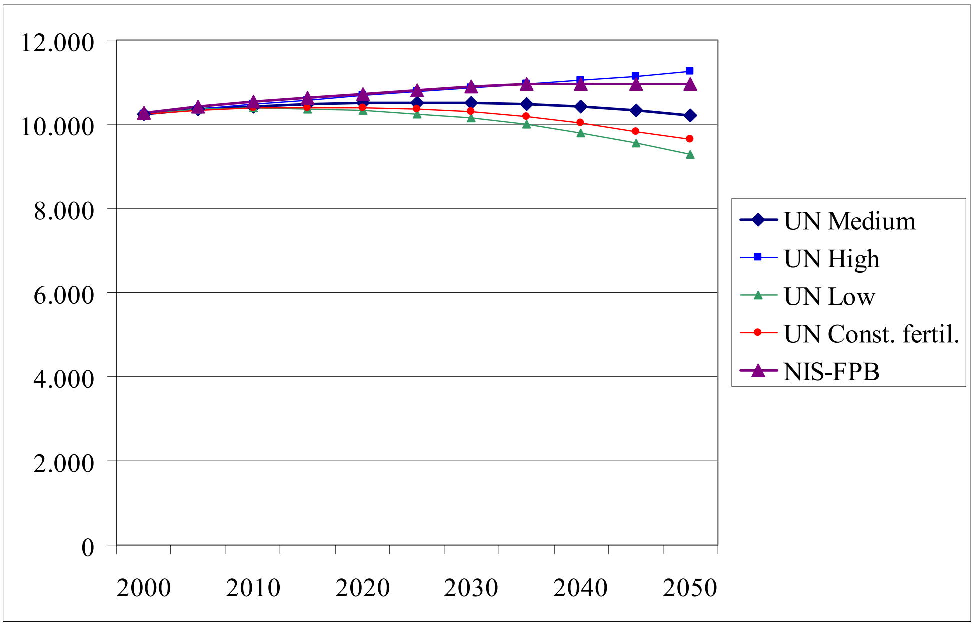
For Belgium, the Eurostat (2000) baseline projection coincides with the UN 2002 medium variant.

The **Federal Planning Bureau** (NIS-FPB, 2001) provides only a single projection, but which is available in great detail by age class, region, etc. It is higher than the medium UN projection, largely because it takes into account an increasing migration, which the UN projections do not, and seems to be confirmed by the latest statistics[27].

The diagram below compares the 4 UN projections with the NIS-FPB projection.

[27] Source: Federal Planning Bureau, March 2005.

Population projections for Belgium (thousands)

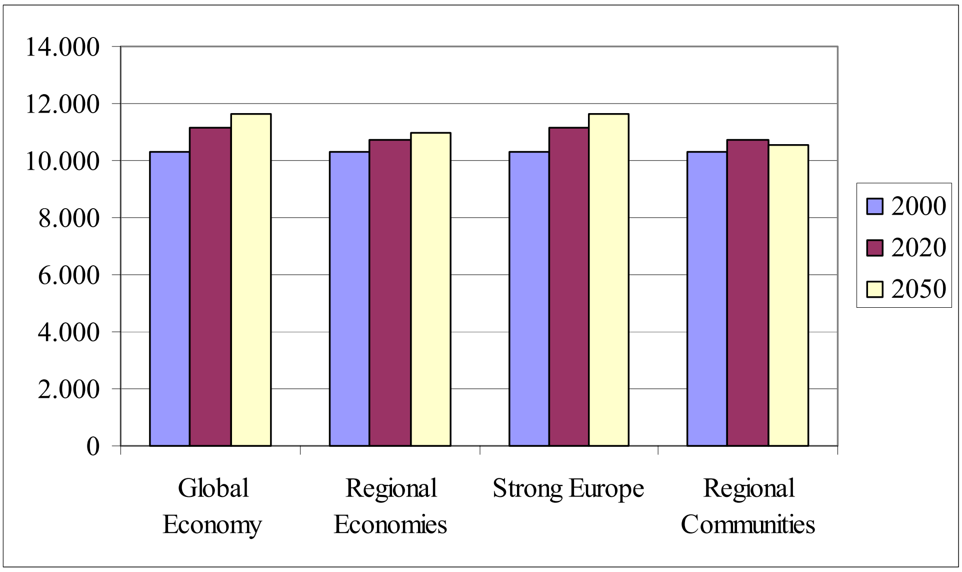


It is suggested to consider the **NIS-FPB demographic projections up to 2050** as "the baseline scenario" for Belgium, which could be used for the scenario REGIONAL ECONOMIES, with two variants:

- a high variant to use for the scenarios GLOBAL ECONOMY and STRONG EUROPE;
- a low variant to use for the scenario REGIONAL COMMUNITIES.

As the detailed impact of different assumptions on migration is not available, we suggest, for these two variants, to take over, and extrapolate to 2050, the population growth differentials between scenarios of the CPB study for EU-15, which gives the results displayed on the following diagram.

Evolution of population for Belgium in the four scenarios (thousands)



4.1.2 GDP

One of the main key parameters for the scenarios is GDP growth. So how can the long term GDP growth in Belgium be related to the long term GDP growth of EU-15? Existing studies hardly provide information on this.

The WorldScan model used by CPB does not consider Belgium as a separate region (it aggregates it with Luxembourg, which differs substantially from Belgium, in particular in terms of GDP per capita and population growth rate).

The "European Energy and Transport Trends to 2030" study, which among the studies analysed is the only one providing detailed long term economic hypotheses by individual EU country, assumes a gradual convergence of the EU economies by 2030 in terms of per capita income (European Commission, 2003a, p. 37). In 2000, the average GDP per capita was 7% higher in Belgium than in EU-15. Convergence over 30 years implies on average a 0,2% lower growth rate[28] for Belgium than for EU-15. As a first approximation, the same relationship will be assumed here for all four scenarios.

On the other hand, in the population projection of the National Institute for Statistics and the Federal Planning Bureau, the average population growth rate over the period 2000-2040 is expected to be 0,16% per year, while CPB considers a median growth of 0% for EU-15 over the same period.

These two effects (lower growth of GDP per capita and higher population growth than EU-15) are both small and tend to compensate each other in their effect on GDP. Therefore and given the level of uncertainty, we have considered for Belgium the same GDP growth

[28] In practice, the speed of convergence will depend on the level of international cooperation. However, given the small initial difference in GDP per capita between Belgium and EU-15, this does not fundamentally alter the conclusion drawn.

assumptions as the CPB study for EU-15. We have also extrapolated the 2020-2040 evolution to 2050. This means a slightly lower average GDP growth than in "European Energy and Transport Trends to 2030"

The GDP growth assumptions for Belgium, taken from EU-15 and extrapolated to 2050, are given in the following table.

GDP growth for Belgium in the four scenarios

	Strong Europe	Regional Economies	Regional Communities	Global Economy
GDP growth (% per annum)				
00-20	1,8%	2,3%	1,1%	2,7%
20-50	1,3%	1,6%	0,2%	2,3%
GDP per capita growth (% per annum)				
00-20	1,4%	2,1%	1,1%	2,3%
20-50	1,1%	1,7%	0,5%	2,1%

Sources: CPB (2003a), CPB (2003b)

As to the growth rates in value added by main final energy consumption sector (manufacturing, construction, services, transport, agriculture), a rough estimate of their values can also be estimated on the basis of "European Energy and Transport Trends to 2030", by assuming for each sector the same evolution relative to GDP as in this study.

It can be verified that the sectoral growth rates for Belgium in "European Energy and Transport Trends to 2030", once corrected for the difference in GDP growth between Belgium and EU-15, are very close to those for EU-15[29]. Therefore, the sectoral growth rates for EU-15 can also be considered as indicative of those for Belgium.

As far as activity variables are concerned, an important factor in the translation of international developments to the Belgian context is the localisation (at home or abroad) of energy intensive activities. This factor will be discussed in section 4 (sub-sections on the energy sector and industry).

4.1.3 Energy prices

4.1.3.1 International fuel prices

For reasons of consistency, it is suggested to consider the 4 scenarios the international fuel prices of the CPB-RIVM study (CPB, 2004). These prices have been calculated using a partial

[29] Except for the energy sector, but this sector only represents about 3% of GDP.

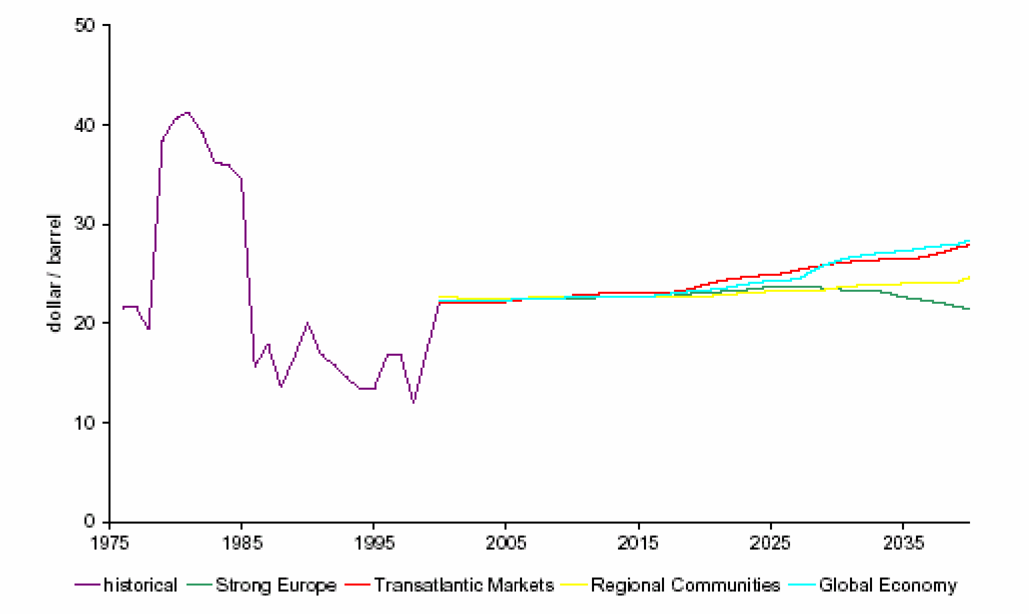
equilibrium model of the global oil market and partial-equilibrium model of the European natural gas and electricity market[30].

Crude oil

The average long term price of oil in the CPB-RIVM study is presented graphically below. It is expected to remain rather flat in all scenarios.

Note that this long term price should not be confused with the short term price of oil, for which, as experience has shown, large fluctuations are probable (which explains the currently higher oil price).

Average annual price of oil; historically and in four scenarios, 1975 - 2040 (all prices in 2000-$)



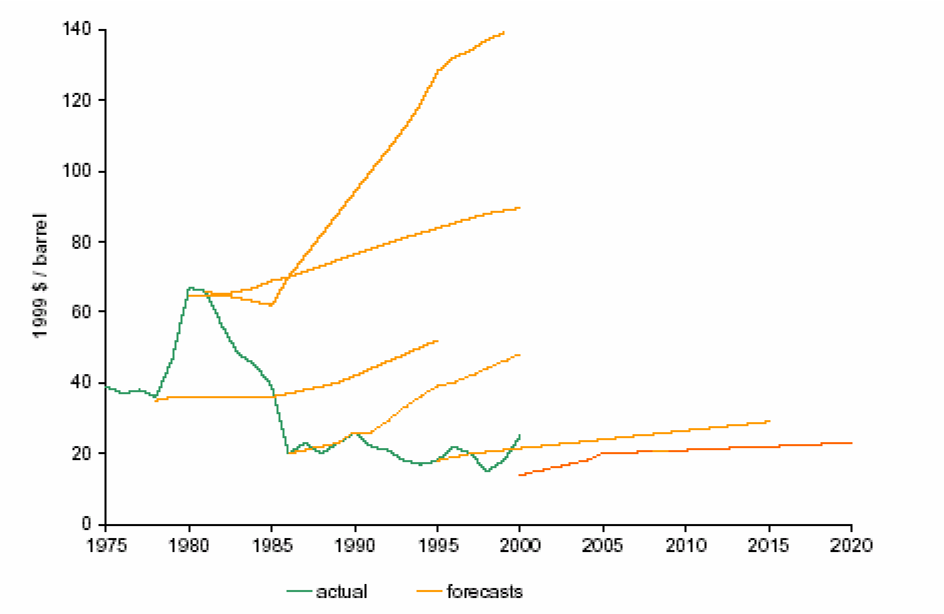
Source: CPB (2004)

This price development is broadly in line with the International Energy Agency's *World Energy Outlook 2004* and recent studies of the European Commission (see below). Such price evolutions are based on a belief in the working of market forces and the fact that price increases will spur investments in oil exploration and production, as well as in energy efficiency and the development of alternative sources.

However, forecasting the long term oil price is a difficult task, and many past forecasts happened to be far away from the observed values (see for example US DOE price forecasts in the figure below). Michael Lynch, who had rightly forecast a stabilisation of the oil price during the nineties, has pointed out the methodological errors in the geophysical models and the difficulties in creating a valid microeconomic model (Lynch, 2002).

[30] Note that these prices are not necessarily the same as those of the IPCC SRES scenarios (IPCC, 2000). The latter were also endogenous, and vary significantly according to the scenario and the model used.

Oil prices: forecasts of the US Department of Energy (DOE) and actual levels[31]



Source: Lynch (2000), as taken over by CPB (2004)

In view of the remaining uncertainties, we suggest to take into account alternative price levels through sensitivity analyses.

In the context of the recent oil price increases, price evolutions such as those of the CPB-RIVM scenarios are getting increasingly questioned. Members of the study's Steering group[32] as well as several stakeholders consider that higher prices in the long term are also plausible and also recommended that sensitivity analyses be carried out.

In OECD (2004) several long term oil price scenarios up to 2030 are calculated, under alternative combinations of assumptions concerning OPEC supply and pricing strategy, GDP growth and income and price elasticities of oil demand. In the most extreme case, the oil price rises by around $20 relative to the baseline price of $35 per barrel in 2030.

[31] The price of Brent crude oil has reached over 50 $/bbl in March 2005. However, it is not comparable with a long term price, as it is influenced by anticipations of possible short term supply disruptions. Besides, the recent increase is less strong when expressed in euros, as the value of the dollar in euros has declined by some 30% since 2000.

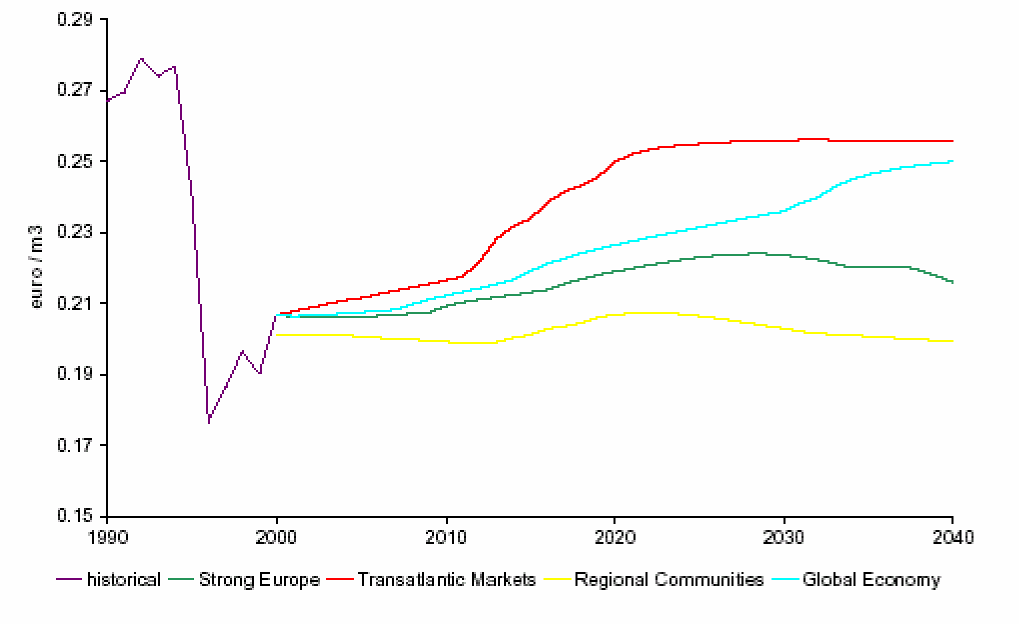
[32] Reference was made amongst other to the arguments of ASPO, the Association for the Study of Peak Oil & Gas, Uppsala, Sweden (www.peakoil.net), which foresees huge price increases because of resource depletion and increasing demand, and expects world oil production to reach a peak soon.

Natural gas

While the market of crude oil is fairly integrated at world scale, it is not the case for natural gas, because of the high transportation costs.

The natural gas price in Europe is expected to increase at the end of the current decade, once European gas fields become depleted. The increase will be higher in GLOBAL ECONOMY and particularly in REGIONAL ECONOMIES, because of more tense relations with the gas supply countries in this scenario.

Price of natural gas in Europe; historically and in four scenarios, 1990-2040 (wholesale prices, average of all consumer groups, excluding VAT)



Source: CPB (2004)

Note that the gas prices shown on the figure are expressed in euros.

Steam coal

No price assumption is mentioned for coal in CPB (2004).

It is generally considered that the long term price of coal should be independent of the oil price and rather reflect the marginal production cost. Assumptions made in the literature depend on expectations about productivity improvements in coal mines. They vary from a stabilization of the international coal price (European Commission, 2003a) to an increase of 15-35% in 2030 from current levels (European Commission, 2003b), while the IEA World Energy Outlook 2004 foresees an increase of about 15% (see tables below).

Comparison with other sources

As mentioned above, the CPB price assumptions are broadly in line with scenario studies of the IEA and the European Commission.

Below are given, for comparison, the price assumptions of the IEA's World Energy Outlook 2004, published in October 2004, the EC's European Energy and Transport Trends to 2030 and the EC's WETO study.

IEA World Energy Outlook 2004

Fossil fuel price assumptions (in year-2000 dollars)

	2003	2010	2020	2030	Evol. 2003-2030
IEA crude oil imports ($/barrel)	27	22	26	29	7,4%
Natural gas ($/MBtu GCV)					
Europan imports	3,4	3,3	3,8	4,3	26,5%
OECD steam coal imports ($/tonne)	38	40	42	44	15,8%

Source: IEA (2004)

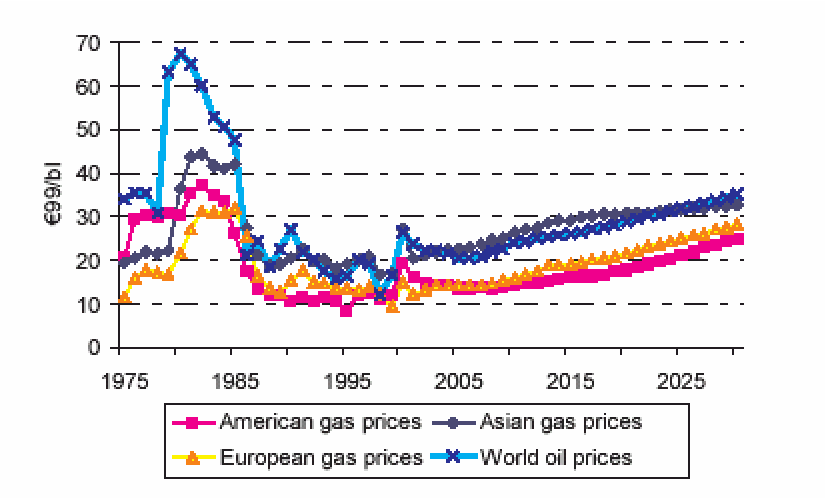
European Energy and Transport Trends to 2030

Average border prices in the EU (in year-2000 $ per barrel of oil equivalent)

	2000	2010	2020	2030	Evol. 2000-2030
Crude oil	28,0	20,1	23,8	27,9	-0,4%
Natural gas	15,5	16,8	20,6	23,3	
Hard coal	7,4	7,2	7,0	7,0	-5,4%

European Commission (2003a)

Oil and gas price assumptions in WETO study



Source: European Commission (2003b)

4.1.3.2 Prices of final energy carriers

It is suggested to assume that the prices of final energy carriers will develop as a function of the impact that the world prices will have on them, taking into account transportation and refining cost, as well as taxes, where appropriate.

The competition between energy carriers will of course also be influenced by the price of CO2, which will be substantial in the STRONG EUROPE scenario.

4.1.4 Number of degree-days

An important part of the energy use in the residential and tertiary sectors is climate dependent.

Therefore, the climate dependent fuel use is to be corrected in correspondence with the assumed number of degree-days in the period 2000-2050. For these degree-days, a reference temperature of 15°C is considered (source: FIGAS). One possibility is to use the observed number of degree-days in 2000. The number of degree-days was 1714 in 2000. Another possibility is to use the mean number of observed degree-days over the last period of 30 years: this is 2010.

Vito analysed the evolution in the number of degree-days during the period 1961-2003. From this statistical analysis, it appears that the decrease in number of degree-days is statistically significant. Therefore, a further decrease of the number of degree-days in the period 2004-2050 is a third possibility.

Several scenarios can be considered on the basis of the evolution of the temperature:

- consider 2010 degree-days as the mean temperature for future scenarios,
- maintain 1714 degree-days for future scenarios,
- consider a further temperature rise and thus a further lower number of degree-days.

4.6 Transport

4.6.1 Introduction

Energy use in the transport sector is divided into different sub-sectors. In general, the following sub sectors are distinguished:

- Road transport
- Rail traffic
- Inland navigation
- Maritime shipping
- Aviation (air traffic)
- Off-road

Off-road is not handled in this study. For this sub-sector we refer to the ongoing study "Emissions of off road mobile machines in the framework of international reporting" financed by the Flemish Innovation Administration (Aminal) (report summer 2005).

To assess greenhouse gas emissions from transport, there are five main groups of influencing parameters:

- activity data (mobility figures);
- share in technologies;
- feedstock differentiation for fuel supply;
- evolution in fuel efficiency;
- emission factors of greenhouse gases.

By analogy with other sectors, we set up four scenarios for transport. In this study we will not present a forecast for the transport sector towards the years 2020 and 2050, but we will illustrate **divergent future developments** in the framework of scenarios GLOBAL ECONOMY, REGIONAL ECONOMIES, STRONG EUROPE (GLOBAL SUSTAINABILITY) AND REGIONAL COMMUNITIES. For transport, the main driving forces for the four different policies become clear and can be discussed, rather than discussing uncertainties of several assumptions. This should be kept in mind when reading the text about the transport sector and in interpreting the results presented for the four different scenarios.

With current policymaking, we are now situated somewhere between the scenarios REGIONAL ECONOMIES and REGIONAL COMMUNITIES. Figure 3 gives a first insight of the differences in scenarios for transport. We give an indicative quantification of the most important parameters affecting greenhouse gas emissions from transport for each scenario. The parameters are influenced by the horizontal axis "economy – equity and environment", and the vertical axis "international cooperation – regionalisation".

- **Activity data**: The level of activity is most influenced by the economic activity, international cooperation has also an effect on freight transport. Model shift and load factor are most influenced by the importance of environment in the pursued policy.

- Development of **new technologies** (primary energy source, additional energy source (mainly for onboard electricity), feedstock differentiation for fuels): The penetration of new technologies is most influenced by international cooperation or not. The sustainability of the new technologies is most influenced by the importance of environment in the pursued policy.

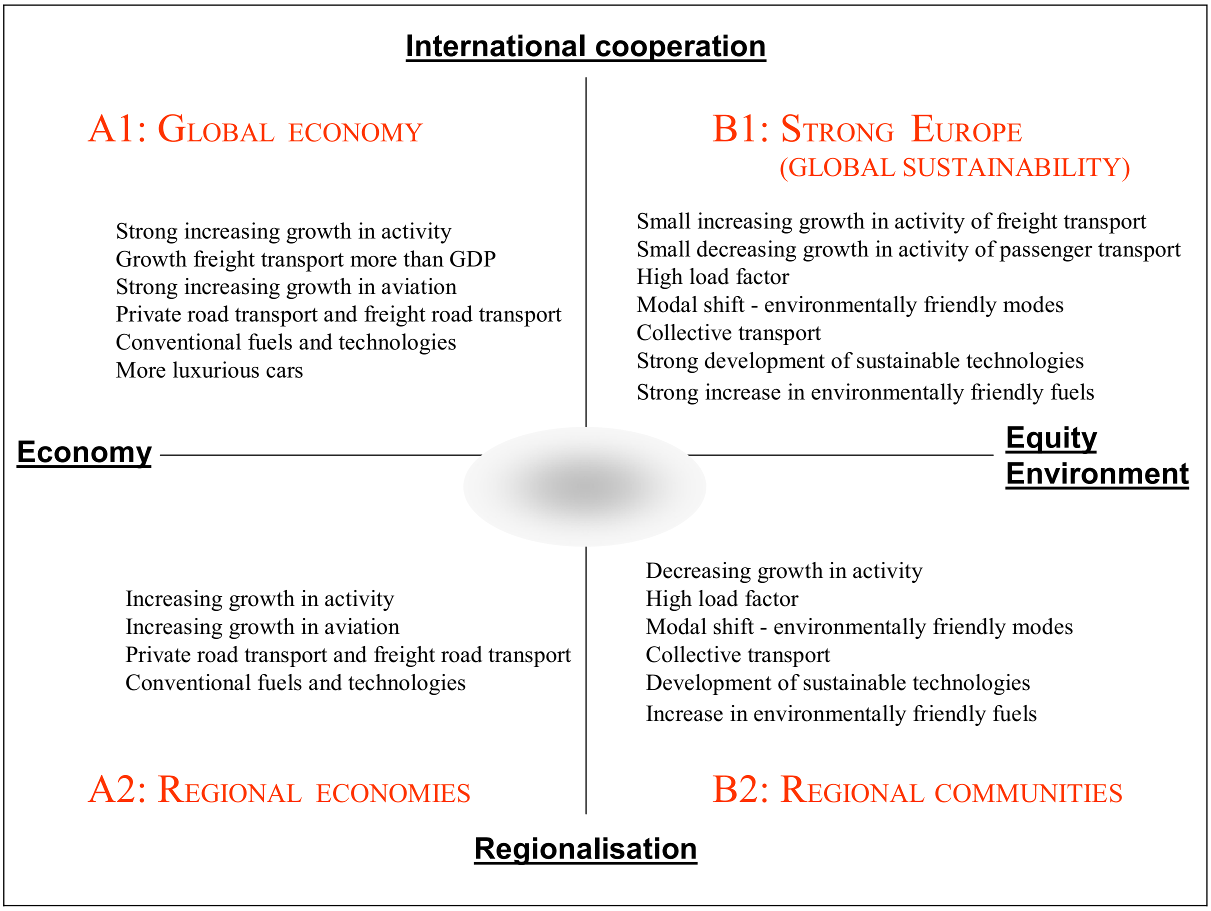


Figure 3: Brief description of the four scenarios for transport

4.6.2 Activity data

As said earlier, the **level of activity** is mostly influenced by the economic activity; international cooperation also has an effect on freight transport. **Modal shift** and **load factor** are most influenced by the importance of environment in the pursued policy.

First we will give an indicative quantification of the influence of economy on the level of activity for the period 2000-2020 and the period 2020-2050. Then we will give an indicative qualification for the modal shift and load factor, that are most influenced by the pursued policy on environment.

For activity data, the remarks given by the stakeholders are partly integrated in the following. Other comments are listed in sections 4.6.7.1 and 4.6.7.5.

4.6.2.1 Economic influence on the activity in the four scenarios

How will the economic environment of Belgium have an influence on the activity of passenger and freight transport? An **indicative quantification** is given in this section for the four different scenarios: GLOBAL ECONOMY, REGIONAL ECONOMIES, STRONG EUROPE (GLOBAL SUSTAINABILITY) and REGIONAL COMMUNITIES.

4.6.2.1.1 Starting point

As the basis information for activity data differs by transport mode, we first describe the different information sources (medium term projections).

For road transport, rail traffic and inland navigation, the starting point is the baseline defined by Vito within the SUSATRANS project [1]. For road transport forecasts are based on historical trends derived from statistics for the last five years [2]. We took the sum of the evolution in the three regions. For rail traffic we took into account a further annual increase of passenger traffic by 1,2 to 1,4 %. For freight transport we assumed a stabilisation of the traffic from 2003 on [3]. For inland navigation, we assumed an annual increase of transport by about 2 % until 2020 [3].

For maritime freight shipping we derived figures from the European Centre for Strategic Analysis for the harbour of Antwerp and applied them to all Belgian sea harbours [4]. For maritime transport of passengers we found no figures. We assumed 1 % less growth in activity than for maritime goods.

For inland navigation, no figures were found for annual activity growth rates for passenger transport. By analogy with maritime shipping, we assumed an annual activity growth rate of 1 % less than freight transport (inland navigation).

For aviation, we took activity growth rates for the four scenarios from Eurocontrol [5]. We assumed that the activity growth rates are the same for passenger and freight transport. No baseline projection was needed for this mode, as Eurocontrol defined four scenarios that are similar with the scenarios in **Figure 3**.

4.6.2.1.2 Period 2000-2020

To give activity growth rates for the four different scenarios, we based ourselves on the above mentioned starting point and the relative differences in scenarios from **global domestic product** (GDP) of the EU-15 (Table 8). For freight transport we took into account the GDP growth to derive the four scenarios from the hereabove baseline activities. For passenger traffic the GDP per capita growth is more suitable.

Table 8: EU-15 GDP for the period 2000-2020

2000-2020 (% per annum)	GLOBAL ECONOMY	REGIONAL ECONOMIES	STRONG EUROPE (GLOBAL SUSTAINABILITY)	REGIONAL COMMUNITIES
Freight - GDP growth	2,7%	2,3%	1,8%	1,1%
Passenger - GDP per capita growth	2,3%	2,1%	1,4%	1,1%

Source: CPB (2003a) [6], CPB (2003b) [7]

For the scenario GLOBAL ECONOMY (except for aviation), we increased the activity growth rate in the period 2000-2020 by **1%** (absolute) because **freight transport** is assumed to grow stronger in this scenario than GDP.

The results are shown in Table 9 for passenger traffic and in Table 10 for freight transport. As mentioned earlier, modal shift and load factor are not included in the annual growth figures. Activity data for passenger and freight road traffic is given in vehicle kilometre (vkm). Whereas for the other transport modes, activity is given in passenger kilometre (pkm) for passenger traffic and tonne kilometre (tkm) for freight transport.

Table 9: Activity 2000-2020: annual growth rates (%) passenger traffic under the four scenarios

	GLOBAL ECONOMY	**REGIONAL ECONOMIES**	**STRONG EUROPE (GLOBAL SUSTAINABILITY)**	**REGIONAL COMMUNITIES**
PASSENGER ROAD (tonkm)				
car	1,6%	1,4%	0,9%	0,7%
bus	1,8%	1,7%	1,1%	0,9%
coach	1,0%	0,9%	0,6%	0,5%
motorcycle	0,7%	0,6%	0,4%	0,3%
PASSENGER RAIL (pkm)				
conventional	2,0%	1,8%	1,2%	1,0%
HST	3,6%	3,3%	2,2%	1,7%
PASSENGER INLAND NAVIGATION (pkm)				
inland navigation	1,9%	1,7%	1,1%	0,9%
PASSENGER MARITIME SHIPPING (pkm)				
Maritime shipping	2,2%	2,0%	1,3%	1,0%
PASSENGER AVIATION (pkm)				
aviation	3,3%	3,0%	2,7%	2,3%

Table 10: Activity 2000-2020: annual growth rates (%) freight transport under the four scenarios

	GLOBAL ECONOMY	REGIONAL ECONOMIES	STRONG EUROPE (GLOBAL SUSTAINABILITY)	REGIONAL COMMUNITIES
FREIGHT ROAD (vkm)				
light duty	2,7%	1,4%	1,1%	0,7%
heavy duty	2,4%	1,2%	1,0%	0,6%
FREIGHT RAIL (tkm)				
rail	0,5%	-0,4%	-0,3%	-0,2%
FREIGHT INLAND NAVIGATION (tkm)				
inland navigation	4,7%	3,1%	2,4%	1,5%
FREIGHT MARITIME (tkm)				
Maritime shipping	5,0%	3,4%	2,6%	1,6%
FREIGHT AVIATION (tkm)				
aviation	3,3%	3,0%	2,7%	2,3%

4.6.2.1.3 Period 2020-2050

For the four scenarios in the period 2020-2050, we took into account the relative difference of the EU-15 **GDP** between the period 2000-2020 (Table 8) and the period 2020-2050 (Table 11).

Table 11: EU-15 GDP for the period 2020-2050.

2020-2050 (% per annum)	GLOBAL ECONOMY	REGIONAL ECONOMIES	STRONG EUROPE (GLOBAL SUSTAINABILITY)	REGIONAL COMMUNITIES
Freight - GDP growth	2,3%	1,6%	1,3%	0,2%
Passenger - GDP per capita growth	2,1%	1,7%	1,1%	0,5%

Source: CPB (2003a) [6], CPB (2003b) [7]

For the scenario GLOBAL ECONOMY (except for aviation), we assumed an additional increase in activity growth rate (1%) in the period 2000-2020. For the period 2020-2050, we do not take into account an additional growth rate (saturation).

The results are shown in Table 12 for passenger traffic and in Table 13 for freight transport. Modal shift and load factor are not includes in the annual growth figures.

Table 12: Activity 2020-2050: annual growth rates (%) passenger traffic under the four scenarios

	GLOBAL ECONOMY	REGIONAL ECONOMIES	STRONG EUROPE (GLOBAL SUSTAINABILITY)	REGIONAL COMMUNITIES
PASSENGER ROAD (vkm)				
car	1,4%	1,1%	0,7%	0,3%
bus	1,7%	1,4%	0,9%	0,4%
coach	0,9%	0,7%	0,5%	0,2%
motorcycle	0,6%	0,5%	0,3%	0,2%
PASSENGER RAIL (pkm)				
conventional	1,8%	1,5%	1,0%	0,4%
HST	3,3%	2,7%	1,7%	0,8%
PASSENGER INLAND NAVIGATION (pkm)				
inland navigation	1,7%	1,4%	0,9%	0,4%
PASSENGER MARITIME SHIPPING (pkm)				
maritime	2,0%	1,6%	1,0%	0,5%
PASSENGER AVIATION (pkm)				
aviation	3,0%	2,4%	2,1%	1,0%

Table 13: Activity 2020-2050: annual growth rates (%) freight transport under the four scenarios

	GLOBAL ECONOMY	REGIONAL ECONOMIES	STRONG EUROPE (GLOBAL SUSTAINABILITY)	REGIONAL COMMUNITIES
FREIGHT ROAD (vkm)				
light duty	1,4%	1,0%	0,8%	0,1%
heavy duty	1,2%	0,8%	0,7%	0,1%
FREIGHT RAIL (tkm)				
rail	-0,4%	-0,3%	-0,2%	0,0%
FREIGHT INLAND NAVIGATION (tkm)				
inland navigation	3,1%	2,2%	1,8%	0,3%
FREIGHT MARITIME SHIPPING (tkm)				
maritime	3,4%	2,4%	1,9%	0,3%
FREIGHT AVIATION (tkm)				
aviation	2,8%	2,1%	2,0%	0,4%

4.6.2.2 Impact of environmental policy on transport activity

How will the environmental policy in Belgium have an influence on the **modal shift** and **load factor** for passenger and freight transport? An **indicative qualification** is given in this section for the four different scenarios: GLOBAL ECONOMY, REGIONAL ECONOMIES, STRONG EUROPE (GLOBAL SUSTAINABILITY) and REGIONAL COMMUNITIES.

The environmental aspect is reflected in modal shift, load factor and shift to more sustainable technologies. The shift to more sustainable technologies will be discussed in section 4.6.3 (share of technologies). To give indications on how modal shift and load factor will affect the annual growth rates for the different scenarios and different transport modes, analyses with a **multi-modal traffic model** are necessary. Figure 1 gives an indication of how the modal shift will occur for the four different scenarios. A thin arrow means a smaller modal shift is happening than is the case for a thick arrow.

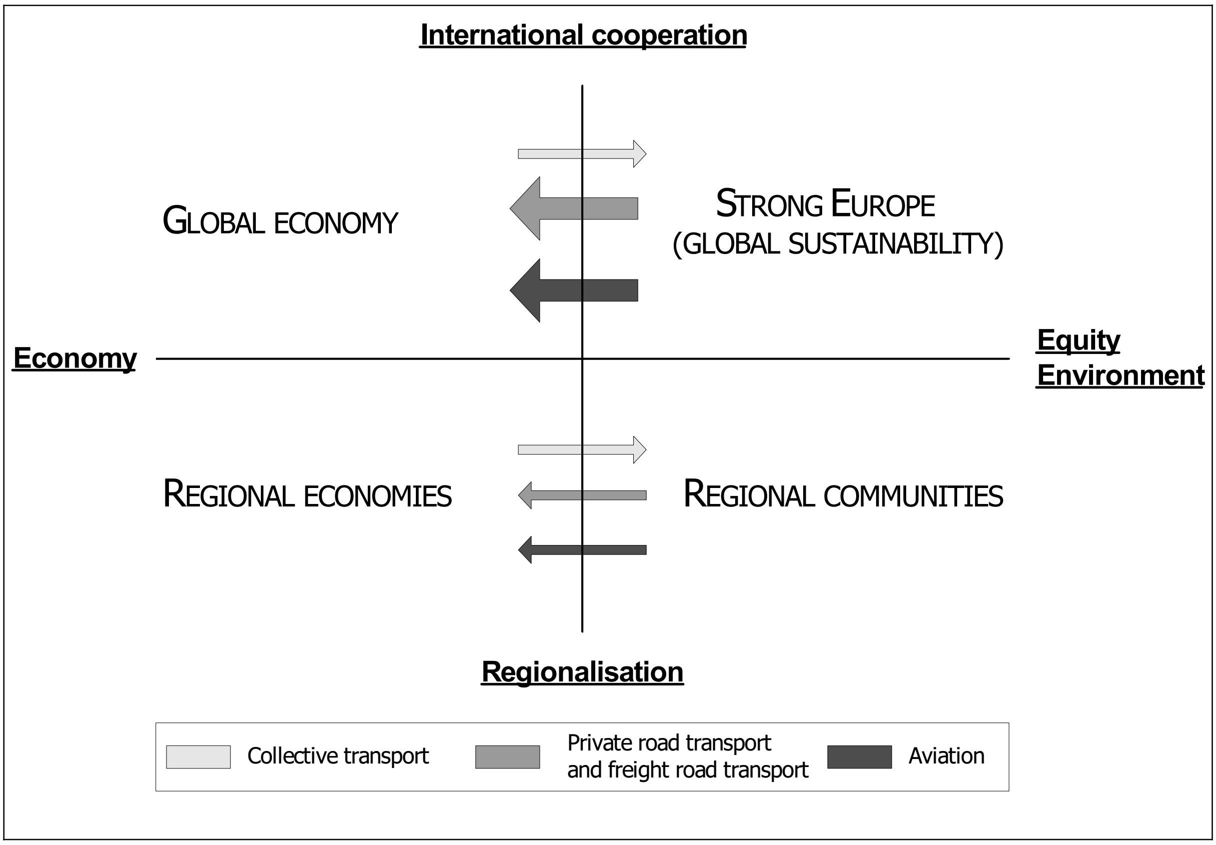


Figure 1: Impact of environmental policy on transport activity.

Collective transport
In this study, we refer to rail traffic, inland navigation, maritime shipping and busses as collective transport. Collective transport with a high load factor is more environmentally friendly than non collective transport. The scenarios STRONG EUROPE (GLOBAL SUSTAINABILITY) and REGIONAL COMMUNITIES will have the greatest shift to collective transport because society is environmentally oriented through the pursued policy.

Private road transport and freight road transport
The scenarios GLOBAL ECONOMY and REGIONAL ECONOMIES will experience the greatest shift to non collective transport because of the society is more economically than environmentally oriented . Modal shift will be even greater in scenario GLOBAL ECONOMY than in REGIONAL ECONOMIES, because of more financial abundance, more freedom in choosing the fastest way to travel, load factor is of less importance.

Aviation
Aviation is an environmentally unfriendly and expensive transport mode and will have the greatest activity in the scenario GLOBAL ECONOMY. In REGIONAL ECONOMIES, there is also a modal shift to aviation, but less than in the scenario GLOBAL ECONOMY because of the financial aspect of aviation.

4.6.2.3 Spatial organisation of the activity

Mobility figures are influenced by the spatial organisation of activities as they directly induce the needs and choices of transport modes. For the final assessments of greenhouse gas emissions from transport, it should be more suitable to apply traffic models integrating parameters that affect the spatial organisation of activities (labour market, European market, investments in infrastructure, …). One has to bear in mind that this approach, although the most appropriate, needs very complex and time consuming traffic modelling.

4.6.3 Share in technologies

As said earlier, the penetration of newly developed technologies (primary energy source, additional energy source (mainly for onboard electricity)) and feedstock differentiation for fuels) is most influenced by the level of international cooperation. The sustainability of the new technologies is most influenced by the importance of environment in the pursued policy.

In this section, we consider engine technologies as such (**primary energy source and additional energy source (mainly for onboard electricity)**) and do not differentiate for fuels used. Here we do not make a distinction between diesel made from crude oil, natural gas, coal or renewable energy sources. Fuel aspects are discussed in section 4.6.4.

In the future, many technologies and combination of different technologies might penetrate. In our assumptions, only the major trends for possible technologies are implemented.

The remarks given by the stakeholders about our approach are partly integrated in section 4.6.3. They are also listed in section 4.6.7.2.

4.6.3.1 General statements

Based on findings of the SUSATRANS project and a brief specific literature study on technologies in 2020 and beyond, we drew up tables with **indicative market shares** of the different technologies of newly purchased vehicles or other transport modes[65]. This was done for each scenario. The figures were discussed and adjusted by a VITO expert judgement. In Table 14, a distinction is made between passenger traffic and freight transport. A subdivision is made per vehicle category. Furthermore, we made a distinction between primary energy source and additional energy source (mainly for onboard electricity), as some technologies such as fuel cells and solar cells will start or will only be introduced in transport applications as additional energy source (mainly for onboard electricity). We give the introduction year of the technologies and the market share in new vehicles for the year 2020 and 2050.

In the year **2020** and beyond we will observe an increased plurality of different propulsion technologies. Hybrid (IC-electric) vehicles will penetrate the market (market share depending on the scenario). Fuel cell automotive application will start from additional energy source (mainly for onboard electricity) in all scenarios and then develop to prime mover application (first in niche markets) in the scenarios STRONG EUROPE (GLOBAL SUSTAINABILITY) and REGIONAL COMMUNITIES. Electricity as prime energy will only penetrate the market with cost-effective advanced batteries / energy storage systems [8]. Effective penetration is foreseen after 2020, the market share depending on the scenario.

Meanwhile **diesel-fuelled passenger cars** will increase in the medium term, as in Belgium consumers prefererence for diesel fuelled vehicles increases when buying a new passenger car. In 1990 about 34 % of the new cars were diesel fuelled. In 2000 and 2003 they were respectively 55 % and 65 %. Under the SUSATRANS baseline scenario Vito assumes a

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[65] For non-road not only new transport modes are mentioned but also renewing of propulsion engines for motive sources or additional energy source (mainly for onboard electricity).

further increase up to 75 % in 2010, afterwards (until 2020) this level stays constant, but also takes into account hybrid diesel-electric. IFEU [9] assumes that among all passenger cars in Belgium, 50 % of them will be diesel fuelled cars by the year 2020. Depending on the source there could be significant differences in the evolution of diesel-fuelled cars.

In 2003 an ESTO study reported that hydrogen vehicles could be cost competitive after the year 2015 [10]. The further deployment of **hydrogen and fuel cells** requires a high priority within the energy and transport policy of the European Union in order to achieve a significant impact of hydrogen and fuel cells on the security of energy, the economic competitiveness of the EU and the targeted greenhouse gas emission reductions until a 2050 time frame [11]. Therefore, we only implement hydrogen technologies as primary energy source in the scenarios STRONG EUROPE (GLOBAL SUSTAINABILITY) and REGIONAL COMMUNITIES. Perhaps this assumption should be adjusted, as some of the **stakeholders**[66], believe that fuel cells are very sustainable, so an introduction could be achieved in all scenarios. In scenarios GLOBAL ECONOMY and REGIONAL ECONOMIES, the shortage of crude oil and fluctuations of energy prices will also have an effect on the **introduction of fuel cells** (even as a primary energy source) and other alternative motor fuels and technologies.

In all four scenarios we do not foresee a penetration of **alternative motor technologies as propulsion systems** for heavy duty freight transport and coaches because of their radius of action. Also no penetration of alternative motor technologies as propulsion systems is foreseen within maritime shipping and aviation. On the other hand alternative energy systems as additional energy sources (mainly for onboard electricity) will be applied in each transport mode.

Solar cells as additional energy sources (mainly for onboard electricity) are also a feasible option for transport applications [12]. This system must not only be seen as environmentally friendly, but also as a **luxury**. A great advantage of solar cells is that they can keep a vehicle cool even when the engine is not running. The cooling system is already in use before starting the vehicle, resulting in a high **energy efficient** process. We do not only foresee solar cells in the scenarios STRONG EUROPE (GLOBAL SUSTAINABILITY) and REGIONAL COMMUNITIES, where solar cells will be present because of environmental concerns, but also in the scenario GLOBAL ECONOMY because of its luxury.

The penetration of fuel cells and solar cells as **additional energy sources (mainly for onboard electricity)** in private passenger cars and light duty vehicles will not be as significant as their penetration in busses, coaches and heavy duty vehicles. Solar cells need a great surface, becoming a design requirement. Fuel cells require a certain flexibility from the drivers, who have to fill up with two different fuels.

Fuel cells can provide a large potential at night, whereas solar cells are better used during the daytime. Therefore, we assumed that solar cells as additional energy sources (mainly for onboard electricity) will penetrate more in busses then in coaches and heavy duty trucks. The penetration of fuel cells as additional energy sources (mainly for onboard electricity) will therefore be greater in coaches and heavy duty vehicles than in busses.

Because of less available surface area in ships (persons, open cargo space, movable cargo space, …), we foresee that the penetration of fuel cells as additional energy sources (mainly

[66] Stakeholders consultation, Brussels, 15th April 2005.

for onboard electricity) will be slightly greater than the penetration of solar cells in inland navigation and maritime shipping.

We assume that the introduction of additional energy sources (mainly for onboard electricity) on airplanes occurs later than for all other modes, because their implementation requires extra research.

Modes that drive mainly on electricity and hybrid and fuel cell vehicles are not foreseen to have an additional energy source (mainly for onboard electricity).

About 10 % (average) of the total energy use of a vehicle is applied for the supply of **onboard electricity**, in peak traffic it may reach20 % . This percentage will rise in the future (the growth varies for each scenario).

As said earlier, we do not present a forecast for the transport sector towards the years 2020 and 2050, but we will illustrate **divergent future developments** for the four scenarios: GLOBAL ECONOMY, REGIONAL ECONOMIES, STRONG EUROPE (GLOBAL SUSTAINABILITY) AND REGIONAL COMMUNITIES. We give an indicative quantification of the share in technologies (primary energy source, additional energy source (mainly for onboard electricity)) for the period 2000-2020 and the period 2020-2050 in the four scenarios.

4.6.3.2 Four scenarios

The scenario **GLOBAL ECONOMY** is a rather conservative scenario as it is focussed on economic growth and environment is of less importance. Even in 2050 we see no introduction of fuel cells on hydrogen for propulsion applications[67].

The scenario **REGIONAL ECONOMIES** is the most conservative scenario of the four scenarios. In 2020 no significant introduction of alternative motor technologies occurs. In 2050 we see only a very small shift towards alternatives.

The scenario **STRONG EUROPE (GLOBAL SUSTAINABILITY)** is the most environmentally-advanced scenario. Based on the present development status of hydrogen and fuel cells, a broader market introduction is expected to start around 2015 leading to a market share of a few percent in 2020 [11]. In 2050, the market will be dominated by (hybrid) combustion engines (biofuels and advanced conventional fuels), electric vehicles and hydrogen (fuel cell and hybrid H2).

The scenario **REGIONAL COMMUNITIES** is an environmentally friendly scenario but in a less advanced way than under the STRONG EUROPE scenario. More opportunities will be created for hybrids. Also significant progress is made towards hydrogen engine systems, but to a less extent than under the STRONG EUROPE (GLOBAL SUSTAINABILITY) scenario.

The indicative quantification of the share in technologies for the four different scenarios is given in Table 14. Stakeholders commented figures of this table as follows :F

- Penetration of fuel cell as a primary energy source;

[67] Remark of some stakeholders: introduction of fuel cell on hydrogen in all four scenarios.

- In a time horizon up to 2050: also innovative options for shipping should be thought of, e.g. solar energy, modern sailing technologies, …;
- Assumptions on fuel cell and solar cell on ships could be underestimated for ships as luxury becomes more and more important in the design of living areas.

Table 7 was however not adapted to stakeholders points of view.

Table 14: Market share technologies (%) for the four scenarios

		Global Economy			Regional Economies			Strong Europe (Global Sustainability)			Regional Communities		
		intro. year	2020	2050	intro. year	2020	2050	intro. year	2020	2050	intro. year	2020	2050
PASSENGER ROAD													
Car	primary energy source												
	CNG	Av.	5	10	Av.	~0	5	Av.	10	~0	Av.	10	~0
	diesel	Av.	69	49	Av.	74	59	Av.	44	10	Av.	34	20
	electric	Av.	~0	5	Av.	~0	5	Av.	5	25	Av.	5	10
	fuel cell H2	Not	~0	~0	Not	~0	~0	2015	2	30	2030	~0	5
	gasoline	Av.	15	10	Av.	25	20	Av.	5	10	Av.	20	15
	H2 ICE	Not	~0	~0	Not	~0	~0	2015	2	~0	2015	5	~0
	hybrid CNG	Not	~0	~0	Not	~0	~0	2015	5	~0	2015	5	~0
	hybrid diesel	2015	5	15	2015	~0	5	2015	15	10	2015	10	25
	hybrid gasoline	Av.	5	10	Av.	~0	5	Av.	10	11	Av.	10	20
	hybrid H2	Not	~0	~0	Not	~0	~0	2015	1	4	2030	~0	5
	LPG	Av.	~1	~1	Av.	~1	~1	Av.	1	~0	Av.	1	~0
	additional energy source (mainly for onboard electricity)												
	none		94	80		98	98		90	70		94	80
	fuel cell	2005	1	5	2005	~1	~1	2005	5	15	2005	3	10
	solar cell	2005	5	15	2005	~1	~1	2005	5	15	2005	3	10
Bus	primary energy source												
	CNG	Av.	2	7	Av.	~0	5	Av.	15	~0	Av.	10	~0
	diesel	Av.	95	80	Av.	~100	85	Av.	60	21	Av.	75	30
	electric	Av.	1	5	Av.	~0	5	Av.	5	25	Av.	5	10
	fuel cell H2	Not	~0	~0	Not	~0	~0	2015	5	33	2030	~0	10
	hybrid diesel	Av.	2	8	Av.	~0	5	Av.	15	21	Av.	10	50
	additional energy source (mainly for onboard electricity)												
	none		90	75		98	98		85	65		92	75
	fuel cell	2005	5	10	2005	~1	~1	2005	5	15	2005	3	10
	solar cell	2005	5	15	2005	~1	~1	2005	10	20	2005	5	15

Table 14 (continue) Market share technologies (%) for the four scenarios

		Global economy			Regional economies			Strong Europe (global sustainability)			Regional communities		
		intro. year	**2020**	**2050**	**intro. year**	**2020**	**2050**	**intro. year**	**2020**	**2050**	**intro. year**	**2020**	**2050**
PASSENGER ROAD													
Coach	primary energy source												
	diesel	Av.	100	100	Av.	100	100	Av.	100	100	Av.	100	100
	additional energy source (mainly for onboard electricity)												
	none		90	75		98	98		85	65		92	75
	fuel cell	2005	5	15	2005	~1	~1	2005	10	20	2005	5	15
	solar cell	2005	5	10	2005	~1	~1	2005	5	15	2005	3	10
Motor-cycle	primary energy source												
	gasoline	Av.	100	100	Av.	100	100	Av.	100	100	Av.	100	100
PASSENGER RAIL													
Conven-tional	primary energy source												
	diesel	Av.	4	4	Av.	4	4	Av.	4	~0	Av.	4	2
	electric	Av.	96	96	Av.	96	96	Av.	96	100	Av.	96	98
TCV	primary energy source												
	electric	Av.	100	100	Av.	100	100	Av.	100	100	Av.	100	100

Table 14 (continue) Market share technologies (%) for the four scenarios

		GLOBAL ECONOMY			REGIONAL ECONOMIES			STRONG EUROPE (GLOBAL SUSTAINABILITY)			REGIONAL COMMUNITIES		
		intro. year	2020	2050	intro. year	2020	2050	intro. year	2020	2050	intro. year	2020	2050
PASSENGER INLAND NAVIGATION													
Inland navigation	primary energy source												
	fuel cell	2015	5	10	Not	~0	~0	2015	10	25	2015	5	10
	gas oil	Av.	95	90	Av.	100	100	Av.	90	75	Av.	95	90
	additional energy source (mainly for onboard electricity)												
	conventional		98	90		98	98		90	75		93	85
	fuel cell	2005	1	5	2005	~1	~1	2005	5	15	2005	5	10
	solar cell	2005	1	5	2005	~1	~1	2005	5	10	2005	2	5
PASSENGER MARITIME SHIPPING													
Maritime shipping	primary energy source												
	heavy fuel oil												
	diesel oil												
	gas oil												
	additional energy source (mainly for onboard electricity)												
	conventional		98	90		98	98		90	75		93	85
	fuel cell	2005	1	5	2005	~1	~1	2005	5	15	2005	5	10
	solar cell	2005	1	5	2005	~1	~1	2005	5	10	2005	2	5
PASSENGER AVIATION													
Aviation	primary energy source												
	kerosene	Av.	100	100	Av.	100	100	Av.	100	100	Av.	100	100
	additional energy source (mainly for onboard electricity)												
	conventional		95	80		100	95		90	65		90	75
	fuel cell	2025	~0	5	Not	~0	~0	2015	5	15	2015	5	10
	solar cell	2015	5	15	2030	~0	5	2015	5	20	2015	5	15

Table 14 (continue) Market share technologies (%) for the four scenarios

		Global economy			Regional economies			Strong Europe (global sustainability)			Regional communities		
		intro. year	2020	2050	intro. year	2020	2050	intro. year	2020	2050	intro. year	2020	2050
FREIGHT ROAD													
Light duty	primary energy source												
	CNG	Av.	5	10	Av.	~0	5	Av.	10	~0	Av.	10	~0
	diesel	Av.	69	49	Av.	74	59	Av.	44	10	Av.	34	20
	electric	Av.	~0	5	Av.	~0	5	Av.	5	25	Av.	5	10
	fuel cell H2	Not	~0	~0	Not	~0	~0	2015	2	30	2030	~0	5
	gasoline	Av.	15	10	Av.	25	20	Av.	5	10	Av.	20	15
	H2 ICE	Not	~0	~0	Not	~0	~0	2015	2	~0	2015	5	~0
	hybrid CNG	Not	~0	~0	Not	~0	~0	2015	5	~0	2015	5	~0
	hybrid diesel	2015	5	15	2015	~0	5	2015	15	10	2015	10	25
	hybrid gasoline	Av.	5	10	Av.	~0	5	Av.	10	11	Av.	10	20
	hybrid H2	Not	~0	~0	Not	~0	~0	2015	1	4	2030	~0	5
	LPG	Av.	~1	~1	Av.	~1	~1	Av.	1	~0	Av.	1	~0
	additional energy source (mainly for onboard electricity)												
	none		94	80		98	98		90	70		94	80
	fuel cell	2005	1	5	2005	~1	~1	2005	5	15	2005	3	10
	solar cell	2005	5	15	2005	~1	~1	2005	5	15	2005	3	10
Heavy duty	primary energy source												
	diesel	Av.	100	100	Av.	100	100	Av.	100	100	Av.	100	100
	additional energy source (mainly for onboard electricity)												
	none		90	75		98	98		85	65		92	75
	fuel cell	2005	5	15	2005	~1	~1	2005	10	20	2005	5	15
	solar cell	2005	5	10	2005	~1	~1	2005	5	15	2005	3	10
FREIGHT RAIL													
Rail	primary energy source												
	diesel	Av.	22	22	Av.	22	22	Av.	20	5	Av.	20	15
	electric	Av.	78	78	Av.	78	78	Av.	80	95	Av.	80	85

Table 14 (continue) Market share technologies (%) for the four scenarios

		GLOBAL ECONOMY			REGIONAL ECONOMIES			STRONG EUROPE (GLOBAL SUSTAINABILITY)			REGIONAL COMMUNITIES		
		intro. year	2020	2050	intro. year	2020	2050	intro. year	2020	2050	intro. year	2020	2050
FREIGHT INLAND NAVIGATION													
Inland navigation	primary energy source												
	fuel cell	2015	5	10	Not	~0	~0	2015	10	25	2015	5	10
	gas oil	Av.	95	90	Av.	100	100	Av.	90	75	Av.	95	90
	additional energy source (mainly for onboard electricity)												
	conventional		98	90		98	98		90	75		93	85
	fuel cell	2005	1	5	2005	~1	~1	2005	5	15	2005	5	10
	solar cell	2005	1	5	2005	~1	~1	2005	5	10	2005	2	5
FREIGHT MARITIME SHIPPING													
Maritime shipping	primary energy source												
	heavy fuel oil												
	diesel oil												
	gas oil												
	additional energy source (mainly for onboard electricity)												
	conventional		98	90		98	98		90	75		93	85
	fuel cell	2005	1	5	2005	~1	~1	2005	5	15	2005	5	10
	solar cell	2005	1	5	2005	~1	~1	2005	5	10	2005	2	5
FREIGHT AVIATION													
Aviation	primary energy source												
	kerosene	Av.	100	100	Av.	100	100	Av.	100	100	Av.	100	100
	additional energy source (mainly for onboard electricity)												
	conventional		95	80		100	95		90	65		90	75
	fuel cell	2025	~0	5	Not	~0	~0	2015	5	15	2015	5	10
	solar cell	2015	5	15	2030	~0	5	2015	5	20	2015	5	15

*AV. = Available
Into. year = introduction year

4.6.4 Feedstock differentiation for fuel supply

In this section, we look at the feedstock differentiation for transport fuel supply. For example, we make a distinction between diesel made from crude oil, natural gas, coal or renewable energy sources.

The feedstock differentiation of transport fuels is influenced by the importance of environment in the pursued policy and by the level of international cooperation.

Remarks from the stakeholders consultation on this section are summarised in section 4.6.7.3.

4.6.4.1 General statements

Fuels can be produced from different primary energy vectors. Mainly we distinguish four groups of fuels.

- **Conventional fuels**: diesel and gasoline fuels derived from crude oil. These fuels will not change dramatically but fuel specifications could further evolve.
- **Advanced conventional fuels**: diesel and gasoline derived from natural gas or coal.
- **Biofuels**: blended in conventional and advanced conventional fuels, but also pure. Liquid fuels from biomass could also be considered within this group.
- (Exotic) **Alternative fuels**: natural gas, hydrogen, electricity, …

Table 16 shows the feedstock differentiation for the relevant transport fuels. The introduction year of a primary energy vector is given together with the **feedstock differentiation for primary energy vectors** for the years 2020 and 2050.

When defining the feedstock differentiation for primary energy fuels for the four different scenarios, we took into account the European strategy towards sustainable sources for energy for climate protection and to improve the security of energy supply. As a part of this strategy the European Commission approved in 2003 two directives dealing with biofuels:

- 2003/30/EC: Directive for the promotion of the use of biofuels or other renewable fuels for transport. Targets for the member states are: 2 % market share by the end of 2005 and 5,75 % by the end of 2010. These market shares are calculated on the basis of energy content of all together petrol and diesel for transport.
- 2003/96/EC: Directive for the taxation of energy products and electricity. Article 16 deals with biofuels and other products produced from biomass. It provides the possibility to apply an exemption or reduced rate of taxation.

The European Commission envisages implementation levels for the use of alternative fuels for transport. **Targets** were proposed for biofuels, natural gas and hydrogen for the years 2005, 2010, 2015 and 2020, see Table 15. Depending on the individual environmental orientation of the four scenarios, the European targets for alternatives are reached or not.

Table 15 : European targets for alternative fuels in transport 2005-2020

Year	Biofuel %	Natural gas %	Hydrogen %	Total %
2005	2			2
2010	6	2		8
2015	(7)	5	2	14
2020	(8)	10	5	23

The European Commission reported that even by 2030 new energy forms, such as methanol, ethanol and hydrogen will remain insignificant in absolute terms under a baseline scenario [13]. This is primarily because of cost considerations but also because of lack of infrastructure for supply and distribution of new fuels.

European strategy currently under discussion within the Alternative Motor Fuel Contact Group are levels up to 15 % biofuels beyond 2010, the feasibility depends on the technological progress and policy priorities [14]. In an earlier stage even a level up to 20 % was mentioned [15]. Depending on the individual environmental orientation of the four scenarios, the European targets for biofuels are met or not.

Figures of ~11 % biofuels (of the total fuel consumption) by 2020 and ~20 % biofuels by 2050 were proposed in a scenario by the study 'Climate Change' of the Umweltbundesambt [16].

Major concerns with biofuels and other alternative fuels are production costs, and for gaseous fuels the **distribution** and improvement of **storage** solutions. If there is no breakthrough in this area, biofuels and alternatives will remain marginal.

We assume a smaller penetration of biofuels for shipping in the year 2020 because currently maritime shipping is not included in the biofuel directive 2003/30/EC.

We foresee that in the year 2020 about 20 % of the hydrogen will be produced through electrolysis. Hydrogen derived from natural gas is much cheaper because of advantage of mass production scale, but hydrogen produced through electrolysis may be obtained from a variety of primary energy sources, among which renewable energy sources. How hydrogen is produced after 2020 is dependent on the pursued policy and therefore different penetration figures for bio-hydrogen and electrolysis are assumed in the scenarios.

4.6.4.2 Four scenarios

The feedstock differentiation for primary transport fuels under the four scenarios is given in Table 16. These figures were also discussed and adjusted by a VITO expert judgment.

GLOBAL ECONOMY

In 2020 only the current EC directive on biofuels is met. The target of 8 % biofuels as stated in de COM document (2001) 547, is only met by 2050 and not by 2020. Biofuels penetrate more slowly in aviation because of the fuel specification. Hydrogen is produced for 80 % from natural gas and 20 % through electrolyse. Advanced conventional fuels penetrate only very slowly into the transport fuel market.

REGIONAL ECONOMIES

In 2020 current EC directive on biofuels is not met on time, but only by 2050. Hydrogen is produced for 80 % from natural gas and 20 % through electrolysis. Advanced conventional fuels penetrate only very slowly into the transport fuel market.

STRONG EUROPE (GLOBAL SUSTAINABILITY)

It is the most advanced scenario concerning share in primary fuels. By 2015, a biofuel level of 15 %, now under discussion, is assumed to be met. In 2020 the 20 % is met due to the decrease of diesel and gasoline as transport fuels (increase of electricity and hydrogen). Under this scenario also a lot of opportunities are given to advanced conventional fuels. In 2050 hydrogen will only be partly produced from natural gas. We assume that bio-hydrogen will have a significant market share.

REGIONAL COMMUNITIES

Initial targets set by the EC on biofuels are met by 2020, afterwards we see only a small increase as Belgium has only a limit possibility to produce biomass or biofuels. In 2050 hydrogen will only be partly produced from natural gas. Hydrogen will be mainly produced through electrolysis, the market share of bio-hydrogen will be small.

Table 16: The feedstock differentiation for primary transport fuels (%) for the four scenarios

	GLOBAL ECONOMY			REGIONAL ECONOMIES			STRONG EUROPE (GLOBAL SUSTAINABILITY)			REGIONAL COMMUNITIES		
	intro. year	2020	2050	intro. year	2020	2050	intro. year	2020	2050	intro. year	2020	2050
diesel												
advanced conventional fuels	2020	~0	5	2020	~0	~0	2020	~0	80	2020	~0	40
biofuels	2005	6	8	2005	6	6	2005	15	20	2005	8	10
conventional fuels	Av.	94	87	Av.	94	94	Av.	85	~0	Av.	92	50
electric (see energy sector)												
hydrogen												
bio-hydrogen	Not	~0	~0	Not	~0	~0	2025	~0	25	2040	~0	10
electrolyse	2005	20	50	2005	20	50	2005	20	55	2005	20	65
natural gas	2005	80	50	2005	80	50	2005	80	20	2005	80	25
gasoline												
advanced conventional fuels	2020	~0	5	2020	~0	~0	2020	~0	80	2020	~0	40
biofuels	2005	6	8	2005	6	6	2005	15	20	2005	8	10
conventional fuels	Av.	94	87	Av.	94	94	Av.	85	0	Av.	92	50
kerosene												
advanced conventional fuels	2020	~0	5	2020	~0	5	2020	~0	80	2020	~0	40
biofuels	2020	~0	4	2020	~0	~0	2005	15	20	2005	8	10
conventional fuels	Av.	100	91	Av.	100	95	Av.	85	~0	Av.	92	50
ship fuels												
advanced conventional fuels	2020	~0	5	2020	~0	~0	2020	~0	80	2020	~0	40
biofuels	2010	2	8	2010	2	5	2005	15	20	2005	8	10
conventional fuels	Av.	98	87	Av.	98	95	Av.	85	~0	Av.	92	50

*AV. = Available
Into. year = introduction year

4.6.5 Evolution in efficiency

The sustainability of the new technologies, including energy efficiency is most influenced by the importance of environment in the pursued policy. Although one has to bear in mind that environmental aspects gain more and more attention, also in a GLOBAL ECONOMY scenario.

Comments of the stakeholders on efficiency and environment are integrated in the current section.

4.6.5.1 General statements

The evolution of efficiency in transport is influenced by different technical parameters:

- improvement of the engine system;
- improvement of the transmission-driveline system;
- improvement of aerodynamics;
- reduction of vehicle weight;
- improvement of safety applications;
- introduction of luxury accessories (air-conditioning, heated seats, …;
- drive optimalisation (board computers, cruise control, personal drive behaviour, …);
- …

Besides these technical (vehicle) parameters, fuel efficiency is also influenced by :
- occupancy level / loading factor;
- transport organisation /logistics.

An appropriate management of these parameters can l avoid (useless) vehicle kilometres.

The European policy has already an influence on the efficiency of cars through the ACEA/KAMA/JAMA agreement upon CO_2 emissions from new passenger cars. In 1998 the European Commission and the European automobile industry (ACEA) – followed in 1999 by the Korean (KAMA) and Japanese (JAMA) car manufacturers – signed a voluntary agreement on the reduction of CO_2 emissions from newly purchased cars. The three main points of the agreement are:
- The reduction of the average CO_2 emission from new cars to 140 g/km by 2008/2009. An intermediate target was set for 2003 at 170 g/km;
- The industry put on the market cars that emit 120 g/km;
- The industry undertakes further improvements beyond 2008. An initial target for average news cars was set at 120 g/km for 2012. This target is now under discussion as not feasible.

Here we start by giving **general figures** for efficiency improvement for transport that we found in literature. To set up the four scenarios for efficiency improvement for transport, **further in depth research is required**. However, this research goes beyond the scope of the current study.

4.6.5.2 General figures

For transport, the ECOFYS study [17] concluded that new propulsion systems could be a factor two higher than nowadays systems. Combined with other measures such as mass reduction, efficiency could be increased by a factor four for passenger cars and light duty vehicles. For heavy duty vehicles, the amelioration is not that big, as they are already relatively efficient. An amelioration by a factor two to three could be realistic.

Table 17 and Table 18 gives growth rates for energy efficiency for in pkm and tkm as reported in other literature.

Table 17 : Grow rates for energy efficiency for passenger transport (per pkm), Belgian and European figures

Source	Segment	00-05	05-10	10-20	20-30
FPB [18] Belgium	Total 00-30	1% (annual)			
EC [13] (PRIMES) European figures	Private Cars	< 1%	20,5%		14,5%
	Rail Transport	39,5%			7,5%
	Aviation	37%			11%
	Total 00-10	7%			
	Total 00-20	17,3%			
	Total 00-30	27%			

Table 18 : Growth rates for energy efficiency for freight transport (per tkm), Belgian and European figures

Source	Segment	Annual 00-30	Period 00-30
FPB [18] Belgium	Road transport		15%
	Rail transport		64%
	Inland navigation		8%
	Total	0.3%	
EC [13] (PRIMES) European figures	Road transport		14.3%
	Rail transport		47.5%
	Inland navigation		6.2%
	Total		7.6%
VITO/PBV [19] Flanders/Belgium	Inland navigation		7%*

* Under baseline scenario within time period 2000-2020.

For inland navigation, more details are available on Belgian fleet energy consumptions per ton kilometre from 1990 until 2020 [1, 19].

For ocean shipping we refer to the ongoing projects ECOSONOS and MOPSEA financed by the Belgian Scientific Policy, first reports will become available in 2005.

As said earlier, the European policy has already an influence on the efficiency improvement of new passenger cars. How this was implemented in different transport models is further discussed in the following.

Table 19 shows the implementation level of the voluntary agreement on CO_2 reduction from new cars as assumed under the baseline in different studies. In most of the studies no correction has been done for the additional fuel consumption due to the operation of air-conditioning systems in cars. Vito assumes (supported by monitoring) that the CO_2 targets are fulfilled for about 50 % and even less when taking into account the energy use (~CO_2) needed for the air-conditioning in cars [20], see Figure 5.

Table 19 : implementation rate of the voluntary agreement on CO_2 reduction from new cars according to different baselines.

Source	Implementation rate		Correction for airco
	140 g/km	120 g/km	
FPB [18]	100 %	100 %	No
Vito 2004[1]	50 %	50 %	Yes
TREMOVE [21]	100 %	0 %	No
EC (PRIMES) [13]	100 %	100 %	No

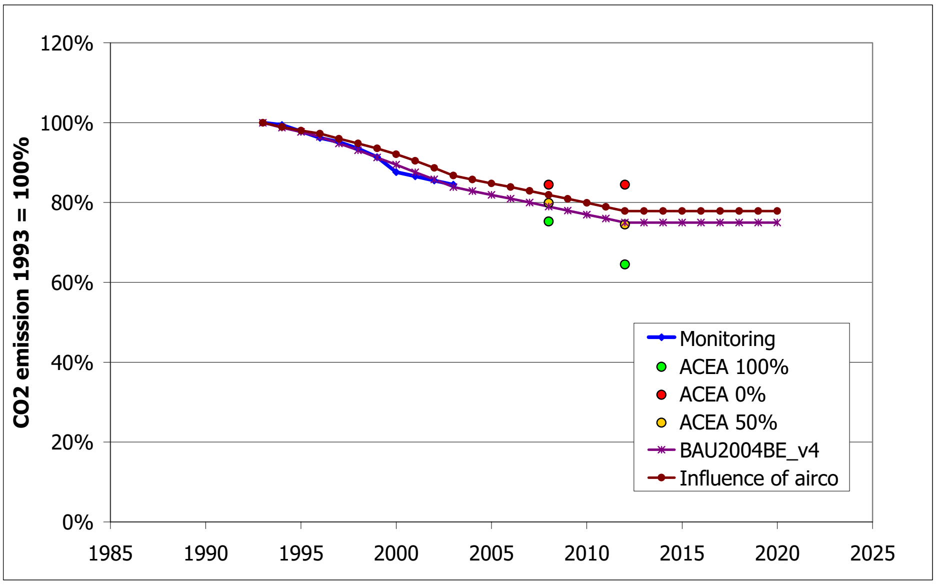

Figure 5: Assumptions by Vito on CO_2 emissions from new passenger cars and effect of air conditioning

4.6.5.3 Four scenarios

For the four different scenarios, we need efficiency improvement figures over the period 2000-2020 and the period 2020-2050 for the different transport modes.

As already mentioned the quantification of the four scenarios as regard to fuel efficiency improvements goes beyond the scope of the current study. It is a **very technical and complex discussion**, asking for a **detailed analysis**. Air conditioning is only one aspect that has an influence on the efficiency

4.6.6 Emission factors

To assess **greenhouse gas emissions** from transport we also need suitable emission factors for the different fuel technologies and generations of technologies. Below we give a brief overview of the available information. The findings of the 6th framework programme Artemis are not yet available, so they could not be integrated.

Furthermore, emission factors for other transport modes than road, are often very rough and do not take into account the technological evolution of these modes. For inland shipping Vito derived emission factors for inland navigation on Belgian waterways for the period 1990-2020 taking into account technological improvements [19].

4.6.6.1 CO_2

Emission calculation for road transport is often based on the emission factor of COPERT III [22]. COPERT III provides only emission factors for conventional (gasoline, diesel, LPG) vehicles.

The COPERT III methodology provides an extensive set of fuel consumption functions for road transport, from which CO_2 emission could be derived.

Although Vito (TEMAT model) and TREMOVE make a further differentiation for small diesel cars as their share in the market increases from 2000 on.

Technological improvements over the fuel efficiency, thus also CO_2 (for fossil fuels), are not taken into account in the emission legislation neither in COPERT III. In section 4.6.5.2 we gave an indication of the (theoretically) efficiency improvement. Current models used in Belgium made other assumptions:

- Vito (TEMAT 2004) only foresees an improvement in fuel consumption for passenger cars (see ACEA agreement), for the other road vehicles no improvements were assumed. This was a result of the recent validation of TEMAT emission model. TEMAT 2000 took into account improvement for all vehicle categories.
- TREMOVE assumes efficiency improvement until 2009.

4.6.6.2 CH_4

For CH_4, a difference is made between vehicles categories, road types. For passengers cars and light duty vehicles speed depending formulas are available. Even reduction factors are available for technologies up to euro 4 (cars and LDV) and euro 5 (HDV).

4.6.6.3 N_2O

For N_2O, COPERT provides only very rough emission factors. For heavy duty vehicles (HDV) and motorcycles no distinction is made between road type, vehicle subcategory and technological generation. For light duty vehicles (LDV) and passenger cars different factors are given for urban, rural and highway traffic. Only for gasoline cars a distinction is made for catalyst and non catalyst cars.

Euro 5 heavy duty vehicles (HDV) repect very stringent emission standards for NO_x. An urea-based selective catalytic reduction system is effective to reduce NO_x emissions. However N_2O is produced as a by-product in the system. The N_2O level should be about a factor 0,022 of the NO_x emissions of a euro 5 (HDV) [23]. When available, findings of the Artemis project have to be analysed and integrated in the greenhouse gas assessments for transport.

4.6.6.4 HFC

More and more road vehicles are equipped with an air-conditioning system, resulting in potential emissions of HFC, strong greenhouse gases. Future emission scenarios have to take into account this evolution towards more air-conditioning systems in cars. Also the improvements in the European legislation as regard to cooling systems have to be taken into account.

4.6.7 Integration of stakeholders comments

4.6.7.1 Activity figures

Remarks about some influencing parameters have not been integrated in the text itself, but are listed here below:

- "STRONG EUROPE" seems to be a normative scenario.
  Answer: no, because only external European taxes are included, no Belgian taxes. Furthermore, no back casting approach has been applied.
- Some questions concerned the feasibility of the STRONG EUROPE scenario. The assumptions made at midterm seem to optimistic.
- A lot of parameters seem to be implicit, but not explicit (e.g. cost of transport).
- Integrated multi modal transport as a separate transport mode?
- Determinants of transport demand only depend upon the global domestic product. In reality, they also depend on labour cost, taxability, ... Also moves between economic sectors and regions are important.
- Effect of environmental town and country planning?
- Capacity of the different transport modes need to be verified. Starting from vehicle kilometres and then splitting up to the different transport modes.
- The concerns of changes of mobility culture? Patterns are difficult to quantify.
- Is transit traffic been taken into account?
  Yes, as we started from Belgian traffic counts, which also integrates kilometres driven by foreign vehicles.

4.6.7.2 Propulsion technologies

Remarks up on this influencing parameters have been incorporated in the text itself, but are not quantified in the tables. The remarks are briefly summarised below:

- Sustainability could be an important factor for the introduction of alternative motor fuels and technologies, also in the scenarios GLOBAL ECONOMY AND REGIONAL ECONOMIES. The shortage of crude oil and fluctuations on energy prices will also have an effect on the introduction of alternative motor fuels and technologies.
- In a time horizon up to 2050 also innovative options for shipping should be thought of: e.g. solar energy, modern sailing technologies;
- Assumptions on fuel cell and solar cell at ships could be underestimated for ships as luxury becomes more and more important in the living areas.
- Do heavy duty vehicles incorporate alternative motor fuels and technologies?

4.6.7.3 Fuels

Remarks on some influencing parameters has not been integrated in the text itself, but are listed here below:

- Biofuels: 20 % in STRONG EUROPE IN 2050?
- Why only in STRONG EUROPE such a high level of biofuels? Market conditions? Blending up to 5 % is technically feasible in current vehicles. Vehicles have to be adjusted when using more then 5 % biofuels.
- Biofuels: limited capacity – apply in transport or other sector.
- Vision of the European Commission on alternative motor fuels: 20 % by 2020. Stakeholders: natural gas is probably the best option to reach this level.

4.6.7.4 Efficiency and emission factors

Discussed at the stakeholders consultation are :

- Influence of air-conditioning systems on greenhouse gas emissions from transport? Important?
- The importance of N_2O as by-product in three-way catalysts and DeNOx catalysts?
- Importance of aspects of loading factor, organisation of transport, …

4.6.7.5 Relevant studies on emission modelling for transport in Belgium

Besides the earlier mentioned studies SUSATRANS, MOPSEA, ECOSONOS and emission from off-road, the stakeholders refer to the following two studies :

- IFEU (Germany) study on future emissions (CO_2) from road transport in Belgium. Study financed by FEBIAC and the Belgian Administration of Transport and Mobility. Results will be available by January 2006;
- Federal Planning Bureau develops a transport model for midterm and long term projections in Belgium (PLANET). Assessments could be performed on the effect of the Belgian Policy on transport, as well as cost-benefit analyses. The PLANET model determines the interaction between the macro economic factors, the transport sector, costs, policies and the environment.

At the stakeholders consultation it has been stated that more detail models are needed to assess future activity figures. Models mentioned were: SCENES, TREMOVE, ….

4.6.8 Abbreviations

CH_4	Methane
HFC	Hydro fluoro carbons
NO_X	Nitrogen oxides
N_2O	Nitrous oxide
CO_2	Carbon dioxide
HDV	Heavy duty vehicle
LDV	Light duty vehicle
COPERT	Computer programme to calculate emissions from road transport
TEMAT	Transport Emissions Model to Analyse (non-) Technological measures
LPG	Liquefied Petroleum Gas
GDP	Gross Domestic Product
EU	European Union
vkm	Vehicle kilometres
pkm	Passenger kilometres
tkm	Tonne kilometres
HST	High Speed Train
IC	Internal combustion
EC	European Commission
COM	Commission of the European Communities

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