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CONSUMPTION AND EMISSIONS

Simulations with the ELSA model

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Framework of the study

This report discusses the scenario calculations performed with the Energy and Lifestyle Simulation Approach (ELSA Model) for the Netherlands in the framework of the EU project 'Consumers' Lifestyles and Pollutant Emissions', which has been co-financed by the EU DG-XII Environment programme (EU contract number EV5V-CT94-0373) and ECN (project number 1.7169). Furthermore, adaptations of the model system carried out in the afore mentioned project, notably with regard to emission sources, goods transport and scenario control, are discussed as well.

Abstract

This report discusses the scenario specification and calculations for the Netherlands performed with the ELSA (energy & lifestyle simulation approach) Model. The study has been carried out in the framework of the EU Environment programme. Co-operating institutes in Germany and France produced similar studies for those countries.

Four scenarios, named Business as Usual, Stagnation, Sustainability though Reflective Consumption and, Sustainability through Technological Breakthrough, have been specified. The results apply to the period 1990-2010. The results illustrate the possible developments of the national economy, household expenditures, the consumption of electricity, natural gas and motor fuels by households, the indirect energy embodied in the expenditures on non-energy goods and services and the aggregate emissions of CO_2, SO_2, NO_x, CO and VOC.

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SUMMARY

In co-operation with IER (Stuttgart, G) and C3ED (Versailles, F) ECN Policy Studies has carried out a project named 'Consumers' Lifestyles and Pollutant Emissions'. The project has been carried out in the framework of the EU DGXII Environment Programme.

The present report discusses the simulation exercises for the Netherlands with the ELSA model based on four scenarios. In addition to backgrounds and simulation results also the principal additions and adaptations of the model are explained. The four scenarios were defined in such a way as to create sufficient contrast between possible future societies, both in terms of social-economic and technical conditions and in terms of consequences for energy requirement and environmental pressures. The scenario calculations were performed stepwise in order to enable the separation of various causes, such as population growth, increasing wealth and lifestyle features and, technological developments.

The model produces simulations about the economy - notably the income distribution and private consumption expenditures, the dwelling stock and natural gas consumption, the appliance stock and electricity consumption, the car stock and the use of motor fuels, the indirect energy requirement of production and transport for non-energy consumer goods and, last but not least the resulting emissions of CO_2, SO_2, NO_x, CO and VOC.

The scenarios run from 1990 to 2010. They contrast each other primarily in three aspects, being economic growth, labour productivity and labour market and, environmental technology. The scenarios have the following names:
Business as Usual (BU);
Stagnation (SG);
Sustainability through Reflective Consumption (SC);
Sustainability through Technological Breakthrough (ST).

The Business as Usual scenario can be regarded as the reference development with an average macro economic growth rate of 2% per year, while the increase of labour productivity is rated at 2.5% per year. However, thanks to 10% labour time reduction in 2010 the number of jobs remains approximately constant. The average energy efficiency improves with 22% in 20 years from 1990 to 2010. The share of renewables in total primary fuel input hardly increases in the BU scenario and the same applies to the SG scenario. On the other hand in the Sustainability through Reflective Consumption scenario (SC) the share of renewables rises up to 8% and in the Sustainability through Technological Breakthrough scenario (ST) a rise of nuclear up to 10% has been assumed.

Partly due to socio-economic differences and partly due to assumed societal differences between scenarios there are also differences in the composition of the dwelling stock (more detached dwellings in ST, more flats in SC) and the size of the private car stock (from 6.5 million in SC up to 8 million in ST). Furthermore, the evolution of consumption varies significantly over the scenarios due to different

income distributions and different price levels in the various scenarios. A summary of key differences compared to the BU scenario can be found in the table S.1 below.

Table S.1 *Key differences between scenarios [%]*

	BU	SG	SC	ST
Economic growth	2,0	1,25	1,25	2,75
Labour productivity	2,5	2,00	0,75	2,50
Labour time reduction	-10,0	0,00	-20,00	-10,00
Energy efficiency	+22,0	+14,00	+33,00	+40,00

The linkage of consumption of households to an input-output system implies that the production effects of what consumers demand can be shown. It also means that the emissions attributed to household consumption can be decomposed by sector of emission. Table S.2 illustrates this by showing the CO_2 emissions in 1990 and in 2010 according to four scenarios. The indirect emissions are decomposed in those created during production (in the Netherlands for endogenous products, abroad for the imported goods) and those created during transportation of raw materials, intermediate goods and finished goods. The direct emissions are decomposed into three segments being, the use of natural gas at home, residential consumption of electricity (in fact also attributed) and motor fuel consumption of private cars.

Table S.2 *CO_2 emissions due to direct and indirect energy consumption [in Mton]*

	1990	BU 2010	SG 2010	SC 2010	ST 2010
Production	49	54	53	41	44
Goods transport	17	23	21	23	27
Households (direct)					
gas	21	28	28	28	29
electricity	8	9	9	7	7
Motor fuels	19	21	21	18	20
Total	114	135	133	116	127

The figures in table S.2 are rounded off, therefore small differences in the table may be actually negligible. The increase of emission levels is remarkable, though it should be noted that the natural gas use at home (and the CO_2 emissions) may have a large reduction potential. On the other hand for electricity and motor fuels the results are fairly optimistic. Moreover, even if the emissions from residential natural gas use would be halved, it appears to be hard to reduce emission levels in other scenarios than the SC scenario. Energy efficiency improvement of the goods transportation sector has been held constant. So, the increasing amounts of CO_2 attributed to this sector reflect the growth of international trade. The contribution of domestic transport amounts only to 12% due to the limited distances and the large share of inland shipping. Clearly, the high economic growth in the ST scenario leads to more haulage of commodities across borders. Remarkably enough the impacts on trade in the SG and SC scenario differ so much. It means that the change in the consumption package in the SC scenario leans more heavily on imports than it does in the SG scenario. This could be termed a lifestyle effect.

The model also produces results for NO_x, SO_2, CO and VOC. For these emissions not only fuel switching and energy efficiency are relevant, but also specific abatement technologies can be very effective, such as catalyst convertors in cars. The reduction of these emissions in the Netherlands is heavily institutionalized through policy frameworks that are in various stages of operationalization. SO_2 abatements are already on track for quite a time and also NO_x emission reductions are implemented widely and often according to sectoral targets. Yet, notably for NO_x some sectors such transport are likely to fail the reduction target, since impacts of technology are more than compensated by growth of output (i.e. vehicle kilometers or tonkilometers). We supposed that the degree to which targets would be met varies by scenario.

Emission reduction is brought about in 3 ways:
1. through increasing energy efficiency, that means the specific energy use is decreasing;
2. through fuel switching, notably in the SC and ST scenario;
3. through specific abatement technology.

Table S.3 *Simulated emissions in four scenarios for 2010*

	1990	BU	SG	SC	ST
CO_2 [Mton]	114	135	133	116	127
NO_x [kton]	310	179	224	144	146
SO_2 [kton]	94	47	63	36	35
CO [kton]	632	661	678	583	653
VOC [kton]	206	122	151	93	98

It turns out to be very difficult to restraint the growth of CO_2 emissions. Nevertheless, the SC and ST scenarios clearly demonstrate that efforts do pay off. At the same time these scenario exercises hint at the fact that the current prevailing energy and emission strategies, which tend to lean for the greater part on technological progress can be risky if no more fundamental thoughts are dedicated about the *way society develops*. We will return to this issue in the next chapter.

The results for the other emissions are influenced by the variation in target fulfilment mentioned above. The results here indicate that major advancements and close-to-target results seem to be achieved for sulphur-dioxide (SO_2). For the other major acidifying emission (NO_x) the results are less reassuring. Whereas an overall reduction target of about 70% is specified, the best result rates just over 50%. Admittedly, the goods transport sector has been left untreated and would account for a substantial reduction. Yet, in the most fortunate case that might result in 60% reduction, however please note that exactly for this sector the achievements are very much dependent on actions abroad.

In conclusion it can be stated that the scenarios are explorative and by no means meant to give definitive information. Rather, elements from the Sustainability through Reflective Consumption scenario and the Sustainability through Technological Breakthrough scenario can be used to formulate new research questions:
1. Is there a level of economic growth that is high enough to enable sufficient technological progess in energy and emission technology without creating such a voluminous extra production that all gains in reductions of emission levels are lost?

2. What is the minimum economic growth required from the viewpoint of social acceptability (this social notion preferably includes also relations between rich and poor countries).
3. What measures with respect to end-use prices, market (re-) regulations, and social and physical infrastructure would facilitate the compromise between economic growth and a (timely) move toward sustainability.

1. INTRODUCTION

Whereas environmental policies and research efforts have been focusing on the production side of economies for a long time, and for good reasons, more recently the demand side receives more attention. The demand side, notably demand for goods and services by private consumers, the government and by other countries through export, is the eventual economic driving force for producing all goods and services. In this respect private consumption is the most important category, particularly if one reckons that a major part of the exports is, though abroad, eventually also caused by private consumption. Bearing this in mind a project has been carried out that aims at analysing and illustrating the influence of changing consumption patterns on energy use and emissions. The project was named 'Consumer's Lifestyles and Pollutant Emissions'. The project involved a co-operation between IER (Stuttgart, G), C3ED (Versailles, F) and ECN (Petten, NL).

The present report discusses the simulation exercises with the ELSA model based on four scenarios. In addition to backgrounds and simulation results also the principal additions and adaptations of the model are explained. The four scenarios were defined in such a way as to create sufficient contrast between possible future societies, both in terms of socio-economic and technical conditions and in terms of consequences for energy requirement and environmental pressures. The scenario calculations were performed stepwise in order to enable the separation of various causes, such as population growth, increasing wealth and lifestyle features and, technological developments.

Chapter two explains the purpose of the study, the study context and the organization, including the distribution of tasks over the research partners. Chapter three gives a brief overview of the model and reviews the main adaptations. The four scenarios will be introduced in chapter four, in which both the philosophy behind them and the operationalization in the ELSA model are explained. Chapter five discusses the scenario results. There are sections about the economy, the dwelling stock and heating, the appliance stock and electricity, the car stock and motor fuels, the indirect energy requirement of production and transport and, last but not least the emissions of CO_2, SO_2, NO_x, CO and VOC. A further integrated evaluation of the results and some additional analysis is dealt with in chapter six. Concluding remarks are made in chapter seven.

This report has been published both as an Annex to the main final report of the project (Weber et al., 1996) and as a separate ECN rapport. Related ECN reports subsequently deal with the description of the energy model ELSA (Perrels et al., 1996) and with the estimation of sets of consumption functions to be used in a separate module of ELSA (Pellekaan and Perrels, 1996).

2. PURPOSE AND CHARACTER OF THE STUDY

2.1 Purpose

The study aims to clarify the contribution of several demand side forces on the evolution on energy consumption and emissions. The focus is on household behaviour in a broad sense, so including household demographics, engagement in paid labour, education level, income distribution, consumption patterns, ownership of appliances and cars. The idea to address household behaviour in its entirety is often referred to as a lifestyle oriented approach, hence the title of the project. The operationalization of lifestyle in the context of energy research as performed in this study is explained in Perrels et al. (1996). Since energy consumption and emissions cannot be sensibly evaluated without consideration of technological development, the evolution of energy efficiency, the fuel mix and, abatement technologies is taken into account as well. The approach is summarized in figure 2.1 below (the model will be further explained in chapter 3).

Household expenditures are disaggregated in expenditures on energy carriers (electricity, natural gas, district heat, and motor fuels - so called 'direct energy') and other expenditures. The direct energy use is determined by means of simulation of ownership rates of appliances and cars and also involves household characteristics. The energy expenditures can be used to check results. The non-energy expenditures are repartitioned over the production system by means of an input-output system. The input output system takes care that the energy contribution of each sector is accumulated until a total indirect energy claim can be established. The computation of direct energy consumption is inter alia based on. Once energy consumption by energy carrier and by sector has been calculated the emission consequences can be simulated.

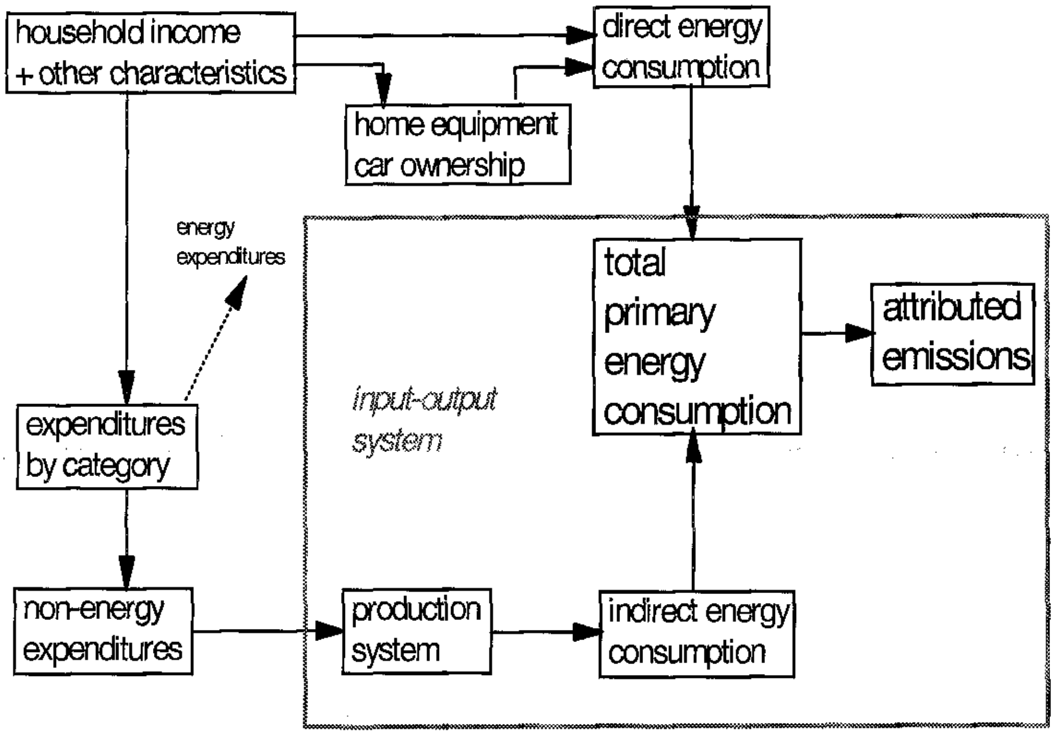

Figure 2.1 *Backtracking lifestyle impacts via direct and indirect energy use*

Eventually, the study should produce:
- a model, or rather a system of models, which can be used in future studies as well;
- an investigation of plausible future levels of energy consumption and related emissions, based on a set of scenarios;
- a decomposition analysis of the expected changes of energy consumption and emissions distinguished by causal factor (demography, economy, technology);
- an investigation of possible incompatibilities in the scenarios regarding its economic and ecological impacts (this is performed by C3ED by means of the SEESM model).

2.2 Character

The study can be best characterized as explorative. It is even explorative in several ways. First, despite the proven usefulness of input-output theory, the construction of the total energy requirement and emission model has various new features, that result in an elaborate non-standard input-output system connected to other hybrid modules. Second, the scenarios are explorative in the sense that they are all guided by possible societal developments or put differently the scenarios stress different inclinations in possible cultural, socio-economic and, technological developments in society. Third, the study also explores the possible evolution trajectories of energy consumption and emissions as well as to what - demand and supply side - forces we can attribute changes in levels of energy consumption and emissions.

Notwithstanding its explorative character the study attempts to apply reasonable assumptions within each scenario. Therefore, the contrasts of the scenarios vary in intensity depending on the phenomenon observed. For example, the contrasts in economic growth are larger than in resulting CO_2 emissions. One could say there is some built-in attenuation in the model. However on top of that such forces are indeed active in society and are partly automatically included in the empirically specified relations used in the model. An underlying reason for this attenuation tendency could be that the compensating mechanisms at work in a society take care that profound changes don't materialize too rapidly or in a somewhat adapted way. In this manner they prevent frequent major shake-ups in the social fabric.

Clearly, the model does not produce customized information, which would be ready-to-use in policy measures. The information to be derived from the model is more of a strategic nature. One can recognize target groups and target categories and see where it seems most likely that technological measures are more than compensated by economic and lifestyle changes.

2.3 Division of tasks

The institutes C3ED, IER, ECN each had specific tasks. IER and ECN both built a simulation model based on an input-output system plus technical-economic relations for the description of direct energy consumption of households. The model of IER is named E^3Life and covers Germany. Additionally IER also constructed a provisional simplified version of E^3Life for France. The E^3Life is described in Weber et al. (1996b). C3ED constructed systems dynamics models for France and the Netherlands. These models are named M3ED and NL-DIOC respectively. A preliminary description of the models can be found in Ryan et al. (1996). These models can be used to explore whether the growth trajectories as specified in the scenarios are compatible with the economic and natural resources carrying capacity of the countries under consideration. The economic carrying capacity will be mainly interpreted in terms of the need for gross investments and the development of the capital stock as well as in terms of balance of payments. The natural resources carrying capacity refers both to possibly damaging pollution levels as well as to limits of extraction speed. Unfortunately, final results of the systems analysis were not available by time of reporting on simulations with ELSA.

ECN focused on the elaboration of ELSA (which also functioned as a 'model' for the whole study) and designed and performed the estimations of the consumption functions (see Pellekaan and Perrels, 1996). Furthermore, extensive simulation exercises with ELSA were carried out by ECN based on the four scenarios specified in close co-operation with C3ED and IER. The remainder of this report will almost exclusively focus on the simulations for the Netherlands carried out with the ELSA model.

3. THE ELSA MODEL IN BRIEF

3.1 Overview of the model

Figure 3.1 provides a fairly detailed overview of the principal relations in the ELSA model. The dotted arrows in figure 3.1 represent connections that - sofar - are only loosely included as a sort of check. Through lines represent connections that play an active role in the calculations. A full explanation can be found in Perrels et al. (1996).

The starting point of the model is the specification of economic growth expressed as increases of value added by main sector (manufacturing, services, etc.). The growth rates have been prespecified exogenously in scenarios (not shown here). The upper part of the figure shows the generation of value added in an economy and its transfer to households by means of income from labour, distributed profit and social security. The modules indicated at the top concern the interplay between economic growth, labour productivity, labour time arrangements and, the resulting employment and income consequences. The next step toward household income brings us at the micro level of the individual household. Prior to establishing consumption patterns, the amount of (free) savings is determined. The amount the household saves depends on features such as income, age and the presence of children (Pellekaan and Perrels, 1996). Contractual savings, such as pension premiums, are already subtracted in earlier steps. The way the remainder, the expenditures, are allocated toward consumption categories depends on income, household characteristics and retail prices (Pellekaan and Perrels, 1996). Households spend a small part of their budget to direct energy use, e.g. for heating and motor fuels. The greater part is spent to other goods and services. The expenditures of individual households on goods and services has to be aggregated and rearranged in order to fit into the categorization used by the National Accounts system. The latter provides the format in which the input-output model works.

The expenditures at the macro level of the whole economy constitute the consumption vector in the input-output system (the shaded area named 'cons' in figure 3.1). From there the money flows are traced back into the productive system as indicated by the set of arrows. Additionally imported goods are added. The production system of countries of origin is assumed to be the same as the Dutch system. Otherwise an input-output model is needed for every country, which would make the model unmanageable. Finally, the consumer expenditures are adding up per sector of origin, hence the term *consumption by origin.*

In the next stage data about industrial energy consumption by sector and energy carrier and goods transport volumes (in tonkm) by sector and transport mode are introduced. For transport there is a separate treatment of domestic and cross-border transport, due to large differences in distances and mode choice. Subsequently, matrices of specific energy consumption (TJ/mln.gld. production value) and specific transport requirement (tonkm/mln.gld. production value) are computed. For every type of energy carrier and for every emission type a specific emission effect (kton/TJ energy) can be computed.

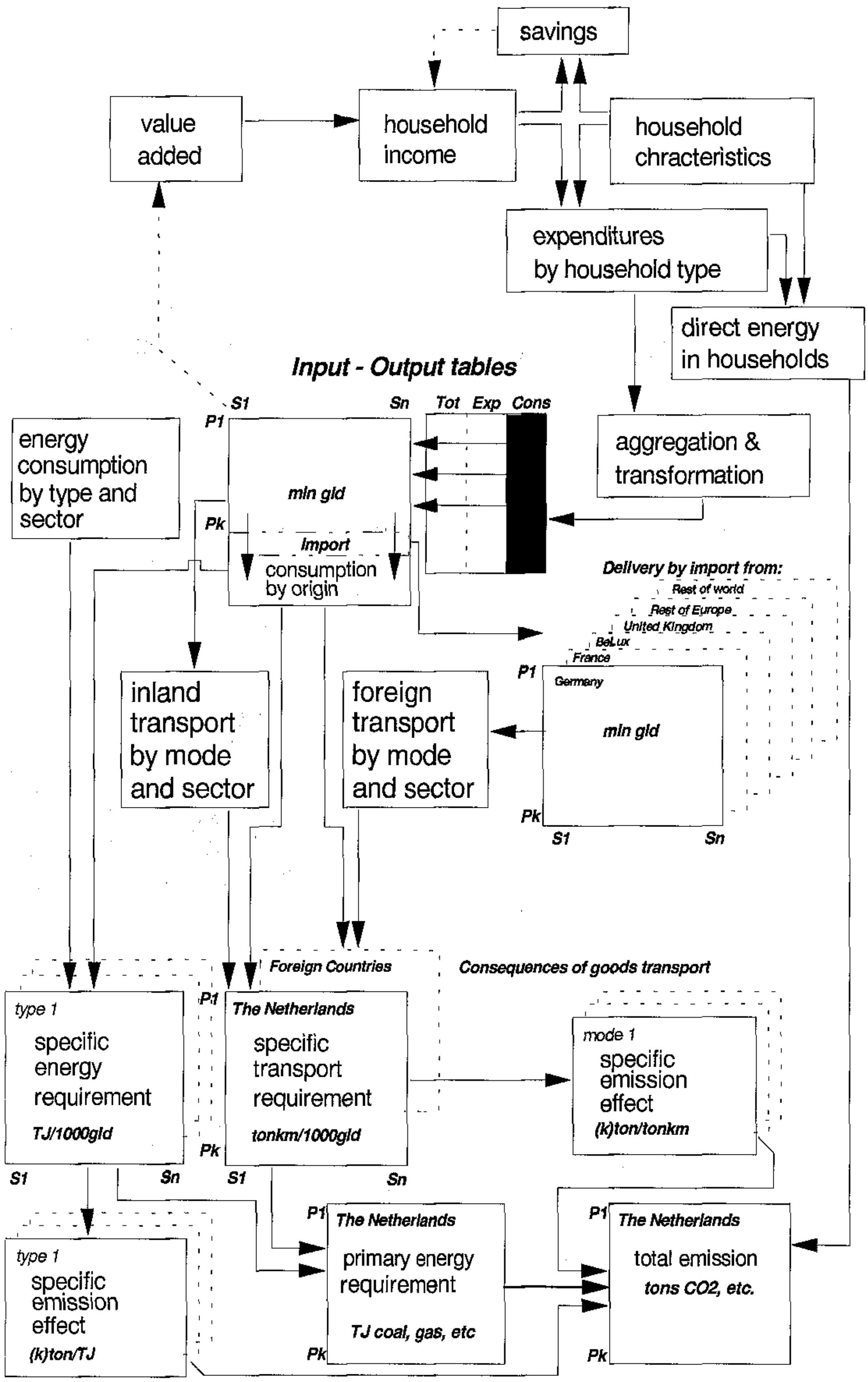

Figure 3.1 *Schematic overview of the ELSA Model*

In the updated version of the model emissions have been separated in energy conversion related emissions, process related emissions including a remainder which is often related to leakage and vaporization during storage and transport of fuels. This update will be discussed in the next section (3.2). Similarly specific emissions from goods traffic (kton/tonkm transport) are constructed. Another addition is to specify upper or lower bounds on the resulting primary fuel mix. This is also highlighted in the next section. All these matrices together in combination with the information about industrial production volume (=consumption by origin) total emission effects and energy requirements can be computed. In order to obtain a complete picture also the emissions from direct energy use of households are added.

In order to be able to calculate the direct energy use for electric applications a two-step approach is applied. In the first step an ownership model is used. The ownership model calculates a certain penetration rate for each appliance based on household characteristics. Once ownership rates have been calculated, the intensity of use of the appliances by household type is calculated. The second model calculates the frequency of use per week. By aggregating the weekly frequencies over a year and accounting for holidays etc. and subsequently multiplying by the specific electricity consumption per run the annual electricity consumption per appliance and by household type can be simulated.

Contrary to the ownership of appliances the choice of a heating system is not (a priori) related to the household type and social economic characteristics of a household, rather it is connected to the dwelling itself. The dwelling module merges the dwelling stock information with the household information and subsequently calculates a direct energy use for heating by household type given its distribution over dwelling types. This direct energy use is in a first stage determined by the technical features of the dwelling and the heating system, thereby producing a reference level. This reference level can change over time due to technical progress in new dwellings and retrofit of existing ones. In a next stage this actual consumption level is determined by allowing for adjustments both in the composition of the population per dwelling category and in the background characteristics of households. The direct energy calculations are explained in detail in Perrels et al. (1996).

3.2 Updates in the model

3.2.1 Distinction between emission sources

The considered emission types in this study are for the greater part directly related to energy conversion, but in addition to that so-called process related emission occur. The connection of emissions to energy use levels and economic and household activity is of necessity diversified. All in all the level of detail increased compared to the first model version, therefore an updated description of emission calculation is provided below.

Eventually, the most condensed model output for emissions V is distinguished by emission type v, where v is coded from 1 to 5 (CO_2, SO_2, NO_x, CO and VOC) and forecast year t (1990, 2000, 2010). Emissions are caused by activities in the production sector, by national and international transport and, by households. These emissions by sector are indicated consecutively as V_p, V_{tn}, V_{tm} and, V_{hh}. So, we have

$$V[v,t] = V_p[v,t] + V_{tn}[v,t] + V_{tm}[v,t] + V_{hh}[v,t] \quad (3.1)$$

For the production sector a further distinction is made between energy conversion related emissions V_{pe} and process related emissions V_{pp}. Furthermore, the distinction by fuel type f is important.

$$V_p[v,t] = \sum_f V_{pe}[v,f,t] + \sum_x V_{pp}[v,x,t] \quad (3.2)$$

where the index v refers to emission types, f to fuels and x to economic sectors.

Energy conversion related emissions are connected to the fossil fuel consumption in a sector, which means that it is assumed that every TJ of fuel used causes a certain amount of emissions. However, not all fuel used in the production sector is used in conversion processes. Instead of gross fuel consumption per sector E, we want to relate emissions to a corrected fuel consumption E^*. The correction simply means that non energetic fuel use (E_{ne}) is subtracted from E. In the present model version non-energetic fuel use E_{ne} is supposed to constitute a fixed fraction of E between 1990 and 2010.

$$E^*[x,f,t] = E[x,f,t] - E_{ne}[x,f,t] \quad (3.3)$$

Subsequently energy related emissions V_{pe} can now be connected formally to corrected fuel use by applying specific emission coefficients v_{pe}.

$$V_{pe}[v,x,t] = \sum_f v_{pe}[v,x,f,t] \times E^*[x,f,t] \quad (3.4)$$

The energy consumption E (and E^* for that matter) is calculated from the Consumption by Origin (= the consumption induced production volume, see section 3.1), by applying specific energy coefficients e.

$$E[x,f,t] = e[x,f,t] \times CBO[x,t] \quad (3.5)$$

The specific energy and emission coefficients change over time due to energy saving and emission abatement efforts. Therefore an evolution over time by means of a growth rate of specific energy consumption (GRSE) or specific emission levels (GRSVE). The growth rate is negative as it lowers the specific coefficient. This is formally described as follows:

$$e[x,f,t] = e[x,f,t_o] \times (1 + GRSE[x,f])^{t-to} \quad (3.6)$$

$$v_{pe}[v,x,f,t] = v_{pe}[v,x,f,t_o] \times (1 + GRSVE[v,x,f]) \quad (3.7)$$

The process related emissions Vpp are directly connected to production levels in the industry and the services (CBO), which reads as:

$$V_{pp}[v,x,t] = v_{pp}[v,x,t] \times CBO[x,t] \quad (3.8)$$

Please note that this type of specific emission coefficient is expressed in tons per mln. guilders of production and not in tons per TJ energy. For this specific coefficient a similar development can be specified as for energy related one (see equation 3.7), the growth rate for the process related specific emission coefficient is GRSVP.

For households the emission levels are connected to the amount of direct energy calculated in relevant modules for homes, appliances and cars. For the electricity consumed by households, a proportion of the emissions caused by the electric power sector is attributed to households. For natural gas and motor fuels the conversion takes actually place in the domestic sector with a specific technology for which the specific coefficients are known:

$$V_{hh}[v,t] = \sum_f v_{hh}[f,t] \times E_{hh}[f,t] \quad (3.9)$$

For transport the calculations are more elaborate due to differences between national and international transport, mode choice and the connections with economic output. Therefore a separate section (3.2.2) is dealing with the transport flows and resulting emissions.

3.2.2 Transport flows in the input-output system

3.2.2.1 Introduction

Transportation is an important energy demand sector, which has distinct features compared to the production system at large as represented in a standard input-output table. Therefore both the fuel consumption of private cars and the fuel consumption of goods transport is dealt with separately in the model system. The fuel consumption of the private car stock is treated in the modules that deal with direct energy consumption of households. The main driving forces for that part of motor fuel consumption are the development of car ownership and car use (mileage) as well as the fuel efficiency of the engine. The fuel consumption due to goods transport is calculated in a special section of the input-output model. Distinctions are made between production and goods transport related emissions. Several matrices of specific energy coefficients (units of energy carriers per unit of production value) and specific emission coefficients (units of emissions per unit of energy carrier used) are calculated.

After having computed the production effect of the private consumption (named *consumption by origin*) the transport impact of the production is calculated by means of two sets of auxiliary matrices. These matrices contain technical coefficients of goods transport effects, that is number of tonkilometers generated (or required) for each mode of transport due to 1 mln. guilders (or ECUs, Euros, etc.) of production in a certain sector. There are separate matrices for inland and cross-border transport flows, since cross-border transport relates to longer trip distances and systematically other mode choices by sector.

Subsequently, since matrices of specific emission effects (ton emission/tonkm.) and specific transport requirement (tonkm/mln.gld. production value) are included, for every type of energy carrier and for every emission type a total emission effect of goods transport can be computed. Finally this information is combined with emission effects attributed to production and direct energy use of households.

3.2.2.2 The method in brief

The principles of an input-output model and the actual basic implementation in this study have been explained in Weber et al. 1996 (the main report) and Perrels et al., 1996. Below the extension of the input-output system with regard to the inclusion of goods transport and its emission effects is discussed. For the sake of sufficient context a few introductory statements and formulas have been added.

Although the eventual I/O-system operates rather straightforward, the construction of the system happens to be less straightforward. One of the complications relates to the treatment of transport in a separate sub-system of I/O tables. Generally one can observe that the distinction into categories has to be adapted to the level of the least detailed system. In the standard I/O-table for 1990, delivered by the Central Bureau of Statistics (CBS, 1993), the intermediate part of the table consists of 59 real sectors (i.c. possible categories). Unfortunately, the data for transport and emissions are disaggregated to a lesser degree. So, the 59 sectors in the I/O table have been merged down to 23 sectors (commodities).

Since the study aims ultimately at attribution of emissions to the demand side, the specific emission per mln gld consumption (v_c) needs to be computed. This specific emission can be calculated by postmultiplying the specific emission accumulated in the production of a commodity (v) with the Leontief inverse, matrix $[I-A]^{-1}$.

In formal terms this reads as:

$$v_c = v\,[I-A]^{-1} \qquad (3.10)$$

In turn v_x, the cumulative specific emission in production sector x, is computed as follows:

$$v_x = E_{pi}/Z_i \tag{3.11}$$

where V_x denotes the observed total emission (per emission type) for production sector x.

The matrix of technical coefficients A in equation 3.10 is not the matrix that can be straightforwardly derived from the I-O table as published in the National Accounts. Subtractions have to be made regarding the monetary flows for the transport sector (treated in a I-O sub-system) and the energy distribution sector (direct energy).

The specific emission vectors for the transport of goods[1] are derived in a similar way. Goods transport is sub-divided into international (v_b) and domestic (v_d). It is supposed that competing imported goods are produced with the same emission coefficients as the domestic production. The aggregation of goods is on such a level that differentiating between competing and non competing import is not meaningful as regards emissions. From different sources the emission coefficients (g/tonkm) are known, so the specific emission per mln gld product can be calculated (v_d).

For the calculation of impacts of international transport data on import are used. The same categories as for inland transport can be distinguished. The official countries of origin are used to calculate a mean distance per category of goods. Multiplying this mean distance with the tonnes and after that with emission coefficients (g/tonkm) gives the total amount of emission from imported category of goods. The emission from import can be seen as additive to the emission of the production. So the specific emission from transport of imported goods can be calculated in tonnes per mln gld production of the same category. The calculation of the specific emission per mln gld for consumption from this source can be done as told before. Data are required for sectoral emissions [weight units per year] and for transportation emissions [weight units per car kilometre or weight units per tonne kilometre]. Eventually 5 types of emissions should be included, being carbon dioxide (CO_2), nitrogen oxides (NO)$_x$ sulphur dioxide (SO_2), volatile organic compounds (VOC, including methane) and carbon monoxide (CO).

The cumulative specific emissions of domestic and international transport can be formally specified as follows:

$$v_{di} = V_{di}/Z_i \tag{3.12}$$

and

$$v_{bi} = V_{bi}/Z_i \tag{3.13}$$

while V_{di} is based on domestic figures by mode:

$$V_{di} = \sum_m se_{dm} \times TKM_{dim} \tag{3.14}$$

[1] Emissions from passenger transport are left in v_p as regards public transport and are treated separately as regards private cars (direct energy).

where se_{dm} denotes specific emission per tonkilometer per mode m for domestic transport and TKM_{dim} the tonkilometers attributed to the delivery of the volume of domestic inputs as specified in the I/O system (the inter-industry table).

Similarly V_{bi} is defined as:

$$V_{bi} = \sum_m se_{bm} \times TKM_{bim} \qquad (3.15)$$

TKM_{dim} is derived from an operation on classification by goods category:

$$TKM_{dim} = O_d\{TKM_{dgm}\} \qquad (3.16)$$

TKM_{bim} is defined as follows:

$$TKM_{bim} = \sum_o(q_o \times d_o \times T_{igm}) \qquad (3.17)$$

Then, total emissions per type of emission attributed to a unit value of private consumption (=specific emission of household consumption) can be formally described as follows:

$$v_c = (v_p + v_b + v_d)[I-A]^{-1} + v_{hh} \qquad (3.18)$$

Specific transport consumption (tonkm/mln.gld. production) and specific emissions (ton emission/tonkm) are regarded as variables that have fixed values, i.e. a kind of model constants. Changes in the specific transport consumption take place, for example through logistic optimization. However, the knowledge base needed for this lies outside the scope and capabilities of the present project, therefore the coefficients have been left unchanged throughout the simulation period. The same applies to specific emissions of modes for goods transport (please note abatement technology is introduced in the private car module). Consequently, in the present version of the model fixed coefficients are used as regards intersectoral deliveries and transport requirements of production, while for energy use and emissions as represented in cumulative energy and emission ratios updating is implemented.

3.2.3 Energy saving for residential space heating

In the previous version of the determination space heating requirement for a typical dwelling energy saving was embodied by a variable referring to construction vintage. On top of that a reinforced amount of saving (expressed in m^3 natural gas equivalents) for future vintages has been introduced. The future reductions are dwelling type and scenario dependent.

Basically the equation can be kept the same as is formulated in Perrels et al. (1996), pp.76, equation 12 ($ECSH[he,hh,j,t] = \sum_i b_i[j,he,t] \times X_i + CONSTANT[j,he]$).

In the above equation X_i denotes a vector of exogenous variables. One of which is YOC (year of construction of a dwelling). In the previous version YOC was coded as a monotonous increasing factor (1 to 5), which was multiplied by a gas consumption discount. This vintage effect on space heating is replaced by contingent sets of gas consumption discounts per dwelling type and vintage. One set for each scenario. The sets are shown below in table 3.1.

Table 3.1 *Savings on natural gas for heating by dwelling type, vintage and scenario in m³ per year*

	SCENARIO : BU				SCENARIO : FG			
	detached	semi-det.	flat	hs.unit	detached	semi-det.	flat	hs.unit
before 1945	0	0	0	0	0	0	0	0
1945-1959	-100	-75	-50	-25	-100	-75	-50	-25
1960-1974	-100	0	-75	-50	-100	0	-75	-50
1975-1990	-200	-150	-75	-75	-200	-150	-75	-75
1991-1995	-500	-400	-175	-100	-500	-400	-175	-100
1996-2000	-750	-675	-200	-100	-650	-600	-175	-100
2000-2010	-850	-775	-225	-100	-700	-675	-200	-100
	SCENARIO : SC & ST				SCENARIO : ZERO			
	detached	semi-det.	flat	hs.unit	detached	semi-det.	flat	hs.unit
before 1945	0	0	0	0	0	0	0	0
1945-1959	-100	-75	-50	-25	-100	-75	-50	-25
1960-1974	-100	0	-75	-50	-100	0	-75	-50
1975-1990	-200	-150	-75	-75	-200	-150	-75	-75
1991-1995	-500	-400	-175	-100	-200	-150	-75	-75
1996-2000	-800	-725	-200	-100	-200	-150	-75	-75
2000-2010	-950	-875	-225	-100	-200	-150	-75	-75

3.2.4 New domestic appliances

In addition to the penetration of existing appliances such as tumble dryers and micro wave ovens, new appliances are introduced to the market from time to time. However, only larger appliances get a separate treatment. Small tools, toys, etc. are lumped together in unspecified 'remainder group'. Appliances that have been recently introduced to the market and of which the penetration rates are still too small to be sensibly observed in surveys are the first relevant group of new (large) appliances. A second group consists of applications that already exist on an experimental basis, but are sofar not available to consumers. In this case there is still a risk that these appliances will not be introduced or will still undergo substantial change before being introduced. Another kind of new appliances are those that already exist, but in which the technology may change drastically. For example, several manufacturers attempt to design new washing machines based on fundamentally different principles than the current machines. As regards selection of new appliances to be included we mainly sticked to the first and second category. Generally, it is not easy to find reliable data, neither regarding expected penetration nor regarding technical features, notably energy consumption.

Relevant candidates for being added to the appliance model are:
- combined washing and drying machine (already available),
- waterbed (already penetrating; but getting less energy intensive),
- tv-sets with lcd screen (smaller ones already on Japanese market),
- integration of phone, tv-set and computer in connection with increasing portability.

Since, the model approach requires as much as possible a reasoned and tractable description of penetration fractions, sofar only for combined washing and drying machines an intoduction has been specified. The approach is based on the idea that after 2005 combined machines have approached the price level of a washing machine only, while producing the same qualitative and quantitative results as the sperate machines would do. Given such circumstances it gets likely that most substituted and new washing machines will be in fact combined washing and drying machines. The process can be summarized as follows.

The penetration of washing machines has already attained saturation levels, whereas these levels vary somewhat from household type to household type. In seven of the ten household types the ownership rate is above 88%. Exceptions are singles, having ownership rates of 70%. For the year 2010 it means that all washing machines substituted after 2005 plus all washing machines purchased by first time buyers are combined washing and drying machines.

$$OR[a3,hh,dw,t_2] = \{OR[a3,hh,t_1] - OR[a11,hh,t_2] \qquad (3.19)$$

$$OR[a11,hh,dw,t_2] = \{SF[hh] \times OR[a3,hh,dw,t_2] \times NHH[hh,dw,t_1] + AF[hh] \times OR[a3,hh,dw,t_2] \times (NHH[hh,dw,t_2] - NHH[hh,dw,t_1])\} / NHH[hh,dw,t_2] \qquad (3.20)$$

Glossary:
variables:

OR	-	ownership rate
SF	-	substitution fraction
AF	-	additional households fraction
NHH	-	number of households

indices:

a3	-	index denoting washing machine
a11	-	index denoting combined washing machine and dryer
hh	-	household type
dw	-	dwelling type
t1	-	first forecast year (2000)
t2	-	second forecast year (2010)

3.3 Modular structure of the model

ELSA is implemented in EXCEL (version 5). For every scenario there is a central input file, a cluster of six calculation files and an output file. The exogenous variables that make up the key distinctions between the scenarios, such as economic growth and energy efficiency improvement, are specified in the central input file. All calculation files are reading from the central input file. In addition the calculation modules may have local exogenous variables, that are only used in that module and which are regarded as less influential for the key results. Once the user is convinced about the data in the input file, he can start calculations. Since some calculation files produce output which is input for other calculation files, normally the following calculation order should be observed:

Calculation modules	Transfer modules
0. Input	
1. Socio-economic	→ CON**nVx.XLS
2. Dwelling stock	
3. Heating home	→ GAS**nVx.XLS
4. Electricity home and	→ ELE**nVx.XLS
Motor fuel car	→ CAR**nVx.XLS
5. Input-Output system	
6. Results summary to Output	

The EXCEL files mentioned at the right hand side are so-called transfer files, containing the key results only. Other calculation files can read from these transfer files. The ** signs denote letter places that are reserved for a scenario abbreviation. The n represents the step-number (see below), while Vx indicates the version number of a particular calculation. The data flow organisation between the modules is summarized in figure 3.2 below.

Next to a distinction by scenario the ELSA model system also allows for distinction by impact steps. This allows the user to decompose the final results by types of influences. In the current version a distinction can be made between:

a. demographic changes,
b. macro-economic changes,
c. social economic changes,
d. changes in relative prices,
e. energy efficiency and fuel mix,
f. abatement efforts.

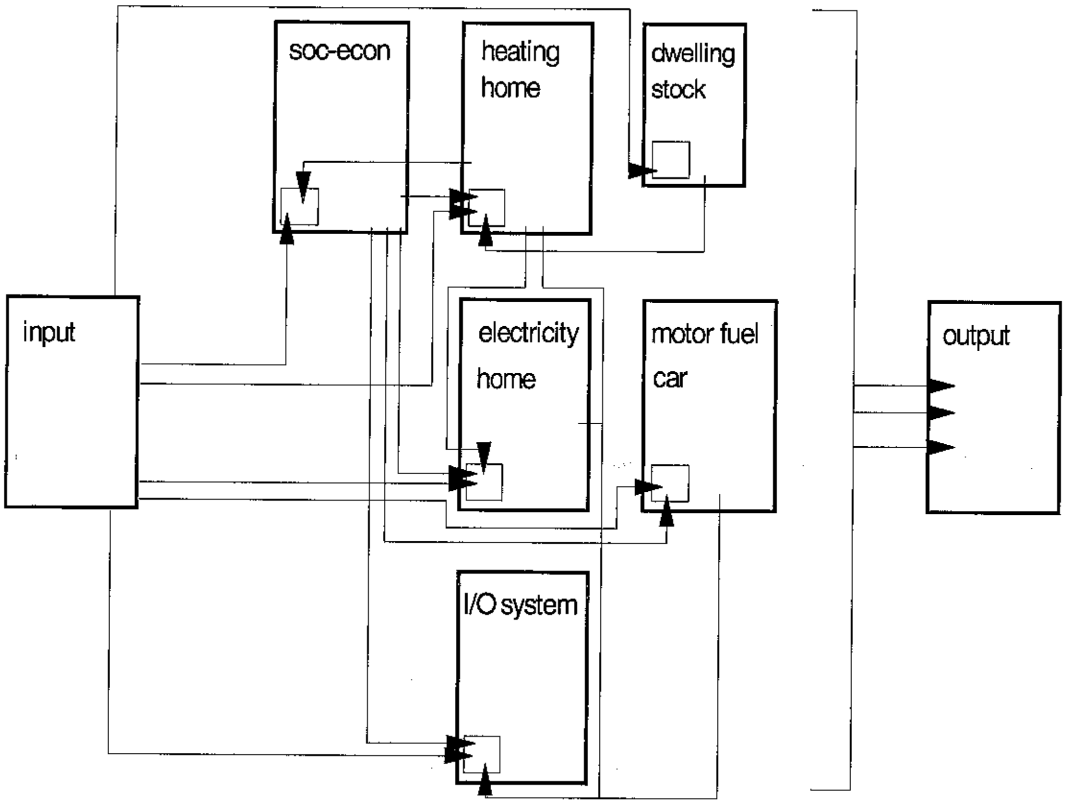

Figure 3.2 *Organisation of data flows between ELSA modules*

4. DESCRIPTION OF THE SCENARIOS

4.1 Introduction

Prior to the scenario specification phase of the project the three partners had already developed partial ideas about scenarios. For example, during the construction of ELSA specific studies have been made regarding the systematic inclusion of social-cultural and socio-economic developments (or trends) in a kind of scenario module. It would be too far fetched to attempt any sort of summary discussion this scenario work or on the prior reflections of scenario building. For the interested reader see Faucheux and O'Connor (1996), Perrels et al. (1996), Friends of the Earth (1995) and Ausubel and Grübler (1995).

Given the purpose of the project the scenarios should evidently take care of sufficient socio-economic description and possibly also reflect on social-cultural changes. However, to produce fair comprehensive pictures of the future, the development of energy efficiency and abatement technology should be differentiated by scenario as well. Moreover neither the social-cultural and socio-economic developments nor the technological developments should be unrealistically swift. So, every scenario should illustrate a particular direction of plausible societal development, without getting too exotic. This means that the scenarios show contrasts, but not to the extreme.

Given the very motivation to start this study lifestyle development (primarily but not exclusively in the socio-economic realm) is the main dimension and therefore a prime source of contrast in the scenarios. The different lifestyle megatrends that could emerge are influenced by technology and by the policy environment (see figure 4.1 below). After having identified principally different lifestyle developments, the concomitant policy environment and technological development is formulated. The following dimensions have been identified in this respect:

- social dimension
- economic dimension
- technological dimension
- environmental policy dimension.

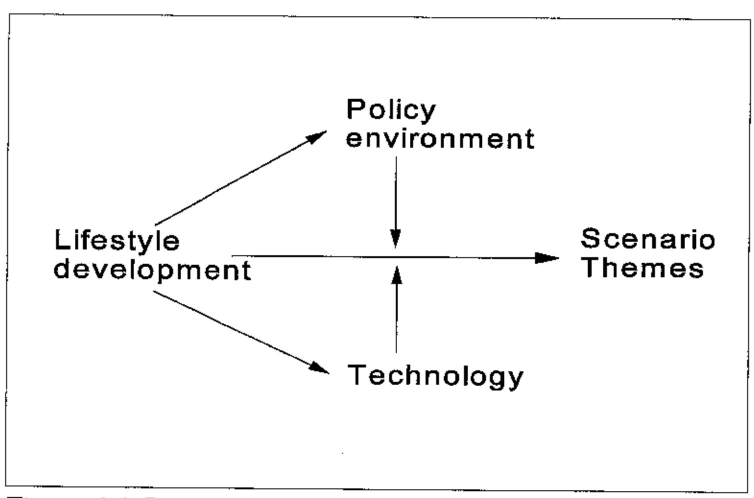

Figure 4.1 *Principal forces for scenario distinction*

As regards the social dimension one can think of trends such as indivualisation, secularisation, etc. In the economic realm globalisation and the attempts to introduce more market transparency are important. For technology the electronics revolution (informatics, telematics, etc.) is assumed to go on and affect both industries and households. Focusing on the needs in this study, energy efficiency technology, renewables and abatement technologies are important. The policy environment refers to the extent governments want to be involved in regulating social economic and environmental processes.

To be able to operationalize these dimensions sets of phenomena types have been defined. Thanks to the sets of phenomena types it becomes feasible to identify exogenous variables that can operationalize the connection between scenario and model. The sets of phenomena types are:
- demographic dynamics
- macro economics
- social economics
- social psychological developments
- technological dynamics.

From these phenomena sets the following clusters of exogenous variables have been identified for the ELSA model (For E3Life the exogenous variables are not exactly identical, notably not the economics section).

Demographics
Growth of the population by household type (10 household types distinguished)
Potentially active population (those between 18 and 61 except fraction of disabled)
Average age of head of household by household type
Household phase (a derived variable)
Average size of residence by household type
Development of dwelling stock through:
- scrapping rates
- renovation rates
- volume of newly built dwellings by dwelling type (four).

Economics and Lifestyle
Annual growth rate of value added by main sector (industry, services, etc.)
Annual growth rate of labour productivity by main sector
Number of working weeks per year
Average duration of full time and part time jobs (hours/week)
Share of part time jobs in total labour force
Education level
Labour participation rate of main wage earners (full time, part time)
Fraction of labour productivity transferred to wage
Average social security income by household type
Marginal income tax rates by income category
Average basic tax exemption by household type
Average mortgage exemption by household type
Retail prices index for six main expenditure categories
VAT rates and levies and subsidies by expenditure category.

Technology
Growth rates of energy efficiency of domestic appliances and private cars
Replacement speed of domestic appliances and private cars
Gas consumption discounts due to energy saving measures in homes
Growth rates of energy efficiency for end use and energy conversion in the production sector (manufacturing industry, services, energy sector)
Fuel choice in the production sector
Improvement of specific emissions
- indicated by growth rates or
- indicated by policy targets.

In addition to the above list there are so-called local exogenous variables, which are not further discussed here.

4.2 Scenarios described in a nutshell

Four scenarios have been formulated. The scenarios run from 1990 to 2010. They differ from each other primarily in three aspects, being economic growth, labour productivity and labour market and, environmental technology. The scenarios have the following names:
Business as Usual (BU);
Stagnation (SG);
Sustainability through Reflective Consumption (SC);
Sustainability through Technological Breakthrough (ST).

Some developments are assumed common to all scenarios. For example, the number of households by household type is identical in all scenarios. In as far as there are differences in demographic forecasts for the Netherlands as made by CBS (1996) and NIDI the overriding impact comes from migration (e.g. van Nimwegen en van Solingen, 1991). This is an uncertain politicized factor and therefore it has been decided to make no distinction on this point between scenarios. It could be argued that, especially in the Stagnation scenario (hereafter referred to as SG) immigration flows are likely to be reduced. The increase of education levels and the gradual equalization of male and female education levels is also assumed identical in all scenarios. For younger cohorts of households this is supposed to be a very fundamental development, that is hardly affected by differences in economic progress. For older cohorts of households in future periods the education level is already largely determinded by today's levels among younger cohorts. The education level is one of the explanatory variables for the wage rate. It is assumed that nationwide increases of the level of education cause result in a reduced pay-off in the wage rate. Moreover this (reduced) pay-off is slightly varied over the scenarios. Cross-cutting technological developments such as informatics and telematics are assumed to be important in all scenarios. Yet, in the SC and ST scenarios these technologies are supposedly applied either in a focused way (SC) and/or more extensively (ST).

As regards the dwelling stock and the degree of urbanisation it has been decided to leave the latter factor unaffected (=constant in all scenarios). A systematic inclusion of this variable would require a connection with the specification of newly built dwellings. This might be implemented in a next version of ELSA. The dwelling stock has the same total size in all scenarios and equals the number of households.

However, in the Sustainability through Reflective Consumption scenario (hereafter referred to as SC) and the Sustainability through Technological Breakthrough scenario (hereafter referred to as ST) the composition of future dwelling stocks deviates from assumptions made in the Business as Usual scenario (hereafter referred to as BU) and SG scenario.

In the BU scenario the current economic and social trends are extrapolated, while it is assumed that existing environmental policies, including targets for 2010 remain in place. In summary, the economic growth is rated at 2% annually, while growth of labour productivity amounts to 2.5%, which means that - without labour time reduction - the number of jobs would diminish with approximately 10% in 2010. However the labour time reduction is 10% over the total period, thereby more or less offsetting the labour saving economic growth. The energy efficiency improvement is on average rated at 22% in 20 years (= 1.23% annually). The efficiency improvement varies over sectors and fuels.

Figure 4.2 shows the key differences between BU and the other scenarios (SG, SC and ST) compared to BU. SG and SC have the same macro economic growth which is 37% lower than in BU, however they differ in growth of labour productivity, and especially in degree of progress of environmental technology. The SG scenario supposes that society fails to resolve socio-economic issues properly. Which means that - unintended - low economic growth is combined with increases of labour productivity, which are near the historical average. So, defensive commercial strategies are assumed to prevail, which implies inter alia that not any (further) labour time reduction is achieved. Similarly, investments in energy efficiency, renewables and emission abatement are reduced to a minimum and depend mainly on inherited commitments.

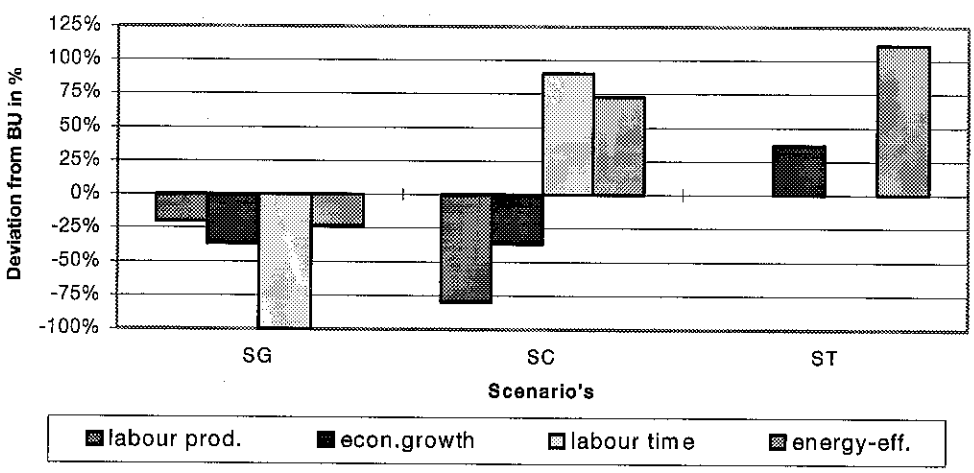

Figure 4.2 *Principal contrasts between scenarios based on key exogenous variables*

In the SC scenario the same low economic growth is supposed to be preferred in the context of a larger societal scheme that attempts to move towards a sustainable economy. The basic assumption in this scenario is that economic growth and increases in private consumption have to be somewhat restrained and redirected in order to enable technological development to become really effective instead of being largely or even entirely offset by economic growth. In order to maintain employment in a low growth economy the accumulated labour time reduction up to 2010 amounts to 20%.

In the ST scenario it is assumed that substantial improvements of energy efficiency and emissions abatement require major nation wide investments and therefore can be achieved only in a high growth economy. Higher economic growth usually leads to speedier technological development, which hopefully makes technological breakthroughs sooner available. For example, this results in the reasoned assumption that energy efficiency in the ST scenario improves twice as much compared to the BU scenario. Detailed quantitative information about the scenarios is given in Annex A.

5. SCENARIO RESULTS

5.1 The organisation of scenario runs

As has been explained in section 3.3 the production of a complete simulation run for one scenario requires a certain sequence of use of the modules. For every impact level and every scenario the whole sequence has to repeated. Consequently for this study there are at maximum 24 sets of output (6 impact levels x 4 scenarios). Each set of output contains information about *consumer expenditures, natural gas consumption of households, electricity consumption of households, motor fuel consumption of households, indirect energy requirement* and *resulting emissions.* Furthermore, every category of output can be accompanied with auxiliary information about for example income, dwelling stock, appliance ownership, efficiency improvements, etc. It will be obvious that not every result can be displayed and discussed here. Furthermore, while running the simulations it has been decided to integrate the impact steps that have to do with economics (steps b, c, d on page 20). This leaves four impact steps to be displayed, being *demographics, economics&lifestyle, energy efficiency&fuel mix*, and *abatement efforts.*

The discussion of results in the following sections has the following structure. First, in the next section the sequence of the model will be followed, implying that results are discussed by module, that is consumer expenditures (5.2.1), natural gas consumption of households (5.2.2), electricity consumption of households (5.2.3), motor fuel consumption of households (5.2.4), indirect energy requirement (5.2.5) and resulting emissions (5.2.6). Next, in section 5.3 the impact steps will be dealt with (section 5.3.1 to 5.3.4). In next chapter (6) the results will be evaluated and analysed in their entirety, while comparing between scenarios. Also derived measures such as elasticities will be presented there.

5.2 Results of the main modules

5.2.1 Income and consumption

The differences in economic growth, growth of labour productivity, marginal tax rates and labour time reduction (see Annex A) result in different levels of aggregate disposable income and different distributions of that income over household types. Since from an economic point of view the model is partial as regards its demand impulse, there have to be checks in order to take care that no serious imbalances are created. The output regarding GDP, aggregated pre-tax and after tax household income and, aggregate private consumption are therefore compared. The following rules have been introduced to prevent practically infeasible macro-economic results:

- the accumulated growth of pre-tax household income upto 2010 should not divert too much from the accumulated growth of GDP,
- the accumulated growth of after tax household income upto 2010 should be near to the growth of pre-tax income,

- the aggregate income tax burden (=total collected income tax/total pre-tax household income) should stay within very small margin (+- 1%).

The balancing was achieved by manipulating the fraction of labour productivity gains passed on to wages and the marginal income tax rates in the various scenarios. The results were guarded by including the labour income fraction (LIF) and the tax burden as defined above. A summary of the results in shown in table 5.1 below.

Table 5.1 *Macro economic key developments by scenario for the Netherlands*

	1990 (abs.)	BU 2010	SG 2010	SC 2010	ST 2010
GDP(10^9 gld)	487.6	48,7%	28,6%	28,6%	71,5%
Pre-tax hh.income (10^9 gld)	317.9	48,2%	29,2%	33,8%	71,2%
After-tax hh.income (10^9 gld)	225.4	47,0%	30,6%	33,0%	68,9%
LIF	0,652	0,650	0,655	0,678	0,651
tax load	0,368	0,368	0,361	0,370	0,366

The percentage figures for the four scenarios represent the total increases of the GDP and household income over the period 1990-2010. With the exception of the SC scenario the test ratings are very stable. Despite the absence of compensating higher wage rates connected to labour time reduction in the SC scenario, the resulting full employment situation with on average elevated education levels leads arguably to higher total wage costs. It can be argued that the overall investment requirement in the SC scenario is lower, save investments in environmental technology and infrastructure. Therefore it assumed there is room for the higher total wage costs.

The after tax household incomes are differently distributed over the household types in the different scenarios. As the demographic evolution boosts some micro economic developments while it compensates others, both the micro-income distribution and the macro-income distribution are shown in table 5.2.

Table 5.2 *Percentage changes in macro and micro income distributions in the four scenarios compared to 1990 levels [%]*

	BU		SG		SC		ST	
	macro	micro	macro	micro	macro	micro	macro	micro
Single <36	46	22	32	10	12	-6	61	34
Single 36-60	60	23	43	10	22	-6	77	37
Single >60	109	12	80	-3	80	-4	145	31
Couple <36	63	29	41	11	52	20	81	43
Couple 36-60	55	13	43	4	49	8	80	31
Couple >60	53	13	30	-4	41	4	85	37
Family <36	12	27	1	14	9	23	26	42
Family 36-60	37	16	26	6	29	10	62	44
1P. family <36	49	30	35	18	14	0	65	43
1P. family 36-60	76	17	53	1	68	11	115	34

The differences between macro and micro can be large due to demographic developments. For example, the number of retired singles will more than double between 1990 and 2010, while the number of young families (<36) is decreasing. The maximum disparity in income development at the micro level varies from 13% (+44 to +31) in the ST scenario upto 29% (+23 to -6) in the SC scenario. In the SC scenario the slow growth is in a way paid by households with only one employable person in present or past. In the SG scenario however the 'social bill' of low growth is especially paid by pensioners and older one parent households (i.e. the traditionally economically weak households). Table 5.2 makes also clear why economic growth is so widely revered by politicians. More growth enables an economy to make everybody happy, though some a bit more happy than others. This seems impossible in a low growth economy, regardless whether the low growth is intentional or not.

Table 5.3 *Stimulated aggregate expenditures by consumption category [mln gld] (output from model)*

Category description	1990	BU 2000	BU 2010	SG 2000	SG 2010	SC 2000	SC 2010	ST 2000	ST 2010
Basic foodstuffs	11391	11726	12197	11601	12112	11216	14997	11211	16156
Non-basic foodstuffs	17314	16437	17005	16231	16863	15816	21846	15618	23539
Alcohol and tobacco	4428	3413	3420	3339	3345	3141	5475	3100	6218
Outdoor meals and holidays	15599	23089	29230	22157	25908	21072	24875	22938	34186
Clothing and footwear	15892	17098	19685	16603	17207	16511	17440	16793	21043
Housing (rents, etc.)	44791	61053	72066	59598	68342	57790	64858	60081	78346
Gardening, furniture, etc.	12725	18249	22681	17340	20496	17235	20027	17727	26939
Domestic appliances	7390	9241	11295	8810	10019	8854	9969	9041	13267
Car and motor purchases	6158	7820	9324	7433	7998	7585	8569	7741	11207
Energy at home (gas, power, heat)	9912	12034	13519	11926	13246	11765	12990	11971	13878
Motorfuels for provate car	5012	5984	6898	5763	6147	5901	6526	5947	7889
Health and personal care	7930	10267	11666	10065	10978	9810	10894	10221	12530
Medical care	21392	24983	27459	24691	26449	24502	26497	24915	28666
Development and leisure	12252	15244	18075	14779	16433	14464	16275	15147	20351
Development and leisure	3632	4621	5350	4532	5080	4435	4985	4614	5620
Transport services, maintenance	14062	16890	19265	16557	18097	16652	18464	16808	20763
Total	209782	258148	299134	251426	278718	246751	284688	253875	340598

Table 5.3 summarizes the simulation results by scenario. The two lines both named 'development and leisure' refer to goods related expenditures and services related expenditures respectively. As can be seen in table 5.3, even with respect to development and leisure, a category strongly associated with services and less with commodities, the greater part of household expenditures is on goods, not services. This observation coincides with the notion that new trends started by elite groups that (perhaps) initially are service intensive and energy extensive, get more goods

intensive and hence energy intensive if a trends trickle down through society. Housing is and definitely remains the most substantial single cost item. Medical care is the second largest one in 1990, but is surpassed by the category 'outdoor meals and holidays' in the BU ans ST scenarios in 2010. In the SC and ST scenario payments on foodstuffs increase inter alia because of quality induced price increases. This is typically a category where the difference between the SC and SG scenario gets clear. The expenditures on appliances, cars, energy at home and motorfuels are modelled independent of the direct energy modules in which ownership and use is dealt with. Yet, the developments have been compared in order to check the plausibility.

Table 5.4 below gives an overview of the changes in aggregate expenditures by category and scenario. It summarizes the different evolutions in consumption patterns. At the same time it gets clear that such changes in patterns and the aggregate impacts can build up only slowly, even if explicit policies are implemented to enhance the changes. Under normal economic circumstances there is a maximum ability (or willingness) to reallocate the household budget. Only with brute economic and social force swifter changes may be realized.

Regardless of prosperity levels, expenditures on holidays and outdoor meals are consistently growing much faster in all scenarios. For this expenditure category a lifestyle change is very apparent. Compared to other free time expenditures the present energy intensity of this category is rather high, notably due to holidays (abroad). The character of holidays or at least the energy intensity needs a change. In the also substantially swelling category 'gardening and furniture', the gardening part can be very energy intensive as well (see Perrels and de Paauw, 1993). Medical expenditures grow relatively modest, despite the greying of society. This can be partly attributed to the fact that observed payments in this category are sort of curtailed due to the insurance schemes. Implicitly it means that the model assumes that disproportionate increases of medical costs are covered by public funds.

Table 5.4 *Evolution of aggregate consumption patterns in four scenarios expressed as percentage changes compared to simulated base year levels [%]*

	BU	SG	SC	ST
Basic foodstuffs	7	6	32	42
Non-basic foodstuffs	-2	-3	26	36
Alcohol and tobacco	-23	-24	24	40
Outdoor meals and holidays	87	66	60	119
Clothing and footwear	24	8	10	32
Housing (rents, etc.)	59	51	43	73
Gardening, furniture, etc.	74	57	54	107
Domestic appliances	51	34	34	78
Car and motor purchases	51	30	39	82
Energy at home	36	33	31	40
Motor fuels	38	23	30	57
Hygiene and personal care	55	46	45	66
Medical care	35	30	30	41
Development and leisure - goods	48	34	33	66
Development and leisure - services	47	40	37	55
Transport services, maintenance	37	29	31	48
Total consumption	43	33	36	63

5.2.2 Dwelling stock and heating

In all scenarios the total number of dwellings matches the total number of households, however the building programmes from 1990 upto 2010 differ among the scenarios. The building programmes in the BU and SG scenarios are the same and can be termed tendencial. In the ST scenario, having the largest material wealth, the building volume of detached dwelling increases, while the building volume of semi detached decreases compared to the BU scenario. In the SC scenario, in which space is also regarded as a scarce resource (observing the high population density in the Netherlands), the building volume of detached dwellings is shrinking compared to the BU scenario. Consequently, more flats are built to match the same total dwelling supply. Figures 5.1 and 5.2 give an overview of the development of the dwelling stock in terms of age structure and dwelling type composition. Since scrapping rates are identical in all scenarios, the age structure of the dwelling stock is the same. The average age of a dwelling rises from 31.2 years to 37.3 years.

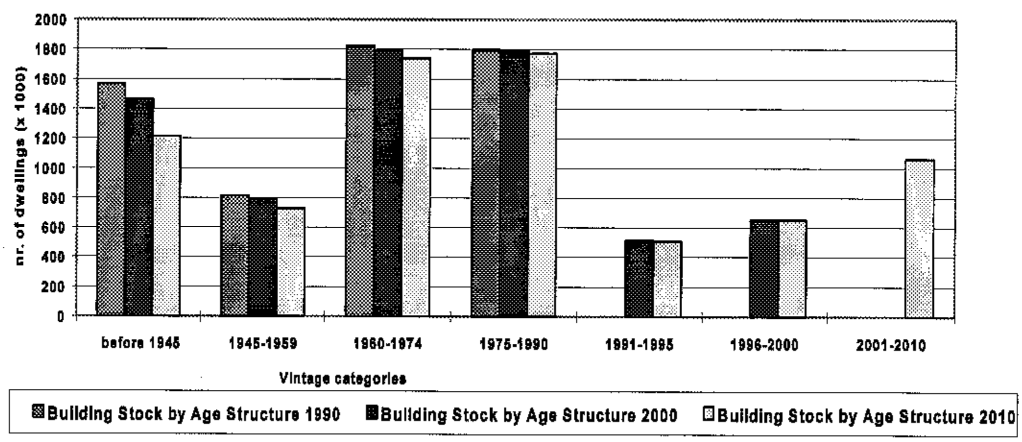

Figure 5.1 *Age structure of the dwelling stock 1990 - 2010*

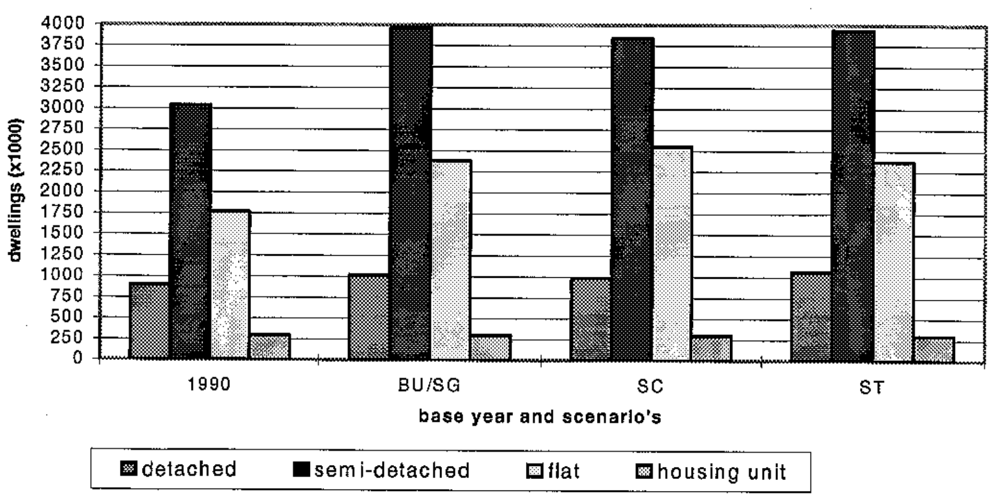

Figure 5.2 *Composition of the dwelling stock by type in 1990 and in 4 scenarios 2010*

The energy consumption for space heating and warm tapwater is to a large extent determined by the combination of dwelling type and heating equipment. On top of that there is a systematic variation due to household size, income and occupation. For newly built dwellings between 1990 and 2010 an increasing reduction on reference gas consumption is assumed (see section 3.2.3). The model assumes that central heating is the default choice of new homes, except for a small fraction of district heating. Furthermore, hot tapwater systems are supposed to be increasingly integrated with the central heating system. A part of the renovated dwellings is assumed to switch from local to central heating. All these system switches tend to increase the reference level of gas consumption. As regards cooking a gradual further penetration of electric cooking ranges is assumed. Yet, cooking constitutes on average only a minor fraction of household gas consumption, so the influence is marginal. It makes more difference for average electricity consumption.

In table 5.5 the levels of natural gas consumption in the four consecutive scenarios are summarized. The results are to a large extent determined by demographic changes. In addition impacts of more energy savings in new dwellings, composition of the dwelling stock and income level are significant. Compared to the currently prevailing expectations it is remarkable that such a significant increase of gas consumption is expected. Correcting for the increase of the number of households, the average consumption per dwelling is increasing with 4% to 9% depending on the scenario. The following considerations apply.

1. The average scrapped dwelling (often fitted with local heating) has below average gas consumption. So, substituted new dwellings may look efficient compared to recently built dwellings but in comparison with what they substitute their gas consumption is higher.
2. The addition to the dwelling stock is very efficient, but it constitutes 'only' 20% of the total stock in 2010.
3. Given the extensive post-insulation programmes in the past, it is assumed that improvement of existing dwellings, e.g. with HR-window panes, will not be a wide spread practice.
4. The influence of household income seems large and might be overscaled. Yet, as the parameter value is derived from statistical analysis, in which many other impacts had been controlled for, we don't want to reduce the parameter value right away. There is evidence that the income variable works as a proxy for home improvement. Over time households tend to enlarge and embellish their homes. This tendency is predominantly fuelled by disposable income.

In addition to the default simulations an extra calculation has been made to estimate the influence of solar collectors used for heating tap water. Due to the tightening of the Energy Performace Standard in 1998 it is very likely that solar collectors become a standard option for new dwellings. Given the thus created significantly larger market it seems likely that also a part of the existing dwellings will be fitted with a solar collector. Solar collector are assumed to penetrate in the BU, SC and ST scenario accounting for 25% (BU) or 40% (SC and ST) of the dwelling stock. The impact of the solar collector is shown in the bottom line named Total 2.

Table 5.5 *Simulated aggregate natural gas consumption by household category in four scenarios [in mln m³]*

	1990	2010 BU		2010 SG		2010 SC		2010 ST	
	Total	Total	Space	Total	Space	Total	Space	Total	Space
Single <36	876	1191	960	1183	952	1128	896	1188	957
Single 36-60	755	1092	891	1088	887	1048	846	1089	888
Single >60	1250	2587	2122	2565	2100	2519	2052	2614	2149
Couple <36	977	1421	1139	1415	1133	1404	1122	1395	1114
Couple 36-60	937	1417	1144	1421	1148	1415	1142	1395	1122
Couple >60	1499	2213	1797	2206	1790	2192	1776	2230	1814
Family <36	2692	2716	2091	2721	2096	2726	2103	2669	2044
Family 36-60	1915	2403	1894	2400	1891	2408	1900	2355	1846
1P. family <36	357	496	383	493	379	481	357	497	383
1P. family 36-60	144	257	199	256	198	255	197	260	203
Total	11403	15795	12620	15748	12575	15564	12391	15693	12520
Total 2		*15479*				*15035*		*15191*	

5.2.3 Domestic appliances and electricity

The electricity consumption of a household may vary due to changes in ownership rates of appliances and/or intensity of use of the appliance. Furthermore, over time new versions of appliances appear on the market that are more energy efficient. At an aggregate level also the composition of the households and the dwelling stock makes a difference. For a given household type ownership is largely determined by income. In specific cases other aspects such as dwelling type, number of children and the presence of other appliances can have significant influences. In connection with building and renovation programmes a certain switch to (cooking) or from (tap water) electricity is implied. The degree of future 'fashionability' of new appliances is hard to assess.

Due to insufficient information the electricity consumption of the category other (unspecified) appliances is underrated, hence the total electricity consumption in the base year is too low. As soon as more insight has been obtained about the category 'remainder' corrections will be implemented. Table 5.6 displays the evolution of appliance ownership by scenario for selected appliances, which still show changing ownership rates. For example, for the refrigerator and the washing machine the penetration is assumed to be already at its maximum. The differences in stock numbers between SC and ST are mostly modest. Significant differences occur for freezers (260000), dishwashers (825000)! and, TV sets (170000). The figures for BU and SG are in between the limits indicated by SC and ST. The 2010 penetration rates of the washing machine and the dryer are of course heavily influenced by the constructed penetration of the combined washing&drying machine. From 2006 onwards it is assumed that the latter machines become competitive in price and functional quality and consequently all substituted and additional new washing machines are supposed to be of the combination type.

Table 5.6 *Simulated stocks of selected appliances in 1990 and 2010 (SC and ST)*

	1990	SC	ST
Freezer	3199300	4028400	4290900
Washing machine	5740000	3580100	3580100
Dryer	1359000	1588400	1609700
Dishwasher	1213200	1790300	2615100
TV set	6431200	8409100	8580700
Video player	2698400	4745600	4745600
PC	2054100	5919500	5919500
Comb. Wash & dry	0	3625100	3625100

Subsequently, table 5.7 summarizes electricity consumption by scenario. In addition to differences in ownership the scenarios apply different improvement speeds of energy efficiency of domestic appliances. The average lifetime of an appliance is set at 10 years in all scenarios. The energy efficiency index of the appliance stock in 2010 has the following values in the scenarios:

1990	100
BU	78
SG	85
SC	74
ST	67

Due to the limited lifetime of appliances the progress in energy efficiency can built up faster than is the case for heating in the dwelling stock. This strong effect of energy efficiency and the relative neglect of the emergence of entirely new appliances and/or new applications compensates largely for the growth of the appliance stock. Therefore the simulated aggregate electricity consumption of households rises with a moderate 9.9% in the SG scenario and with a very modest 2.5% in the ST scenario. Taking into account that new appliances will presumably penetrate faster the more purchasing power is available, the BU and notably the ST scenario will experience the largest addition to the electricity consumption reported here.

Table 5.7 *Simulated aggregate electricity consumption by household category in 1990 and 2010 [TWh]*

	1990	BU	SG	SC	ST
Single <36	0,86	0,89	0,93	0,86	0,85
Single 36-60	0,75	0,84	0,88	0,81	0,81
Single >60	1,18	1,88	1,96	1,83	1,80
Couple <36	1,10	1,28	1,32	1,25	1,24
Couple 36-60	1,07	1,29	1,33	1,26	1,25
Couple >60	1,55	1,84	1,91	1,80	1,77
Family <36	3,70	2,91	3,01	2,86	2,83
Family 36-60	2,48	2.48	2,56	2,43	2,42
1P. family <36	0,52	0,53	0,55	0,51	0,51
1P. family 36-60	0,20	0,28	0,29	0,27	0,27
Total	13,41	14,21	14,74	13,87	13,75

5.2.4 Car ownership and motor fuels

For a given household type car ownership depends on income, household size, size of the city, and occurrence of shift work. Income is the most influential of these. In the present study average city size and the fraction of shift work are kept constant. Average household size is slightly decreasing for families. In addition to simulating the share of households owning at least one car, also the fraction of households with multiple car ownership is specified (contrary to car ownership this is exogenously set by scenario). Last but not least the fuel efficiency improvement varies by scenario. In terms of stock efficiency the following evolution is simulated per scenario:

1990	100,0
BU	83,6
SG	88,4
SC	80,6
ST	78,8

The development of the total car stock by household type is given in table 5.8. Multiple car ownership (expressed as the share of car owning households having more than one car) is assumed to increase slightly in the BU and SG scenario, while it increases at a somewhat higher pace in the ST scenario. Conversely in the SC scenario multiple car ownership is supposed to reduce as the result of explicit policies to attenuate car ownership and use while promoting public transport. The bottom line of table 5.8 gives the aggregate motor fuel consumption of the private car stock. The sluggish improvement of fuel efficiency in the SG scenario results in the highest total consumption. On the other hand thanks to the extra efficiency effort in the ST scenario the total fuel consumption hardly surpasses the volume required in the BU scenario, although the stock counts 650000 more cars. Last but not least the results of the SC scenario show that in case efficiency improvement is accompanied with attenuated growth in ownership (or more broadly: consumption) really substantial reductions can be achieved in total energy requirement.

Table 5.8 *Stock of private cars by household type 1990 and 4 scenarios 2010 [x 1000] and total consumption of motor fuels [in mln liter weighed fuel mix of gasoline/diesel/lpg]*

	1990	BU	SG	SC	ST
Single <36	388	540	508	437	589
Single 36-60	340	505	476	416	546
Single >60	503	1006	907	905	1173
Couple <36	564	796	776	715	853
Couple 36-60	503	736	732	668	800
Couple >60	680	1046	947	889	1130
Family <36	1380	1309	1300	1184	1389
Family 36-60	886	1101	1097	995	1172
1P. family <36	174	225	218	199	236
1P. family 36-60	76	119	112	113	139
Total stock	5494	7384	7072	6521	8027
Total fuel use	7696	8304	8493	7403	8347

5.2.5 Indirect energy requirement and emissions

The consumer expenditures by household type and consumption category are transformed into one aggregate consumption vector by sector for the input-output system (see Perrels et al.,1996). This procedure also includes a correction for VAT, levies and subsidies. The corrected (lower) amounts are fed back into the system to calculate the production effect, the transport effect and subsequently the energy requirement and the impact on emissions. The resulting consumption patterns that are the input to this segment of the model are discussed in section 5.2.1. This section will purely deal with indirect energy and emissions.

Anterior to presenting results about energy demand, the assumptions about energy efficiency in manufacturing industry, the services and the energy conversion sector are dealt with. Some scenarios additionally assume specific targets about the composition of the fuel mix. Table 5.9 gives an overview of the applied annual reduction rates on specific energy use in the productive sectors. As regards efficiency rates the energy conversion sector is included in the manufacturing industry. The figures for the BU and SG scenario are derived from van Hilten et al. (1995). The reductions are understandably higher in the SC and ST scenarios. Given the supposition of fastest technological advancements in the ST scenario, the largest reductions can be found in that scenario. All reduction speeds are still well within the technology possibility envelope, but the main constraints are thought to be economic, social and institutional.

Table 5.9 *Annual reduction of specific energy coeffcients in % by scenario 1990-2010*

	BU	SG	SC	ST
Manufacturing				
Fossil fuels	1.0	0.8	1.8	2.2
Electricity	0.7	0.5	1.5	2.0
Services				
Fossil fuels	0.8	0.6	1.8	2.2
Electricity	0.5	0.5	1.2	1.5

The primary fuel mix is supposed to develop proportionally in the BU and SG scenarios. In the SC scenario the share of renewables is set at 8% in 2010, while in the ST scenario a share of 10% nuclear is applied. Both measures are carried out in the context of boosting CO_2 reductions and will require major technical, financial and planning efforts for the remaining time upto 2010. The resulting indirect energy requirement and emission levels are summarized in tables 5.10 below. The fuel mix targets in the SC and ST scenario have a relatively strong impact on coal, which is the most effective fuel switch with respect to CO_2 reduction. The category other consists of renewables, nuclear and waste.

Table 5.10 *Indirect primary energy requirement of production and goods transport [PJ]*

	1990	BU	SG	SC	ST
Coal	240	257	256	155	123
Oil	103	121	116	94	111
Natural gas	461	496	489	401	435
Other	32	35	35	104	134
Total	837	908	896	755	803

Table 5.11 *CO_2 emissions due to direct and indirect energy consumption [Mton]*

	1990	BU 2010	SG 2010	SC 2010	ST 2010
Production	49	54	53	41	44
Goods transport	17	23	21	23	27
Households (direct):					
Gas	21	28	28	28	29
Electricity	8	9	9	7	7
Motor fuels	19	21	21	18	20
Total	114	135	133	116	127

The figures in table 5.11 are rounded off, therefore small differences in the table may be actually negligible. Energy efficiency improvement of the goods transportation sector has been held constant. So, the increasing amounts of CO_2 attributed to this sector reflect the growth of international trade. The contribution of domestic transport amounts only to 12% due to the limited distances and the large share of inland shipping. Clearly, the high economic growth in the ST scenario leads to more haulage of commodities across borders. Remarkably enough the impacts on trade in the SG and SC scenario differ so much. It means that the change in the consumption package in the SC scenario leans more heavily on imports than it does in the SG scenario. This could be termed a lifestyle effect.

The model also produces results for NO_x, SO_2, CO and VOC. For these emissions not only fuel switching and energy efficiency are relevant, but also specific abatement technologies can be very effective, such as catalyst convertors in cars. The reduction of these emissions In the Netherlands is heavily institutionalized through policy frameworks that are in various stages of operationalization. SO_2 abatements are already on track for quite a time and also NO_x emission reductions are implemented widely and often according to sectoral targets. Yet, notably for NO_x some sectors such transport are likely to fail the reduction target, since impacts of technology are more than compensated by growth of output (i.e. vehicle kilometers or tonkilometers). We supposed that the degree to which targets would be met varies by scenario. A brief explanation of the procedure follows below.

Emission reduction is brought about in 3 ways:
1. through increasing energy efficiency, that means the specific energy use is decreasing;
2. through fuel switching, notably in the SC and ST scenario;
3. through specific abatement technology.

Ad 1

For final energy consumption a decrease of specific energy use is specified as shown in table 5.9. A distinction is made between manufacturing and services, while electricity and other fuels have both their own efficiency improvements. The decreases vary over scenarios. The electricity production sector has been treated as manufacturing industry so as regards the use of fossil fuels to generate electricity the fuel efficiency development is applied.

Ad 2

In the BU and SG scenarios the fuel mix composition is only depending on calculated demand. Specific renewable targets etc. are absent. So, it means that the category 'other' (including renewables and nuclear) is growing more or less proportionally.

In the SC scenario there are targets for renewables in 2000 and 2010. The targets are:
3% of primary energy mix in 2000
8% of primary energy mix in 2010

In the ST scenario there is assumed a resurgence of nuclear, resulting in 10% of the primary fuel mix nuclear in 2010.

Ad 3

To specify effects from abatement technology the reduction impacts of the previous steps are calculated first. Subsequently, the current emission reduction targets for 2010 were considered. Based on this impact overview a net reduction target by emission type and sector is specified which is to be achieved by means of abatement technology. For CO_2 we did not apply any abatement technology in step 3. That means any reduction or reduced growth of CO_2 emissions stems from energy efficiency and fuel switching (notably CO_2 'free' options such as renewables and nuclear). Table 5.12 gives an overview of official reduction targets for NO_x, SO_2, CO and VOC. These emission targets are guidelines for implementation plans and sectoral agreements.

Table 5.12 *Allowed emission levels in 2010 as a fraction of 1990 level according to official NMP targets*

	SO_2	NO_x	VOC
Stationary			
Agriculture	-	-	0,11
Electricity generation	0,40	0,22	-
Manufacturing	0,14	0,09	0,28
Refineries	0,21	0,15	0,23
Households	-	0,30	0,14
Other sectors	0,08	0,30	0,24
Mobile			
Private cars	-	0,27	0,25
Trucks	0,42	-	-
Other transport	-	-	-

The following fulfilment factors have been applied to the remaining net abatement targets for NO_x, SO_2, CO and VOC:

BU 95%
SG 70%
SC 110%
ST 120%

Table 5.13 *Simulated emissions in four scenarios for 2010*

	1990	BU	SG	SC	ST
CO_2 [Mton]	114	135	133	116	127
NO_x [kton]	310	179	224	144	146
SO_2 [kton]	94	47	63	36	35
CO [kton]	632	661	678	583	653
VOC [kton]	206	122	151	93	98

It turns out to be very difficult to restraint the growth of CO_2 emissions. Nevertheless, the SC and ST scenarios clearly demonstrate that efforts do pay off. At the same time these scenario exercises hint at the fact that the current prevailing energy and emission strategies, which tend to lean for the greater part on technological progress can be risky if no more fundamental thoughts are dedicated about the *way society develops*. We will return to this issue in the next chapter.

The other results are ofcourse influenced by the target setting treatment explained above. As stated before also the results here indicate that major advancements and close-to-target results seem to be achieved for sulphur-dioxide (SO_2). For the other major acidifying emission (NO_x) the results are less reassuring. Whereas an overall reduction target of about 70% is specified, the best result rates just over 50%. Admittedly, the goods transport sector has been left untreated and would account for a substantial reduction. In the most fortunate case that might result in 60% reduction, however please note that exactly for this sector the achievements are very much dependent on actions abroad.

5.3 Decomposing impacts

5.3.1 Introduction

The simulations have been carried out stepwise. In each step more scenario variables were activated. By comparing the simulation results of the various steps one can obtain insight about the influence exerted by the various sorts of developments (i.e. demographic, economic, etc.). Though it was feasible from a model technical point of view, it has been decided to merge the contributions of economic and social (lifestyle) factors, since the developments are very much intertwined. For example, a higher education level not only exerts influence on the propensity to buy more in particular

categories, but it also improves the earning capability and therefore it affects household income. All in all the following steps or in fact types of influences are distinguished:
1. demographic changes,
2. socio-economic developments,
3. energy efficiency improvements and fuel mix targets,
4. progress in emission abatement technology.

Demographic changes are expressed by the number of households by household type and the average size of households by household type. Socio-economic developments comprise of growth of value added, growth of labour productivity, labour participation rates of main wage earners and other earners (endogenous in the model), wages (endogenous), social security level, marginal income tax rates, and relative prices of expenditure categories (see also section 5.2.1). Energy efficiency improvements are expressed as decreases of specific energy coefficients per fuel type per sector for industry and services. For CO_2 no specific abatement technology is assumed to be implemented prior to 2010. For example, power stations could be fitted with CO_2.

For households energy efficiency is specified as a decrease of an efficiency index per appliance and private car. As regards direct energy use, the consumption of natural gas is also influenced by the way the future dwelling stock develops in the various scenarios. Flats require less heating energy compared to detached houses (see also section 5.2.2). Similarly, the development of the car stock is endogenized for the greater part, however the development of multiple car ownership (having a lower mileage) is specified exogenously and varies over scenarios (see also section 5.2.4). Both impacts of stock variation are comprised in second step. An over view of all the exogenous variables by impact step is provided in Annex B.

The discussion of impact steps will focus on the impacts on emission levels of CO_2 and NO_x. For CO_2 the last impact step (abatement) is not relevant, conversely it is very relevant for the other emissions.

The emissions can be divided in so-called indirect emissions, related to the non-energy expenditures and in direct emissions related to direct energy use of households. The indirect emissions are attributed to production and goods transport (inland and abroad). The direct emissions are composed of emissions from natural gas use, the attributed share of household electricity consumption and, motor fuel consumption. The various segments of direct and indirect emissions develop to quite different degrees in the subsequent impact steps.

5.3.2 CO_2 emissions decomposed

The figures 5.3 to 5.6 illustrate the decomposition of impacts on CO_2 emission levels. Since the graphs originate straight from the model the scale varies per scenario! The stacked bars in each figure compare the contributions of the separate impact steps with the original emission level of a segment (i.e. production, passenger car, etc.). Parts of the bar above the 0% axis denote additions to the 1990 emission level, while downward pointing parts of the bar denote reductions of the 1990 emission level. Since no efficiency improvement is included for the goods transport sector these segments (2nd to 4th) only show additions to the 1990 level, with the exception of the

SG scenario in which the total consumption package turns out to be slightly less import dependent, hence the small downward pointing black bars for the economic effect in figure 5.4. It is directly obvious from the graphs that population growth becomes relatively more important influence, when economic growth is lower. The increase of 25% in the total number of households upto 2010 establishes a substantial 'minimum' growth in the energy and emission development, notably of home related energy use.

Other aspects being equal the demographic development boosts the overall CO_2 emission level 20,6% (see the first -dark grey- part of the stacked bar at the extreme right of figures 5.3 to 5.6). Whereas natural gas use seems to grow even faster due to changes in structure of the dwelling stock and heating equipment-dwelling type combinations, car ownership and use stays behind due to the ownership rates held constant in this demographic impact step. In next impact steps it shows that notably the car ownership rates increase due to economic effects (the large black parts in the stacked bar for the use segment 'passenger cars').

The overall contribution of socio-economic changes (in the graphs indicated as 'economic' and represented by the black parts of the stacked bars) varies from 6,6% in the SG scenario to 22,1% in the ST scenario. The impact of extra income is mostly exerted via indirect energy and emissions (production and goods transport) and through private car ownership. The consumption mix in the SC and ST scenario seems to be more import dependent, which causes an extra contribution to the emission level.

The impact of energy efficiency and fuel switching (indicated as 'energy eff.' in the graphs and represented by the light parts in the stacked bars) varies from -9,0% in the SG scenario to -24,1% in the ST scenario. Notable differences between the scenarios can be found for the segments production (from -13% in SG to -40% in ST), electricity at home (from -9,8% in SG to -32.8% in ST) and, private cars (-11,6% in SG to -21,5% in ST). Please note that these figures refer to contribution of entire machinery or appliance stock. The newest appliances and machines in 2010 are already much more efficient. Therefore, even if further - marginal - efficiency improvements would not materialize, the efficiency improvement would continue until 2020 thanks to substitution of old appliances (having a lifetime of 10 years).

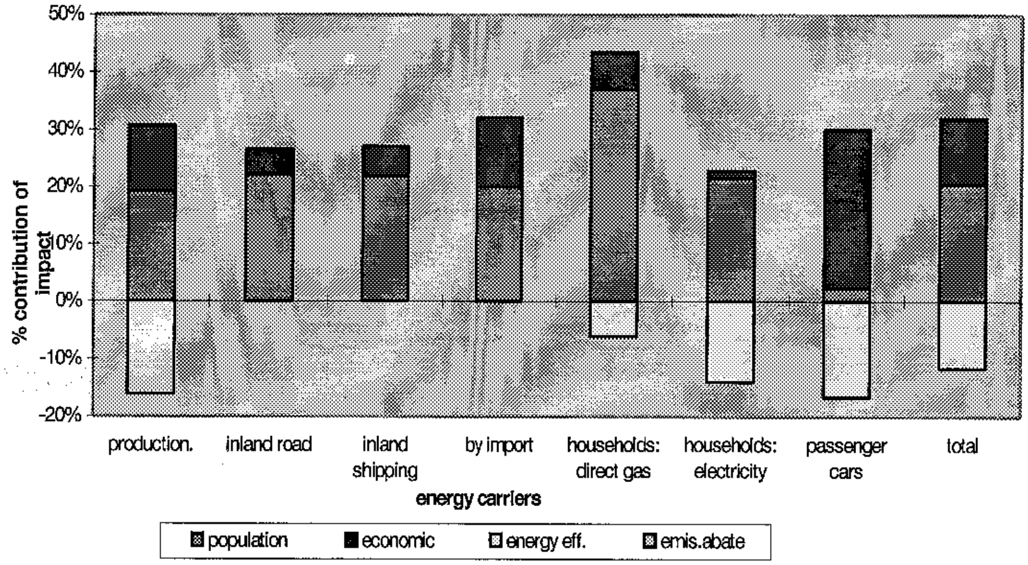

Figure 5.3 *Contribution to CO_2 emission changes by user segment, BU scenario 2010*

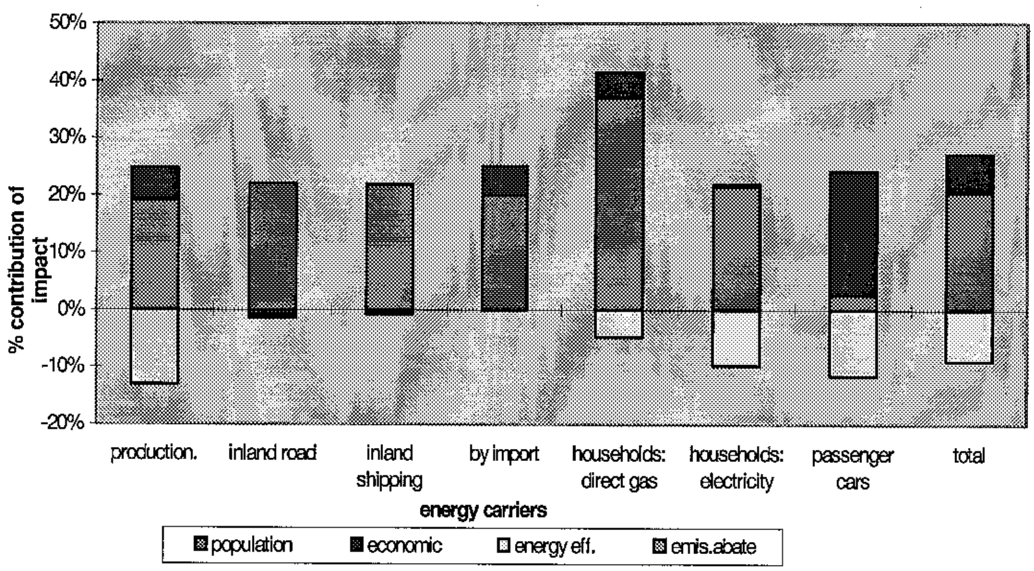

Figure 5.4 *Contribution to CO_2 emission changes by use segment, SG scenario 2010*

Consering the overall emissions of CO_2 we can argue on the one hand that it is quite disturbing that even the scenarios meant to bring about change, result in no reduction of CO_2 emission levels. On the other hand several technical possibilities have been hardly or not included, while the influence of household income on natural gas consumption at home seems to be overrated. Yet, even if energy efficiency improvement in goods transport and lower income elasticities for energy use at home would be applied, only the SC scenario seems to achieve a reduction of about -5%. Furthermore, whereas natural gas consumption could be lower, electricity consumption of households is generally expected to be higher. So, by and large the simulations give a good picture of the dynamics and the order of magnitude of what might be achieved in the considered time span. The time span is indeed important, notably in the ST scenario. It should be noted that a continued emphasis on technological breakthroughs may make available dramatic reductions in specific energy use, fossil fuel dependency, and specific emission levels, though over a longer time span. These dilemma's will be further discussed in the following chapter.

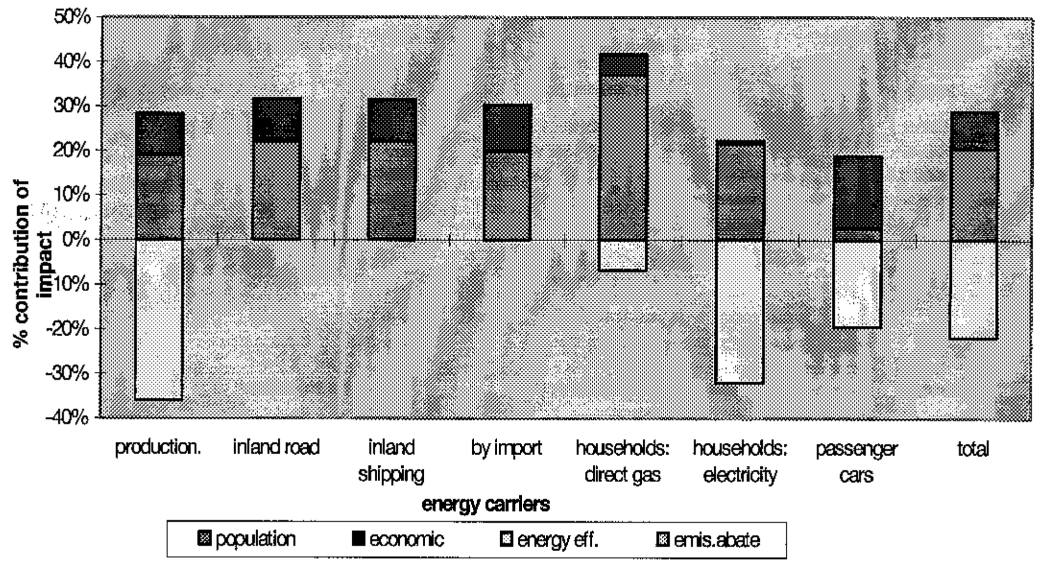

Figure 5.5 *Contribution to CO_2 emission changes by user segment, SC scenario 2010*

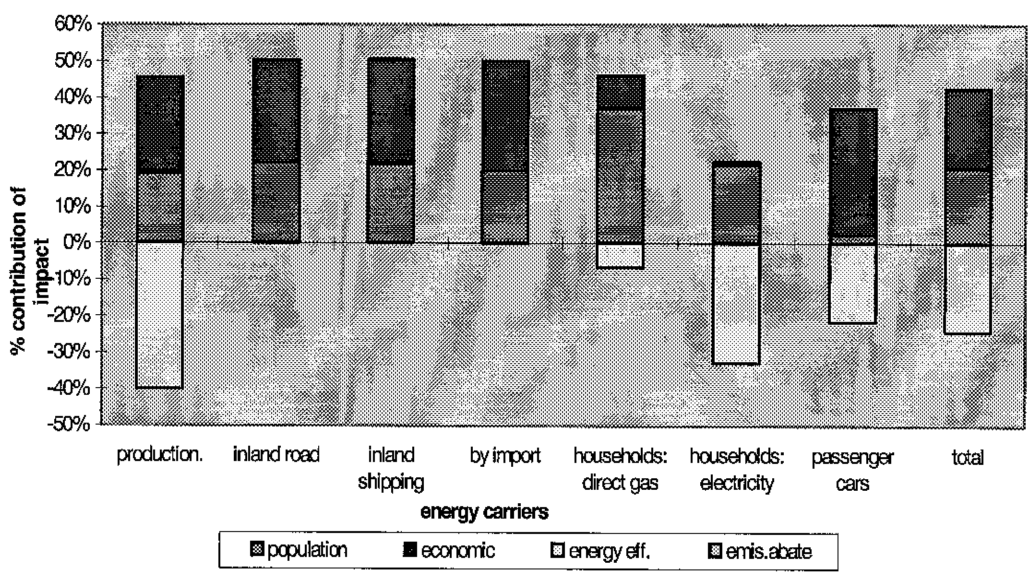

Figure 5.6 *Contribution to CO_2 emission changes by user segment, ST scenario 2010*

5.3.3 NO_x emissions decomposed

The NO_x emissions are reduced in all scenarios. The difference with CO_2 is that policies are already put in place for reduction of these emissions. The same applies to the reduction of SO_2 emissions. Yet, for these acidifying emissions the targets are also sharp for several sectors (see section 5.2.5).

The contributions of demographic changes, socio-economic changes and energy efficiency and fuel mix are largely the same as for CO_2. The big difference is however the wide scale application of abatement technologies. The overall impact of abatement technology varies from -36,8% in the SG scenario to -59.4% in the ST scenario. Table 5.14 shows that in the SC and ST scenarios three out of four main sectors approach or meet the reduction targets.

Table 5.14 *Emission targets in percentage reduction and expected achievements in two scenarios in 2010*

	Target	SC	ST
Production sectors	-90	-78	-82
Goods transport	-	+33	+56
Homes	-70	-61	-69
Private cars	-73	-81	-87

Due to the large increase of transport the overall impact is slightly worse in the ST scenario. Nevertheless, for the other sectors the larger advancements in abatement technology and energy efficiency are capable to compensate for the impact of economic growth. The same mechanism is active for SO_2, where it even results in a slightly lower overall emission level for the ST scenario. The figures 5.7 to 5.10 exhibit the decomposed results for NO_x.

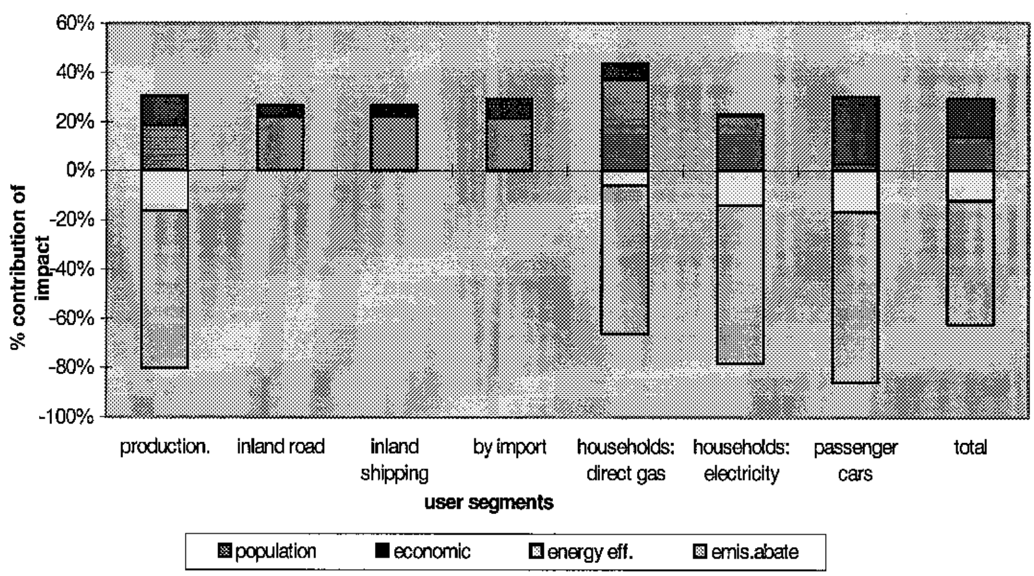

Figure 5.7 *Contribution to NO_x emission changes by use segment, BU scenario 2010*

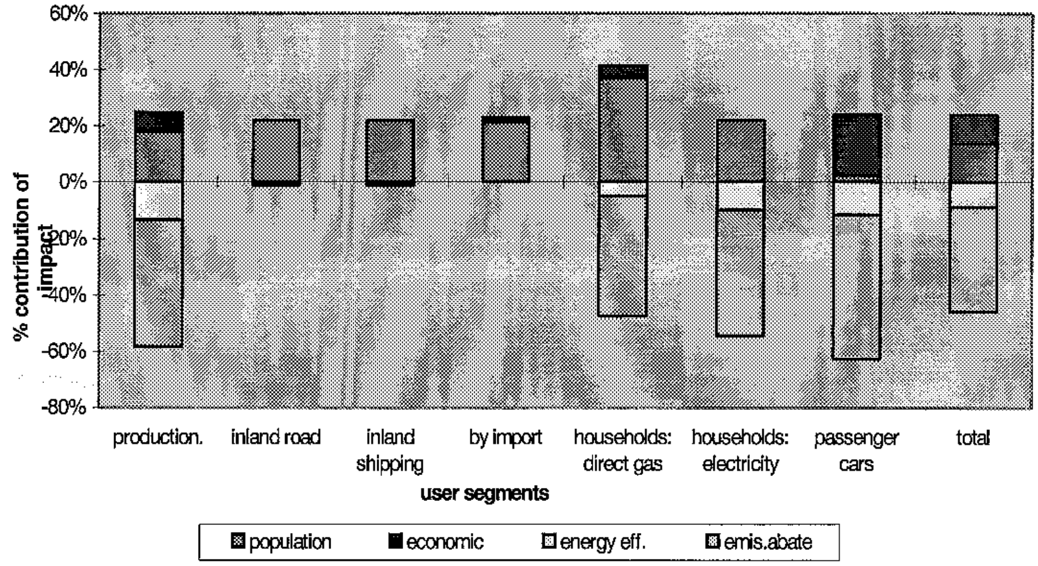

Figure 5.8 *Contribution to NO_x emission changes by user segment, SG scenario 2010*

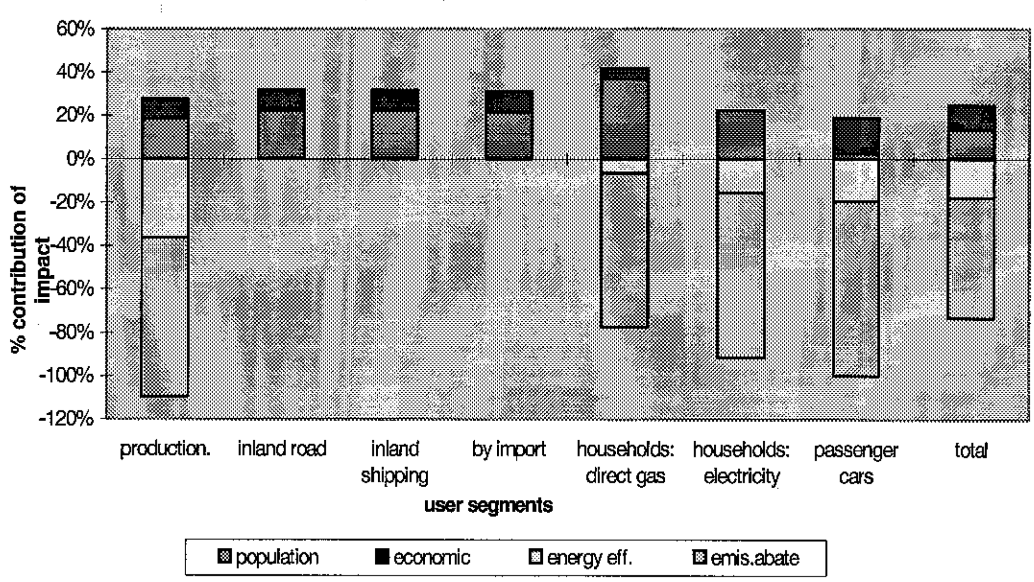

Figure 5.9 *Contribution to NO_x emission changes by euser segment, SC scenario 2010*

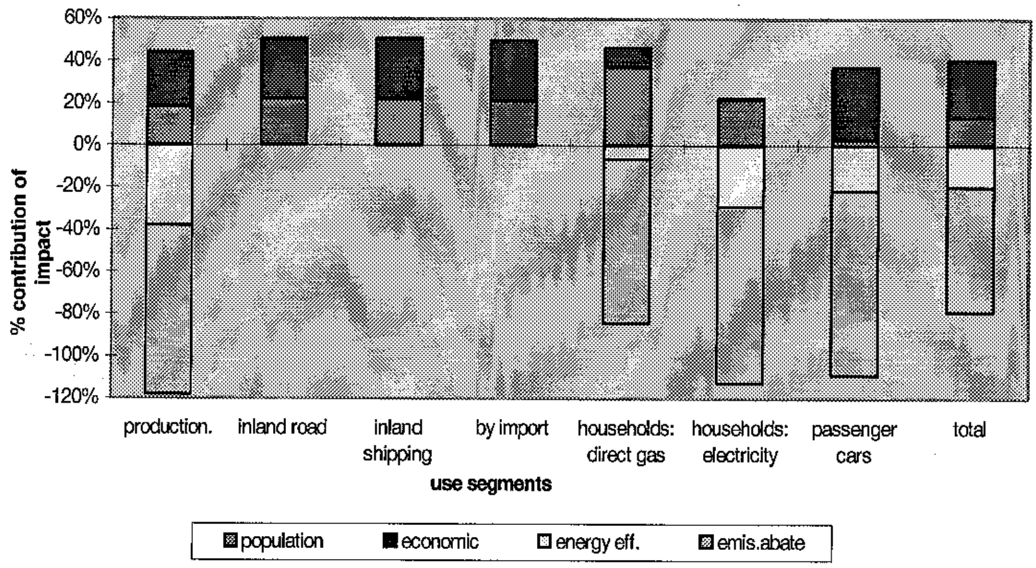

Figure 5.10 *Contribution to NO_x emission changes by user segment, ST scenario 2010*

6. OVERALL EVALUATION OF SCENARIOS

6.1 Macro level comparisons

The scenarios were meant as explorative, but in such a way that each scenario represents distinct elements of a plausible future. In this chapter the plausibility of the scenarios is evaluated, inter alia by considering various implied elasticities in the model. In order to be plausible it is assumed that changes at more aggregate levels cannot be extremely drastic. Within one sector or regarding one energy carrier changes could be dramatic. Under normal circumstances that becomes unlikely for the society and the economy at large. In that case the time span 1990 - 2010 is too short. So, in that sense, the direction of and pace of change is more important than the absolute levels. There are plenty of empirical studies in economics to obtain an impression of what is a reasonable interval for a particular elasticity, notably at aggregate levels. In this chapter several aggregate and disaggregate - implied - elasticities will be discussed. They provide hints both to the plausibility of the scenarios and to the plausibility of the model parts. Table 6.1 summarizes several key developments and connected elasticities for the four scenarios.

Table 6.1 *Key developments and elasticities in the four scenarios*

	Growth of		Elasticities of GDP and		
	p.e.r[1]	GDP	p.e.r.[1]	CO_2	NO_x
BU	15,2%	48,7%	0,31	0,39	-0,87
SG	14,3%	28,6%	0,50	0,59	-0,97
SC	2,0%	28,6%	0,07	0,07	-1,88
ST	8,8%	71,5%	0,12	0,16	-0,74

[1] Primary energy requirement

The displayed GDP-energy elasticities are systematically lower than the GDP-CO_2 elasticities. A priori equal numbers would be expected or even lower figures for GDP-CO_2 elasticities since there is - in theory - an extra possibility of abatement technology. Yet, apparently the segments with lower energy efficiency- such as goods transport - seem to grow faster than those with higher efficiency. In case energy efficiency measures for goods transport would have been activated in the model the difference between the two figures would have been smaller but still significant. In other words, other things being equal, if economic growth causes a disportionate growth of trade, it aggravates the emission reduction problem. Though the model may overstate the problem to some extent, it still identifies rightfully the problem of international trade growing faster than GDP. This is a worldwide phenomenon.

Keng (1992) applies a variable elasticity model to demand for electricity in Canada. He finds a drop from 1,52 to 1,07 over the period 1961-1987. This implies a drop of roughly 1 percent point a year. The current long run elasticity for the Netherlands lies in an interval between 0,35 and 0,50 (see also Perrels and Rouw, 1992). Consequently, applying the findings of Keng to the Netherlands yields that a decrease of an average 20 to a high 30 percent points of the long term elasticity seems feasible in the period 1990 to 2010. In that context the elasticity implied in the SC scenario seems to lie already near the lower bound of a feasible trajectory. Negative long term elasticities may be achieved around 2020. Otherwise stated, substantially more dramatic reductions within the considered time span require definitely dramatic societal and technical changes.

Given the uncertainties about transferability of findings another test has been applied. In Perrels (1994) a cross country GDP/capita-energy/capita ratio has been discussed. The investigation suggests that energy per capita strongly increases for lower GDP values but starts to level off when higher (OECD) levels of GDP/capita are reached. The countries with the highest GDP per capita (Switzerland, Japan) suggest even a downward sloping curve beyond a certain high income level (approx. 19000 US$ of 1987). However skipping the outlier (Switzerland) suddenly leads only to stabilisation not to reduction of energy use per capita (see Annex B for details). After all, also this test leaves us with a wide margin of possible results. Taking into account the latter considerations, the model results could be regarded as being on the cautious side but are giving more precision and explaining underlying causes than simply applying estimated elasticities directly.

Finally, based on recent IEA figures (IEA, 1994) the expected uncompensated (gross) GDP - primary energy elasticity has been derived for 2000 and 2010. According to the IEA expectations the elasticity for the period 1991-2000 is 0,21 and for 2000 -2010 0,44. So, the plausibility of the scenario results seems to be hardly an issue, provided one continues to observe the function of the scenarios.

As regards household direct energy use the CO_2 emission change attributed to social - economic changes has been analysed by scenario. The elasticities are displayed in table 6.3. CO_2 elasticities come near to or coincide with the energy elasticity. The average change of household income is used here. There can be significant differences by households. That the elasticity decreases with higher income is correct and coincides with the expenditure behaviour as described in the consumer expenditure system. The levels seem however too high for natural gas and too low for electricity. For motor fuel it is more in line with other findings, except for the SG scenario. This deviation for SG is possibly due to a too high rate of multiple car ownership. Table 6.4 shows overall CO_2 elasticities related to net household income, however here all effects, including stock composition, energy efficiency etc. has been included.

Table 6.3 *Specific CO_2 emission elasticities of direct energy use with respect to net household income implied by the ELSA model, 1990-2010*

	Natural gas	Electricity	Motor fuel
BU	0,37	0,08	1,6
SG	1,04	0,09	5,0
SC	0,76	0,13	2,6
ST	0,27	0,03	1,0

Table 6.4 *Overall CO_2 emission elasticities by sector of use with respect to net household income implied by the ELSA model, 1990-2010*

	Production	Transport	Natural gas	Electricity	Motor fuel
BU	0,25	0,73	0,79	0,13	0,19
SG	0,31	0,85	1,18	0,33	0,34
SC	-0,50	0,98	1,02	-0,50	-0,11
ST	-0,14	0,85	0,58	-0,25	-0,12

Contrary for the GDP elasticities at the macro level we can observe here more differentiation with some sectors already having achieved negative values in some scenarios. As regards future research the elasticities of (goods) transport and of natural gas use at home deserve attention in order to find out whether the prospects are indeed so modest.

Grouping the scenarios in a tendencial segment (containing Business as Usual and Stagnation) and a sustainability oriented segment (containing Sustainability through reflective Consumption and Sustainability through Technological breakthrough) the different messages from the scenarios are clear enough. If the society would proceed along tendencial lines the emission levels will be too high compared to the stabilisation and reduction targets. So, the choice should be to intensify the sustainability orientation, provided we want to take the emission targets seriously. At the same time the two sustainability oriented scenarios demonstrate that there are different ways that can be followed and various elements to be guarded. The present results from the latter scenarios show that it is very likely that more has to done to achieve stabilisation and subsequently reduction of CO_2 emission levels. Also for NO_x some intensification of measures is necessary to meet the targets.

6.2 Emission profiles of households

Given the organisation of the information in the ELSA model it is possible to connect energy and emissions to the 'individual wallet' of a household. For the average household or for one of the ten households types a so-called profile can be produced. In such a profile the allocation of the money budget is compared with the related energy requirement and emissions. Similarly profiles for consumption categories can be produced, which show the energy and emission intensity per guilder spent for the 16 categories.

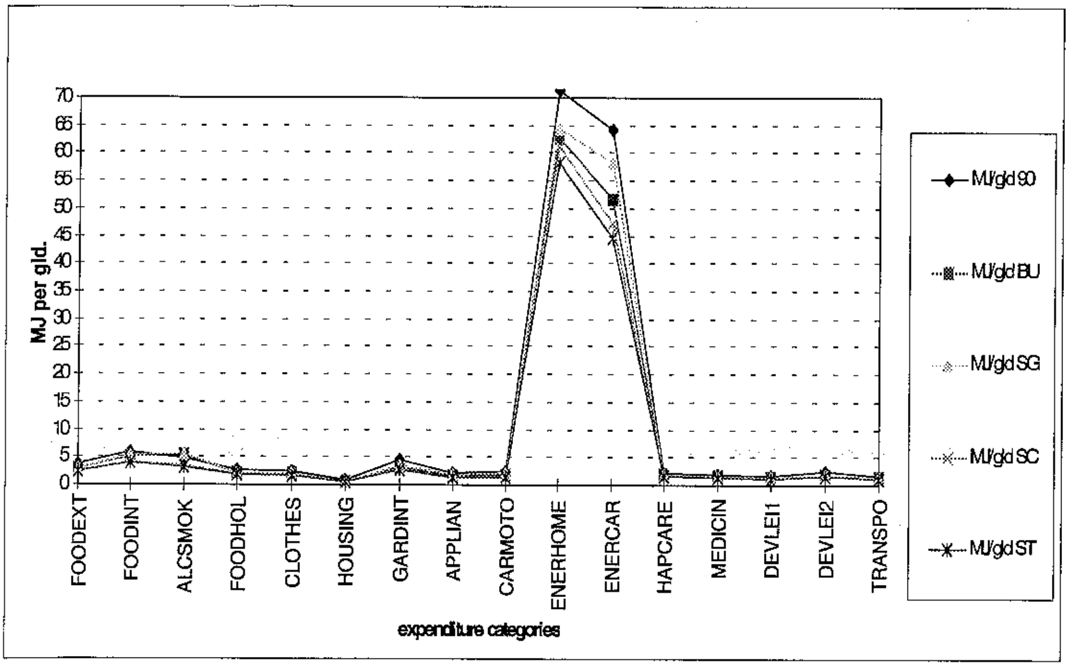

Figure 6.1 *Energy intensities of 16 consumption categories in 1990 and 4 scenarios*

Figure 6.1 shows the energy intensities as calculated by the ELSA model. The intensities for ENERHOME and ENERCAR which represent direct energy use are higher than previous calculations made by Vringer and Blok (1993). The direct energy use is obtained by technical economic simulations in the model while the expenditure levels are in fact too. Therefore the quotients (= intensities) are higher. In addition the under recording of car fuel purchases and the significant share of company cars (for which the fuel is not paid by households) results in a very high intensity for motor fuels. Furthermore it turns out that the intensity for FOODHOL (outdoor meals and holidays) is lower than expected. This can be partly regarded as a correction on earlier results while on the other hand fuel use abroad and bunker fuels of airplanes and international ferries are presumably missed in the input-output system. Given the earlier discussions about the scenario results it will be no surprise that the energy intensities decrease though the extent of reduction is not the same for every commodity group. Figure 6.2 gives more detail for the non-energy goods.

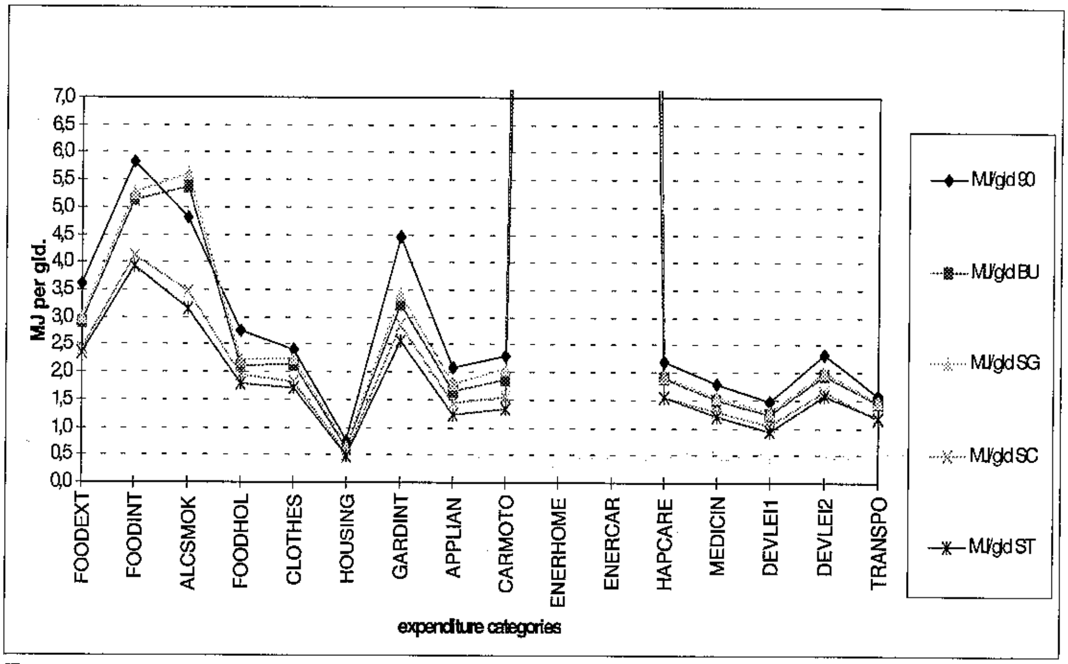

Figure 6.2 *Energy intensities of 16 consumption groups (detail), 1990 and 4 scenarios*

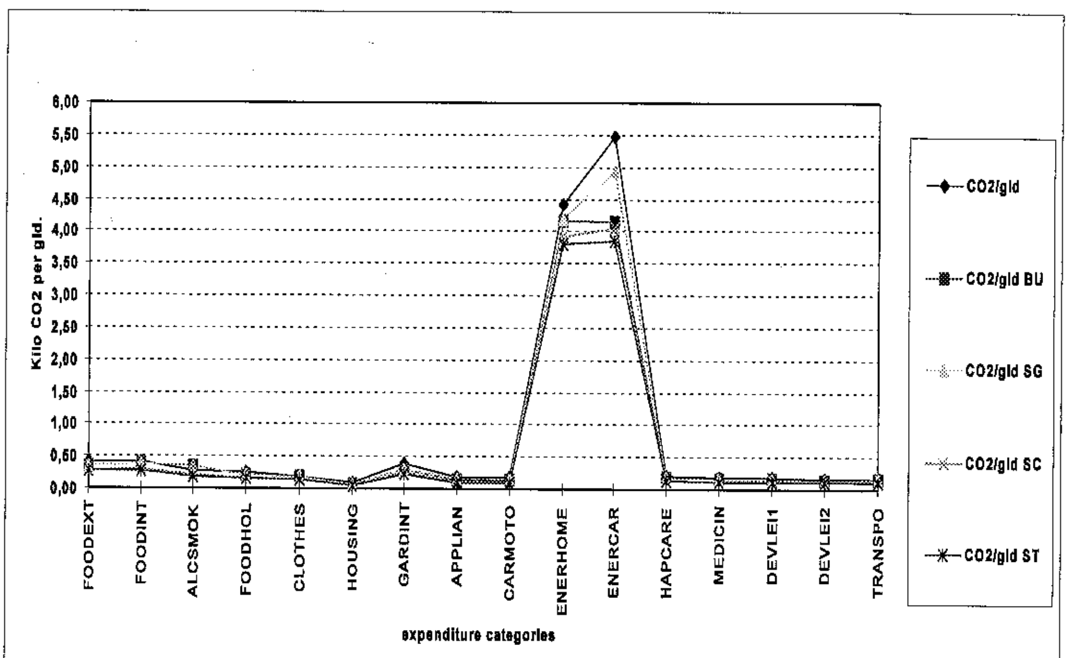

Figure 6.3 *CO_2 emission in kilo per guilder for 16 consumption categories*

Figure 6.3 gives the emission profile of CO_2 for 16 consumption categories in 1990 and four scenarios. Notwithstanding the close similarity with the energy profile there are some differences. For example motor fuels are relatively more CO_2 intensive.

Figures 6.4 and 6.5 show the equivalent kind of graphs for the NO_x intensity. Figure 6.5 is a detail of 6.4 compable to figure 6.2 relating to 6.1.

The general shape of the NO_x profile differs significantly from the CO_2 profile and also the development of the scenarios differs from that for CO_2. The dominance of the car as an emission source is striking, while also the impact of efficiency improvement and abatement technology in cars impressive. Figure 6.5 provides better insight for the non-energy commodities. The categories with modestly reducing intensities can be more depending on imports, which involves long distance transport. This applies for example to clothing.

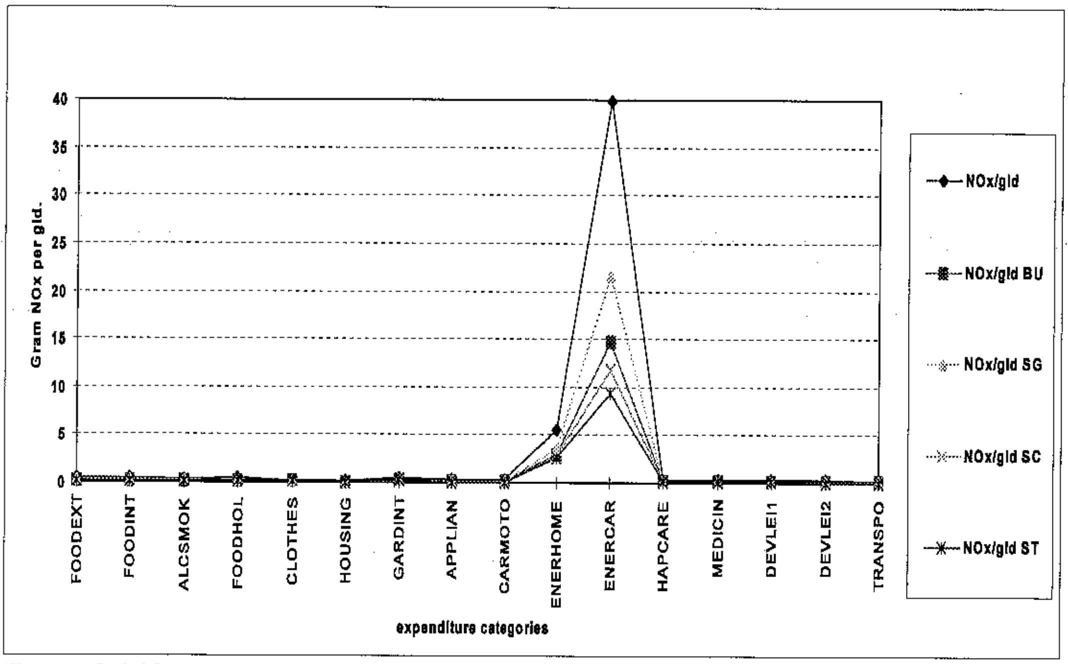

Figure 6.4 NO_x *intensities of 16 consumption categories, 1990 and 4 scenarios*

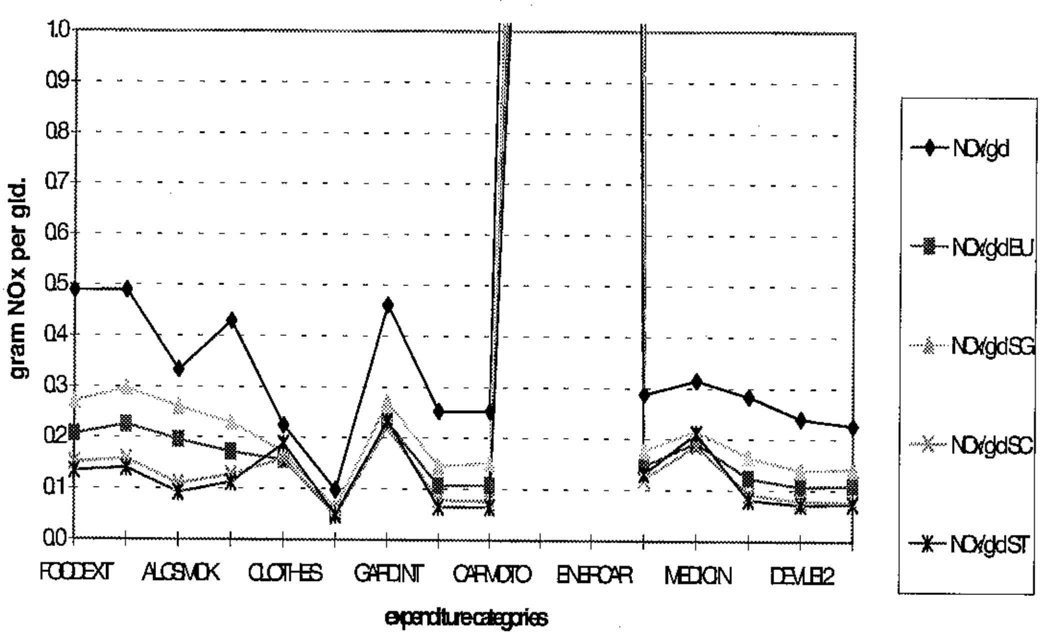

Figure 6.5 NO_x *intensities of 16 consumption categories (detail), 1990 and 4 scenarios*

The graphs 6.1 to 6.5 have demonstrated clearly that both the distribution of energy and emission intensities in 1990 and the reduction of intensities in future shows a large variation over consumption categories. In other words it really makes a difference how a household spends its money. This will be further shown in table 6.5 below, in which the money budgets of several household types is matched with energy and emission 'budgets'. Not only the sheer volume of the money budget but also the allocation over categories counts. For example in the BU scenario middle aged singles and young one-parent families have almost the same budget in guilders (± 34100), but the resulting CO_2-'budgets' differ substantially (13,9 and 17,0 respectively). According to the results displayed in table 6.5, an increase of purchasing power results in an increase of the CO_2-'budget', if the initial level of purchasing power in 1990 was low. However two of the three household types with higher initial purchasing power in 1990 demonstrate that increase of their purchasing power can go along with a *reduction* of their CO_2-'budget'. The table also indicates that a carbon tax, provided it works out commensurate to carbon contents of taxed commodities, will affect the income distribution in sometimes unexpected ways. By and large it holds that an increase of purchasing power is accompanied by a less than proportionate increase of CO_2 emission, but the effect varies over household types. A second striking feature is that notably younger families have relatively higher emission budgets.

Table 6.5 *Money and emission budgets by household type and scenario*

	1990			BU			SG		
	[gld]	CO_2	NO_x	[gld]	CO_2	NO_x	[gld]	CO_2	NO_x
Single <36	26862	11,1	34,0	31516	13,7	18,7	29615	13,7	24,6
Single 36-60	28169	11,6	27,4	34206	13,9	16,8	31745	13,6	21,7
Single >60	26491	9,8	15,8	29824	13,1	14,2	27177	12,9	18,3
Couple <36	36554	16,5	44,0	43111	20,2	31,4	39330	19,2	36,4
Couple 36-60	39677	14,8	35,1	44044	19,1	23,0	31739	18,2	28,2
Couple >60	34011	17,7	38,5	36796	18,2	24,3	33208	17,3	28,9
Families <36	39037	23,4	75,2	48098	21,1	30,8	45502	21,7	39,5
Families 36-60	41987	21,4	56,3	47655	21,6	29,0	45342	21,7	37,6
1_Parent fam. <36	28785	14,3	29,0	34078	17,0	20,4	32378	16,9	26,0
1_Parent fam. 36-60	33216	13,3	28,2	36936	18,0	22,0	33993	17,5	27,0
	SC			ST					
	[gld]	CO_2	NO_x	[gld]	CO_2	NO_x			
Single <36	25519	10,5	13,7	33027	12,2	14,1			
Single 36-60	27374	10,6	12,6	36173	12,3	13,2			
Single >60	26303	10,9	11,4	32875	11,6	11,4			
Couple <36	42434	17,6	24,2	48806	19,4	25,5			
Couple 36-60	44567	16,9	19,6	51461	18,2	19,9			
Couple >60	36278	15,9	19,3	44459	18,3	21,2			
Families <36	48787	19,2	26,2	54495	19,7	24,6			
Families 36-60	47507	19,3	24,5	56421	20,8	24,2			
1_Parent fam. <36	30016	13,2	14,1	38110	15,8	16,6			
1_Parent fam. 36-60	37387	15,8	17,5	44470	17,8	19,2			

7. CONCLUSIONS

The scenarios simulated by means of the ELSA model have demonstrated the importance of social, economic and technological developments for understanding the overall dynamics in energy consumption and resulting emissions. Notwithstanding model details that would benefit from improvement, the ELSA model is capable of transforming socio-economic changes into energy consequences. In other words, it shows the consequences of the evolution of (western) lifestyles for energy consumption of a country. The kind of lifestyles that emerge and the societal structures implied by them in economic, social and technological sense definitely make a difference to the size and composition of the primary energy requirement of a country. It has also been demonstrated that not only the level of economic growth as such, but also the way consumption patterns evolve makes a difference.

The Sustainability through Reflective Consumption scenario comes close to a stabilisation of the CO_2 emission levels in 2010. The Sustainability through Technological Breakthrough scenario experiences still an increase of CO_2 emission levels of approximately 11%. The scenarios differ substantially in societal evolution and consequently the risks to be taken are of different nature. In the scenario following the road of Reflective Consumption there is a socio-economic risk. For single-earner households, notably single person households, the slow growth and redivision of work leads to loss of purchasing power. There is a problem of social acceptation here. Furthermore, the economy attempts to shift from growth based on labour productivity to growth based on natural resource productivity. It remains to be seen to what extent differences in the basis of growth between countries can be sustained, observing that world capital markets are only becoming more transparant and more responsive to short term returns on investment. The other scenario puts great trust in large technological advancements, which however can only be achieved or rather paid for when there is enough economic growth to pay for it. The problem is how fast the returns on investment will diminish when more money is put into R&D. There is a serious risk that the volume of economic growth wipes out all the potential gains of technological improvements. It means that in the long run a very high share of for example renewables and nuclear might be achieved, but in the meantime much higher emission levels have to be sustained. Furthermore, the rebound effect may cause a substantial amount of extra energy demand notably in the ever wealthier household sector.

The period 1990-2010 is regarded as long in social research, but is regarded medium term from a physical science point of view. The length of the period is a compromise between both viewpoints. It should be noted that technological studies considering longer time spans usually identify more possibilities for dramatic technology based changes. The present study can also be regarded as an attempt to investigate whether there are societal feasible trajectories to get there, and if so, to identify what are the crucial conditions to follow such trajectories.

The scenarios are explorative and by no means meant to give definitive information. Rather, elements from the Sustainability through Reflective Consumption scenario and the Sustainability through Technological Breakthrough scenario can be used to formulate new research questions. Is there a level of economic growth that is high enough to enable sufficient technological progress in energy and emission technology without creating such a voluminous extra production that all gains in reductions of emission levels are lost? A second question would be to specify what minimum economic growth level would be required from the viewpoint of social acceptability (this social notion preferably includes also relations between rich and poor countries). A third related question would be what measures with respect to end-use prices, market (re-)regulations, and social and physical infrastructure would facilitate the compromise between economic growth and a (timely) move toward sustainability.

Thanks to the disaggregated approach the following consumption categories and household types deserve special attention in the sense of showing disproportionate large growth. The category outdoor meals and holidays grows strongly in all scenarios and can be certainly identified as a robust lifestyle feature. Outdoor meals as such are not problematic from an energy point of view. However, the trip to the location often requires car transport. Furthermore, it is often integrated in holiday patterns (hence their treatment in one sub-category) and holidays abroad are above average energy intensive. The elderly singles are becoming an important consumer category. Yet, the increase of their aggregate outlays is rather sensitive to economic growth and the distribution of wealth. The robust tendency in all scenarios to spend more on housing and interior may enhance perspectives for more (implicit) investments in energy efficiency at home.

The experience to co-operate and link model approaches in several countries has been very instructive and showed to be not easy. Institutional differences between countries often lead to inevitable differences in model construction. For Germany and the Netherlands the models are fairly similar, but the differences and their consequences for responsiveness to scenario assumptions needs still more attention. The ELSA model for the Netherlands has several features that need elaboration. The following can be mentioned:

Electricity in households
- more new appliances to be included,
- more attention for remaining (unspecified) electricity use,
- linkage with the SAVE-Households model.

Natural gas in households
- easier inclusion of small scale renewable options such as solar collectors,
- more possibilities for energy saving in existing dwellings,
- linkage with the SAVE-Households model.

Cars
- linkage with the SAVE-Transport model.

Dwellings
- additional differentiation by location (urban/non-urban).

Economics
- treatment of relative end-use prices in relation VAT, subsidies and levies;
- inclusion other final demand vectors (government, investments, exports);
- transformation into general equilibrium model;
- linkage of Input-output systems of major import countries;

- improvement of linkages between (physical) ownership modules and consumer expenditure system;
- improvement of linkages between direct energy use of households and expendituresson energy.

Energy-efficiency, fuel mix en emission technology
- more differentiation of energy-efficiency in energy conversion sector,
- endogenizing fuel mix policies.

There is plenty of scope for further research. First the comparability and international scenario operation for E3LIfe and ELSA could be enhanced. In due course the potential interest from other EU countries regarding this modelling approach should be (further) investigated in order to involve more EU countries in future applications of the model. Second, the model will also be used for further analysis of consumption patterns in the Netherlands in connection with the ECN SAVE model family. Third, in the framework of a tender for the NWO[2] programme 'Economics and Environment' a national research cluster is formed. This research will inter alia attempt to merge so-called metabolic approaches with the approach in ELSA, for example by connecting product quality with production consequences. Last but not least it would be interesting to investigate linkage possibilities with the materials use extended MARKAL model used by ECN.

[2]. NWO is the Dutch Science Foundation (Nederlandse Organisatie voor Wetenschappelijk Onderzoek)

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ANNEX A. Specification of Scenarios

Exogenous variables with common values in all scenarios

1. Population, households and number of employable persons [x 1000]

	1990				2000				2010			
	Employable		Unemployable		Employable		Unemployable		Employable		Unemployable	
	MWe	Other	MWe	Other	MWe	Other	MWe	Other	MWe	Other	MWe	Other
Single <36	538	0	50	0	689	0	50	0	657	0	50	0
Single 36-60	425	0	50	0	521	0	50	0	567	0	50	0
Single >60	0	0	764	0	0	0	1068	0	0	0	1425	0
Couple <36	528	558	30	50	635	615	30	50	677	707	30	50
Couple 36-60	464	494	30	50	598	578	30	50	649	679	30	50
Couple >60	0	0	765	765	0	0	838	838	0	0	1033	1033
Family <36	1267	1297	30	2587	1189	1189	30	2346	1119	1149	30	2118
Family 36-60	727	1486	95	999	788	1700	126	926	824	1774	146	739
One parent family <36	194	0	30	351	214	0	30	400	227	0	30	396
One parent family 36-60	33	133	50	21	64	169	49	49	72	180	53	45
Total	4176	3968	1894	4823	4698	4251	2301	4659	4792	4489	2877	4431
Total population	14861				15909				16590			
Total households	6070				6999				7669			

2. Age of adult household members

	1990		2000		2010	
	MWe	Other	MWe	Other	MWe	Other
Single <36	27.01	0.00	27.01	0.00	27.01	0.00
Single 36-60	43.47	0.00	43.47	0.00	43.47	0.00
Single >60	68.16	0.00	68.16	0.00	68.16	0.00
Couple <36	27.15	23.05	27.15	23.05	27.15	23.05
Couple 36-60	48.08	47.27	48.08	47.27	48.08	47.27
Couple >60	67.20	62.97	67.20	62.97	67.20	62.97
Family <36	27.99	27.54	27.99	27.54	27.99	27.54
Family 36-60	41.92	37.66	41.92	37.66	41.92	37.66
One parent family <36	27.81	0.00	27.81	0.00	27.81	0.00
One parent family 36-60	43.70	0.00	43.70	0.00	43.70	0.00

3. Education level of adult household members

	1990		2000		2010	
	MWe	Other	MWe	Other	MWe	Other
Single <36	4.39	0.00	4.70	0.00	4.94	0.00
Single 36-60	4.03	0.00	4.30	0.00	4.45	0.00
Single >60	3.19	0.00	3.60	0.00	3.70	0.00
Couple <36	4.03	0.93	4.70	4.70	4.94	4.94
Couple 36-60	3.68	1.07	4.10	4.00	4.30	4.10
Couple >60	3.60	1.11	3.70	3.40	3.80	3.50
Family <36	3.75	0.92	4.70	4.60	4.94	4.83
Family 36-60	3.64	1.03	4.10	4.00	4.30	4.00
One parent family <36	3.57	0.00	4.60	0.00	4.83	0.00
One parent family 36-60	3.78	0.00	4.10	0.00	4.30	0.00

Socio-economic variables

Growth rate of value added [% per year]

Sector	BU ->2000	BU ->2010	SG/SC ->2000	SG/SC ->2010	ST ->2000	ST ->2010
Primary	0,75	0,75	0,60	0,50	0,75	2,00
Manuf.	2,25	2,25	1,50	1,00	2,25	4,00
Building	2,25	2,25	1,75	1,00	2,25	2,75
Trade	2,25	2,25	1,75	1,20	2,25	3,50
Transp.	2,00	2,00	1,75	1,50	2,50	4,25
Com.serv.	2,35	2,35	1,75	1,20	2,25	4,00
Oth. serv.	1,50	1,50	1,30	0,70	1,50	2,60

Growth rate of labour productivity [% per year]

Sector	BU ->2000	BU ->2010	SG ->2000	SG ->2010	SC ->2000	SC ->2010	ST ->2000	ST ->2010
Primary	2,00	2,00	1,75	1,75	0,50	0,50	2,00	2,50
Manuf.	3,60	3,60	2,20	2,20	0,70	0,70	2,40	3,75
Building	1,75	1,75	1,75	1,75	0,50	0,50	1,70	2,00
Trade	2,00	2,00	2,00	2,00	0,60	0,60	2,00	2,75
Transp.	2,75	2,75	2,20	2,20	0,70	0,70	2,40	3,40
Com.serv.	2,90	2,90	2,40	2,40	0,70	0,70	2,25	3,25
Oth. serv.	1,50	1,50	1,50	1,50	0,00	0,00	1,30	2,00

Labour time of full time job in hours per year by sector

Sector	(SG) 1990	BU/ST 2000	BU/ST 2010	SC 2000	SC 2010
Primary	1741	1654	1571	1570	1415
Manuf.	1713	1627	1546	1544	1392
Building	1702	1617	1536	1535	1384
Trade	1715	1630	1548	1547	1394
Transp.	1779	1690	1606	1604	1446
Com.serv.	1668	1585	1506	1504	1356
Oth. serv.	1668	1585	1506	1504	1356

Part time jobs are assumed to have constant amount of hours per year.

Share of part time jobs in total labour force [in %]

Sector	1990	All scenarios 2000	All scenarios 2010
Primary	29	29	29
Manuf.	19	20	21
Building	12	15	17
Trade	38	40	42
Transp.	24	26	28
Com.serv.	13	15	18
Oth. serv.	49	50	50

Marginal Income Tax Rates

Applicable tax rate by taxable income stratum

Stratum	1990	BU 2000	SG 2000	SC 2000	ST 2000	BU 2010	SG 2010	SC 2010	ST 2010
< 20 kFl.	0,35	0,33	0,34	0,33	0,33	0,30	0,35	0,32	0,24
20-60	0,50	0,47	0,49	0,48	0,48	0,45	0,50	0,47	0,39
> 60 kFl.	0,60	0,57	0,59	0,58	0,57	0,54	0,60	0,57	0,48

Rates have been specified iteratively aiming at a constant overall tax burden at the macro level

Average Social Security Income

Annual average social security income [x 1000]

Household Type	1990	BU 2000	SG 2000	SC 2000	ST 2000	BU 2010	SG 2010	SC 2010	ST 2010
Single	18	16	16	18	18,5	16	16	18	19
Other	24	22	23	24	25	22	23	24	25

ANNEX B. GDP PER CAPITA AND ENERGY PER CAPITA

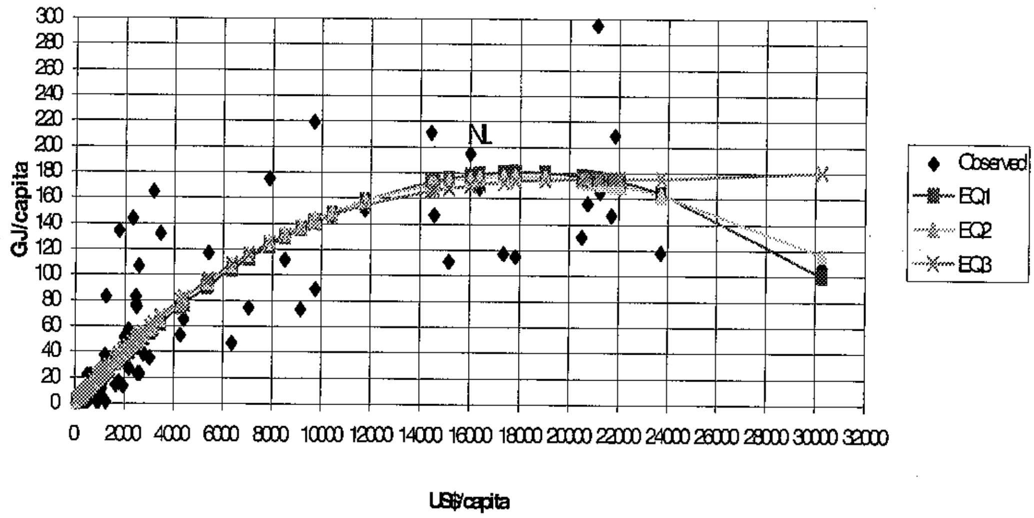

Figure B.1 *GDP per capita and energy per capita, 114 countries, 1987*

The above figure shows the observations of GDP/capita and Energy/capita for 114 countries in 1987. Specified as Taylor series expansions three curves have been fitted by means of regression analysis. Energy per capita is the dependent variable and GDP per capita the explanatory variable. The three resulting equations have been used to produce energy per capita ratios, while making use of the ELSA model output for GDP and primary energy. The energy per capita produced by the equations and the same ratios implied by the model simulations per scenario are listed below in table B1. The energy per capita ratios in the scenarios simulated in ELSA are systematically higher than produced by the first two estimated equations, with the exception of the SC scenario. It should be noted however that the estimated equations are based on a cross-section observation (1987 data). So, the possible move of the curve itself over time is not taken into consideration. Furthermore, the downward sloping trend for high GDP/capita levels looks overstated due to one outlier (Switzerland). Therefore equation represents the estimation like equation2 but without outlier Switzerland. In that case a slight increase of energy use per capita is expected. So, after all also this test leaves open a wide margin of possible results. Taking into account the latter considerations, the model results could be on the cautious side but are giving more precision and explaining underlying causes than simply applying estimated elasticities directly. So, the plausibility of the scenario results should be hardly an issue, provided one continues to observe the function of the scenarios.

Table B.1 *Implied energy intensities from ELSA and separate equations*

	1990	BU	SG	SC	ST
GJ/capita ELSA*	188	194	193	172	183
GJ/capita EQ1	180	152	173	173	113
GJ/capita EQ2	176	153	170	170	125
GJ/capita EQ3	174	176	175	175	179

*) For 1990 observed data