Are there different routes leading to sustainable consumption ?

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Synopsis

The paper discusses investigations with new lifestyle models. The study investigates the conditions under which the evolution of consumption starts to follow sustainable trajectories.

Abstract

To achieve sustainability, efforts at the supply side of an economy- such as changes in energy conversion technologies - are certainly important. Yet, the demand side is a very important force, when it comes to overall efficiency and sustainability instead of efficiency per activity. The 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 commodities. 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. This approach is underlying energy&lifestyle models applied to several EU countries, in order to analyse the influence of changing consumption patterns on energy use and emissions.

We conclude that the kind of lifestyle that emerges and the societal structures that it brings with it in economic, social and technological sense definitely makes a difference to the size and composition of the primary energy requirement of a country. It is demonstrated that not only the level of economic growth as such but also the way consumption patterns evolve makes a difference. The study can also be regarded as an attempt to investigate how to move onto societal feasible trajectories leading to sustainable consumption, in particular to identify what are the crucial economic, social and technological conditions to follow such trajectories.

1. Introduction

Until recently research concerning sustainability tended to focus predominantly on technical features of the production of commodities and the extraction and conversion of energy carriers and other natural resource materials. For the achievement of a sustainable society private consumption and the consumers should be addressed as well. Private consumption is the largest demand category in most economies. Furthermore, it directly and indirectly affects large parts of the international trade flows. In this wider perspective, i.e. regarding export production as meant for foreign consumption, household consumption is eventually the main driving force influencing the volume and assortment of commodities produced.

This paper attempts to contribute to the operationalization of trajectories - hopefully - leading to sustainable consumption. It is based on a recent study for Germany, Holland and France (see also Weber et al. 1996a; Weber et al 1996b; Perrels and van Arkel 1996). The study called for a multi stage approach. The volume and composition of consumption is influenced by social-cultural, social-economic and technical factors. Consequently, a given level and composition of consumer demand may have different levels of energy and emission impacts depending on the technologies applied and the environmental policy instruments put in place.

The next section (2) introduces the overall approach. Section 3 discusses the scenarios, while section 4 highlights some main results. Section 5 offers a concluding discussion, inter alia referring to the title of the paper and pointing at further research requirements.

2. Approach and Operationalization

2.1 The Rationale of the Approach

To date economic and technical-economic energy models hardly allow for behavioural aspects. In as far as behavioural assumptions are regarded as relevant in such studies, they are included in the scenario descriptions. In fact the improvement of internal model rigour tends to push the uncertainties and intangibles beyond the model perimeter into the scenario description. Consequently, scenario specifications are based on sets of assumptions that - at best - are only partially tested. For example, assumptions about population development can be derived from demographic studies, however the evolution of lifestyles and its interaction with the political process and infrastructural developments are difficult to assess. Therefore, the internal consistency of scenarios is often taken for granted, for example regarding compatibility between (desired vs. enforced) technological change and social and economic changes.

The models discussed here describe the evolution of energy requirements and resulting emissions by starting from a consumer - that is household - perspective. This approach aims to serve several goals. Firstly, by focussing on the consumer perspective the influence of a changing volume and composition of total consumer expenditures on total energy requirement can be separated from other influences and shown in more detail. This includes the ownership and use of home equipment. Secondly, by making households such a principal factor in driving the model the scope for inclusion of non-economic influences is improved. Either non-economic influences are endogenized in the model or they operate on economic phenomena from the scenario module. Both options have been used in the study. Thirdly, the inclusion of non-economic influences is not merely a means to ‘enrich’ an economic model, but should result in better integrated assessment of technological, economic and social factors. A modelling approach placing consumers at the focal point may help to give this perspective real standing in the political decision making process.

Sofar, the social or behavioural factor is often underrated in operationalization and quantification stages of energy studies. It is often included as an add-on instead of as an integrated factor. Operationalization of social science concepts occurs mainly in focused studies, e.g. for marketing support. Broader modelling concepts that make extensive use of social science theories are very rare, certainly in the field of energy studies. On the other hand the usefulness of quantitative modelling is questioned by some social scientists. We have sympathy for the point made by social scientists such as Strang (1996), that both technology and economy should be viewed as just two phenomena in the wide field of society/culture. The approach adopted here, starting from a model rooted in economics and trying to capture at least some of the underlying societal driving forces, seems sofar the only way to *operationalize* non-economic and non- technical influences on energy use and related emissions. If we qualify these as behavioural or social effects, it is by no means meant that technical and economic phenomena are considered as outside the social realm. Yet many of the thinkable interactions seem sofar beyond the scope of quantitative modelling. Although imperfect, this approach aims at an improved dealing with the human dimension of energy use in the context of operationalized models of energy use and emissions. It can provide useful support for the public and political discourse (cf. e. g. Schade, Weimer 1995) - both by obliging more precise definitions of the relationships to be considered (and those omitted) and by allowing for a quantitative and not only qualitative evaluation of the different interconnections.

2.2 Identifying major trends

Given the time perspective of the models, about 10 to 25 years ahead, the identification of relevant principal exogenous drivers should allow for representation of the key factors influencing household expenditures and household energy use. Prior to specifying the exogenous drivers the key developments in the considered time span have to be identified in order to have an overview of what could change and what changes seem robust and versus what changes are volatile due their dependence on other factors.

Three principle trends are distinguished, being (1) the need for extended production times and a more flexible use of production capacity, (2) the ongoing individualisation and the search for personal development and, (3) the rapidly increasing high quality capabilities regarding automatisation and telecommunication (telematics). The three factors represent economic interests, socio-cultural interests and technological interests respectively. The considerations about production times and production capacity as well as the individualisation and personal development trends may be regarded as driving forces. Traditionally, the technological factor has more the role of a mediating party, a solution (a way out of a dilemma). Its exact role and eventual appearance will be determined to a large degree by the way the driving forces interact. This doesn't deny the interactive relations between these main factors. Obviously, new technology influences consumer (and producer) choices. Yet, if we wish to put certain limits to technological solutions it implies one of the other factors should function (also) as mediator. This implies that socio-economic interests and/or socio-cultural interests cannot be pursued without constraints. It raises questions about the choice of constraints, the dosage of constraints and last but not least the distribution of constraints. In this context the structuring and specification of environmental objectives and the concomitant consumer preferences will depend heavily on the choice of the principal mediator.

The above was a summary of considerations about scenarios and socio-economic and socio-cultural interactions discussed in the study (see also Weber et al 1996a and Perrels et al 1996). In a supporting study (Bode, 1996) various elements of a framework for identifying trends and the development of plausible scenarios have been tested, with special reference to implementation in the ELSA model (ELSA=Energy and Lifestyle Simulation Approach).

2.3 Operationalization and modelling

The models distinguish between direct energy use and indirect energy use. Direct energy use refers to the consumption of energy carriers purchased by the household itself, in order to cater for energy services, such as space heating, tap water heating and propulsion of a car. The indirect energy use refers to the energy used during various stages of production (and distribution) of commodities, also referred to as 'embodied energy'. The evolution of direct energy use can be adequately described by technical-economic models (with social entries), while the description of indirect energy depends more heavily on (socio-)economic concepts, notably consumption functions and input-output models. The approach is summarized in figure 1.

The description of direct energy use is split up in:

- thermal applications usually connected to the heating equipment fitted in dwellings, this is further distinguished in space heating, tap water heating, and cooking
- electricity use of appliances and lighting
- demand for motor fuels for private cars

The thermal applications module is modelled around the evolution of the dwelling stock. Dwellings are simultaneously distinguished by vintage, building type and type of space heating - hot tap water equipment combination. New vintages are assumed to consist of better insulated dwellings. Furthermore, the entire household population, distinguished by ten household types, is distributed over the available dwelling stock. Different household types in the same dwelling type can have different energy consumption levels and respond differently over time to changes in background variables. For further details see de Paauw and Perrels (1995), Perrels et al (1996) and Weber et al (1996b).

The modules for electricity use and the consumption of motor fuels both utilize discrete choice models to describe the evolution of ownership. Admittedly, for new or recently penetrated appliances such an approach is not feasible. In that case either an ad-hoc expert opinion based penetration curve is entered (e.g. an electrically heated water bed) or a reasoned substitution mechanism with respect to an existing appliance is applied (e.g. an integrated washing machine and dryer). Appliances can be further distinguished between those continuously running, such as a refrigerator, and those that need a signal from the user, the so-called discrete appliances. For the major discrete appliances, the intensity of use is assumed to depend on the size and type of the household. For every appliance and for private cars an annual improvement of the energy efficiency of newly sold appliances and cars is specified. This means that the lifetime of appliances and the share of first-time buyers influence the speed with which the actual national stock of appliances reduces its specific energy consumption. Further details

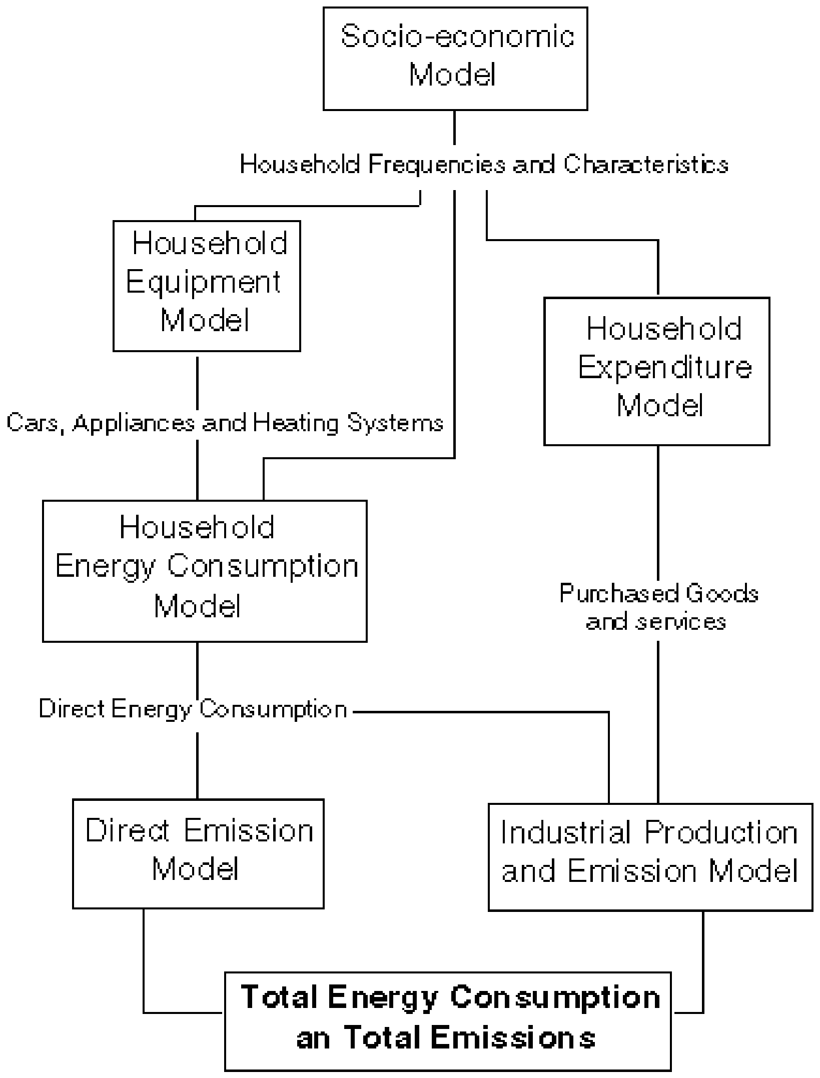

Figure 1. *General structure for the analysis of consumption-environment links*

are given in Weber et al. (1996b), de Paauw and Perrels (1995) and Perrels et al (1996a).

The total indirect energy requirement of a household depends on the volume of its non-energy expenditures and its distribution over expenditures categories. In some categories the average energy intensity of the products and services is much lower than in other ones. For example, on average food products have a higher energy intensity than textiles. It should be noted that - sofar - the approach does not allow for specific consumer choices between high quality versus low quality products (often implying a lower vs. higher energy intensity per monetary unit spent) nor for the related problem concerning the extent of environmentally aware purchases. This would require a much more detailed treatment i.e. on a product by product basis. However, such level of detail is methodologically very difficult to combine with a dynamic description of consumption and production in a society. There are developments regarding so-called hybrid methods (e.g. Wilting 1996), but they still lack a lot of information concerning the dynamics on the consumption side. Another solution could be offered by the so-called metabolism concept (Noorman et al., 1996), but this approach is still in a development stage. We chose to combine an elaborate set of consumption functions with an input-output system that traces back the required production by sector given the simulated expenditures by category. All models have been empirically validated using large data sets from the countries involved. Differences in available data caused some differences between the models.

3. Scenarios used

Because the formal representation for modelling purposes is of economic production, intersectoral exchange, and consumption activities, the description of possible evolutions in social terms (lifestyle) appears as a matter of "underlying" social determinants of economic change. There is no single theoretical perspective which stands out as "the best" for articulating the social to the economic; hence the development of scenario "storylines" does not depend on a specific sociological perspective. Though a systemized approach has been pursued (see section 2.2). By analysing in a preliminary step major trends and drivers for household behaviour and societal changes, the consistency of the scenarios used is expected to be considerably improved.

Corresponding to the focus of the 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. After having identified principally different lifestyle developments, the concomitant policy environment and technological development is formulated. The following scenario dimensions have been identified in this respect:

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

As regards the social dimension one can think of trends such as individualisation, secularisation, community spirit and solidarity, etc. In the economic realm globalization 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 socio-economic and environmental processes and the nature of their involvement. Obviously, the social, economic and technological trends are not independent. Therefore, compatibility of trends has been given special attention in the scenario specification.

To be able to operationalize these dimensions sets of phenomena types have been defined. The sets of phenomena types enable the identification of exogenous variables that can operationalize the connection between scenario and model. The sets of phenomena types are:

- demographic dynamics (e.g. numbers by household type, dwelling stock)
- macro economics (e.g. growth of GDP and labour productivity by sector, prices)
- social economics (e.g. working times, share of part time labour, education levels)
- social psychological developments (reallocation of work time and tasks, acceptance of higher costs for environmental purposes)
- technological dynamics (energy efficiency rates, progress in abatement technology)

Since both descriptive and normative scenarios are of interest, two pairs of scenarios have been investigated. The first pair of scenarios has mainly a descriptive character. It represents two different prolongations of current trends into the future. The second pair is centred around the vision of sustainable development and investigates different ways for achieving substantial emission reduction through important policy changes. The scenarios run from 1990 to 2010. They differ from each other notably in the following aspects: economic growth, labour productivity and labour market (i.e. solidarity versus individual career orientation), environmental investment and regulation efforts (also having price implications), environmental technology (see summary of key scenario assumptions in table 1). The scenarios carry the following names (the abbreviations indicated in brackets will be used the following sections):

Business as Usual (BU);
Stagnation (SG);
Sustainability through Reflective Consumption (SC);
Sustainability through Technological Breakthrough (ST).

The difference from earlier economic models is that implications for private consumers are shown in detail and indications are given of the feasibility of desired changes in consumer behaviour. 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 (e.g. CBS 1996; van Nimwegen en van Solingen 1991) the overriding impact comes from migration. This is an uncertain political factor. Therefore it has been decided to make no distinction on this point between these scenarios. Obviously, it is likely that the scenarios will differ somewhat in net migration flows, but this issue needs specific study. 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 determined by today's levels among younger cohorts. 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) or more extensively (ST).

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 by approximately 10% in 2010. However the labour time reduction is 10% over the total period, thereby 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.

Table 1 Key differences between scenarios for the Netherlands

	BU	SG	SC	ST
economic growth *	2,0%	1,25%	1,25%	2,75%
labour productivity *	2,5%	2,0%	0,75%	2,5%
labour time reduction **	-10%	0%	-20%	-10%
energy efficiency **	+22%	+14%	+33%	+40%
abatement efforts	tendencial	lagging	strong	strong
electric power fuel mix	unchanged	unchanged	8% renewable	10% nuclear

*) annual change; **) total change over period 1990-2010;
Assumption for France and Germany mainly differ for residential energy efficiency and electric power fuel mix.

Table 1 summarizes the key differences for the Netherlands between BU and the other scenarios (SG, SC and ST), with BU as the reference level. Except for efficiency in the residential sector and for the fuel mix in the electric power sector the assumptions for the other countries differ only slightly. SG and SC have an economic growth which is 37% lower than in BU, however they differ in growth of labour productivity, and especially in the progress of environmental technology. The SG scenario supposes that society fails to resolve socio-economic issues properly. Which means that 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. Such developments are complementary to trends in the social realm that are dominated by protection of individual interests instead of seeking co-operative solutions.

In the SC scenario the same low economic growth (as in the SG scenario) is supposed but in this case in the context of a larger societal scheme that attempts to move towards a sustainable economy. The idea is that with increasing wage rates for most employees, the inclination to swap income for free time becomes stronger especially among two earner households. Given the experiences in the Netherlands this is indeed what actually can happen, provided the labour market becomes less rigid and people have a choice. Furthermore, new cohorts of (-

young) households are assumed to have a larger awareness of environmental issues and are prepared to dedicate larger efforts to obtain better environmental conditions. In other words in this scenario economic growth and the increases in private consumption are 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%.

The ST scenario embraces a technologically optimistic view. It is characterised by the assumption, that scientific and technological progress in the future will be very important, both inducing and requiring high economic growth. Simultaneously, the technological progress leads to significant improvements in energy and environmental efficiency. So, from a purely economic viewpoint the majority of households is assumed to pursue maximization of income. However, at the same time the high standards of living are also translated to the environment and consequently, both individuals and society at large are prepared to dedicate substantial efforts to the improvement of environmental conditions, yet, without significantly sacrificing wealth. The society as a whole is very open-minded to new technologies. Consumers and producers are inclined to invest in most effective technologies and critical views expressed on some technological developments, such as nuclear power, are decreasing in importance. For example, this results in the assumption that energy efficiency in the ST scenario improves twice as rapidly as in the BU scenario.

Referring to section 2.2 one can conclude that the Sustainability through Reflective Consumption Scenario investigates the possibilities to use institutional arrangements next to technology as a moderator. The Sustainability through Technology Breakthrough Scenario investigates the possibilities for a maximum exploitation of technology as a moderator.

4. Highlights of Scenario Results

In the following first some general results for all countries studied are given (section 4.1). Given space limitations, after a brief impression of consumption patterns, some results for CO_2 are presented, although other airborne emissions have been investigated too. For the Dutch case a decomposition of observed emission changes according to driving factors is briefly discussed (section 4.2) and more detail of the scenario results is given at the micro level (section 4.3).

4.1 Overall Results

4.1.1 Consumption Patter ns

For each country separate sets of consumption functions have been estimated by household type. The estimations follow a common concept in all countries (Pellekaan and Perrels 1996). The exact specifications and the scenario environments allow for country specific differentiations. Expenditures at the household level respond to age, household size, education and prices. 10 types of households are distinguished. At the aggregate level the influence of demographics is added. Table 2 below gives an overview of the changes in aggregate expenditures by category and scenario for the Netherlands. It demonstrates that 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 (Perrels and de Paauw 1993).

Table 2 Evolution of aggregate consumption patterns in four scenarios eFpressed as percentage changes compared to simulated base year levels for the Netherlands

	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%

4.1.2 Emissions

Whereas for the classical airborne emissions SO_2, and NO_x in the period up to 2010 emission decreases are obtained for all scenarios and all countries - although at different degrees, the picture for CO_2 is more contrasted. As indicated in table 3 below emissions for West Germany remain roughly at the same level in the tendencial scenarios, with a slight decrease for the rosy variant (- 3 %) and contrarily a small increase for the bleak case (+ 6 %). Particularly the CO_2 emissions related to direct energy use are substantially higher in the bleak than the rosy variant which is of course related to the higher direct energy consumption of households in the Stagnation case. In contrast the two sustainable scenarios indicate that substantial emission decreases can be obtained - about 23 % in both cases - although they differ substantially in the way this goal is achieved.

Table 3 CO_2 emissions induced by households in Western-Germany, France and the Netherlands (in Mton)

	1990	BU 2010	SG 2010	SC 2010	ST 2010
Western-Germany					
- total CO_2	557	539	589	431	426
- CO_2 per household	19.8	17.1	18.7	13.7	13.5
Franc					
- total CO_2	297	329	331	263	328
- CO_2 per household	13.8	12.9	13.0	10.3	12.9
Netherlands					
- total CO_2	114	135	133	116	127
- CO_2 per household	18.8	17.6	17.3	15.1	16.5

As already stated above the energy efficiency improvements are rather similar in the two scenarios as far as industry and households are concerned, yet major differences arise from the fact that nuclear is supposed to fade out in the reflective consumption path by the year 2010, whereas in the technology oriented path contrarily its share in electricity production is assumed to increase from 32 % in 1990 to 60 % in 2010. Thereby CO_2 emissions of about 60 Mt are avoided - by expanding a technology, of which the risks are still rather controversially debated.

For France the potentials for fuel switching are less important - due particularly to already largely carbon free electricity generation. Consequently, the emission levels of all scenarios except the Sustainability through reflective consumption case are higher in 2010 than in 1990 (see table 3). Still, the CO_2-emissions per household remain lower than in Germany. They amount to 12.4 t/hh for all scenarios except for the Sustainable Consumption case (10.0 t/hh), compared to a range from 13.5 t/hh (Sustainability through technological Breakthrough) to 18.7 t/hh (Stagnation) for West Germany in 2010.

For the Netherlands CO_2 emission reduction appears to be even more difficult according to the scenario results (see table 3). Only in Sustainability through Reflective Consumption a stabilisation of CO_2 emissions in the year 2010 vs. 1990 is obtained, for all other scenarios increases by 10 % or more are observed. Whilst socio-economic developments are by and large similar across countries, differences in energy efficiency improvements as well as different demographic developments are sources of diverging results. For insulation considerably lower potentials are assumed in the Dutch case, while the growth of the dwelling stock in the Netherlands (+26%) amply exceeds that of Germany (+10%). Possibly the efficiency estimates used from different national studies are not fully comparable. Here further investigations appear to be necessary to obtain more reliable estimates of saving potentials both within countries and across countries.

4.2 Decomposition of emission changes

An advantage of the approach adopted here is that resulting emission changes may be decomposed according to the relevant influencing factors. Thereby in a stepwise approach for the projection years, first, only the demographics (household numbers and distribution over types) have been modified versus the base year, in a next step changes in economic parameters are added (growth of GDP and labour productivity, price changes etc.), then the efficiency improvements and fuel switches and, finally, emission abatement improvements are superposed. As an example the decomposition of the emissions in the Sustainability through Reflective Consumption (SC) scenario are shown in figure 2.

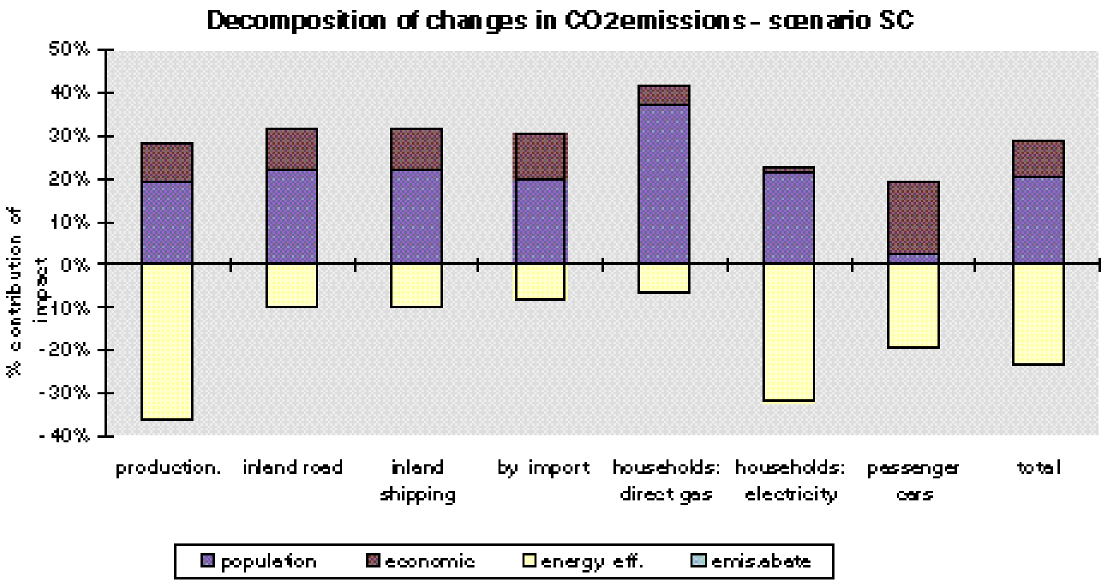

Figure 2. Contribution to CO_2 emission changes by user segment, SC scenario 2010

Whereas demographic household developments contribute in all scenarios to an emission increase by about 20 %, the effect of economic factors varies considerably according to the scenarios considered. 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). It has to be noted that these figures refer to the contribution of entire machinery or appliance stock. The newest appliances and machines in 2010 are much more efficient. Therefore, even if further efficiency improvements would not materialize, the efficiency improvement continues until 2020 due to substitution of old appliances (having a lifetime of 10 years).

4.3 Micro evaluation

It is not only the sheer volume of the money budget which counts, but also its allocation over categories. Table 4 summarizes some information at this point, as it shows that the relation between outlays and attributed emissions is not linear, since it depends on how the money is spent. For example, in the BU scenario middle aged singles and young one-parent families have almost the same budget in ECU (Å 15860), but the resulting CO_2-‘-budgets’ differ substantially (13,9 and 17,0 respectively). According to the results displayed in table 4, 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, assuming 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_2emission, but the effect varies over household types. In Perrels and van Arkel further attention is given to implicit elasticities in the ELSA-model. A second striking feature is that younger families have relatively higher emission budgets. All in all, interpreting the results optimistically, we can state that they hint at the possibility that beyond a certain income level extra purchasing power could enable households to ‘buy’ a reduction of their attributed CO_2 budget.

Table 4 Simulated emissions by household and per capita in four scenarios for 2010 (NL)

	1990 gld	CO_2	NO_x	BU gld	CO_2	NO_x	SG 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,	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 gld	CO_2	NO_x	ST 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

5. Conclusions and Discussion

The investigated scenarios differ substantially regarding societal evolution and the resulting emission levels. For France and the Netherlands the absolute reduction levels turn out to be disappointing, while they look optimistic for Germany. Given the recent experiences with the pre-Kyoto discussions concerning an overall EU target and a differentiation by country, the results (despite their biases) nicely indicate the difference between countries regarding ease to reduce emissions. The absolute levels as such are however not the most interesting results, it is the decomposition by main forces, by household type, etc. which gives further insight.

The risks to be taken in the two sustainability oriented scenarios are of a 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 acceptability here. It exemplifies the sofar somewhat subdued discussion about the social distributional effects of environmental efforts. 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 transparent 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 support them. Apart from social acceptance of various technology options, the problem arises of 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.

Though ex-post analysis of long term developments is not uncommon in social science, long term ex-ante analysis is rarely seen. Therefore 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 practices. 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 hint at directions for further research: A shortcoming of the models in their current version certainly is that economic growth rates and efficiency gains of technologies are exogenous scenario settings (their relations with household behaviour are however endogenized and compatibility of scenario segments was tested). Here further research would be necessary to identify robust empirical relationships between major societal choices, economic growth and technical efficiency gains. Another open question is in our view the social acceptability of low-growth scenarios vs. high-growth scenarios. Sofar the prevailing view among political decision makers is that lower or selective growth is a taboo, while the distributional aspects of environmental measures are often obscured in the public debate. In this respect the finding that beyond some level of wealth sustainable consumption may become affordable provides new guidelines to both growth strategies and distributional policies. For example one may wonder whether the attainment of this income level can be accelerated or that the location of the ‘bend in the curve’ can be shifted. This comes close to a choice between strategies similar to the St and SC scenarios. Obviously, measures with respect to end-use prices, market (re-) regulations and social and physical infrastructure facilitating the compromise between economic growth and a (timely) move towards sustainability require further investigations as well.

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