Analysis of the energy requirement for household consumption

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Analyse van het energieverbruik voor huishoudelijke consumptie

(met een samenvatting in het Nederlands)

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Cornelis Richard (Kees) Vringer

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Promotor: Prof. Dr. K. (Kornelis) Blok
Verbonden aan de Faculteit Scheikunde van de Universiteit Utrecht

Co-promotor: Dr. Th. G. (Theo) Aalbers
Verbonden aan het Milieu en Natuur Planbureau

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Chapter 1

Introduction

1 ► Introduction

Humans in households use energy for their activities. This use is both direct, for example electricity and natural gas, but also indirect, for the production, transport and trade of other goods and services.

The main objective of this thesis is to gain insight into the energy requirement associated with household consumption patterns, with a focus on (I) the quantification of the energy requirement of the present consumption pattern and its various components, (II) differences in the energy requirement between groups of households and, (III) the development of the average consumption pattern in the past and future. The underlying motive stems from the interest in reducing or limiting the energy requirement of society to contribute to a more sustainable world. The total (direct plus indirect) energy requirement of consumption patterns will first have to be quantified before an answer can be given to the question of how the energy requirement caused by consumption can be decreased.

This chapter will first explore the relationship between human energy requirement and the pursuit of sustainability. This will be followed by the motivation for choosing consumption patterns to describe society's energy requirement. The chapter will end with the thesis objective and outline.

2 ► Energy requirement and sustainability

The availability of energy allows many people to enjoy unprecedented comfort, mobility and productivity. In industrialised countries humans now use 100 times more energy than in the past, i.e. before they had learned to exploit the energy potential of fire (WEA, 2000).

In Agenda 21, the United Nations and its member states strongly endorse the goal of sustainable development (UN, 1992), a concept that implies meeting the needs of the present generation without compromising the needs of the future generations (WCED, 1987). Sustainable development is also required for the global energy system. Energy is very important in maintaining economic activities and the accompanying consumption level. In the World Energy Assessment (WEA, 2000) sustainable energy is defined as energy that is produced and used in ways that support human development in the long term with all its economic, ecological and social dimensions. Today's energy system can be concluded as not being sustainable. This is due to equity issues, and environmental, economic and geopolitical concerns, with implications reaching far into the future. According to WEA (2000), the following aspects in the current energy system reflect unsustainability:

- Energy carriers such as fuels and electricity are not universally accessible,
- The current energy system is not sufficiently reliable for widespread economic growth, and
- Negative local, regional and global environmental impacts of energy production and use are threatening to the health and well-being of current and future generations.

WEA (2000) mentions the use of renewable energy sources, next-generation technologies and greater energy efficiency as options to address these aspects of unsustainability. WEA’s interpretation of 'greater energy efficiency' is related to the improvement of products and processes in technical or operational terms. However, energy consumption may not only be limited or reduced by improving the energy efficiency, but also by changing consumption patterns. IPCC (2001) mentions change in consumption patterns as a possible option for alleviating the effects of climate change.

Changes in consumption patterns normally go hand in hand with changes in the economic structure of society. According to IPCC (2001), the option of 'changing consumption patterns' is insufficiently explored. Analyses outlined here should be helpful in exploring the feasibility of changing consumption patterns.

3 ► Energy requirement from the perspective of consumption patterns

All products and services produced by an economic system are ultimately meant for consumption, mainly by households. Even if the products or services concerned are not directly meant for consumption in households, they do lead to investments or other products to make consumption in the future or later in the production–consumption chain possible. If consumption patterns change, the economic structure will also change. As economic activities vary in energy intensity[1], changes in economic structure may very well affect the energy requirement of society.

In this thesis the choice was made to examine the energy requirement of society from the household perspective to give insight into the possibilities of reducing or limiting the energy requirement of society through changing consumption patterns. Contrary to the traditional sector approach, here, we are required to look at an alternative cross-section of the economy, where all the energy required by society is allocated to the products, ‘consumed’ by consumers living in households.

The allocation of the required energy to the products and services that consumers purchase can be done using an input–output analysis or by applying process analysis. Energy input–output analysis as a method to achieve this aim was described and applied long ago, for instance, by Wright (1974) and Bullard and Herendeen (1975). Using an input–output analysis, Schipper et al. (1989) calculated that about half the energy requirement of households in the USA in 1986 was indirect. The respective calculations for the Netherlands in 1987 and 1990, made by

1 The energy intensity of a product/service is defined as the required primary energy for the product/service divided by the costs of the product/service in monetary units. Energy intensity can be expressed, for instance, in megajoules per Euro.

Van Engelenburg et al. (1991) and Wilting (1996), also showed that about half the household energy requirement is indirect.
An input–output analysis gives a good view of the total required energy for household consumption, providing a breakdown into main consumption categories such as food, dwelling or transport. However, to observe the effect of more detailed changes in the consumption pattern on the energy requirement, a more accurate method such as process analysis (see e.g. Boustead and Hancock, 1979) is required for analysing the energy requirement of consumer products. Since the application of process analysis is very labour intensive, we applied a hybrid energy analysis method combining input–output analysis and process analysis. A hybrid energy analysis, also suggested by Bullard et al. (1978), combines the rapidity of the input-output analysis and the accuracy of the process analysis.

4 ► Objective and outline of this thesis

The main objective of this thesis is to gain insight into the energy requirement associated with household consumption patterns, with emphasis on:

- Quantification of the energy requirement of the present consumption pattern and its components;
- The household characteristics responsible for differences between the energy requirements due to the consumption patterns and
- The development of the consumption pattern in the past and trends for the future.

The underlying motive is the interest in reducing or limiting the energy requirement of society to contribute to a more sustainable world.

The main objective gives rise to the following specific research questions:
1. How do the energy intensities (defined as the ratio of the primary energy requirement to the consumer price) for the different consumer goods/services for Dutch households differ from each other? If the energy intensities related to consumer goods/services differ sufficiently, changes in consumption patterns can lead to a significant change in the energy requirement of society.

2. What is the average composition of the present Dutch household consumption pattern in financial and energetic terms, and which consumer goods or services are the most important in determining the energy requirement of consumption? To develop a strategy to reduce society's energy requirement by changing consumption patterns, it is important to know, on average, which consumer goods or services contribute more and which contribute less to the total energy requirement.

3. Do individual Dutch consumers have a choice in influencing their consumption patterns and the accompanying energy requirement? To find out how large the reduction in the energy requirement can be by changing consumption patterns, it is important to have a view of how large the reduction in energy requirement can be if alternative consumer products are chosen. This question will be dealt with only briefly in this thesis.

4. Do the consumption patterns of Dutch households and the resulting energy requirements of various groups of consumers differ from each other? We may be able to learn from groups of consumers who require more or less energy than the average consumer. What household characteristics mainly determine the total energy requirement of consumption? It will be especially interesting to learn to what extent consumer values have influence on the energy requirement.

5. How have the average Dutch household consumption pattern and the resulting energy requirement changed in the past decades, and how can the consumption pattern change in the coming decades? More knowledge on changes in the consumption pattern in the past and possible changes in the future will provide important information on how easy or difficult it will be to realise changes.

Chapter 2 describes the hybrid energy analysis method, and reviews its suitability for calculating the energy requirement of consumption patterns. By calculating the energy requirement of consumption patterns, the energy requirement for the complete life cycle for all consumed products and services have to be taken into account. This includes the energy requirement to extract, refine and transport the energy carriers themselves.

Chapter 3 contains a case study on the energy reduction potential as applied to one single consumption category[2], flowers, which can be achieved by changing consumption patterns (research question 3). The aim of this chapter is to examine how households can reduce their primary energy requirement for the decorative and gift functions provided so far by cut flowers without reducing their consumption level, also taking into account the financial cost.

Chapter 4 answers the research questions 1 and 2 in an overview of the energy intensities of all consumer goods in Dutch households in 1990. The consumption patterns of these households are also presented here, including an outline of the influence of several important variables determining the total energy requirement of consumption (research question 4).

Chapter 5 outlines how the energy requirement varies, due to differences in consumption patterns of consumer groups (research question 4). The consumer groups are distinguished according to their values, problem perception or motivation to save energy. In addition to the method used in Chapter 3, the energy requirement here has been largely assigned to consumption on a physical basis, which is more accurate than consumption on a financial basis.

Research question 5 is answered in Chapters 6 and 7. Chapter 6 presents the development of the average consumption pattern of households between 1948 and 1992, a period in which the indexed household consumer expenditure approximately tripled. Chapter 7 shows, for two widely accepted scenarios, how the average consumption pattern and the energy requirement due to this consumption pattern can develop autonomously between 1995 and 2030.

2 A consumption category is a group of consumer goods or services which belong together.

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Chapter 2

Determining the primary energy requirement of consumption patterns[1]

► Abstract

We need a fast and accurate method for analysing the energy requirement of consumption patterns that are inherent to many individual consumption categories. Here, we present and discuss a hybrid method of input-output analysis and process analysis to establish the energy requirement for the various consumption categories. This hybrid method for energy analysis is suitable for rapidly and accurately calculating the direct and indirect energy requirement associated with the purchase and use of large numbers of consumption categories. The method detects differences between consumption categories, even if they are produced by the same economic sector.

For individual products, of which the price level deviates from the mean price, the use of input–output analysis for parts of the calculations can cause errors. However, on average, the calculated energy requirement will be correct. The error margins for individual products can be reduced by using more process data, but more effort will be needed to make the analysis.

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1 This chapter is a slightly adapted version of Vringer, K., Blok, K. and Van Engelenburg, B. 'A step-wise guide for energy analysis, how to calculate the primary energy requirements of households?', In: Suh (ed.) 'Handbook of input-output analysis for industrial ecology' (preliminary titles, in preparation).

1 ▶ Introduction

One of the aims of this thesis is to determine the energy requirement associated with consumption patterns. Another is to analyse differences in consumption patterns. To this end, we need a method to analyse the energy requirement necessitated by the consumption patterns. The level of detail applicable here led us to choose an analysis at the individual consumption category level[2]. Because of the required large number of relevant consumption categories, a quick method is needed to analyse the total primary energy requirement for each separate consumption category. The energy analysis method must also be accurate enough to detect possible differences between the consumption categories.

This chapter first discusses the two existing basic methods, process analysis and input–output analysis, for analysing the energy requirement for the life cycle of consumer products and services. This will be followed by a proposal for creating a hybrid of these two methods to allow analysis of the energy requirement for the various consumption categories. The hybrid method will be illustrated with an example of a concrete product, i.e. a refrigerator. The chapter ends with a discussion on the suitability of this method for calculating the energy requirement of household consumption patterns.

Here, we distinguish between the direct and indirect energy requirement. Consumers can use energy directly: e.g. natural gas for space heating, electricity for lighting and petrol for transport. The primary energy required for these three energy carriers, along with their combustion energy, is called the *direct* energy requirement. The *indirect* energy requirement of consumers is composed of the cumulative primary energy required to create, trade and dispose consumer goods and services, excluding energy carriers. The total energy requirement of consumption is then the direct plus the indirect energy requirement.

2 A consumption category is a group of consumer goods or services which belong together, e.g. 'flowers and pot-plants', or 'bread and rusks'.

2 ► Determining the energy requirement of consumer goods

The analysis of the required energy for the whole life cycle of products had been widely practised since the early 1970s. The methods originally developed for life cycle energy analysis have been much further developed and refined in environmental Life Cycle Analysis (LCA). Even ISO made standards apply to LCA analyses (see e.g. ISO 14040, 1997). However, in contrast to LCA, the focus in this thesis will not be on environmental impacts. As in the original life cycle energy analysis, the focus will be on energy use, which is an important determinant for a variety of environmental impacts.

2.1 ► Input-output analysis and process analysis

The two basic methods for calculating the energy requirement for the life cycle of a consumer good[3], (I) input–output analysis and (II) process analysis, will be described in this section.

In *input–output* analysis the energy requirement is determined using an economic-statistical approach. The transactions between the various sectors of an economy are collected in an input–output matrix (Leontief, 1966). For each combination of two sectors, the input–output matrix contains, in monetary terms, the supply from one sector to the other sector. A certain direct energy requirement can be attributed to each sector in the input–output matrix, for instance, on the basis of energy statistics. Subsequently, by applying several mathematical operations to the matrix, one can calculate the energy requirement associated with the delivery of the final goods to consumers. The use of input–output analysis for this aim was described and applied by Bullard and Herendeen (1975) and Wright (1974).
We can easily calculate the energy requirement of a complete life cycle from a consumer good through an input-output analysis. The method, however, is not very accurate because no distinction can be made between different products produced in the same sector, e.g. cut flowers and cherries are both produced in the same sector,

i.e. horticulture. Input–output analysis implicitly assumes a sector in the input–output table to be homogeneous. In reality, a range of products is produced in one sector; some products may be relatively energy-intensive (cut flowers) and others not very energy-intensive (cherries). The input–output approach ignores these differences.

The second approach is *process analysis*, Process analysis for a certain product starts with a definition of the *life cycle*, in which all the activities required for producing, transporting, using and disposing of a product are listed. This means that an inventory has to be made of the feedstock and intermediate products and the processes involved in the production of each feedstock. Subsequently, each process occurring in the life cycle is analysed to calculate its direct energy requirement. An initial extended description of the method was given at an IFIAS meeting in 1975 (IFIAS, 1978). In the years following, this method was developed further and applied widely (Boustead and Hancock, 1979). Process analysis is more accurate than input–output analysis. However, typical life cycle analysis methods based on process analysis are very data-intensive and therefore also labour-intensive. Another problem is that in many cases not all data required for a process analysis are available.

2.2 ► Hybrid analysis

Input-output analysis can be applied relatively quickly for complete consumption patterns but is not very accurate. Process analysis is much more precise but also very laborious. In this thesis we use a so-called hybrid method.

A hybrid approach, already suggested by Bullard et al. (1978), combines the best elements of the two methods discussed before. On the basis of this proposal we developed a concrete calculation method (first published in 1994, see Van Engelenburg et al. (1994)). Nowadays, there is a growing interest in hybrid methods, both for energy analysis and for environmental LCA. Suh et al. (2004) puts the

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3 The phrase ‘consumer goods’ is not only used for material goods but also for services purchased by consumers.

hybrid approaches into three groups, namely, tiered hybrid analysis, input-output based analysis and integrated hybrid analysis. In a tiered hybrid analysis the life cycle is split into two parts: major processes and so-called remaining processes. The major processes are those that will most probably make an important contribution to the energy requirement of the product. The process analysis approach is used for the main processes, while the input–output analysis approach is used for the remaining processes. In the input-output based hybrid analysis, important input-output sectors are further disaggregated if more detailed sectoral monetary data are available. In integrated hybrid analysis the process-based system is represented in a technology matrix by physical units per operation time of each process, while the input-output-based system is represented by monetary units. Detailed unit process level information in physical quantities is fully incorporated into the input-output model. In this taxonomy, the approach used in this thesis can be considered as a tiered hybrid. The hybrid method will be described in section 3.

3 ► The hybrid method for energy analysis with the domestic refrigerator as an example

In this hybrid method for energy analysis, we calculate the primary energy requirement of a consumer good in ten steps. In the first step a flow chart of the life cycle has to be constructed, while in steps 2 and 3, a mass balance and a financial balance of the product are determined. In steps 4 to 10, numerical values are attributed to the energy requirements of the various activities in the life cycle. Finally, the various contributions made by the activities to the energy requirement are added up. The hybrid method for energy analysis is described below and illustrated by applying it to the production and use of a domestic refrigerator. For an extended description see Van Engelenburg et al. (1991; 1994).

Note that all megajoules (MJ), mentioned in this chapter refer to primary mega-joules. All monetary units are converted from Dutch guilders (Dfl.,1990) to Euros. One Dfl. is about 0.45 Euro. In April 2005 one Euro (€) was about equivalent to 1.28 dollar (US$).

3.1 ► The first step: construction of a flow chart

The first step is to make a flow chart of the life cycle for the consumer good concerned. The flow chart should include all the activities that will probably make an important contribution to the energy requirement: i.e. production, trade and transport, consumption and waste disposal. In elaborating the flow chart one also has to select the so-called **basic materials**. These play an important role in the energy requirement connected with the complete life cycle of the product. The energy requirement for the basic materials is determined using process analysis.

In addition to the basic materials, other inputs are required for the production of the consumer good, e.g. materials with an expected small energy impact, some final processing of basic materials and services to the production. These inputs are called **residual goods**. The energy required for residual goods is determined using an input–output analysis. The energy requirement of **capital goods**, such as production equipment or an office building, is relatively small, and much effort will be needed to establish the energy requirement using process analysis. For this reason, the energy requirement for capital goods is established with an input–output analysis and considered separately.

In this first step, a number of choices has to be made. One can achieve greater accuracy by making a more detailed flow chart and selecting an increased number of basic materials; however, this also increases the amount of work involved. See Figure 2-1 for an example of the elements in a flow chart showing a life cycle.

The life cycle of the domestic refrigerator starts with the assembly of the refrigerator in the factory (industry sector). In the next phase, the refrigerator will be delivered to the consumer (trade sector). The refrigerator will then be disposed after use. Part of the waste will be disposed of and the remainder recycled. The refrigerator is produced in the electrical engineering industry. A standard domestic refrigerator with a capacity of 140 litres and a lifetime of 15 years is chosen as the functional unit.

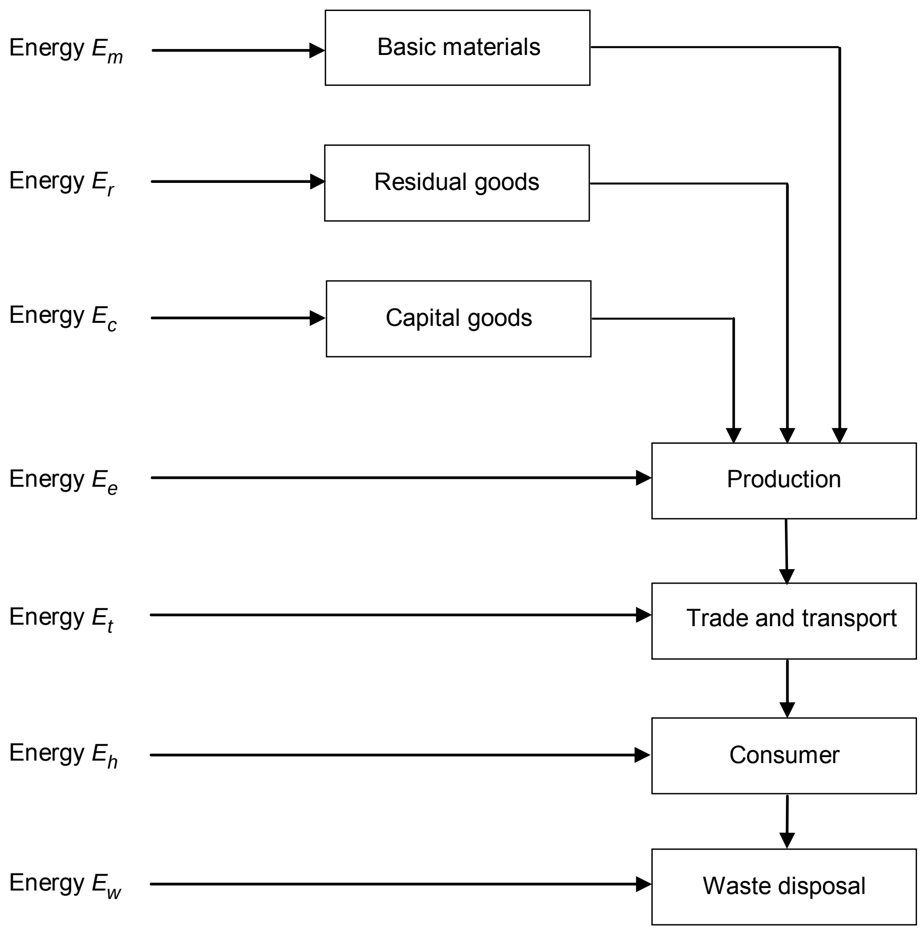

Figure 2-1 Example of the elements requiring energy in a flow chart showing a life cycle.

The basic materials used for the refrigerator are steel (compressor, outside wall, etc.), polyethylene (inside wall), polyurethane (insulation), aluminium (evaporator) and copper (wiring). The packaging for the refrigerator consists of a cardboard box, plastic protection materials and a wooden pallet. These packaging materials are also added to the basic materials (Philips, 1989). Figure 2-2 shows the flow chart for the refrigerator's life cycle.

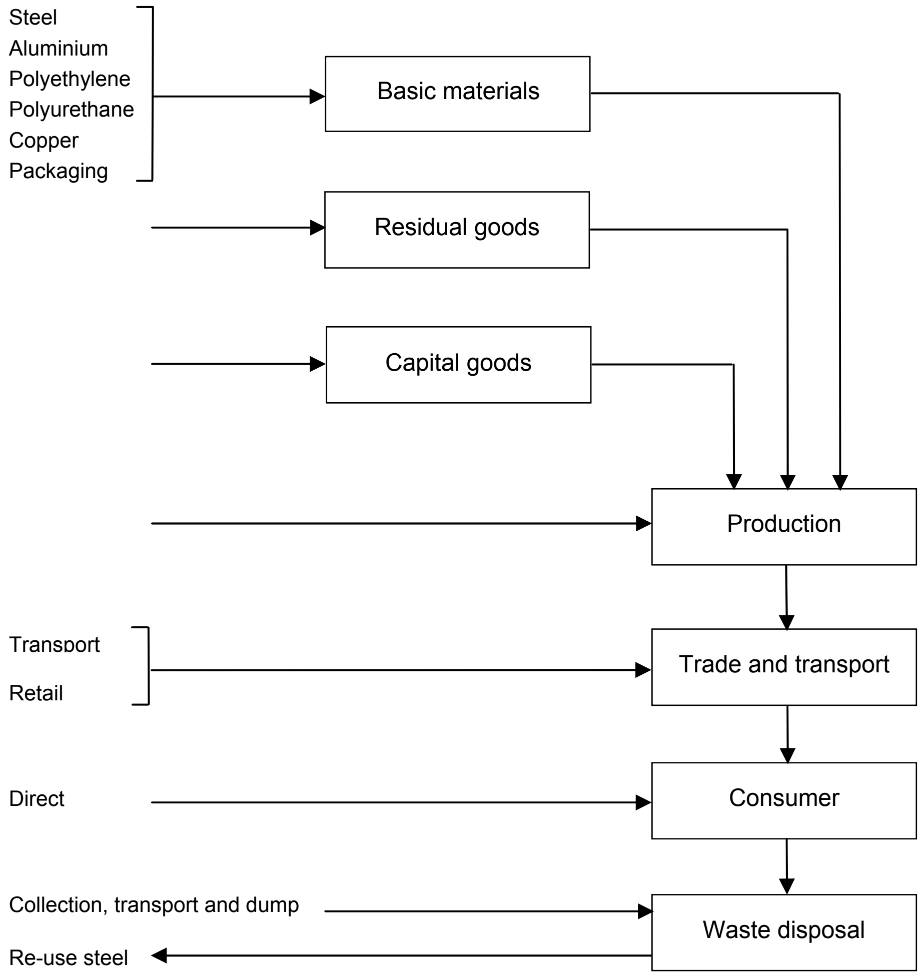

Figure 2-2 Flow chart of a refrigerator's life cycle.

3.2 ► The second step: the mass balance

With regard to the basic materials selected, a mass balance is first compiled for the life cycle determined in the first step. In many cases the composition of the product allows us to make a fairly accurate estimate of the total basic materials used in the life cycle. If there is a considerable loss of material during production, this loss should be taken into account too. Special attention should be paid to packaging materials.

The total weight, excluding packaging, of the one-door refrigerator chosen is 35 kg (Philips, 1989) and the refrigerator consists of the basic materials listed in Table 2-2 (Jacobs, 1991; Willink, 1991).

3.3 ► The third step: the financial balance

The costs of all the activities in the life cycle are defined in this step. The retail price of the product must be broken down into the following components:

- trade margin (including taxes),
- costs of the basic materials purchased by the manufacturer,
- costs of the direct energy requirement of the product manufacture,
- depreciation incurred by the manufacturer,
- added value (excluding depreciation) realised by the manufacturer and
- purchase of residual goods by the manufacturer.

In most cases there are no specific figures available from the manufacturers or the trade sector involved in producing and selling a specific product, so approximations have to be made. In the approximation made here, one first of all has to determine an average product price, for example, on the basis of information provided by retailers, retailers' associations or consumer associations. The costs of basic materials are assessed on the basis of the mass balance, combined with the specific costs for the various materials, and expressed as costs per kg. From national statistical data, such as production statistics and input–output tables, one can obtain sector-averaged values for the trade margin, depreciation and value added. The remaining costs are attributed to the closing entry: the so-called *residual goods*.

The consumer price of the refrigerator was about 360 Euro, incl. 18.5% VAT (Philips, 1989). This price can be broken down as shown in Table 2-1.

Table 2-1 Breakdown of the price of a refrigerator (excl. VAT).

Cost component	**Costs* per refrigerator** (€)
Basic materials in costs per kg (steel 0.9, aluminium 1.4, polyethylene 0.7, polyurethane 3.6, copper 1.6, cardboard 0.9, polystyrene 1 and wood 0.4)	43
Energy requirement for manufacturing a refrigerator (see step 5)	1.2
Depreciation	8.2
Value added	67
Retail margin	130
Residual goods	57

* Most of the costs for basic materials are derived from national statistics data for 1986 or 1990, collected by Wilting (1992).

3.4 ► The fourth step: energy requirement for the production of the basic materials (E_m)

The cumulative energy E_m required for producing the basic materials is calculated by adding up the gross energy requirements for all basic materials. The energy requirement relating to the use of basic materials for the refrigerator is shown in Table 2-2.

Table 2-2 Energy requirement for the production of basic materials (Van Heijningen et al., 1992/1993, Fraanje, 1990 and Krekel van der Woerd Wouterse, 1983).

Basic material	**Mass** (kg)	**GER** (MJ/kg)	**Primary energy requirement** (MJ)
Steel	25.0	23.4	585
Aluminium	0.5	198	99
Polyethylene	2.5	71	178
Polyurethane	6.0	190	1140
Copper	0.5	100	50
Cardboard (packaging)	1.5	26	39
Plastic (packaging)	0.5	70	35
Wood (packaging)	10.0	33	330
Total	**46.5**		**2456**

3.5 ► The fifth step: energy requirement for residual goods (E_r)

In addition to basic materials, various other goods or modifications, called residual goods, are used by the manufacturing sector. The cost of residual goods was calculated in step 3. The energy intensity of residual goods was calculated with an input–output analysis. However, this approach will have to be modified, since the basic materials, of which the energy requirements have already been taken into account, have to be omitted from the analysis. This modification is carried out by 'ignoring' the contribution made to the energy requirements by the sectors producing the selected basic materials, i.e. by setting the direct energy requirement of these sectors at zero (see Wilting (1996) for an extended description).

In the second step, the cost price of the residual goods for the refrigerator was calculated at 57 Euro. The basic materials used in the production sector come from the:

- timber industry, including furniture,
- paper and paper-product industry,
- chemical industry and
- base metal industry.

According to our hybrid approach, the energy requirements of these sectors will be set at zero. The energy intensity for the residual goods can be calculated using this assumption. Energy intensity is calculated at 5.7 MJ/€, resulting in an energy requirement for the residual goods of 323 MJ per refrigerator.

3.6 ► The sixth step: direct energy requirement for manufacturing the product (E_e)

This step determines the direct energy requirement of the production process. This energy requirement can be calculated using process analysis. Since, in most cases, no process data are available, we can use the average energy intensity derived from national statistics data for the production sector in which the product was manufactured.

The direct energy requirement for the production of a refrigerator could not be calculated through process analysis because of lack of data. We therefore used the average energy requirement of the sector as derived from the National Statistics (CBS). The direct energy intensity (= energy requirement per unit production value) in the electrical engineering industry is 2 MJ/€ (CBS, 1991). Since the production price was € 176, the direct energy requirement per refrigerator is calculated at 351 MJ.

3.7 ▶ The seventh step: energy requirement for the manufacture of capital goods (E_c)

The input–output tables published by national statistics offices generally include the investments (purchase of capital goods required to produce consumer goods, e.g. buildings) in the final demand category and not in the internal supplies of the various sectors delivering to each other. Consequently, the investments in buildings and other capital goods are not included in the energy requirement calculated for consumer goods by means of input–output analysis. To correct for this deficiency we have to calculate the demand that the production of capital goods makes on primary energy carriers. The energy intensity of investments is calculated through a separate input–output analysis based on depreciation, results in one figure, 9 MJ/€, for all sectors.

The depreciation of the capital goods in the manufacturing industry per refrigerator is 8.1 Euro. The associated energy requirement is calculated at 73 MJ per refrigerator.

3.8 ▶ The eighth step: energy requirement for the transport and trade sector (E_t)

Transport and trade form part of most life cycles. The product is usually transported from the factory (sometimes via the wholesale trade) to the retailer and from the retailer to the household. The weight of the product (i.e. the load) and the distance over which the product has to be transported must be specified for each mode of transport (e.g. train, lorry, ship). Energy is also used by the wholesale, distributive and retail trades.

The refrigerator is transported from factory to retailer and from retailer to household. The distance from the factory to the retailer is estimated at 500 km (the refrigerator is produced in Germany and sold in the Netherlands). This route, covered by lorry/truck, requires 2.5 MJ/ton-km (Boustead and Hancock, 1979 and BGC, 1991). The distance from the retailer to household, estimated at 15 km, is made by a delivery van and requires 8.5 MJ/ton-km (Boustead and Hancock, 1979 and BGC, 1991). The energy requirement for transport of the refrigerator (including packaging) can now be calculated at 65 MJ.

The trade sector also uses energy by supplying the product or service to the household. The value added from the trade sector was calculated in step 3. The value added (CBS, 1992a), multiplied by the energy intensity of the trade sector results in the energy requirement for the trade sector, which, per refrigerator, is 130 (€) x 4.6 (MJ/€) = 600 MJ.

3.9 ► The ninth step: direct energy requirement in the consumption phase (E_h)

Some products, such as cars, refrigerators and cookers, require energy during the consumption phase. With an ambient temperature of 18 °C, the refrigerator uses approximately 0.5 kWh electricity in 24 hours or 180 kWh per year (Philips, 1989). This annual requirement is equal to 1854 MJ of primary energy. The lifetime of a refrigerator is assumed to be 15 years, so the total direct energy requirement of the refrigerator is 27.8 GJ of primary energy.

3.10 ► The tenth step: energy requirement for waste disposal (E_w)

The life cycle ought to take into account the waste disposal associated with the consumer good. Waste disposal can consume energy, for instance, in connection with collection and transport. But disposal can also yield energy if the materials are recycled or incinerated.

The energy needed for collection and transport of the refrigerator amounts to about 14 MJ primary energy (DHV, 1985). The steel of the refrigerator will be re-used, while the remainder will be dumped, with 22 kg waste requiring 2.0 MJ (DHV, 1985). The re-use of 25 kg steel saves 400 MJ (Wilting, 1992). So the waste disposal for the refrigerator results in an energy gain of 384 MJ per refrigerator.

3.11 ► The final step: adding up the energy requirements

Finally, the various contributions made to the energy requirement by feedstock supply, manufacturing, use and disposal of a product can be added up. We have now calculated the total energy requirement of the product and its use. If the fraction of the residual goods contained in the cumulative energy requirement is too large, a more detailed life cycle should be constructed and the whole analysis for the modified part of the life cycle repeated.

Figure 2-3 shows the results of the preceding steps, inserted into the flow chart of the life cycle for the refrigerator, as shown in Figure 2-2. The cumulative energy requirement for the production, consumption and disposal of one refrigerator is calculated at 31 GJ over its entire lifetime of 15 years. The figures show the indirect fraction for the refrigerator to be about 10%. The energy intensity of a consumer good is defined as the total energy requirement divided by the purchase costs of the product. The energy intensity of the refrigerator is 9.5 MJ/€ when only the equipment itself is taken into account and 51 MJ/€ when the direct electricity requirement in the household is also included.

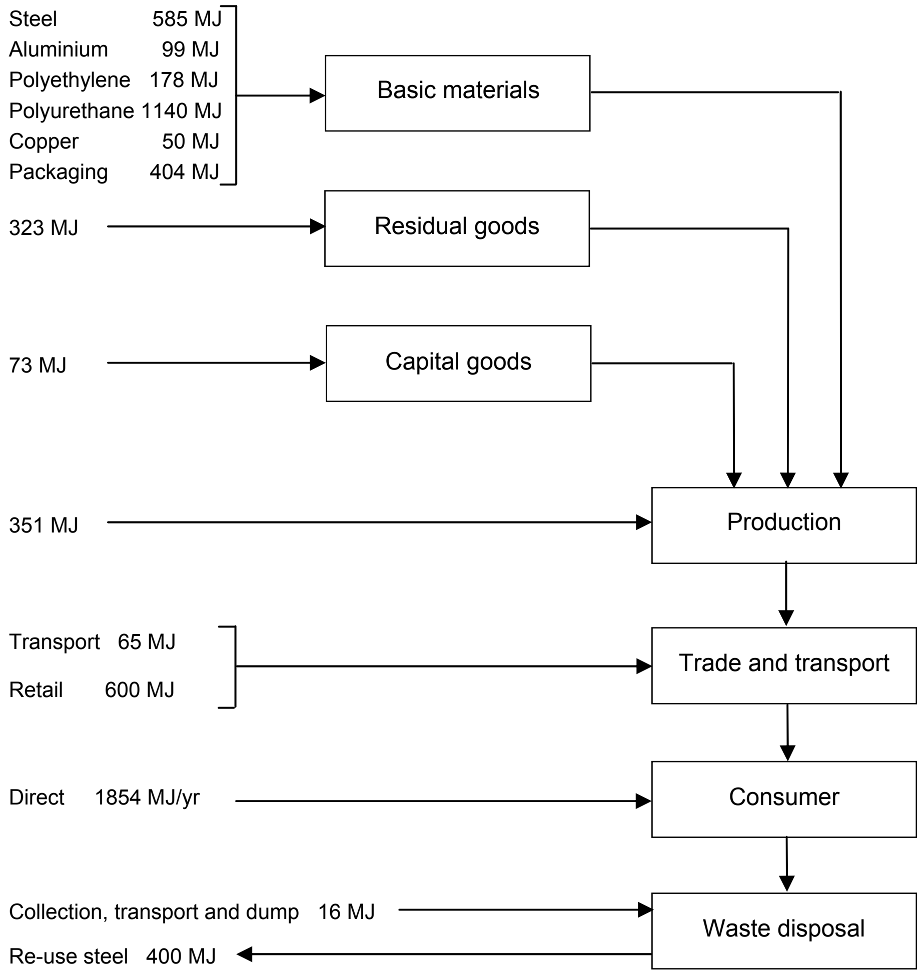

Figure 2-3 Flow chart of the life cycle of the refrigerator, together with the energy requirements in the various steps.

4 ► The suitability of the hybrid method for determining the energy requirement of consumption patterns

As previously stated, if the primary energy requirement of consumption patterns is to be analysed, the energy analysis method has to be rapid. The energy analysis method must also be accurate enough to detect the differences between consumption categories and consumption patterns. Below, we discuss the calculation speed and the accuracy of the hybrid method in analysing the energy requirement of consumer goods.

4.1 ► Making a quick energy analysis of consumer goods

The hybrid method for energy analysis described above may look very labour-intensive due to the large amount of input data required. But it should be pointed out that these input data can be standardised to a large extent and thus be used for many consumer goods. The hybrid method for energy analysis, along with databases containing a standardised input data set for the Netherlands, have been incorporated into a computer program called the Energy Analysis Program (EAP) (Wilting, 1992; 1999 and Benders et al., 2001). The energy requirement and energy intensity of large numbers of consumer goods can be calculated relatively quickly with the EAP.

A lot of data are available in the EAP program. Only limited additional data of the product analysed (e.g. weight, price, country of production and most important materials) are required for the analysis. The rest of the required data can be estimated quite easily, e.g. data from the production and trade sectors, transportation distances and kinds of waste disposal. In this way all 350 consumption categories from CBS (1992b) (covering the complete Dutch consumption package) were analysed in about two person-years (see De Paauw and Perrels (1993), Kok et al. (1993), Vringer and Blok (1993) and Vringer et al. (1993)). This comes to only about 10 hours per consumption category, which makes the hybrid method for energy analysis applicable to calculating the energy requirement of consumer goods without the classic data problems of process analysis.

4.2 ► Accuracy of the hybrid method for determining the energy requirement of consumer goods

The highest inaccuracy in the hybrid method for energy analysis in calculating the energy requirement of consumer goods will probably be caused by the use of input–output analysis to calculate the energy requirement for producing residual goods and the energy requirement for trade. However, the uncertainties that stem from the use of input–output analysis for residual goods can be partly avoided by minimising the use of this analysis through incorporation of sufficient process data on the basic materials.

4.3 ► Accuracy in the energy requirement of trade

The energy requirement for retail trade is an example of a component of the life cycle of a product, where the energy requirement is calculated by using energy intensities on a monetary basis. For some products, the share of retail trade in the total calculated indirect energy requirement is more than 25% (see, for example, Vringer et al. (1993) and De Paauw and Perrels (1993)). The energy requirement for retail trade is assigned on a financial basis. This means that if the price of the product doubles, the energy requirement allocated to retail trade also doubles. This 'financial' way of assigning the energy requirement to retail trade may result in an overestimation of the retail trade energy requirement for more expensive products and an underestimation of cheaper products of the same kind. The retail trade energy requirement can also be assigned on a physical basis. In this case the energy requirement is assigned per item, per kilogram or cubic metre of product and is not affected by the price of the product. This assignment or ‘physical’ accounting method may result in an underestimation of the energy requirement of the retail trade for the more expensive products, since fewer products per square metre of retail space will have to be sold to realise the same turnover per square metre.

Vringer and Blok (1996) have provided an estimation of the error, made by assigning the energy requirement of the retail trade, either on a financial or physical basis. They made a detailed energy analysis, based on the annual sales per square metre floor, of two retail branches: clothing shops and shoe shops. Compared with this alternative detailed accounting method of the energy requirement of the retail trade, the *financial* accounting method indicates an overestimation for expensive clothes and shoes (4 to 14%), and an underestimation for cheaper clothes and shoes

(-6%). The calculated energy requirement for clothes and shoes using the *physical* accounting method is about 2 to 10% too high for the low-price level shops and 2 to 17% too low for the high-price level shops. It is quite conceivable that more expensive shops will require relatively more energy for lighting and heating per square metre than cheaper shops. This means that the energy requirement of the retail trade will be higher for more expensive products and lower for cheaper products of the same kind than estimated here.

Vringer and Blok (1996) concluded that both financial and physical accounting methods for the energy requirement of retail trade would cause errors for products with a price level deviating from the average price. For individual purchases of clothes and shoes, the systematic error may be about 5 to 15% of the total indirect energy requirement. However, for the average of all shoes or all clothes, the energy requirement would be about right.

5 ▶ Conclusions

The hybrid method for energy analysis as proposed by Van Engelenburg et al. (1994) and worked out by Wilting (1992) and Wilting et al. (1999) can be concluded as being suitable for rapidly calculating the direct and indirect energy requirement associated with the purchase and use of large numbers of consumer goods. The hybrid method detects differences between consumption categories, even if they are produced by the same economic sector. The use of input–output analysis, based on a financial accounting method, for parts of the calculations can cause deviations for individual products, with a price level deviating from the average price. However, on average, the calculated energy requirement will be correct. Although the error margins for individual products can be reduced by using more process data, more effort will be needed to make an analysis.

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Chapter 3

The energy requirement of cut flowers and consumer options to reduce it[1]

► Abstract

Like all consumer products, cut flowers require energy during their life cycle. The aim of this chapter is to examine how households can reduce their primary energy requirement for the decorative and gift functions provided so far by cut flowers without reducing their consumption level, also taking into account the financial cost. In 1990, an average Dutch household purchased one or more bouquets 11 times during the year, coming to a total of about 250 flowers for Dfl. 170[2] (ca. EUR 77), requiring a total of 2.2 GJ or 1% of the total primary household energy requirement. The energy put into flowers (energy intensity) is among the highest of all non-energy household purchases, costing an average of 12.9 MJ/Dfl. Knowing the high energy requirement of cut flowers should motivate us to take a closer look at less energy-intensive alternatives; for example, replacing flowers as gift with other gifts, making more use of flowering indoor plants and selecting flowers that are less energy-intensive in their production and distribution (e.g. flowers of other species & other seasons). The calculations suggest that if all the energy reduction options discussed here are applied to a substantial extent, the cumulative energy required for flowers purchased by an average Dutch household can be halved. More research is needed to investigate the acceptance of the proposed measures and the feasibility of a combination of measures.

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1 This study reported here represents a slightly adapted version of Vringer, K. and Blok, K. 'The energy requirement of cut flowers and consumer options to reduce it', *Resources, conservation and recycling* 28 (2000): 3-28.

2 All monetary quantities are expressed in Dutch guilders (Dfl., 1990). One Dfl. = approximately 0.45 Euro or 0.6 US$ (1995).

1 ▶ Introduction

The energy required for production and distribution of consumer products during the life cycle of the product generally leads to CO_2 emissions. According to Vringer and Blok (1995a) about half the primary energy requirement of Dutch households is related to energy carriers like electricity, petrol and natural gas (direct energy requirement)[3]. The other half is embodied in the products and services consumed (indirect energy requirement). These products and services have different energy intensities[4]. Replacing products and services by less energy-intensive products and services can reduce the total primary household energy requirement and the concomitant CO_2 emissions. In this chapter we will explore the possibilities of such replacements by focusing on cut flowers.

Initial calculations of indirect energy requirements for cut flowers and indoor plants of Dutch households in 1990 show a relatively high energy requirement of 4.3 GJ per household, nearly 2% of the total household energy requirement. The energy intensity for cut flowers and indoor plants was found to be one of the highest (about 15 MJ/Dfl.) of all consumer products. Only the energy carriers used by households (petrol, electricity and natural gas) have a higher energy intensity, namely, 22, 49 and 59 MJ/Dfl., respectively (Vringer and Blok, 1995a). The generally high energy intensity of cut flowers and indoor plants is all the more reason for taking a closer look at less energy-intensive alternatives. In this chapter we will focus only on cut flowers.

Cut flowers in this thesis will be seen as a decorative element in households and as items to give as gifts. The aim of this chapter is to examine the extent to which households can reduce their energy requirement by using alternatives to cut flowers in these functions. We will discuss the role of cut flowers and indoor plants in the framework of total sources for household decoration. This will be followed by the determination of the energy required for cut flowers in terms of type and season of

3 To calculate primary energy we applied average factors to transform primary energy requirement into final energy requirement for the Netherlands, as described by Van Engelenburg et al. (1994).

4 Energy intensity (expressed as MJ/Dfl.) is the total primary energy requirement divided by the consumer price.

purchase. Finally, we will discuss the household function of cut flowers and then proceed to discuss and quantify energy reduction options for cut flowers as a household decoration and gifts.

2 ► The role of cut flowers and indoor plants in household decoration

Many activities are carried out in households, decorating is being one of them. This activity consists of all actions, deliberations and decisions needed to decorate the house (Groot-Marcus et al., 1996) and requires several resources, including time and money[5]. Let us look at the energy requirement in terms of household time and money. The resources described here for household decoration include all time and money needed to furnish the house and garden. The energy requirement figures will apply then to furniture, upholstery, shopping and transport (this is to obtain the relevant products), housecleaning, waste disposal and wall decoration. Resources for heating and lighting the house are excluded. Financial expenditure (S) for the relevant consumption categories (*i*) was derived from the 1990 Household expenditure survey (CBS, 1992) and time expenditure from the 1990 Dutch time expenditure survey (TBO, 1990). The total household energy requirement (E) was calculated according to equation (1). Energy intensities (ε) are from Vringer and Blok (1995a).

$$\mathrm{E} = \Sigma(S_i * \varepsilon_i) \qquad (1)$$

The time, money and calculated energy requirements for household decoration in the Netherlands in 1990 are given in Table 3-1[6]. Expenditures for the consumption categories of transport (shopping), water (cleaning), domestic services (cleaning) and direct energy requirements (cleaning), given by CBS (1992) and TBO (1990),

5 Groot-Marcus et al. (1996) mentioned more household resources, such as 'goods facilities' (in this chapter: vases, pots, plant food & potting compost), 'space' (for the flowers and plants themselves), 'knowledge', 'skills' and 'labour capacity'. These resources are not regarded as important factors for alternatives and are not further analysed in this chapter.

6 The time expenditure in Table 3-1 is valid for persons above 12 years of age. The average household has 2.2 household members above 12 (CBS, 1992). To calculate the average time expenditure per household, time expenditures in Table 3-1 will have to be multiplied by 2.2.

relate to the portion attributed to the activity of household decoration. Expenditures for these partial attribution categories come to Dfl. 380 and an energy requirement of 4 GJ.

Table 3-1 Time, money and energy requirements for average Dutch household decoration in 1990.

	Financial expenditure (Dfl. per household)	**Time expenditure** (minutes per person per week)	**Energy intensity** (MJ/Dfl.)	**Energy requirement** (GJ per household)
Garden	241	47	8.3	2.0
Flowers and plants	279	17	15.6	4.4
Furniture	1334	-	4.0	5.3
Upholstery	79	-	4.6	0.4
Cleaning	349	150	9.1	3.2
Shopping	58	30	7.2	0.4
Other	252	32	5.4	1.4
Total	**2592**	**276**	**6.6**	**17.1**
Percentage of total	**6%**	**3%**		**7%**

Table 3-1 shows that household decoration in 1990 required nearly Dfl. 2600 (6% of the average net income), 17 GJ (7% of the average total household energy requirement) and 4.6 hours per person per week (3% of the total time expenditures) per average household. Cut flowers and indoor plants are responsible for 11% of the financial expenditures, 26% of the energy requirement and 6% of the time expenditures for household decoration. The energy intensity of cut flowers is twice that of the average energy intensity for household decoration.

3 ► The energy requirement of cut flowers

We calculated the cumulative primary energy requirements for 37 of the most common cut flowers grown in the Netherlands as a function of the season of purchase. The data required for the energy analysis is taken from IKC-GenB (1991), where cost calculations for many types of cut flowers were divided into the required expenditures for decontamination, herbicides, water, packaging, transport to the auction, interest, depreciation and auction. The expected selling price, number of cut flowers produced[7] and natural gas and electricity requirements (for heating the glasshouse and assimilation lighting) were given for 13 periods of four weeks throughout the year.

Table 3-2 Calculated energy intensities for cost items of cut flowers expressed as the primary energy requirement per unit purchased.

Cost item	Energy intensity	Unit
Natural gas	32.0	MJ/m^3
Electricity	10.3	MJ/kWh
Seeds	21.1	MJ/Dfl.
Preparation	7.5	MJ/Dfl.
Fertilisation	54.1	MJ/Dfl.
Pot / container	11.5	MJ/Dfl.
Potting compost	3.0	MJ/Dfl.
Other materials	11.5	MJ/Dfl.
Insecticide / weed killer	7.9	MJ/Dfl.
Cold storage	10.0	MJ/Dfl.
Packaging	11.5	MJ/Dfl.
Auction	2.2	MJ/Dfl.
Interest	0.2	MJ/Dfl.

Energy intensities for all cost items are needed to calculate the energy requirements for flowers. These energy intensities are calculated with the EAP computer programme (Wilting et al., 1999), which is based on hybrid energy analysis[8] as described by Van Engelenburg et al. (1994). EAP also contains all additional necessary input-output data. Table 3-2 shows the calculated energy intensities for all cost items used for the energy analysis for cut flowers.

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7 In this chapter, one stalk is equal to one flower. Some types of flowers have more than one flower on a stalk.

8 The hybrid energy analysis method allows the cumulative energy requirement of a consumption item to be calculated relatively easily and accurately. This is achieved by combining the elements of two existing methods for determining the cumulative energy requirements of goods and services by using process analysis and input-output analysis.

To calculate the energy requirements for flowers, expenditures according to IKC-GenB (1991) are multiplied by the energy intensities in Table 3-2 and the energy requirements for retailing and transport finally added. The retailing of flowers and plants accounts for 3.8 MJ per Dutch guilder added value, and cut flowers are sold for an average of 165% of the purchase price (Wilting et al., 1999). The energy requirement per flower can be calculated using this information.

To factor-in the influence of the season in which the flowers are purchased, we added the energy requirement to heat and light the glasshouse in the 4-week period to that of the two 4-week periods preceding the purchase of flowers, dividing the result by three. The eight extra weeks are taken into account, because flowers usually need about eight weeks to grow (Vermeulen, 1995).

Seven of the 37 cut flowers analysed were bulbous flowers such as tulips, hyacinths and lilies. IKC-GenB (1991) gives no extended figures for bulbous flowers, but Elderman et al. (1994) mention the total amount of natural gas required for cultivating a certain amount of several types of bulbs. The amount of natural gas needed for cultivation in Elderman et al. (1994) was distributed over 13 periods of four weeks, as in IKC-GenB (1991) for the other cut flowers described. If the time a bulbous flower needs to grow is taken into account, the energy requirement attributed to heating will be based on average energy requirements in the relevant period and the preceding 4-week period. We also assumed that all other steps in the production and distribution process of bulbous flowers would require 3 MJ of primary energy per flower, being equal to the average energy required by cut flowers grown out in the open. We also assume that cultivating one bulb would result in one flower.

Figure 3-1 shows the variation in energy required per month for six of the cut flowers most often sold. Appendix 3A contains the season-dependent energy requirements and energy intensities for all flowers analysed in all 13 periods of four weeks over the year.

The energy requirement and energy intensity varies considerably per month purchased and per type of flower. We found variation in the energy requirement ranging from 3 to 195 MJ per flower. Flowers grown outdoors generally require about a quarter of the energy consumed by flowers grown in a glasshouse, but glasshouse flowers are available the whole year round. The energy intensity of some flowers like bouvardia, Peruvian lily and carnation in the wintertime is higher than the energy intensity of natural gas[9]. In wintertime, flowers such as the carnation require, per single flower, an amount of primary energy equal to 1 − 1.5 litre of petrol[10].

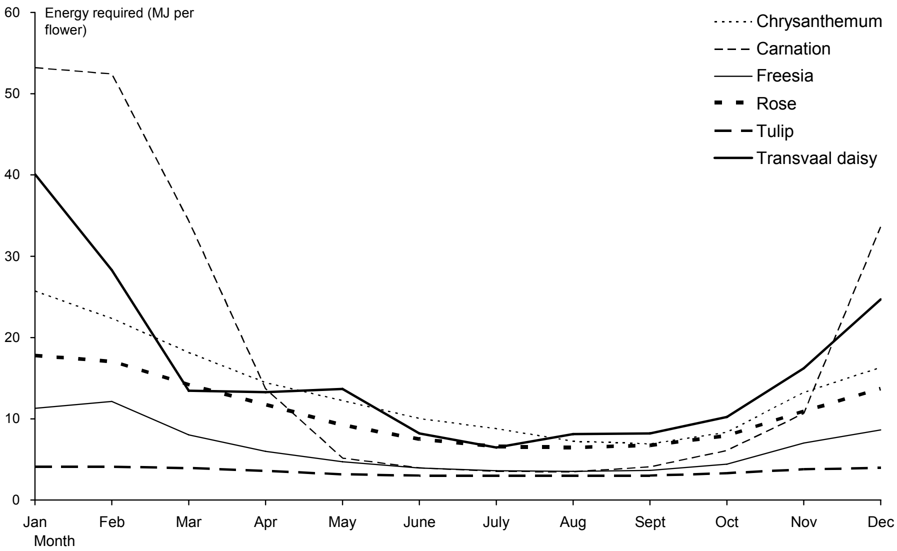

Figure 3-1 The seasonal variation in the primary energy required for six of the most sold cut flowers.

Most Dutch auction sales are destined for export[11]. However, according to CBS (1994) auction sales accurately represent the composition of flower types purchased by Dutch consumers as in Ten Hag and Van der Ham (1996). Using auction sales of

9 The energy intensity of natural gas as sold to households is about 60 MJ/Dfl. (Vringer and Blok, 1995). The energy intensity for these flowers may be higher because natural gas prices for glasshouse horticulture is much lower than that for households.

10 One litre of petrol requires 35 MJ (Wilting et al., 1995).

11 Seventy per cent of the cut flower production in the Netherlands in 1990 was for export and in the same year the Netherlands was responsible for nearly 60% of the total export of flowers worldwide (Hack and Heybroek, 1992).

15 of the most commonly sold flowers (CBS, 1994), we calculated the average energy requirement and energy intensity for these flowers, taking into account the period of auction and the energy requirements per type of flower (see Table 3-3).

Table 3-3 Auction sales measured as percentage of flowers sold, consumer price, energy requirement per flower and energy intensity for the 15 most auctioned types of flowers.

Type of flower	**Auctio sales** (flowers sold in %)	**Consumer price** (Dfl. per flower)	**Energy requirement** (MJ per flower)	**Energy intensity** (MJ/Dfl.)
Peruvian lily	2.7	0.8	15.0	19.1
Flamingo flower	0.4	3.1	51.6	16.8
Michaelsmas daisy	1.0	0.9	10.9	12.8
Chrysanthemum	18.1	0.8	12.5	14.8
Carnation	7.3	0.6	4.9	7.9
Freesia	8.2	0.4	6.5	14.9
Transvaal daisy	5.3	0.7	13.4	20.5
Baby's breath	1.6	0.8	7.9	10.4
Amaryllis	0.9	0.7	10.7	15.7
Rose	29.8	0.6	9.5	16.2
Tulip	12.7	0.7	4.0	5.4
Iris	3.1	0.5	4.5	9.9
Lily	4.8	1.2	8.1	6.8
Daffodil	2.3	0.4	3.6	10.0
Sword lily	1.7	0.3	3.0	11.7
Total auction sales (weighted average)		**0.7**	**8.8**	**12.9**

Table 3-3 shows the average energy requirement per flower to be about 9 MJ and the average energy intensity at about 13 MJ/Dfl. An average household in 1990 spent Dfl. 280 on flowers and indoor plants (CBS, 1992). About 60% of this was spent on flowers (ten Hag and van der Ham, 1996) (van der Velden, 1997). This brings the total expenditure per average household in 1990 to Dfl. 170, for which one or more bouquets was/were purchased 11 times, coming to a total of about 250 flowers (Bertens et al., 1997). Assuming that the average energy requirement of all the flowers is the same for the 15 sellers, the total energy requirement will come to

2.2 GJ. Collectively, chrysanthemums and roses are responsible for half of all the flowers purchased and 60% of the average household energy requirement for cut flowers.

Figure 3-2 shows the average energy requirement and energy intensity for the 15 best sold flowers, assuming that the price of the bulbous flowers varies in the same way each month as the unweighted average price of the other 30 cut flowers in the analysis. Compared to the information in Figure 3-1, the seasonal effect of the energy requirement is reduced because flowers exhibiting high energy consumption are sold mainly in the summertime and vice versa. Furthermore, the energy intensity in the summertime is not much lower than in the wintertime because of the lower summertime prices.

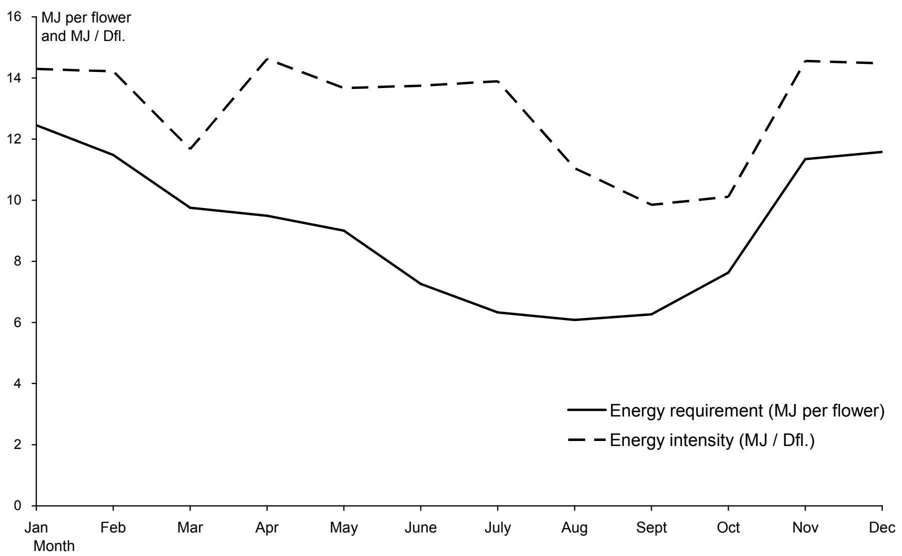

Figure 3-2 Average energy requirement and energy intensity for the 15 most commonly grown flowers in the Netherlands.

4 ► Functionality of cut flowers and consumption characteristics

Before we can start analysing energy reduction options, we have to elaborate on the functionality of cut flowers, as this is relevant to the degree to which alternatives are feasible. In general, we can distinguish two functions for cut flowers: 1) as decorative element in the home and 2) as gifts.

Ultimately, cut flowers are (finally) used in most cases to decorate the house. But, flowers are not suitable for every kind of household decoration. Cut flowers often decorate a table, but indoor plants are more frequently chosen to decorate window sills (van Tilburg, 1984).

The most popular gift in the Netherlands is flowers (Komter and Schuyt, 1993; van der Velden, 1996). Flowers represent about 30% of the smaller gifts given[12] (van der Velden, 1996). About 50% of all the flowers purchased in 1995 were for gifts; the average price was Dfl. 15 (ten Hag and van der Ham, 1996).

In 1995, 70% of the households in the Netherlands bought flowers (ten Hag and van der Ham, 1996). About 20% of the flower purchases were unplanned, while 75% of the households who planned to buy flowers had no specific type of flowers in mind before the actual purchase (van Tilburg, 1984). No relationship was found between the type of house (flat/apartment or detached house with a garden) and expenditures on flowers and indoor plants (CBS, 1996). However, there is a relationship between household expenditures on cut flowers and indoor plants and the total net household income. Households with twice the average net income spend 70% more on flowers and indoor plants than households with an average net income (CBS, 1996). Nevertheless, the range in flower expenditures within the same income category is broad.

12 Up to Dfl. 30

5 ► Reduction options

Here, consumer energy reduction options will be discussed for cut flowers as household decoration and gifts consisting of cut flowers. Since all the options can nowadays be applied by households themselves, we have excluded energy reduction options that can be carried out by others, e.g. growers and retailers. If the energy reduction options described are applied, the total number of functional units will, as far as possible, be kept the same. A functional unit is defined as one gift or one decorative item, in most cases comparable to one bouquet of flowers.

First, the maximum annual energy reduction per option was calculated for an average Dutch household and, if relevant, also the impact on expenditures. Constraints of the reduction options will be subjectively discussed below.

We divided the energy reduction options into two main groups:

- Replacement by other kinds of product within the same product category
- Replacement by other products having a comparable function

These two groups of options and the maximum energy reduction will be discussed below. See Table 3-6 for an overview of all the options discussed, including additional constraints.

5.1 ► Replacement by other products in the same product category

There are a number of ways for households to reduce the energy requirement for cut flowers without replacing them with other kinds of decorative items, for example:

1. Buy more cut flowers in the summertime and fewer in the wintertime.
2. Buy less energy-intensive cut flowers.
3. Extend the lifetime of cut flowers by looking after them.
4. Buy cut flowers grown using environment-friendly methods.
5. Buy cut flowers grown in warm countries, instead of Dutch cut flowers.
6. Buy bulbs instead of bulbous cut flowers.

5.1.1 ► Buy more cut flowers in the summertime and fewer in the wintertime

A shift in season purchased can reduce the energy requirement of flowers. By buying some of the flowers (see Figure 3-2) in summertime[13] instead of wintertime, the energy requirement for cut flowers may be decreased by 20%[14]. The average weighted price of the 15 most common flowers in summertime is about 14% lower than the average for the whole year. Assuming that the month of purchase cannot be changed for gifts (50% of all flowers bought) (ten Hag and van der Ham, 1996)), the maximum achievable energy reduction for cut flowers for an average Dutch household is 10% (224 MJ/year). The reduction of expenditures is then Dfl.12 per year.

5.1.2 ► Buy less energy-intensive cut flowers

A shift to less energy-intensive flowers can, for some households, reduce the total energy required for flowers. Table 3-3 shows the average energy requirement per flower to be 8.8 MJ, varying from 3 to 51 MJ. The four flowers with the highest energy requirement per flower are chrysanthemums, Transvaal daisies, Peruvian lilies and Flamingo flowers all require more than 11 MJ per flower. About 66 of these four types of flowers are purchased per Dutch household per year. If chrysanthemums are replaced by Michaelmas daisies, Transvaal daisies by carnations, Peruvian lilies by lilies and flamingo flowers by amaryllis, the average energy required per flower decreases by 30%. We assume that this measure is only applicable to 85% of the four flowers with the highest energy requirement per flower, bought by households that do not always have flowers at home[15]. We also assume that this option is applicable for both flowers bought for household decoration and flowers purchased as gifts. The energy reduction is then about 10%

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13 Summertime is defined here as the period between 1 May and 31 October and wintertime as the period between 1 November and 30 April.

14 Average energy requirement per flower for the whole year is 9 MJ; average energy in summertime is 7 MJ per flower. About 46% of all flowers are sold in wintertime.

15 A household has to make 3.4 flower purchases per month in order to renew a bouquet of cut flowers immediately after an average and optimal lifetime of 8.9 days (see Table 3-4). Households who buy flowers 7 times or more per month buy about 30% of all flowers (Bertens et al., 1997), but only half of these purchases is for decoration. So it can be assumed that about 15% of all cut flowers purchased are immediately replaced when they die.

(231 MJ) per year for an average household. The expenditures will remain unchanged.

Table 3-4 Lifetime under optimal conditions and the energy requirement.

Type of flower	**Lifetime** (days)	**Energy requirement** (MJ/flower)	**Energy requirement per day** (MJ/flower/day)
Peruvian lily	8.5	15.0	1.8
Flamingo flower	17.5	51.6	2.9
Michaelmas daisy	8.5	10.9	1.3
Chrysanthemum	14	12.5	0.9
Carnation, small	10	4.9	0.5
Carnation, large	8	4.9	0.6
Freesia	7.5	6.5	0.9
Transvaal daisy	8.5	13.4	1.6
Baby's breath	6	7.9	1.3
Amaryllis	10	10.7	1.1
Rose (small)	8.5	9.5	1.1
Rose (large)	6	9.5	1.6
Tulip	6	4.0	0.7
Iris	3.5	4.5	1.3
Lily	8	8.1	1.0
Daffodil	4	3.6	0.9
Sword lily	8	3.0	0.4
Average	**8.9**	**8.8**	**1.1**

Households which always have flowers, can reduce their energy requirements by buying cut flowers with a longer lifetime. Table 3-4 shows the lifetime of the 15 best-selling species under optimal conditions, along with the calculated energy required per flower per day. Assuming that the flowers receive optimal treatment, without using plant food for cut flowers, the average energy required per flower per day is about 1.1 MJ. We assume less energy-intensive flowers to replace the four flower types requiring the most energy per flower per day.

Flamingo flowers are replaced by Amaryllis, Peruvian lilies by lilies, Transvaal daisies by carnations and large roses by carnations. Taking into account that this option is only applicable to 15% of all flowers purchased, the average energy requirement of cut flowers decreases by 2% (37 MJ per year per average household). The expenditure will remain unchanged, with the lifetimes of the three types of replacement flowers taken into account. The total effect of this option for all flowers purchased is a reduction of 12% (268 MJ).

5.1.3 ► Extend the lifetime of cut flowers by proper treatment

Proper treatment such as the use of clean vases and water, fertiliser and avoidance of direct sunlight, etc.) extends the lifetime of cut flowers substantially. Adding fertiliser extends the lifetime of Michaelmas daisies, carnations (small), freesias and roses by about 30%. Collectively, these four types account for 44% of all the flower-days[16] (see Table 3-4). Extending the lifetime by fertilising is less advantageous for other flowers (Nieuwenhoven, 1998).

There are no figures on actual treatment of flowers in households. The effect of better treatment is based here only on lifetime extension, obtained by fertilising Michaelmas daisies, carnations (small), freesias and roses. Taking into account that this option only applies to 15% of all purchased flowers that are replaced immediately at the end of their lifetime, we find that the average energy requirement of cut flowers decreases by 2% (41 MJ per year per average household), while expenditures decrease by Dfl.3. The lifetimes of the three types of replacement flowers have been taken into account. We assume the extra costs and energy requirement for the extra fertiliser to be negligible.

5.1.4 ► Buy cut flowers grown using environment-friendly methods

Environment-friendly growers in the Netherlands try to reduce the energy required for growing their cut flowers. However, there are no unambiguous standards for the energy required for these flowers; nor are there signs that these flowers are grown more efficiently (Franke, 1995; Sperling, 1995).

Environmental-friendly flowers have been experimentally launched on the Dutch market and cost between 10% and 30% more than the cut flowers grown using

16 A flower-day relates to the presence of one cut flower in the house for one day. The lifetime of a small rose is 8.5 days (see Table 3-5), so ten small roses are good for 85 flower-days.

regular methods (Sperling, 1995). Calculations of the energy requirement of 'green flowers' could not be made because of lack of data. We excluded this option in further calculations.

5.1.5 ► Buy cut flowers grown in warm countries instead of Dutch cut flowers

Imported flowers from countries like Kenya, Israel, Spain and Morocco can be grown in a more energy-efficient way than in the Netherlands because of the relatively warm climates of these countries. The energy required for roses grown in Israel, Morocco and Spain is about 10% less than in the Netherlands, including the energy required for air transport (about 1 MJ per flower). This relatively slight difference in energy requirement per rose is mainly due to the relative low flower production per square metre in these warmer countries. Compared with the Netherlands, the production of roses per square metre is 50% lower in Israel and 75% lower in Spain and Morocco (Verhaegh, 1996). Figures for other types of flowers are unavailable (van der Velden, 1998).

Flowers from Kenya are generally not grown in heated glasshouses (Kortlandt, 1998). According to Lenggenhager (1997)[17], the total energy requirement of Kenyan roses is about 2 to 3 MJ per rose, including transport. This energy requirement is 85% less than for Dutch roses. We assume the prices of imported flowers to be comparable with flowers grown in the Netherlands. Van Vliet (1998) and Van der Velden (1998) expect the energy requirement for Kenyan flowers to rise due to advances in flower cultivation. A reduction in the required energy by at least 10%, and maybe up to 85%, by buying flowers from warm countries seems feasible. The energy required for air transport of flowers is relatively insignificant (1 to 3 MJ per flower).

5.1.6 ► Buy bulbs instead of bulbous cut flowers

Buying bulbs instead of bulbous cut flowers saves the energy required for cultivating the bulbs. The energy required to cultivate one bulb is about 1 MJ, except

17 For the calculation, we used figures for the same type of rose (First Red) from the appendix in Lenggenhager (1997). We also included the energy needed for the production of electricity (total 10.3 MJ/kWh; see Table 3-2).

for lilies, which is 6 MJ per bulb. The total average energy required for bulbous flowers is 3 to 4 MJ per flower, except for lilies, at 9 MJ per flower. The energy reduction, which can be achieved by buying bulbs instead of bulbous flowers, is about 10% per bulb and about 60% for lilies[18]. Total energy reduction amounts to 80 MJ, or about 4% of the total energy required for all cut flowers purchased per average Dutch household, while a reduction in expenditures is not expected. We ignored the effect of a possible extension of the lifetime.

5.2 ► Replacement by other products with a comparable function

Households can reduce the energy requirement for cut flowers by replacing flowers with alternative decorations, such as:

1. indoor plants instead of cut flowers,
2. plastic/textile flowers instead of cut flowers,
3. paintings and sculptures, and
4. alternative gifts.

5.2.1 ► Buy indoor plants instead of cut flowers

Indoor plants have a much longer lifetime than cut flowers. Replacing relatively short-lived cut flowers with indoor plants can result in a reduction in energy requirement. The average number of cut flowers in the house, including flowers as gifts, is about six per day or, on average, about half a bouquet at a time. This means that all cut flowers in a household can, on average, be replaced by one indoor plant. If we assume the average flowering time of the flowering indoor plant (replacing the cut flowers) to be twice in three weeks, about eight plants per year are needed to replace all the cut flowers, including flowers given as gifts.

18 We added the extra energy required for the pot, in which usually multiple bulbs (we assumed four) are sold. The energy required for a plastic pot with a diameter of 14 cm is estimated at 2 MJ (Potting et al., 1995).

We assume that the energy required for one flowering plant is equal to that of a 60 cm *Ficus Benjamina*[19], i.e., 50 MJ each (Potting et al., 1995). The replacement of all flowers by indoor plants, excluding flowers purchased as a gift, saves 0.9 GJ per year, 41% of the annual energy requirement for cut flowers per average Dutch household. The energy intensity of indoor plants is almost the same as that of cut flowers (Potting et al., 1995), which means that financial expenditures decrease by 41%.

5.2.2 ► Buy plastic/textile flowers instead of cut flowers

Replacing cut flowers with imitation flowers made of plastic or cloth with a much longer lifetime can reduce the energy required dramatically. We assume that the daily average of 6 flowers in the house will be replaced by 10 high-quality imitation flowers amounting to 0.5 kg nylon with a lifetime of 10 years, costing Dfl. 10 each. The energy required for these 10 high-quality imitation flowers is calculated at about 500 MJ (calculated with Wilting et al., 1999). The reduction of the required energy is then about 48% (excluding flowers purchased for gifts) and can save Dfl.75 per year.

5.2.3 ► Buy paintings and sculptures instead of cut flowers

Decorations of art such as paintings and sculptures can replace a bouquet of flowers. If all flowers are replaced by art that costs the same and the lifetime of this art is 20 years, it will cost a household Dfl.2080[20]. We assume that the energy intensity of an art object as being equal to 1 MJ/Dfl. If all flowers are replaced by art, excluding flowers purchased for gifts, the annual net energy reduction will be about 48% of the total energy requirement for cut flowers.

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19 We chose *Ficus Benjamina* because it is one of the most often sold larger indoor plants at the auction (CBS, 1994).

20 Net current value of the annual expenditure of Dfl.170 for 20 years, including an inflation rate of 3% per year and 8% interest.

5.2.4 ► Buy alternative gifts

Flowers are not only used to decorate the house, but 50% are bought as gifts. The average price of flowers given as a gift is Dfl.15 (ten Hag and van der Ham, 1996). If households do not buy flowers for gifts anymore and choose a mix of the other most common gifts for the same price (see Table 3-5) with an (unweighted) average energy intensity of about 3 MJ/Dfl., 39% can be saved.

Table 3-5 Top 10 gifts most commonly purchased (Komter and Schuyt, 1993) and their respective energy intensities (Vringer and Blok, 1995a).

	Gift	Energy intensity (MJ/Dfl.)
0	Flowers	12.9
1	Food (chocolates, sweets)	5
2	Toys	3
3	Cosmetics, finery	2-3
4	Liquor	1-4
5	Books	2
6	Gift voucher	2
7	Household articles	3
8	CDs	2
9	Crockery	3
10	Clothes	3

6 ► Energy reduction options surveyed

Table 3-6 summarises the maximum achievable reduction of energy requirement for the options discussed. But every energy reduction option has constraints because of the limited consumer acceptability of the various options: alternatives may differ in their functionality. Data on these constraints is unavailable. On the basis of expected willingness of consumers, we have made the following rough assumptions of the effect of constraints:

- In lengthening the lifetime of flowers by adding fertiliser and a shift to less energy-intensive flowers, we assume an achievable reduction of 75% of the maximum. Most consumers decide the type of flowers they will buy at the place of purchase (van Tilburg, 1984). Only when the consumer buys and puts the flowers in a vase, some extra effort is required.

- Fifty per cent is assumed to be really achievable for the maximum achievable shift from bulbous flowers to bulbs and from cut flowers as gifts to alternative gifts. These options induce a change of product, which may require greater effort from the consumers and may be less acceptable due to changes in functionality.
- Twenty-five per cent is assumed to be really achievable for the maximum achievable shift in the purchase season from wintertime to summertime and from cut flowers to indoor plants. These options show a larger shift in decorative functionality than the previous solution and may be less acceptable.
- Only 5% is assumed to be achievable for the maximum achievable shift from cut flowers to artificial flowers, and from cut flowers to paintings and sculptures. It is very plausible that the artificial aspects of the plastic or textile flowers are unacceptable to many people. Art is also not in demand by many people because of the large difference in functionality compared with flowers.
- For flowers from warmer countries, we assume that for the time being the availability of high-quality flowers on the market will be limited and that this will limit replacement rates to 50%.

When all constraints are included, the total energy reduction per average household will be about 1 GJ per average household if all options are applied. This is about half the annual energy required for cut flowers. About Dfl.25 will be saved. If this Dfl.25 is spent on average goods[21], the energy reduction will be about 0.1 GJ smaller. Figure 3-3 shows the part of the total current flower sales affected by the options and the achievable reduction of energy requirement, including all constraints and excluding the interactions between the options.

Again it should be emphasised that there is no data available on the feasibility of these options and that the calculation should be considered as an analysis of *what* can happen *if* the options discussed here are applied to a substantial extent.

21 The average energy intensity of goods and services (excluding natural gas, electricity and petrol) is 3.5 MJ/Dfl. (Vringer and Blok, 1995).

Table 3-6 Overview and effects of the options to reduce the energy requirement and expenditures of an average Dutch household, with achievable reductions, established subjectively.

Option	Maximum effect on the requirement for cut flowers (Percentage)	(MJ/year)	Maximum eff. on expenditures (Dfl./year)	Estimated potential due to constraints	Effect on energy requirement (MJ/year)	Effect on Expenditures (Dfl./ year)
Replacement by other types of products of the same category						
Buy cut flowers in the summertime *	-10 %	-224	-12	25 %	-56	-3
Buy less energy-intensive flowers	-12 %	-268	0	75 %	-201	0
Extend the lifetime of cut flowers by adding fertiliser	-2 %	-41	-3	75 %	-30	
Buy cut flowers grown with environment-friendly methods	0 %	0				
Buy imported cut flowers instead of Dutch cut flowers	-10 / -85 % #	-220 / 1870	0	50 %	-281	0
Buy bulbs instead of bulbous cut flowers	-4 %	-80	0	50 %	-40	0
Replacement by other products with a comparable function						
Replace cut flowers with indoor plants *	-41 %	-900	-70	25 %	-225	-17
Buy plastic/textile flowers instead of cut flowers *	-48 %	-1050	-75	5 %	-52	-4
Buy art e.g. paintings and sculptures	-48 %	-1047	0	5 %	-2	0
Do not buy flowers for a gift but alternative gifts	-39 %	-860	0	50 %	-430	0
Total, corrected for overlapping of effects from individual measures**					-1067	-25

* For these options, we took into account the unsuitability of replacing flowers bought as a gift.
** The total is corrected for overlap by assuming that the first option in the table is carried out first, followed by the second and so on. The additional saving of each following option is calculated by applying the percentage of each saving on the resulting energy requirement after applying the options, which were already taken into account beforehand.
# We took an average of 30% for further calculations.

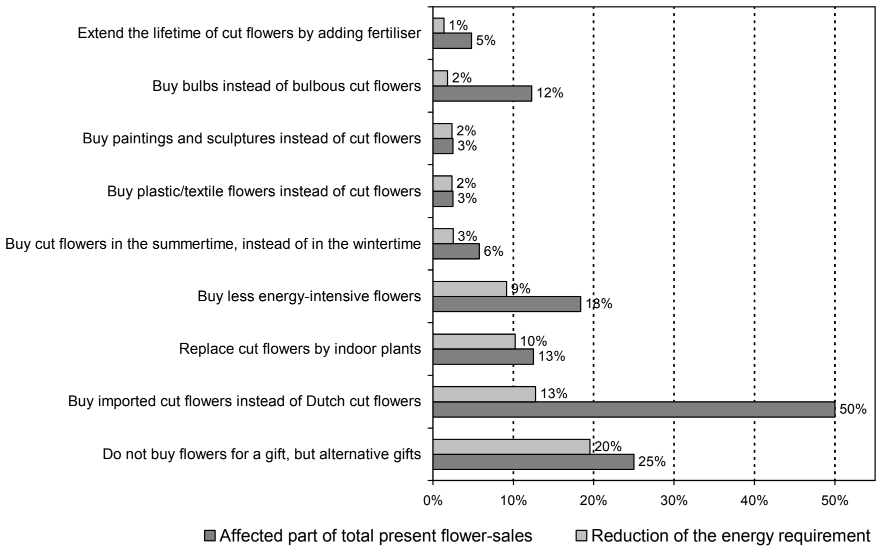

Figure 3-3 The part of the total current flower sales affected by the options and the achievable reduction of the energy requirement, including all constraints and excluding the interactions between the options.

7 ► Discussion

First, we will discuss the uncertainties in calculating the energy required for cut flowers. This will be followed by a discussion on the uncertainties of the reduction options and completed with a few additional comments.

Calculation of the primary energy required has raised several comments on uncertainty:

1. The energy required for cut flowers in this study was partly calculated through an input-output energy analysis, a less accurate method than process analysis; this is because energy is assigned on a financial and not on a physical basis. However, the possibility for error is limited because about two-thirds of the assigned energy requirement is calculated using a very accurate process analysis.

2. The energy analysis for cut flowers performed here on the basis of figures for flowers grown in the Netherlands by modern and well-managed companies in 1991.

The average energy requirement for cut flowers in 1991 will probably be higher (up to 20%) than calculated here (Ruis, 1998). But differences for flowers in 1999 will be less due to improved efficiency in the production sector. In four years time (between 1990 and 1994), a higher energy efficiency of glasshouse horticulture resulted in a decrease in the energy requirement of about 5% (Farla and Blok, 1997).

3. The energy required for cut flowers is based on such aspects as the direct energy required to light and heat the glasshouse in the 4-week period in which the flowers are purchased and the 8 preceding weeks. To check the influence of these 8 extra weeks, we varied this period from 4 to 12 weeks for the calculation of the energy required for a rose. The influence of the exact length of the period on the results is relatively small (Vringer and Blok, 1995b).

4. According to Vermeulen (1995) it is not profitable for growers to grow only flowers in the summertime, which makes it unrealistic to differentiate the energy required for flowers per season. However, it is technically possible to grow flowers only in warmer periods. The energy required to keep the glasshouse frost-free in wintertime (necessary for some flowers like roses) is negligible in comparison with keeping the glasshouse at the proper growing temperature.

Calculation of the reduction options has raised several more comments on uncertainty:

5. We assumed that households only select from the 15 best-selling flowers. Real household consumption patterns include many more flowers, which can increase the possibility of some energy reduction options such as opting for other species and extending the lifetime of flowers. However, we do not expect that this will have a significant impact on energy reduction potential. This is because these 15 types of flowers account for about 70% of the auction sales. Furthermore, the unweighted average energy required for the 15 best-selling flowers does not differ much from the other 17 flowers analysed in Appendix 3A.

6. The calculated total energy reduction potential includes the purchase of more imported flowers from warmer countries. Unfortunately, florists generally do not know the origin of the flowers they sell, which makes this choice only possible for consumers when flowers are labelled.

7. This chapter offers rough estimates of the achievable energy reduction potential for all options. However, some field data were available to evaluate the total energy reduction potential estimated here. These data come from a project called 'Perspective', in which 10 to 15 households had to substantially reduce their total energy requirement for a longer period of time. On the basis of data in CEA (1998) we calculated that these households managed to reduce their energy requirement for flowers by about 80%. CEA does not expect long-term feasibility to be reduced. However, it should be noted that expenditures on alternative products for replacing cut flowers is not given in the CEA analysis, and that it is not likely that the number of the functional units purchased will be maintained on the same level.

Final comments:

8. Although extra time expenditures for households − applying to (all) energy reduction options − is expected, it is difficult to estimate how much time is needed due to lack of data. Especially extra time investments are expected when the alternatives are first applied. The effect of extra time expenditure on the total energy requirement can be positive (no other activities are possible during the extra time expenditure) or negative (lack of time leads to use of time-saving options, e.g. taking the car instead of public transport).

9. The extent to which cut flowers are environment-friendly cannot be expressed solely in the total energy requirement for cut flowers. The quantity and kind of insecticides, weed killers and soil surface used are also important factors in the total environmental impact of cut flowers. To give an overview of all environmental aspects, a complete Life Cycle Assessment (LCA) would have to be carried out per type of flower.

10. A change in the production process which leads to a (substantial) reduction in the energy required for flowers can have an impact on the effects of the consumer options discussed here. A study by Schoonderbeek et al. (1996) suggests that specific energy consumption by glasshouse horticulture may decrease by 80%. It is clear then that if such a technical change should materialise, it would drastically alter the outcomes of our calculations.

11. Dutch households spend, relatively speaking, twice as much money on flowers as households in several other European countries (Eurostat, 1988). This means that the energy savings for Dutch households presented here will be typically twice as much as energy savings for households in other European countries.

12. The worldwide average energy requirement per flower is possibly lower than for flowers produced in the Netherlands. Roses grown in warmer countries like Morocco, Israel, Spain and Kenya are produced with less energy (10 to 85%). However, in 1990, nearly 60% of all exported flowers worldwide were produced in the Netherlands (Hack and Heybroek, 1992). Therefore the results of the energy analysis presented in this chapter can be applied to more than half of all the flower exports worldwide.

8 ► Conclusions

Cut flowers are responsible for about 1% of the total primary household energy requirements; in 1990 this was about 2.2 GJ per household. In 1990, an average Dutch household paid Dfl.170 (US$ 102) for a total of 250 cut flowers (one or more bouquets purchased 11 times a year) with an energy intensity of 13 MJ/Dfl. (about 29 MJ/€ or 22 MJ/US$), which is relatively high. It is important to recognise that the energy required per flower depends on the type of flower and season of purchase.

In this chapter we have examined various ways of reducing the energy requirement of cut flowers without the household decoration being affected. Some options with a current high potential are replacing flowers as a gift; here more use is made of flowering indoor plants and less energy-intensive flowers (from abroad, other species and other seasons) are selected. A preliminary analysis in this chapter suggests that if all the consumer energy reduction options discussed here are applied to a substantial extent, the cumulative energy requirement for flowers of Dutch households can be halved.

The findings in this chapter can certainly not be extrapolated to other consumption categories, be it only because of the extremely high energy intensity of cut flowers. However, this analysis does show that there may be a variety of options with a substantial collective potential for reducing the primary energy requirement. This variety seems to make achieving this potential a difficult task. Further research in this area is necessary before an effective policy directed at changing consumption patterns can be developed.

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▶ Appendix 3A

This appendix shows the calculated primary energy requirement per flower and the energy intensities for 13 4-week periods. Period 1 corresponds with January and period 13 with December.

Table 3A-1 contains the energy required by 37 flowers for 13 4-week periods in MJ per flower. Table 3A-2 contains the energy intensities of 30 flowers (excluding the bulbous flowers) in MJ/Dfl. for all 13 4-week periods. All figures are up to the time the flowers are harvested.

Table 3A-1 Energy requirement of the commonly grown flowers per 4-week period in which they are harvested (MJ per flower).

Name	Common name	Period												
		1	2	3	4	5	6	7	8	9	10	11	12	13
ACTONIUM NAPELLUS (average)	Monkshood					21	17	2	2					
ACTONIUM NAPELLUS (glasshouse)	Monkshood					21	17							
ACTONIUM NAPELLUS (outdoors)	Monkshood							2	2					
ALCHEMILLA (outdoors)	Alchemilla						1							
ALSTROMERIA (glasshouse)	Peruvian Lily	76	91	37	14	9	9	9	8	9	9	9	11	19
ANEMONE (glasshouse)	Windflower	11	8	5	6	5			7	5	4	6	8	9
ANTHURIUM (glasshouse)	Flamingo flower	86	115	195	102	52	29	23	22	23	26	34	49	58
ANTIRRHINUM MAJUS (glasshouse)	Snapdragon				16	11						6		
ASTER ERICOIDES (glasshouse)	Michaelmas daisy				15	13	11	10	10	10	10	10	13	14
ASTILBE (outdoors)	False goat’s beard								2					

Table 3A-1 Energy requirement of the commonly grown flowers per 4-week period in which they are harvested (MJ per flower). (Cont.)

Name	Common name	Period												
		1	2	3	4	5	6	7	8	9	10	11	12	13
BOUVARDIA SINGLE (glasshouse)	Bouvardia	23	24	21	12	9	7	6	6	5	6	7	10	18
BOUVARDIA DOUBLE (glasshouse)	Bouvardia	39	41	22	14	11	8	7	6	6	7	8	11	22
BOUVARDIA SINGLE+DOUBLE (glasshouse)	Bouvardia	31	32	22	13	10	8	7	6	6	6	7	11	20
CALLICARPA (outdoors, unheated glasshouse)	Callicarpa											6	6	
CARTHAMUS TINCTORIUS (outdoors)	Chartamus								1					
CHRYSANTHEMUM (average)	Chrysanthemum	26	23	19	15	13	11	9	9	7	7	8	13	16
CHRYSANTHEMUM (glasshouse)	Chrysanthemum	26	23	19	15	13	11	9	9	9	8	10	13	16
CHRYSANTHEMUM (outdoors)	Chrysanthemum									3	3	3		
DIANTHUS, Large (glasshouse)	Carnation	53	56	41	19	6	4	4	3	4	4	6	10	34
DIANTHUS, Bunch (average)	Carnation	44	44	29	20	5	4	4	3	3	3	4	6	31
DIANTHUS, Bunch (glasshouse)	Carnation	44	44	29	20	5	4	4	3	3	4	5	9	31
DIANTHUS, Bunch (outdoors)	Carnation									3	3	3	3	
DIANTHUS BARBATUS (glasshouse)	Sweet William					8								
DIANTHUS BARBATUS (outdoors)	Sweet William							1						
DRIED FLOWERS (outdoors)									6					
ERYNGIUM PLANUM (outdoors)	Sea holly								2					
EUPHORBIA FULGENS (glasshouse)	Sun spurge													19
FORSYTHIA (average)	Forsythia	6	4	4										6
FREESIA (glasshouse)	Freesia	11	13	9	7	5	4	4	4	3	4	4	7	9
GERBERA (glasshouse)	Transvaal daisy	41	32	15	10	18	9	8	6	9	8	10	16	25
GYPSOPHILIA (average)	Baby’s breath				29	10	9	9	3	3	6	8	12	29
GYPSOPHILIA (glasshouse)	Baby’s breath				29	10	9	9			7	8	12	29
GYPSOPHILIA (outdoors)	Baby’s breath								3	3	3			
HIPPEASTRUM (glasshouse)	Amaryllis	12	14									10	15	11
LIATRIS (glasshouse)	Button snakeroot						11					9		
LIMOMIUM SINATUM (average)	Sea lavender				16	10	9	14	2	4	5	6		

Table 3A-1 Energy requirement of the commonly grown flowers per 4-week period in which they are harvested (MJ per flower). (Cont.)

Name	Common name	Period												
		1	2	3	4	5	6	7	8	9	10	11	12	13
LIMOMIUM SINATUM (glasshouse)	Sea lavender				16	10	9	14		6	5	6		
LIMOMIUM SINATUM (outdoors)	Sea lavender								2	2				
MATTHIOLA (glasshouse)	Stock				13		7							
PHLOX (outdoors)	Phlox							2	2	2				
PRUNUS (glasshouse)	Flowering cherry	5	6	6										
ROSA Small/average (glasshouse)	Rose (Motrea, Frisco, Mercedes)	15	15	12	11	8	7	6	6	6	6	7	9	11
ROSA Large (glasshouse)	Rose (Madelon)	27	26	22	19	15	12	10	9	9	10	12	16	21
ROSA (average, glasshouse)	Rose	18	18	15	13	10	8	7	6	6	7	8	11	14
SOLIDAGO (outdoors)	Golden rod								1					
TRACHELIUM (glasshouse)	Blue throatwort				23	22	9	8						
VIBURNUM (glasshouse)	Snowball	22	20	22	24	25								
TULIPA	Tulip	4	4	4	4	3	3	3	3	3	3	3	4	4
HYACINTHUS	Hyacinth	4	4	4	4	3	3	3	3	3	3	3	4	4
IRIS	Iris	5	5	5	5	4	4	4	4	4	4	4	5	5
LILIUM	Lily	13	14	13	11	8	6	6	6	6	6	8	10	12
NARCISSUS	Daffodil	4	4	4	4	3	3	3	3	3	3	3	4	4
GLADIOLUS	Sword lily	3	3	3	3	3	3	3	3	3	3	3	3	3
CROCUS	Crocus	3	3	3	3	3	3	3	3	3	3	3	3	3

Table 3A-2 Energy intensity of the commonly grown flowers per 4-week period in which they are harvested (in MJ/Dfl.).

Name	Common name	Period 1	2	3	4	5	6	7	8	9	10	11	12	13
ACTONIUM NAPELLUS (average)	Monkshood					11	16	3	3					
ACTONIUM NAPELLUS (glasshouse)	Monkshood					11	16							
ACTONIUM NAPELLUS (outdoors)	Monkshood							3	3					
ALCHEMILLA (outdoors)	Alchemilla						3							
ALSTROMERIA (glasshouse)	Peruvian Lily	62	64	26	15	14	16	19	14	11	8	10	13	24
ANEMONE (glasshouse)	Windflower	16	15	12	11	17			59	22	10	10	10	11
ANTHURIUM (glasshouse)	Flamingo flower	26	29	44	26	17	16	13	10	8	9	9	17	12
ANTIRRHINUM MAJUS (glasshouse)	Snapdragon				14	17						12		
ASTER ERICOIDES (glasshouse)	Michaelmas daisy				17	15	12	14	15	11	10	12	13	18
ASTILBE (outdoors)	False goat's beard								3					
BOUVARDIA SINGLE (glasshouse)	Bouvardia	45	47	36	21	16	14	16	16	11	10	11	15	28
BOUVARDIA DOUBLE (glasshouse)	Bouvardia	67	73	36	21	17	13	14	16	11	9	11	16	36
BOUVARDIA SINGLE+DOUBLE (glasshouse)	Bouvardia	56	60	36	21	17	13	15	16	11	10	11	16	32
CALLICARPA (outdoors, unheated glasshouse)	Callicarpa											3	3	
CARTHAMUS TINCTORIUS (outdoors)	Chartamus								5					
CRYSANTHEMUM (average)	Chrysanthemum	15	16	18	18	14	14	17	16	9	11	11	16	19
CRYSANTHEMUM (glasshouse)	Chrysanthemum	15	16	18	18	14	14	17	16	12	14	13	16	19
CRYSANTHEMUM (outdoors)	Chrysanthemum									3	3	2		
DIANTHUS, Large (glasshouse)	Carnation	71	82	80	30	8	7	7	7	6	6	8	16	46
DIANTHUS, Bunch (average)	Carnation	106	97	84	43	10	7	7	7	8	7	7	13	46
DIANTHUS, Bunch (glasshouse)	Carnation	106	97	84	43	10	7	7	7	8	8	10	20	84
DIANTHUS, Bunch (outdoors)	Carnation									7	6	5	6	
DIANTHUS BARBATUS (glasshouse)	Sweet William					18								
DIANTHUS BARBATUS (outdoors)	Sweet William							3						
DRIED FLOWERS (outdoors)									4					

Table 3A-2 Energy intensity of the commonly grown flowers per 4-week period in which they are harvested (in MJ/Dfl.). (Cont.)

Name	Common name	Period												
		1	2	3	4	5	6	7	8	9	10	11	12	13
ERYNGIUM PLANUM (outdoors)	Sea holly								3					
EUPHORBIA FULGENS (glasshouse)	Sun spurge													16
FORSYTHIA (average)	Forsythia	6	6	5										5
FREESIA (glasshouse)	Freesia	21	25	19	16	12	12	11	11	10	8	9	13	17
GERBERA (glasshouse)	Transvaal daisy	25	27	38	27	39	20	15	14	14	11	12	17	18
GYPSOPHILIA (average)	Baby's breath				18	10	13	17	6	5	6	8	12	30
GYPSOPHILIA (glasshouse)	Baby's breath				18	10	13	17			7	8	12	30
GYPSOPHILIA (outdoors)	Baby's breath								6	5	4			
HIPPEASTRUM (glasshouse)	Amaryllis	19	26									14	17	12
LIATRIS (glasshouse)	Button snakeroot					19						24		
LIMOMIUM SINATUM (average)	Sea lavender				25	10	13	24	5	9	8	11		
LIMOMIUM SINATUM (glasshouse)	Sea lavender				25	10	13	24		14	8	11		
LIMOMIUM SINATUM (outdoors)	Sea lavender								5	4				
MATTHIOLA (glasshouse)	Stock				14		15							
PHLOX (outdoors)	Phlox							4	5	5				
PRUNUS (glasshouse)	Flowering cherry	6	7	8										
ROSA Small/average (glasshouse)	Rose (Motrea, Frisco, Mercedes)	18	16	21	19	14	15	17	17	14	13	12	15	18
ROSA Large (glasshouse)	Rose (Madelon)	21	17	21	23	16	16	19	19	13	12	13	16	17
ROSA (average)	Rose	19	16	21	20	14	15	18	18	14	13	12	15	18
SOLIDAGO (outdoors)	Golden rod								5					
TRACHELIUM (glasshouse)	Blue throatwort				19	20	10	15						
VIBURNUM (glasshouse)	Snowball	5	6	6	7	13								

Chapter 4

The direct and indirect energy requirements of Dutch households[1]

► Abstract

One way of reducing CO_2 emissions is to reduce direct and indirect household energy requirements. Before discussing how this can be done, we need to have quantitative information about these energy requirements. This chapter aims to provide that information. The total average energy requirement per household in the Netherlands in 1990 was 240 GJ, of which 54% was indirect. Of this total, 17% was required for food, 8% for household effects, 4% for the house, 3% for clothing and footwear, 2% for hygiene, 5% for medical care, 2% for education, 8% for recreation, 1% for communication, 4% for transport (excluding petrol), 9% for petrol, 25% for heating energy and 12% for electricity. Among the analysed socio-economic variables, the net income was found to have the most important relationship with the total energy requirement. The elasticity of the energy requirement with respect to income was found to be 0.63. There is, however, a considerable spread in energy requirement within a particular income class (standard deviation about 20%).

1 This study is a slightly adapted version of Vringer, K. and Blok, K. 'The direct and indirect energy requirement of households in the Netherlands', *Energy Policy* 23, 10 (1995) pp 893-910.

1 ► Introduction

The use of fossil energy sources is one of the main causes of CO_2 emissions. One way of reducing CO_2 emissions is to reduce household energy requirements by influencing the consumption pattern. A household uses not only direct energy in the form of natural gas, electricity and petrol but also indirect energy embodied in consumer goods such as food, furniture and services. Van Engelenburg et al. (1991) estimated the direct energy requirement of households to be about half the total domestic energy requirement. This means that the indirect energy requirement can be all but ignored.

The aim of this study is to obtain an overview of the total energy requirement of households and the energy requirement per consumption category. We also attempted to quantify the relationship of net household income, household expenditure, age and number of household members to the total energy requirement of households. To obtain an overview of the cumulative energy requirement of Dutch households, we analysed the total consumption package for its cumulative energy requirement. The energy intensities of about 350 basic consumption categories were calculated using a hybrid energy analysis method. The energy requirement of Dutch households was calculated by combining the 350 energy intensities with data from the Household Expenditure Survey of 1990. In this survey the expenditure data was collected of 2767 representative Dutch households in 1990. What resulted was an overview of the total energy requirement of Dutch households.

In this chapter, we first describe the method, review the expenditure survey, and give definitions of the terms we use, along with some details on the hybrid energy analysis method. We then present the results on the energy requirement and household expenditure, energy intensity, net household income, the number of household members and age of the first respondent.

All monetary quantities are expressed in Dutch guilders (1990) (1 Dfl. ≅ 0.6 US$ in 1995).

2 ► Method

We started by reviewing the expenditure survey and describing how we determined the cumulative energy requirement of the consumption items. We then considered how the energy requirement of households was calculated.

2.1 ► The Household Expenditure Survey

The Household Expenditure Survey of 1990 (CBS, 1992a) is based on a representative sample consisting of 2767 Dutch households whose expenditure was recorded in a detailed manner. All purchases exceeding Dfl. 25 were noted by each household for one year. All purchases were noted by each household for about two weeks. The amount of natural gas, electricity and water used (expressed in physical units) as well as some other physical parameters (like the floor space of the rooms of the house) were recorded (CBS, 1992b). The household expenses were extrapolated to a whole year. The total consumption of the households in the expenditure survey was divided into about 350 basic consumption categories. These categories are listed in Appendix 4A.

The most important definitions in the expenditure survey:
- *Household*: defined as a single person or group of persons who live together domestically and run a household together. People living in homes for the elderly and tramps are not included in the survey. A lodger and a family living independently in the same house are counted as two households. A lodger living with the family forms a part of the family-household. One person living alone in a separate dwelling is also defined as a household.
- *Net income:* the sum of income from employment, enterprise, capital, social security benefits and other income such as subsidies for house rental, state assistance with mortgages and employers' contribution to the state medical insurance scheme, minus pension contributions, social security contributions and income tax. All the incomes of the individual household members are added up.
- *Total household expenditure:* defined as the financial value of acquired goods and services for non-productive goals, including value added tax. Purchases in general are accompanied by financial transactions, but also included is the consumption of free products e.g. fruit from one's own garden or presents received from other households. Not all of these household expenditures were included in our

analyses. Because of a lack of specified data in the expenditure survey the following categories are excluded: transfers to third parties (like local taxes, examination-, school- and lecture-fees), payments to other households, investments and payments by instalment, subscriptions to trade unions, gifts to charity and legal charges (CBS, 1992b). In this chapter the remainder is indicated as ‘household expenditure’ or simply as ‘expenditure’. Note that the 'total household expenditure' is not equal to the 'net income'. The difference is caused by loans received and savings made (see Table 4-1).

Table 4-1 Average net household income, total household expenditure, household expenditure and expenditure included in this study of Dutch households in 1990 (1 Dfl. ≅ 0.6 US$, 1992).

	Total (Dfl.)	**Percentage of net income**
Average net income	45601	100
Total household expenditure	42646	93
Household expenditure (used in this chapter)	40107	88
• Expenditure included in our analysis	39449	87
• Expenditure for which no energy requirement is determined	658	1

2.2 ► Determining the cumulative energy requirement of the consumption items

The 350 basic consumption categories in the expenditure survey are aggregated into 13 main consumption categories; food, household effects, house, clothing & footwear, hygiene, medical care, education, recreation, communication, transport, petrol, heating and electricity. The main category 'heating' does not only include expenditure on fuel for heating the house, but also expenditure on collective and district heating of the house. The main category, 'household effects', includes expenditure on the maintenance of the house, garden and flowers, stoves, boilers, central heating systems, furnishing, tools and all kinds of household machines such as washing-machines and food-mixers.

To determine the cumulative energy requirement of a consumption item we used a hybrid energy analysis method (Van Engelenburg et al, 1994). This hybrid energy analysis method allows relatively easy calculation of the cumulative energy requirement of a consumption item in a fairly accurate way. This is achieved by combining the best elements of two existing methods for determining the cumulative energy requirement of goods and services: process analysis and input–output analysis.

The cumulative energy requirement is calculated in ten steps. The first step is to construct a flow chart of the production network for the consumption item. A mass balance and a financial balance of the product's life cycle are determined in steps 2 and 3. In steps 4 to 10, figures are allocated to the requirement that various activities make on primary energy carriers. These activities comprise the production of the basic materials and residual goods, the production of the goods themselves, and the capital goods, trade and transport and waste disposal. Finally, the various contributions that these activities make to the cumulative energy requirement are aggregated. The energy analysis method, as described by Van Engelenburg et al. (1994), has been incorporated in a computer program, together with databases containing a data set for the Netherlands called the Energy Analysis Program (Wilting, 1992). The output of the Energy Analysis Program is the total cumulative energy requirement per item (expressed in megajoules (MJ) per physical unit of product). The energy intensity is defined as the total primary energy requirement of a product divided by the total consumer price of the product and is expressed in MJ/Dfl. The energy intensity has been calculated for 350 basic consumption categories by Kok et al. (1993) (food), De Paauw and Perrels (1993) (clothing & footwear, hygiene, medical care, education, recreation, communication, transport and petrol), Vringer and Blok (1993) (house) and Vringer et al. (1993) (household effects). The energy intensities can be found in Appendix 4A. The basic consumption categories may be fairly uniform (e.g. tea) or very non-uniform (e.g. living-room furniture). For the non-uniform categories we take an estimated average of the products that belong to the consumption category. For the uniform categories we choose a standard product with a standard price.

The energy requirement of a household (E) can now be calculated according to equation (1), because both the expenditure (S_i) per category i and the energy intensities (ε_i) of the consumption categories are known:

$$E = \sum_{i=1}^{350} (\varepsilon_i * S_i) \qquad (1)$$

This calculation method is not used to calculate the energy requirement of the house and the amount of natural gas and electricity used. The energy requirement for these consumption categories is calculated on the basis of physical quantities. To calculate the energy requirement connected with the natural gas and electricity used, we start from the physical units (m^3 and kWh) used, as recorded in the expenditure survey.

Rent depends not only on the size of the house (which is directly related to the energy requirement), but also on the condition and location of the house, price of the ground and other infrastructural components. Therefore, rent is not considered to be a good indicator of the energy requirement of a house. Instead, the energy requirement of the house is calculated on the basis of the area of living space, as recorded in the expenditure survey (Vringer and Blok, 1993)[2]. Deviations from the average energy intensity may also occur with regard to other consumption categories (see also 'Discussion' in this chapter).

The direct energy requirement of a household is defined in this chapter as the sum of the primary energy required to obtain the energy carriers (petrol, electricity, natural gas) and their energy content. Similarly the indirect energy requirement of a household is defined as the total primary energy required to obtain all the other products and services included in this study. The total energy requirement of households is the sum of the direct energy requirement and the indirect energy requirement.

2 The minimum number of households in this analysis is put at 25 households per measurement point.

3 ▶ Results

Table 4-2 gives the average energy requirement of the Dutch households with respect to the main categories. More extended results can be found in Appendix 4A.

Table 4-2 Total energy requirement and energy intensity of an average Dutch household in 1990 per main category and the total, direct and indirect energy requirement.

	Energy requirement		Energy intensity
	(GJ)	(% of total)	(MJ/Dfl.)
Total	**240**	**100**	**6.3**
Indirect energy requirement	**130**	**54**	**3.5**
Food	41	17	5.6
Household effects	19	8	5.5
House	9	4	1.4
Clothing & footwear	8	3	2.7
Hygiene	5	2	4.1
Medical care	12	5	3.4
Education	5	2	4.2
Recreation	19	8	3.7
Communication	1	1	1.7
Transport	9	4	3.6
Direct energy requirement	**110**	**46**	**45.0**
Petrol	22	9	22.4
Heating	60	25	57.8
Electricity	28	12	46.5

The average Dutch household uses 240 GJ per year, 46% of which is in the form of direct energy carriers (natural gas and other energy carriers for space heating purposes, petrol and electricity) and 54% of which is the indirect energy requirement (goods and services). The year 1990 was a fairly warm year in the Netherlands. If the average temperature in the Netherlands between 1950 and 1980 is taken as a reference for the outside temperature, the energy requirement in 1990 for heating has to be multiplied by 1.17 (Farla, 1993). If the average outside temperature is taken into account, then the total energy requirement of households increases from 240 GJ to about 250 GJ per year per household. The category 'petrol' is probably underreported in the expenditure survey (CBS, 1992c). According to CBS (1992d) private cars in the Netherlands in 1990 used 212 PJ, of which about 25% was for business purposes. From these figures we calculated that the energy requirement connected with petrol amounts to about 26 GJ per household, which is 4 GJ more than the energy requirement found on the basis of the expenditure survey.

In 1990 the Netherlands had 6.13 million households and 14.9 million inhabitants (CBS, 1992e). Therefore the total allocated energy requirement of households in the Netherlands in 1990 was 1470 PJ per year or 99 GJ per person. The total direct energy use in the Netherlands in 1990 was about 2900 PJ (CBS, 1991). The difference between the total energy requirement in the Netherlands and the total energy requirement of households in the Netherlands can be attributed to the consumption via public services (paid by taxes) and the net export of products embodying energy, mainly in the form of products from the basic chemical industry.

We will now proceed to discuss the relationship between energy requirement and household expenditure, net household income, number of household members and the age of the first respondent.

3.1 ► Energy requirement, household expenditure and energy intensity

Figure 4-1 shows the relationship between the total energy requirement and the household expenditure. In order to make the distribution of the total energy requirement more understandable, we used percentile lines (see Figure 4-1). These lines are constructed as follows: households in the expenditure survey are divided into deciles according to the level of expenditure, so that 10% of the households are represented in every expenditure group. For these 10 deciles we computed the 10, 25, 50, 75 and 90 percentile values of the total energy requirement. Next the percentile values were plotted as a function of the weighted mean of the expenditure deciles. The boxes on the 50 percentile line (median) mark the weighted mean expenditures through which the lines are drawn. Figure 4-1 shows that the relative deviation from the 50 percentile line does not vary with household expenditure, so it is not surprising that the energy requirement increases with household expenditure, as we see in Figure 4-1.

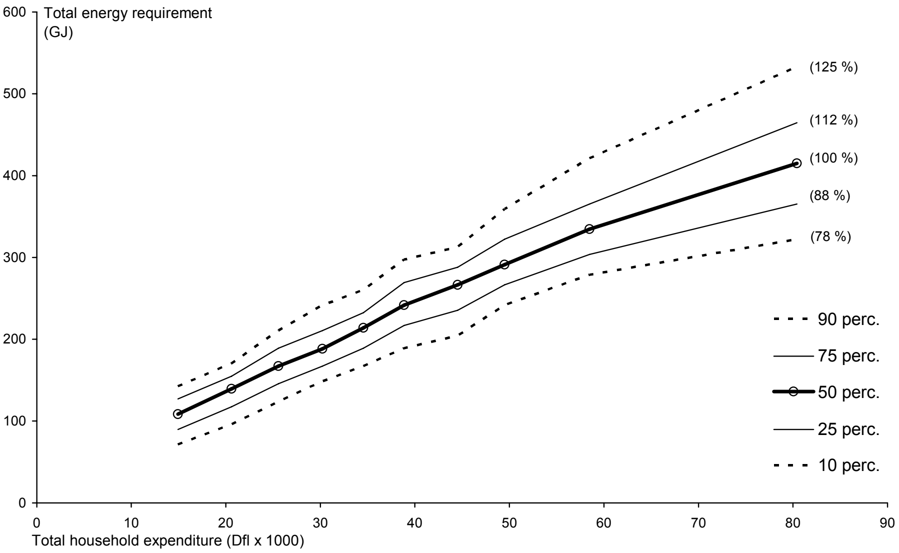

Figure 4-1 Total energy requirement plotted against household expenditure.

However, the relationship is not proportional. To explore this further, we calculated the elasticity of the energy requirement, in relation to expenditure level. This elasticity is defined according to equation (2).

$$E_{tot} = c * S_{tot}^{\alpha} \qquad (2)$$

in which:
E_{tot} = total energy requirement
S_{tot} = household expenditure
α = elasticity
c = a constant

The elasticity is calculated by fitting the mean values of the energy requirement for the ten expenditure levels according to the least squares method. Then a value of 0.83 is found for the elasticity.

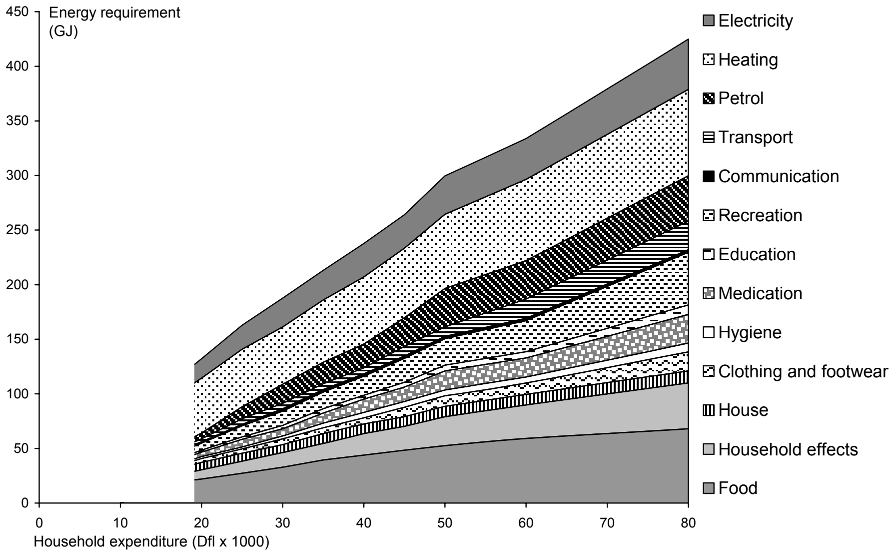

Figure 4-2 The energy requirement of the main categories plotted against household expenditure.

In Figure 4-2 the fractions of the energy requirement per main category are plotted against the household expenditure. The energy requirement of all the main categories increases with increasing household expenditure.

Figure 4-3 shows the relationship between energy intensity and household expenditure. The average total energy intensity over all the expenditure categories is 6.3 MJ/Dfl. The total energy intensity decreases from 7.3 MJ/Dfl. to 5.5 MJ/Dfl. when the net household income increases from about Dfl. 15,000 to 80,000. The energy intensity for the indirect energy requirement remains fairly stable (approx. 3.5 MJ/Dfl.), even when the household expenditure increases. The decrease in the total energy intensity with increasing expenditure is due to the decreased proportion of the expenditure on direct energy. The energy intensity of the main categories, food, education and house, decreases (by about 0.5 MJ/Dfl. for each category) when the household expenditure increases from about Dfl. 15,000 to 80,000. The energy intensities of the main categories, household effects, communication and recreation,

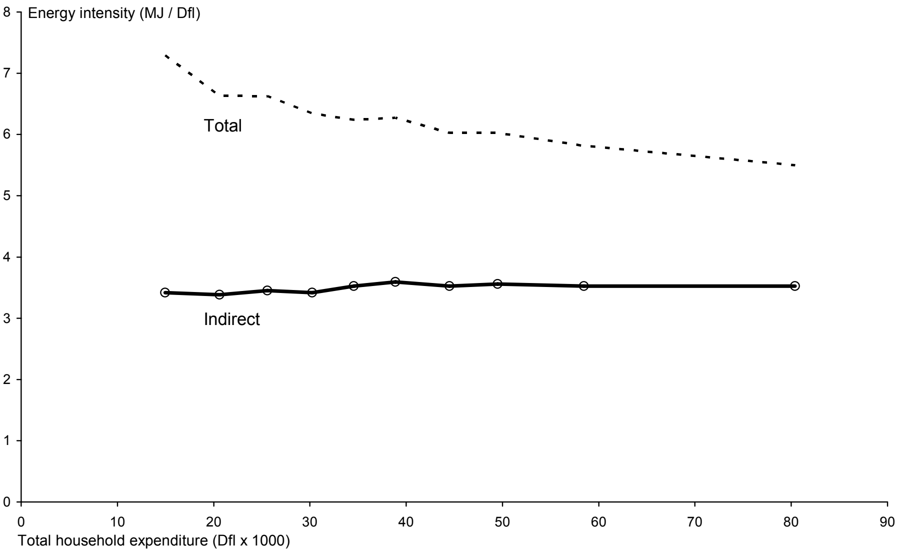

Figure 4-3 Energy intensity plotted against household expenditure.

increase (by about 0.5 MJ/Dfl.) when the household expenditure increases over the same range.

The energy intensity of the main category, transport, decreases from 6 to 3 MJ/Dfl. when the household expenditure increases from about Dfl. 15,000 to 80,000. This is due to the fact that the proportion of the expenditure on public transport decreases and the proportion of the expenditure on cars increases.

In Figure 4-4 the cumulative household expenditure of an average household is depicted in order of increasing energy intensity and is plotted against energy intensity. Figure 4-4 gives a picture of the distribution of the energy intensities over the amount of money spent. About Dfl. 15,000 of the household expenditure of an average Dutch household in 1990 was used for energy-extensive products and services with an energy intensity from 0 to 2 MJ/Dfl. The energy intensity increases from 2 to 10 MJ/Dfl. for the next Dfl. 20,000. For the last Dfl. 5,000 the energy intensity increases rapidly from 10 to 60 MJ/Dfl. This energy-intensive category

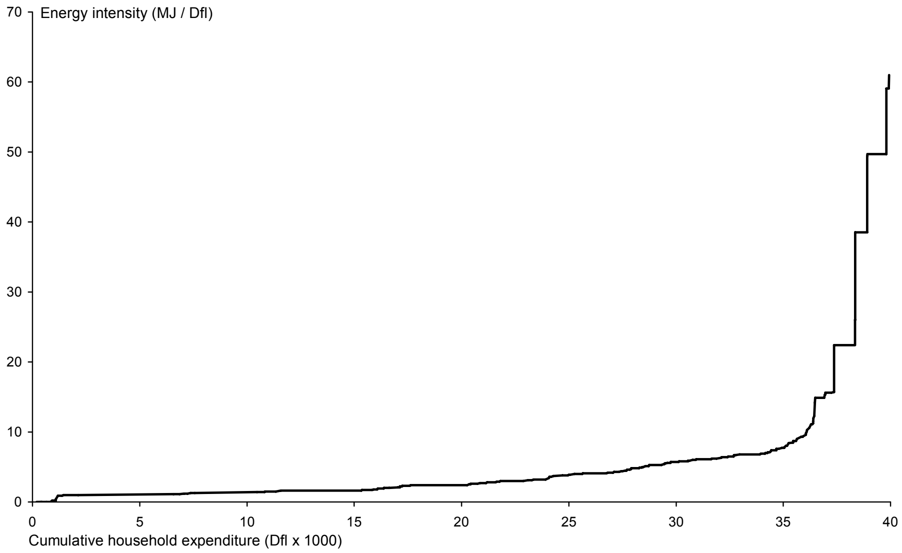

Figure 4-4 Energy intensity plotted against cumulative expenditure.

includes not only the energy carriers but also flowers and various food products such as glasshouse vegetables, fats and frozen food.

3.2 ► Energy requirement and net household income

The relationship between energy requirement and net household income is given in Figure 4-5 in the same way as the relationship to expenditure was given in Figure 4-1. Figure 4-5 shows that a growth in net household income goes hand in hand with a growth in the energy requirement. The spread is larger than the spread shown in Figure 4-1 because of differences between income and expenditure.

On the basis of the values shown in Figure 4-5 the elasticity of the energy requirement related to net income is calculated at 0.63. This elasticity is lower than the elasticity of the energy requirement relating to expenditure due to the fact that households with a higher net income spend a smaller part of their net income than households with a lower net income; the figures vary from 70% income for the highest income group to 122% for the lowest income group. The difference does not have anything to do with the part of the total household expenditure not included in our analysis; this part is, in fact, almost the same for all the income groups, namely about 7%.

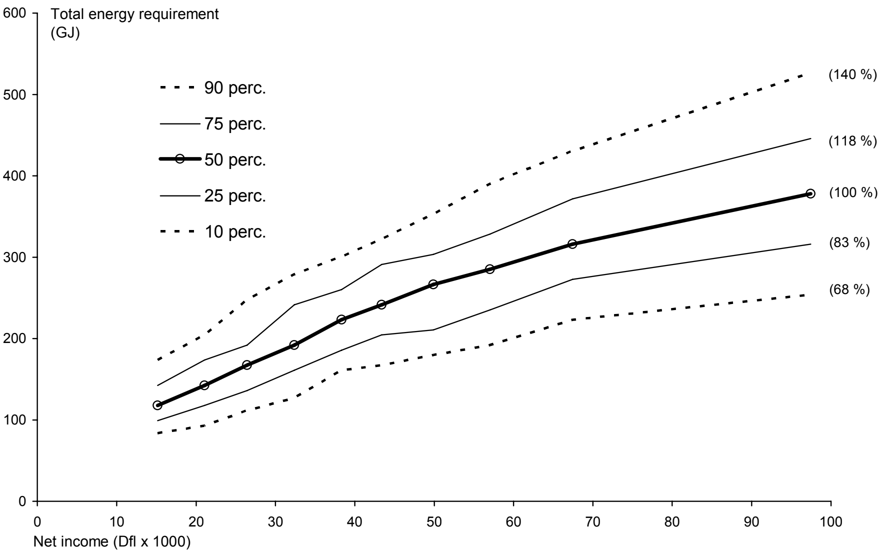

Figure 4-5 Total energy requirement plotted against net household income.

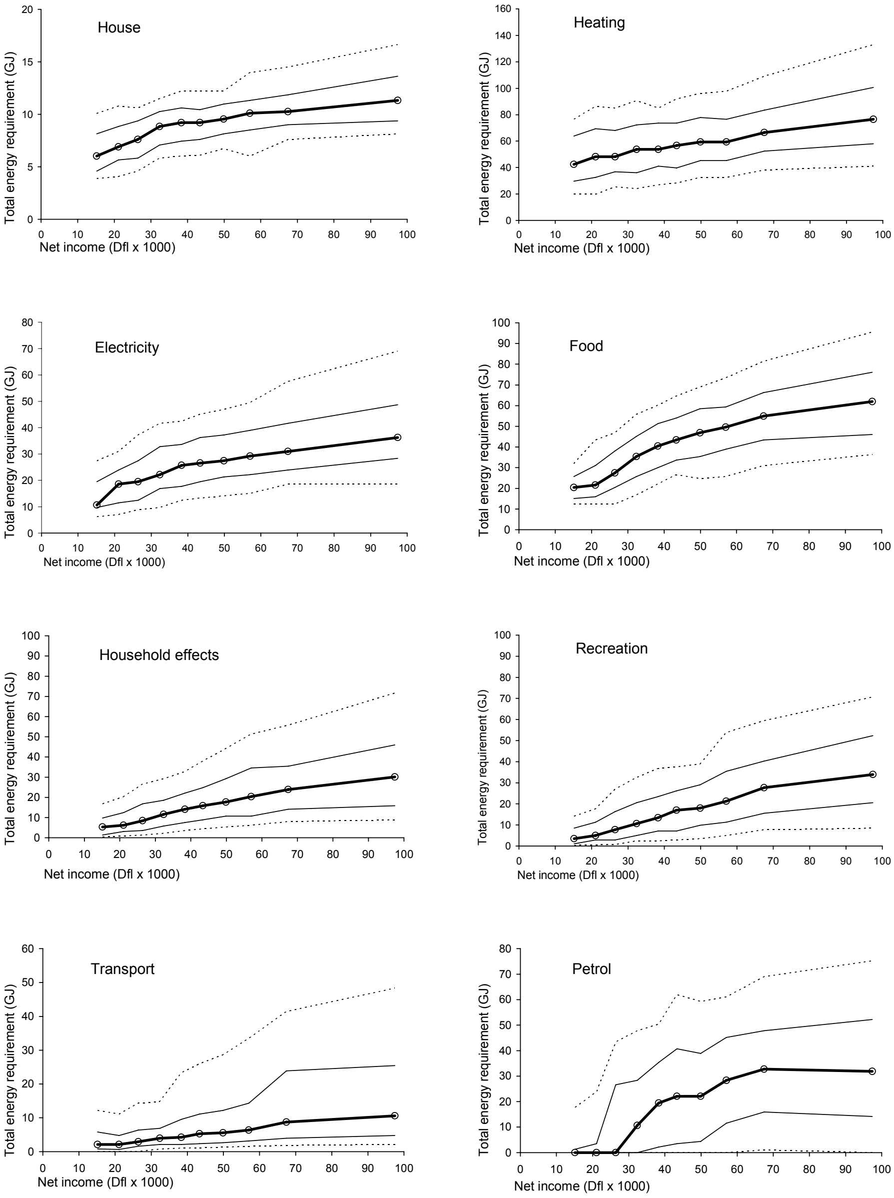

Figure 4-6 Energy requirement for several main consumption categories versus the net household income. Note that the vertical axes have a different scale.

The energy requirement of the main categories plotted against the net household income is depicted in Figure 4-6 in the same way as in Figure 4-5. The fairly small main categories, 'hygiene', 'education' and 'communication', are not dealt with here. The relationship between the energy requirement for 'clothing and footwear' and net household income appears to be the same as the relationship between the energy requirement for 'education and recreation' and the net household income. There is no relationship between household expenditure on medical care and the energy requirement for medical care, because nearly all household expenditure on medical care is connected to health insurance. This is why the main category, 'medical care', is not dealt with here.

The spread for the main consumption categories clothing & footwear, education, recreation, household effects, transport and communication, which include some of the luxuries of life, is larger than the spread for the other categories which contain the more basic needs of life.

3.3 ► Energy requirement and number of members of a household or age of the first respondent

To investigate whether the energy requirement is dependent on the number of household members, apart from the dependence that can be explained by difference in net income, we plotted the total energy requirement against the net income for various numbers of household members (see Figure 4-7)[3]. This figure makes it clear that the largest difference in energy requirement, independent of the net household income, is found between a one-person household and several-person households (approx. 45 GJ). This difference is significant for the group as a whole. The difference between the total energy requirement of two-person and several-person households is not significant[4].

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3 The minimum number of households in this analysis is put at 25 households per measurement point.

4 The deviation from the mean is calculated by dividing the standard deviation by the square root of N. The deviation from the mean of the total energy requirement varies between 3 and 10 GJ for the one-person households and between 5 and 7 GJ for two-person households. This means that the difference in the energy requirement of one-person and several-person households is significant but the difference between several-person households is not.

With respect to the households which have an income falling in the fifth income decile, a closer analysis has been made of the significant difference in the energy requirement of one-person and several-person households. The difference between one- and two-person households can be attributed mainly to the main consumption category, 'food' (approx. 13 GJ extra), and the categories, 'electricity', 'heating' and 'household effects' (7 to 8 GJ extra each). Because these are categories with high intensities, the energy intensity of the household expenditure rises from 5.8 to 6.4 MJ/Dfl. when the size of the household increases from 1 to 4 persons.

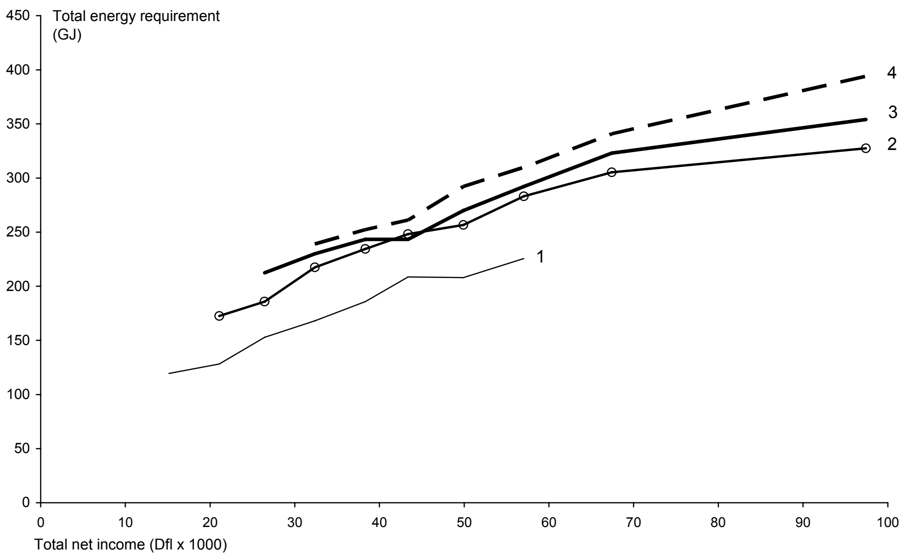

Figure 4-7 The total energy requirement versus net household income for 1 to 4 household members.

Figure 4-8 shows the relationship between the total net household income and the total energy requirement for several age groups[5]. Age is defined as the age of the 'first respondent': the person in the household who is responsible for completing the questionnaires. We see that the relationship between energy requirement and net income is more or less the same for all age groups. The age group from 40 to 50 has the highest average energy requirement, but this group also has the highest average net income.

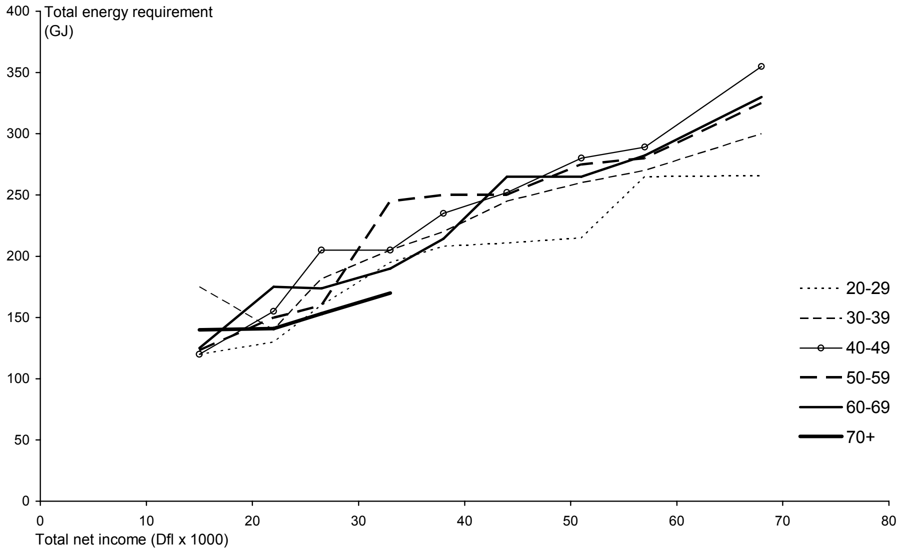

Figure 4-8 Total energy requirement plotted against net household income in various age groups.

5 The minimum number of households in this analysis is set at 20 households per measurement point.

4 ▸ Discussion

This discussion will be handling a few explanatory notes to allow the results to be interpreted.

a. The expenditure survey has its limitations.
Expenditure on durable consumer goods (e.g. cars, furniture or floor-coverings) may peak in the year of survey for some of the households. For instance, a household in the expenditure survey purchasing a car in 1990 will have a high expenditure (and also a high energy requirement). The energy requirement of a household may be particularly high if the household moves in the year of the survey. In addition, the spread of the expenditure over products and services costing less than Dfl. 50 (surveyed only for two weeks) can be partly explained by the season in which the household had to write down these expenses (e.g. drinks may be a larger expense in summer). These effects will not influence the average results, but part of the spread in several consumption categories (e.g. transport) can be explained by this factor.
In the expenditure survey the household expenditure in some categories is underreported. The most underestimated expenses are those in connection with the hotel and catering industry, leisure, (alcoholic) drinks and smokers' requisites and motor fuels (CBS, 1992c). This may cause some limited underestimates of these consumption categories. The contribution of these categories -excluding motor fuels- to the total energy requirement is so small that it will not affect our results significantly. If we were to correct for the underestimated expenses connected with motor fuels, the total energy requirement would rise by an average of 4 GJ per household per year.

b. There is no one-to-one relationship between energy requirement and expenditure in several categories of household purchases. The energy intensities in our sources are based on average products and average prices. The expenditure survey places all the same kind of products in one consumption category. For instance, a hand-made (very expensive) chair is placed in the same category as a cheap chair. The first one probably has a much lower energy intensity than the latter. In this survey, a household which, in fact, shows a very energy-extensive lifestyle (e.g. buying as much as possible expensive biological food, hand-made furniture etc.) may be regarded as an energy-intensive household because of its high household expenditure. This uncertainty, however, will have no effect on most of the results presented in this chapter since it will be averaged out over larger groups. However, there is one notable exception. It is conceivable that households with a higher income (or a higher expenditure level) systematically buy products that cost more per physical unit. The consequence of this is that the real elasticity of the energy requirement related to income (or expenditure level) can be smaller than the value computed here. However, the effect turns out to be very moderate. Vringer and Blok (1997) found a maximal decrease of the elasticity of the energy requirement related to net household income due to price income relationships, from 0.63 to somewhere between 0.56 to 0.60. For more details, see Appendix 4B.

c. Consumption of public services and a small part of the household consumption are not included. The total energy requirement calculated in this survey does not take all the energy requirements of households into account. A small part (7%) of the net household income is excluded before we made our calculation of the (total) household energy requirement. The demand on public services (including infrastructure) is excluded from this survey as well, because of the difficult individual allocation. The direct energy requirement of government services, defence, social insurances, religious organisations, homes for the elderly and schools, excluding infrastructure, amounts to about 65 PJ per year for the Netherlands (CBS, 1991), which is equivalent to 11 GJ per household per year. If we assume the total energy requirement to be twice the direct energy requirement, then we estimate the total energy requirement for the public services to be about 22 GJ per household. This means that if the energy requirement of the collective sector were included, the total average energy requirement of households would be about 10% higher than calculated here.

5 ► Conclusions

Because at least 54% of the total energy requirement of households consists of an indirect energy requirement, there is a need for further research into this indirect energy requirement. Future energy policy will have to pay attention to the indirect energy requirement of households. The positive relationship between income and total energy requirement suggests that, with further increases in income levels, the average household energy requirement will probably rise as well. However, the large differences between the energy intensities of the various consumption categories indicate that the total household energy requirement can be reduced if we change our consumption patterns. The substantial spread in the total energy requirement of households within the same income category also supports this view.

This analysis can form the basis for further research into ways of reducing household energy requirement. Attention needs to be given not only to the direct energy consumption (including the category 'petrol') but also to the consumption categories, 'transport', 'education' and 'recreation'. This is because these categories have a relatively large spread and form an important part of the indirect energy requirement of households.

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Appendix 4A ► Energy intensities and energy requirement of an average Dutch household

This appendix contains Table 4A-2, showing the energy intensity (in MJ/Dfl.), calculated energy requirement (in GJ), expenditure (in Dfl.) and the deviation from the mean in the expenditures[6] (in %) for an average Dutch household. If the deviation from the mean is too large (> 20%), the expenditure and energy requirement are not given. If the deviation is larger than 15% the data are written in italics.

The data on energy intensities were taken from Kok et al. (1993) (food), de Paauw and Perrels (1993) (clothing & footwear, hygiene, medical care, education, recreation, communication, transport and petrol), Vringer and Blok (1993) (house) and Vringer et al. (1993) (household effects). The expenditure and the net income are taken from CBS (1992a).

The categories summarised here consist of approximately 350 consumption categories at the lowest level in the available version of the expenditure survey, including cumulative consumption categories (like the main consumption categories). The cumulative consumption categories are composed of one or more consumption categories at a lower level. For example, the main consumption category v11, 'food' (with two digits), is composed of all the consumption categories at the 3-digit level, which belong to the main consumption category, 'food'. These categories comprise 'bread, pastry and flour products' (v110), 'potatoes, vegetables and fruit' (v111), 'beverages & products containing sugar' (v113), 'oils and fats' (v115), 'meat, meat products and fish' (v116), 'dairy products' (v118) and 'other food products' (v119). The consumption categories at the 3-digit level are divided into one or more categories at the 4-digit level, and so on.

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6 The deviation from the mean is calculated by dividing the standard deviation by the square root of N (here N = 2767).

The expenditure belonging to the category 'other expenditure' (v6), at a total Dfl. 658, is excluded from the energy requirement and energy intensity calculations (see 'Method') but included in the total expenditure.
Table 4A-1 shows the classification of the main categories in this study, along with the index numbers corresponding to Table 4A-2.

We stress that Table 4A-2 does not answer questions such as: ‘What is the 'best buy' (i.e. the 'product' with the lowest energy requirement), because such a question can only be answered after a functional analysis of the expenditure has been performed.

Table 4A-1 Main expenditure categories and their index numbers corresponding to CBS (1992a).

Main consumption category	Index number
Food	v11
Household effects	v22 - v2200 - v2290 - v2292 - v2295 - v229600 - v2291
House	v2200
Clothing & footwear	v33
Hygiene	v44 - v446
Medical care	v446
Education	v550
Recreation	v551 + v553 + v556
Communication	v5582
Transport	v557 + v558110 + v5582
Petrol	v558110
Heating	v2290 + v2292 + v2295 + v229600
Electricity	v2291

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990.

Index number	Level	Energy intensity (MJ/Dfl.)	Energy requirement (GJ)	Expen-diture (Dfl.)	Deviation (%)	Consumption category
H224				45601	1	TOTAL NET INCOME
V1	1	6.0	239.8	40107	1	TOTAL EXPENDITURE
v11	**2**	**5.6**	**41.6**	**7408**	**1**	**Food**
v110	3	4.1	4.0	984	1	Bread, pastry and flour products
v1100	4	4.0	1.7	431	1	Bread and rusks
v110000	6	4.0	0.8	209	2	Wholemeal bread
v110100	6	4.0	0.5	133	2	White bread
v110200	6	3.9	0.1	38	2	Rusks and other sorts of bread
v110300	6	4.2	0.2	51	3	Bread with dried fruit
v1105	4	3.8	1.6	427	2	Cake, biscuits and pastry
v1107	4	5.9	0.6	97	2	Flour and dry goods
v110710	7	5.7	0.1	18	5	Wheatmeal
v110720	7	5.7	0.1	23	4	Rice
v110730	7	4.7	0.1	19	4	Pastry
v110740	7	5.9	0.0	3	7	Potato flour, starch
v110750	7	6.9	0.2	35	4	Other flour and dry goods
v1108	4	4.1	0.1	29	6	Bread and other products
v111	3	6.6	6.9	1035	1	Potatoes, vegetables and fruit
v1110	4	4.4	0.4	100	2	Potatoes
v1111	4	8.8	3.7	422	1	Vegetables
v11110	5	8.5	2.7	319	1	Fresh vegetables
v111100	6	7.1	0.5	71	2	Green (leafy) vegetables
v111110	7	9.4	0.3	35	3	Endive and lettuce
v111120	7	7.8	0.0	4	8	Spinach
v111130	7	4.4	0.1	33	3	Other (leafy) vegetables
v111200	6	5.2	0.3	49	2	Cabbage
v111210	7	4.6	0.1	29	3	Cauliflower
v111220	7	4.6	0.0	7	5	Sprouts
v111230	7	7.0	0.1	13	5	Other cabbages
v111300	6	5.2	0.2	30	4	Fresh pulses/leguminous plants
v111310	7	5.3	0.1	27	4	Green beans
v111320	7	4.0	0.0	4	10	Other fresh pulses/leguminous plants
v111400	6	8.0	0.3	39	2	Carrots and tubers
v111410	7	7.1	0.1	16	4	Carrots
v111420	7	6.7	0.1	13	4	Onions
v111430	7	11.1	0.1	10	4	Other carrots and tubers
v111500	6	11.5	1.5	130	2	Other fresh vegetables
v111510	7	15.3	0.4	25	3	Tomatoes
v111520	7	10.6	1.1	105	2	Other fresh vegetables
v11160	5	9.9	1.0	103	2	Preserved and dried vegetables
v111600	6	15.4	0.1	8	9	Dried vegetables
v111700	6	9.4	0.9	95	2	Other preserved vegetables

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990. (Cont.)

Index number	**Level**	**Energy intensity** (MJ/Dfl.)	**Energy requirement** (GJ)	**Expen-diture** (Dfl.)	**Deviation** (%)	**Consumption category**
v111710	7	8.4	0.6	73	3	Vegetables canned or bottled
v111740	7	5.0	0.0	5	5	Sauerkraut
v111750	7	14.9	0.3	18	5	Frozen vegetables
v1120	4	5.2	2.7	509	1	Fruit
v11200	5	5.0	1.8	370	2	Fresh fruit
v112000	6	5.0	0.6	120	2	Apples and pears
v112010	7	5.1	0.5	102	2	Apples
v112020	7	4.4	0.1	18	5	Pears
v112100	6	4.8	0.3	71	4	Other indigenous fruits
v112110	7	4.2	0.1	22	5	Strawberries
v112120	7	4.8	0.0	7	13	Cherries
v112130	7	4.0	*0.0*	*3*	17	Berries and raspberries
v112140	7	4.6	0.0	5	10	Prunes
v112150	7	5.0	0.1	12	7	Peaches
v112160	7	6.4	0.1	10	8	Melons
v112170	7	4.8	0.1	14	6	Grapes
v112200	6	5.3	0.6	119	2	Citrus fruit
v112210	7	5.6	0.4	79	3	Oranges
v112220	7	4.7	0.1	27	5	Mandarins
v112230	7	5.0	0.1	14	6	Other citrus fruit
v112300	6	4.3	0.2	40	3	Bananas
v112400	6	5.0	0.1	19	6	Other fresh fruit
v11250	5	6.4	0.5	73	2	Preserved fruit
v112500	6	6.5	0.2	25	4	Jams and marmalades
v112600	6	6.9	0.1	12	6	Fruit, dried/candied
v112700	6	5.1	0.1	18	5	Fruit in juice
v112720	6	7.4	0.1	18	4	Fruit, compote/puree
v11280	5	5.2	0.3	65	3	Nuts etc.
v112810	7	5.1	0.3	54	3	Nuts and peanuts
v112820	7	5.5	0.1	11	5	Peanut butter
v1129	4	6.6	*0.0*	*4*	16	Potatoes, vegetables & fruit not specified
v113	3	4.6	6.1	1339	2	Beverages & products containing sugar
v1130	4	7.0	1.1	162	2	Sugar and confectionery
v113000	6	11.2	0.5	45	3	Sugar
v113100	6	4.6	0.1	12	6	Sugar products on bread
v113110	7	11.5	0.0	1	12	Treacle
v113120	7	2.6	0.0	8	8	Honey
v113130	7	6.6	0.0	3	8	Sugar products on bread
v113200	6	5.4	0.6	104	3	Confectionery
v1133	4	4.3	0.6	142	2	Chocolate
v113300	6	4.8	0.2	31	3	Chocolate paste/butter for bread
v113400	6	4.1	0.5	110	3	Other confectionery

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990. (Cont.)

Index number	Level	Energy intensity (MJ/Dfl.)	Energy requirement (GJ)	Expen-diture (Dfl.)	Deviation (%)	Consumption category
v1135	4	3.5	0.6	174	2	Coffee, tea and cocoa
v113500	6	3.4	0.5	141	2	Coffee
v113600	6	4.3	0.1	30	3	Tea
v113700	6	2.6	0.0	3	10	Cocoa
v1140	4	4.4	3.8	861	2	Beverages
v11400	5	7.3	2.0	270	2	Non-alcoholic beverages
v114010	7	6.1	0.1	19	5	Mineral and soda water
v114020	7	7.0	0.7	97	3	Fruit and vegetable juices
v114030	7	7.7	1.2	154	3	Other non-alcoholic beverages
v11410	5	3.0	1.7	573	3	Alcoholic beverages
v114100	6	3.6	1.5	424	3	Beer and wine
v114110	7	3.1	0.6	208	4	Beer
v114120	7	4.0	0.9	217	4	Wine
v114200	6	1.3	0.2	149	5	Spirits and liquors
v11430	5	4.1	0.1	18	8	Beverages not specified
v115	3	13.2	1.3	96	2	Oils and fats
v115000	6	11.0	0.7	65	2	Margarine
v115100	6	17.9	0.6	31	3	Other oils and fats
v115110	7	15.3	0.4	23	4	Fats for frying and deep frying
v115120	7	26.0	0.2	8	8	Salad oil
v116	3	7.1	10.1	1415	1	Meat, meat products and fish
v1160	4	7.7	5.9	760	2	Meat
v116000	6	5.7	0.9	157	3	Beef and veal, fresh
v116010	7	5.6	0.8	144	3	Beef, fresh
v116020	7	6.6	0.1	13	9	Veal, fresh
v116100	6	5.7	1.1	202	2	Pork, fresh
v116110	7	10.0	0.3	30	5	Pork, (fat), fresh
v116120	7	6.5	1.1	172	3	Other pork, fresh
v116200	6	9.3	1.8	191	2	Minced meat, fresh
v116300	6	9.0	0.4	43	5	Offal
v116400	6	9.3	0.5	51	5	Meat and meat products, frozen
v116500	6	8.2	0.2	21	8	Other meat products
v116510	7	9.8	0.1	7	14	Horse meat
v116520	7	7.3	0.1	13	9	Other meat products
v116550	6	7.7	0.7	95	4	Fresh meat, unspecified
v1166	4	6.0	2.4	407	2	Meat products and meat dishes
v116600	6	4.2	0.1	24	5	Smoked beef
v116700	6	5.4	0.6	111	2	Ham and bacon
v116710	7	5.1	0.4	84	3	Ham
v116720	7	6.5	0.2	27	4	Bacon
v116800	6	6.4	1.5	231	2	Other sausages and meat products
v116900	6	6.1	0.2	38	4	Ready-to-use meat dishes
v116910	7	7.0	0.1	9	5	Baked minced meat
v116920	7	4.9	0.0	8	13	Ready-to-use meat dishes

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990. (Cont.)

Index number	Level	Energy intensity (MJ/Dfl.)	Energy requirement (GJ)	Expen-diture (Dfl.)	Deviation (%)	Consumption category
v116930	7	6.2	0.1	22	4	Canned or bottled meat
v116940	6	7.2	*	*	21	Other meat products not specified
v1170	4	5.9	0.8	139	3	Venison and poultry
v117010	7	1.7	*	*	24	Venison
v117020	7	6.0	0.8	136	3	Poultry
v1171	4	8.7	0.9	108	4	Fish
v117100	6	5.8	0.2	33	6	Fish, fresh
v117130	6	14.2	0.2	17	6	Fish, frozen
v117200	6	6.5	0.1	17	7	Herring
v117210	7	5.8	0.1	14	8	Herring
v117220	7	9.8	0.0	3	11	Herring, pickled
v117300	6	10.1	0.3	33	5	Other preserved fish
v117310	7	9.3	0.1	12	9	Fried fish
v117320	7	7.6	0.1	7	13	Dried and smoked fish
v117340	7	12.0	0.2	14	6	Preserved fish
v117500	6	8.7	0.1	8	11	Other fish
v1180	4	5.9	3.0	499	1	Milk and milk products
v118000	6	6.3	1.4	225	2	Milk
v118100	6	5.3	0.3	59	3	Yoghurt
v118200	6	6.0	0.6	96	2	Custard and porridge
v118300	6	5.4	0.4	68	2	Evaporated milk and cream
v118310	7	5.3	0.3	49	3	Coffee milk
v118320	7	5.5	0.1	20	4	Cream
v118350	6	5.3	0.2	32	5	Milk products with fruit juice
v118400	6	5.8	0.1	18	6	Other milk products
v1185	4	6.5	2.9	440	1	Butter, cheese and eggs
v118500	6	6.7	0.2	32	4	Butter
v118600	6	5.8	2.0	353	2	Cheese
v118700	6	11.1	0.6	54	2	Eggs
v1188	4	6.5	*	*	29	Other dairy products not specified
v119	3	4.5	7.1	1600	2	Other food products
v1190	4	6.8	1.5	219	2	Condiments, soup and oriental food
v119000	6	7.0	0.8	113	2	Condiments, spices and dressings
v119010	7	6.4	0.4	55	3	Salt, spices and condiments
v119040	7	7.6	0.4	58	3	Dressings, mayonnaise etc.
v119100	6	7.6	0.4	48	3	Soup and meat stock
v119250	6	6.9	0.4	59	5	Main course dishes, frozen/canned etc.
v1193	4	4.1	5.6	1369	2	Outdoor consumption
v119300	6	3.8	1.0	252	4	Beverages
v119310	7	3.8	0.3	74	5	Coffee
v119320	7	3.8	0.7	178	4	Other beverages
v119400	6	4.2	2.9	705	2	Meals etc. outdoor
v119410	7	4.3	0.6	130	4	French fries, rolls and snacks
v119420	7	4.1	1.8	436	3	Other meals, outdoor

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990. (Cont.)

Index number	Level	Energy intensity (MJ/Dfl.)	Energy requirement (GJ)	Expen-diture (Dfl.)	Deviation (%)	Consumption category
v119440	7	4.2	0.6	140	3	Other ready-to-use meals
v119500	6	4.1	0.3	76	4	Ice cream
v119550	6	4.1	1.4	336	5	Outdoor consumption not specified
v1196	4	5.4	0.1	12	12	Other food products and beverages
v22	**2**	**9.1**	**116.7**	**12835**	**1**	**Household effects**
v220	3	2.1	18.5	8666	1	Rent, maintenance and garden
v2200	4	1.2	9.1	7532	1	Rent and rental value
v220010	6	1.4	4.0	2891	2	Rent
v220020	6	1.1	4.8	4453	2	Rental value
v220040	6	1.2	0.2	203	3	Additional costs
v2202	4	6.9	2.3	335	4	Maintenance
v220200	6	4.5	0.6	136	5	Wallpaper and painting-costs
v220300	6	8.5	1.7	199	6	Other maintenance costs
v2210	4	3.1	0.8	273	5	Fixed equipment
v221000	6	2.7	*	*	25	Construction of fixed equipment
v221010	7	2.3	*	*	110	Construction of central heating
v221020	7	2.4	*	*	25	Boilers and geysers
v221030	7	3.1	*	*	27	Construction of other fixed equipment
v221100	6	3.2	0.7	228	5	Maintenance fixed equipment
v221110	7	2.2	*0.0*	*6*	20	Materials/maintenance central heating
v221120	7	8.0	0.6	72	7	Materials, maintenance of other fixed equipment
v221140	7	1.0	0.1	52	5	Servicing for maintenance of central heating
v221150	7	1.0	0.1	98	10	Servicing of other fixed equipment
v221400	6	1.7	0.0	29	4	Rent of fixed equipment
v2220	4	12.2	6.3	520	3	Garden and flowers
v222000	6	1.1	0.1	122	10	Rent and maintenance of garden
v222100	6	15.7	1.9	119	6	Other costs for garden
v222200	6	15.6	4.3	279	2	Indoor plants and flowers
v224	3	4.1	5.9	1451	3	Furniture, upholstery and linen
v2240	4	3.4	2.3	666	4	Furniture
v224000	6	3.2	1.2	388	6	Dining- and living-room furniture
v224010	7	3.2	0.3	88	13	Furniture (set), cabinet
v224020	7	3.2	1.0	300	6	Other dining- and living-room furniture
v224100	6	3.1	0.6	179	8	Bedroom and nursery furniture
v224110	7	3.2	*	*	21	Bedroom furniture (set)
v224120	7	3.2	0.4	119	8	Other bedroom and nursery furniture
v224140	7	2.3	0.0	14	14	Prams, buggies, baby-carriages
v224200	6	4.6	0.5	99	11	Other furniture
v224210	7	4.6	*	*	30	Garden-, kitchen- & study-furniture
v224220	7	6.1	0.2	32	8	Other garden-, kitchen- & camping-furniture

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990. (Cont.)

Index number	**Level**	**Energy intensity** (MJ/Dfl.)	**Energy requirement** (GJ)	**Expen-diture** (Dfl.)	**Deviation** (%)	**Consumption category**
v224240	7	3.2	0.1	33	7	Other furniture
v2243	4	5.1	2.1	416	4	Upholstery
v224300	6	5.8	0.9	153	6	Curtains and blinds
v224310	7	4.8	0.1	14	12	Net curtains
v224320	7	4.5	0.3	65	7	Material for curtains, draw-curtains
v224330	7	7.1	0.5	74	8	Blinds and gauze-blinds
v224400	6	5.6	0.3	57	11	Floor covering and parquet
v224410	7	4.2	0.1	26	10	Linoleum and smooth floor coverings
v224420	7	6.7	*0.2*	*31*	19	Parquet
v224500	6	5.3	0.9	170	6	Carpets, etc.
v224600	6	1.0	0.0	36	13	Other furniture textiles
v2247	4	3.0	0.3	107	6	Decoration
v224700	6	3.0	0.1	45	8	Wall decoration
v224800	6	3.0	0.2	62	8	Statues, vases and baubles
v2249	4	4.6	0.9	196	4	Bedding and household linen
v224900	6	6.5	0.3	45	10	Mattresses
v225000	6	2.3	*	*	29	Blankets
v225200	6	3.7	0.4	108	5	Other bedding
v225210	7	4.8	0.3	55	6	Sheets and pillow-cases
v225220	7	2.4	0.1	48	6	Quilts, eiderdown
v225230	7	4.7	*0.0*	*5*	18	Other bedding
v225300	6	4.8	0.2	40	6	Household linen
v2255	4	4.1	*0.3*	*67*	16	Domestic decoration not specified
v226	3	3.5	3.7	1081	2	Household appliances and tools
v2260	4	5.2	1.7	317	4	Cutlery, kitchen utensils and appliances
v226000	6	3.0	0.1	50	7	Food processors and kitchen utensils
v226010	7	2.9	0.1	48	8	Electric food processors/utensils
v226050	7	4.2	*0.0*	*2*	20	Other food processors/utensils
v226100	6	4.1	0.2	56	8	Refrigerators and deep freezers
v226300	6	3.0	0.1	42	8	Pottery and glassware
v226330	6	6.8	1.2	169	5	Other cutlery and kitchen utensils
v2265	4	2.7	0.2	67	7	Cookers
v226500	6	2.4	*	*	21	Kitchen cookers
v226600	6	2.8	0.2	55	7	Other cooking-apparatus
v2267	4	2.4	*0.0*	*19*	18	Heating appliances (except central heating)
v226720	7	2.4	*	*	25	Gas-heaters
v226730	7	2.4	*	*	26	Other heaters and stoves
v2268	4	3.7	0.4	113	5	Lighting appliances
v226800	6	4.3	0.3	71	6	Lamps and armatures
v226900	6	2.6	0.1	42	7	Other lighting appliances
v226910	7	2.3	0.1	28	8	Bulbs and fluorescent lamps
v226920	7	3.1	0.0	14	12	Cords, plugs and switches
v2270	4	3.1	0.5	160	5	Cleaning appliances and tools

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990. (Cont.)

Index number	**Level**	**Energy intensity** (MJ/Dfl.)	**Energy requirement** (GJ)	**Expen-diture** (Dfl.)	**Deviation** (%)	**Consumption category**
v227000	6	3.1	0.4	128	6	Cleaning appliances & tools (electric)
v227010	7	3.1	0.1	25	7	Vacuum cleaners
v227100	7	3.1	0.3	97	7	Washing- machines and dryers (electric)
v227210	7	2.4	0.0	6	13	Electric irons
v227215	6	3.1	0.1	32	6	Cleaning appliances & cleaning tools (n-electric)
v227220	7	4.3	0.0	8	11	Washing and ironing requisites
v227310	7	2.6	0.1	21	7	Brushes, brooms, sponges etc.
v227340	7	3.6	*0.0*	*3*	16	Accessories for cleaning apparatus
v2275	4	4.0	0.5	129	5	Other household appliances and tools
v227500	6	2.9	*	*	24	(Alarm) clocks
v227510	7	2.6	*	*	28	Alarm clocks
v227520	7	2.9	*	*	28	Clocks
v227600	6	2.6	0.1	31	12	Sewing and knitting tools
v227610	7	2.2	*0.1*	*23*	16	Electric sewing machines
v227620	7	4.7	*0.0*	*5*	16	Needlework tools
v227630	7	2.3	*	*	27	Other textile apparatus and accessories
v227700	6	4.7	0.4	87	5	Other household appliances and tools
v227710	7	2.2	0.1	31	10	Other electric apparatus
v227730	7	6.0	0.3	56	6	Other tools and articles
v2278	4	1.1	0.0	29	7	Repair and hire of household appliances
v227800	6	1.1	0.0	27	7	Repair and maintenance of household appliances
v227900	6	1.1	*	*	24	Hire of household appliances
v2280	4	1.6	0.4	247	2	Fire- and burglary-insurance
v228000	6	1.6	0.4	247	2	Fire- and burglary-insurance
v229	3	54.4	88.6	1628	1	Heating and lighting
v2290	4	58.9	51.7	878	1	Gas
v229010	7	59.1	51.5	872	1	Natural gas
v229020	7	35.1	*	*	28	Calor and propane gas
v2291	4	48.0	28.1	585	1	Electricity
v229620	7	59.1	7.1	120	5	Coll. energy costs for central heating
v229640	7	49.7	0.7	13	6	Energy costs included in rent
v229700	6	5.4	0.1	15	7	Matches and candles
v33	**2**	**2.7**	**7.6**	**2816**	**2**	**Clothing & footwear**
v330	3	3.0	6.3	2095	2	Clothing
v3300	4	3.0	1.4	475	3	Men's clothing
v330000	6	3.9	0.2	40	5	Men's coats
v330100	6	3.0	0.6	216	3	Suits, jackets and trousers
v330200	6	3.0	0.2	60	5	Cardigans and jersey/sweater
v330300	6	2.5	0.2	87	5	Shirts
v330400	6	3.9	0.1	16	9	Other outer wear
v330500	6	2.8	0.1	28	9	Nightgowns and underwear

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990. (Cont.)

Index number	**Level**	**Energy intensity** (MJ/Dfl.)	**Energy requirement** (GJ)	**Expen-diture** (Dfl.)	**Deviation** (%)	**Consumption category**
v330550	6	3.0	0.1	29	7	Men's clothes not further specified
v3306	4	2.4	1.7	698	2	Women's clothing
v330600	6	3.0	0.2	66	5	Ladies' coats
v330700	6	2.1	0.8	402	3	Dresses, blouses, trousers and skirts
v330750	6	2.1	0.0	12	10	Ladies' stockings
v330800	6	2.7	0.3	108	4	Cardigans and jersey/sweater
v330850	6	5.2	*	*	32	Other outer wear
v330900	6	2.8	0.2	57	6	Nightgowns and underwear
v330950	6	3.0	0.2	52	5	Ladies' clothes not further specified
v3310	4	3.5	0.7	212	6	Boys' and girls' clothes
v33100	5	4.3	0.3	78	8	Boys' clothes
v331000	6	5.0	0.1	13	11	Boys' coats
v331100	6	4.9	0.1	25	10	Suits, jackets and trousers
v331200	6	3.4	*0.0*	*14*	16	Cardigans and jersey/sweater
v331300	6	2.7	*0.0*	*14*	16	Shirts
v331400	6	2.8	*0.0*	*4*	19	Other outer wear
v331500	6	7.8	*0.0*	*6*	18	Nightgowns and underwear
v331550	6	2.9	*0.0*	*3*	19	Boys' clothes not further specified
v33180	5	2.8	0.3	94	8	Girls' clothes
v331800	6	3.6	0.0	14	10	Girls' coats
v331900	6	2.4	0.1	49	9	Dresses, blouses, trousers and skirts
v332000	6	2.8	0.0	14	14	Cardigans and jersey/sweater
v332050	6	2.3	0.0	5	15	Other outer wear
v332100	6	4.2	0.0	9	15	Nightgowns and underwear
v332200	6	3.0	*	*	21	Girls clothes not further specified
v33250	5	3.2	0.1	39	11	Babies' clothes
v3327	4	3.0	1.5	488	3	Clothes unspecified (age, sex, unknown)
v3328	4	2.4	0.1	23	10	Clothing accessories men/boys
v3329	4	2.4	0.0	15	11	Clothing accessories women/girls
v3330	4	3.0	0.1	27	8	Clothing accessories etc. unspecified
v3331	4	5.2	0.8	146	5	Materials and charge for making clothes
v333100	6	5.9	0.5	77	7	Material for clothes
v3350	4	1.6	0.2	93	4	Men's footwear
v335000	6	1.6	0.1	48	5	Men's shoes
v335100	6	1.7	0.1	45	5	Other men's footwear
v3360	4	1.7	0.3	157	3	Women's footwear
v336000	6	1.6	0.1	84	4	Ladies' shoes
v336100	6	1.8	0.1	73	4	Other ladies' footwear
v3370	4	1.6	0.1	72	6	children's footwear
v33700	5	1.5	0.0	14	10	Boys' shoes
v33710	5	1.4	0.0	19	11	Girls' shoes
v33720	5	1.7	0.1	40	8	Other children's footwear
v337200	6	1.7	0.0	20	10	Other boys' footwear
v337300	6	1.7	0.0	18	11	Other girls' footwear

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990. (Cont.)

Index number	**Level**	**Energy intensity** (MJ/Dfl.)	**Energy requirement** (GJ)	**Expen-diture** (Dfl.)	**Deviation** (%)	**Consumption category**
v337400	6	1.6	*	*	30	Infants' and babies' footwear
v3375	4	1.8	0.2	122	4	Footwear unspecified (age, sex unknown)
v3376	4	1.3	0.0	6	14	Hire of footwear
v3380	4	2.1	0.1	31	8	Shoe repairs and material
v338000	6	2.3	0.1	24	10	Shoe repairs
v338100	6	1.3	0.0	7	15	Repairing materials
v3382	4	2.0	0.5	237	4	Finery
v338200	6	2.8	0.2	68	5	Leather goods etc.
v338300	6	1.6	0.2	133	5	Jewellery and watches
v338400	6	1.9	0.0	21	8	Other finery
v338500	6	2.0	0.0	14	11	Repairs to finery
v339	3	2.4	*0.0*	*4*	19	Clothing, footwear & access; not specified
v44	**2**	**3.2**	**17.1**	**5561**	**1**	**Hygiene and medical care**
v440	3	3.5	2.1	770	3	Domestic services and cleaning
v4400	4	0.6	0.2	338	6	Domestic services
v440000	6	0.0	0.0	171	9	Wages for domestic staff/servants
v440100	6	3.0	0.1	25	8	Laundry, dry cleaning, dye-works
v440200	6	0.8	0.1	141	8	Other domestic services
v440230	7	0.1	0.0	41	7	Window-cleaning service etc.
v440240	7	1.1	0.1	100	11	Babysitting, nursery etc.
v4410	4	5.7	1.9	432	1	Cleaning articles
v441000	6	2.4	0.5	223	1	Water
v441100	6	6.8	1.0	150	3	Washing powders, detergents etc.
v441110	7	3.0	0.0	3	10	Household soap
v441200	7	6.9	0.9	126	3	Washing powders etc.
v441210	7	6.8	0.1	21	5	Detergents
v441300	6	7.2	0.4	59	3	Other cleaning articles and insecticides
v442	3	3.6	2.7	746	2	Physical care
v4420	4	6.0	1.7	273	3	General physical care
v442000	6	4.8	0.9	186	3	Toilet-articles
v442100	6	12.3	0.6	47	3	Toilet paper
v442200	6	4.8	0.1	27	5	Sanitary towels
v442300	6	4.0	0.1	14	12	Visits to (public) baths/toilet/sauna
v4430	4	2.0	0.7	343	2	Services of hairdressers
v443000	6	1.4	0.3	237	3	Hairdresser
v443100	6	3.5	0.4	106	3	Articles for hair-care
v443110	7	1.8	0.0	12	9	Electrical articles for hair-care
v443120	7	3.7	0.3	94	4	Other articles for hair-care
v4440	4	2.5	0.3	130	4	Cosmetics and perfumery
v444000	6	1.4	0.0	33	9	Chiropodist, manicurist, beauty-salon
v444100	6	2.9	0.3	96	4	Cosmetics and perfumery
v446	3	3.0	12.3	4046	1	Medical care

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990. (Cont.)

Index number	**Level**	**Energy intensity** (MJ/Dfl.)	**Energy requirement** (GJ)	**Expen-diture** (Dfl.)	**Deviation** (%)	**Consumption category**
v4460	4	11.5	6.8	593	3	Medical care (excluding insurance)
v44600	5	1.7	0.6	331	3	Medicines, wound-dressings & protheses
v44700	5	14.9	6.2	419	4	Medical care
v4490	4	1.6	5.5	3448	1	Health insurance
v449000	6	1.6	3.9	2429	2	Health insurance premium
v449100	6	1.6	1.6	1020	3	Other health insurance
v55	**2**	**5.2**	**56.5**	**10828**	**2**	**Education, recreation and transport**
v550	3	3.6	4.7	1293	2	Education
v5600	4	1.7	0.8	486	3	Schooling
v555000	6	0.2	0.0	42	7	School-, course-fee & professional training
v550100	6	0.2	0.0	167	5	Music-, dancing- and sports lessons
v550200	6	2.6	0.5	196	4	Study-books and educational appliances
v550300	6	3.6	0.3	81	7	Other educational costs
v5504	4	4.8	3.9	807	2	Stationery and reading
v550400	6	6.1	1.3	216	5	Stationery and the like
v550410	7	2.0	0.2	98	10	Typewriter, counting-machine / calculator
v550420	7	9.6	1.1	118	4	Other stationery
v550500	6	5.7	1.9	340	1	Newspaper and weekly papers
v550600	6	2.4	0.6	251	4	Books and magazines
v550610	7	2.4	0.4	168	5	Books
v550620	7	2.4	0.2	83	3	Journals, periodicals and magazines
v551	3	5.6	13.9	2468	3	Sports, games and holidays
v5510	4	2.6	0.8	303	8	Sports and games
v551100	6	0.9	0.1	100	5	Hire of sport-accommodation
v551200	6	3.5	0.3	94	5	Sportswear and camping clothes
v551210	7	4.2	0.1	18	9	Men's sportswear and camping clothes
v551240	7	4.2	0.1	13	14	Boys' sportswear and camping clothes
v551280	7	2.9	0.1	28	7	Ladies' sportswear and camping clothes
v551320	7	2.8	0.0	12	14	Girls' sportswear and camping clothes
v551350	7	3.5	0.1	24	8	Sportswear not specified
v551400	6	2.2	0.1	23	9	Sports shoes
v551410	7	2.1	0.0	7	13	Men's sports shoes
v551420	7	2.3	*0.0*	*6*	16	Boys' sports shoes
v551440	7	2.2	*0.0*	*5*	16	Ladies' sports shoes
v551450	7	2.3	*0.0*	*6*	20	Girls' sports shoes
v551500	6	3.7	*	*	28	Sports goods and games
v551510	7	7.6	*	*	83	Sailing- and motor-boats
v551530	7	1.7	0.1	42	8	Sports goods
v551570	7	1.8	0.0	15	11	Games
v5516	4	6.0	13.1	2166	3	Camping, weekend and holidays
v55160	5	3.8	*0.6*	*155*	16	Camping equipment and caravans
v551610	6	3.7	*	*	29	Caravans etc.

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990. (Cont.)

Index number	**Level**	**Energy intensity** (MJ/Dfl.)	**Energy requirement** (GJ)	**Expen-diture** (Dfl.)	**Deviation** (%)	**Consumption category**
v551620	6	6.2	0.2	40	9	Other camping equipment
v551640	6	1.3	0.0	33	13	Hire & maint. of camping equipment
v55170	5	2.3	0.1	40	5	Holiday insurance
v55180	5	4.9	0.4	91	6	Other weekend expenditure
v55190	5	5.6	1.7	300	4	Holidays in the Netherlands
v551900	6	4.6	0.5	113	6	Organised holiday trips
v551950	6	6.2	1.2	187	5	Other holiday costs
v55210	5	6.5	10.2	1568	3	Holiday abroad
v552100	6	6.1	4.0	661	4	Organised holiday trips
v552200	6	6.8	6.2	907	3	Other holiday costs
v55250	5	6.7	*0.1*	*12*	20	Holiday costs not specified
v553	3	2.7	4.8	1764	2	Other recreation
v5530	4	1.9	0.2	115	7	Music, singing and theatre
v553100	6	2.0	0.1	62	6	Entrance fees for concert, theatre
v553200	6	2.1	*0.1*	*37*	19	Musical instruments
v553300	6	1.4	0.0	17	12	Hire and repair of musical instruments
v5535	4	2.1	1.9	888	3	Radio, television and gramophones
v553500	6	2.2	0.2	72	8	Radios and amplifiers
v553510	7	2.5	0.0	14	10	Radios
v553520	7	2.2	0.1	42	13	Audio amplifier
v553530	7	1.8	0.0	16	10	Car radios including accessories.
v553600	6	2.3	0.3	131	7	Television sets
v553700	6	2.6	0.5	180	6	Gramophones and tape-recorders
v553710	7	2.7	*	*	24	Gramophones
v553720	7	2.5	0.1	52	7	Cassette- and tape-recorders
v553730	7	2.7	0.3	124	7	Videos
v553800	6	2.6	0.3	104	8	Sound-equipment (combined)
v553900	6	1.4	0.1	51	6	Hire/repairs audio/video equipment
v554000	6	1.9	0.3	163	5	Records, cassettes and compact disks
v554100	6	1.6	0.3	187	1	Other costs of radio and TV
v554110	7	1.2	0.2	146	1	Radio and television licence fee
v554120	7	3.1	0.1	41	2	Radio/tv programme magazine
v5542	4	3.7	2.4	641	3	Other recreation
v554200	6	5.8	0.1	23	9	Entrance fee to cinema
v554300	6	2.7	*	*	36	Film- and projection-equipment
v554400	6	1.6	0.1	37	9	Photo-cameras and accessories
v554410	7	1.6	0.0	28	10	Photo-cameras
v554420	7	1.7	0.0	9	15	Film- and photo-accessories
v554500	6	2.7	0.4	148	4	Other costs of photography and films
v554600	6	5.1	1.4	277	4	Pets
v554610	7	1.5	*	*	32	Purchase of pets
v554620	7	5.3	1.4	264	4	Costs of tending pets
v554700	6	1.7	0.0	6	15	Services supplied by clubs
v554800	6	2.0	0.2	77	5	Other entrance fees

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990. (Cont.)

Index number	**Level**	**Energy intensity** (MJ/Dfl.)	**Energy requirement** (GJ)	**Expen-diture** (Dfl.)	**Deviation** (%)	**Consumption category**
v554900	6	2.1	0.1	32	10	Other hobbies
v555000	6	3.2	0.1	38	9	Party articles
v5551	4	2.8	0.3	120	5	Toys
v556	3	1.1	0.4	367	3	Smoking
v556000	6	1.2	0.0	18	14	Cigars
v556100	6	0.9	0.2	197	5	Cigarettes
v556200	6	1.3	0.2	146	4	Other tobacco articles
v556300	6	1.8	0.0	5	13	Smokers' accessories
v557	3	6.6	32.7	4935	2	Transport & communication
v5570	4	7.6	2.9	389	4	Public transport
v557000	6	7.4	1.7	233	5	Train
v557100	6	7.8	1.2	156	5	Other expenditure for public transport
v557110	7	1.1	0.0	18	13	Taxi
v557120	7	8.7	1.2	139	5	Other public transport
v5572	4	2.2	0.4	193	4	Bikes
v557200	6	1.9	0.2	125	5	Purchase of bikes
v557300	6	2.8	0.2	67	6	Bike accessories and repairs
v5574	4	2.3	*0.1*	*60*	18	Mopeds, motor-cycles etc.
v557400	6	2.1	*	*	25	Mopeds, motor-cycles and scooters
v557500	6	2.8	0.1	20	13	Repair of mopeds, motor-cycles, scooters
v557510	7	2.8	0.0	6	20	Repair of and accessories for mopeds
v557530	7	2.8	*0.0*	*14*	17	Rep. & access. motor-cycles/-scooters
v5576	4	2.4	4.9	2062	5	Cars
v5579	4	15.0	22.8	1519	2	Other costs of personal transport
v557900	6	4.4	0.1	31	6	Storage of car, motor-cycle, bike
v557910	7	5.5	0.1	24	7	Car/motor-cycle storage
v557920	7	0.4	0.0	7	12	Bike/moped storage
v558000	6	1.5	0.8	509	2	Insurance cars etc.
v558010	7	1.5	0.7	470	2	Insurance car
v558020	7	1.5	*0.0*	*11*	16	Insurance motor-cycle, scooter
v558030	7	1.5	0.0	13	9	Insurance moped and bike
v558040	7	1.5	0.0	16	9	Other insurance vehicles/vessels etc.
v558100	6	22.4	21.9	980	2	Petrol and motor oils
v558110	7	22.4	21.9	977	2	Petrol, oil for cars and motor-cycles
v558120	7	19.9	*	*	29	Other petrol and oil
v5582	4	1.9	1.4	712	2	Other transport & communication costs
v558200	6	1.0	0.6	560	1	Telephone
v558300	6	8.0	0.5	62	5	Postal expenses
v558400	6	3.7	0.3	90	9	Other transport and communication
v558420	7	2.3	0.1	63	11	Driving-lessons
v558430	7	6.8	*0.2*	*27*	*16*	Cargo services
v66	**2**			**658**		**Other expenses**
v661	3			365		Private insurances not mentioned before

Table 4A-2 Energy intensities and the energy requirement of an average Dutch household in 1990. (Cont.)

Index number	**Level**	**Energy intensity** (MJ/Dfl.)	**Energy requirement** (GJ)	**Expen-diture** (Dfl.)	**Deviation** (%)	**Consumption category**
v661000	6			199		Insurances against damage and income loss n.b.m.
v661200	6			167		Life insurance, other endowment insurances
v662	3			293		Other expenditure not mentioned before
v662100	7			58		Family ceremonies
v662210	7			3		Pocket-money expenses unspecified
V662230	7			233		Various services not mentioned before

Appendix 4B ► Price - income relationships

In this chapter we distinguished 350 product categories, together making up nearly the total household consumption pattern. To each category we assigned an energy intensity (MJ/Dfl.). This energy intensity value per category is assumed to be the same for all the income levels. In this chapter we found an important relationship between net household income and the direct and indirect energy requirement of households. The energy requirement elasticity related to income was found to be 0.63, i.e. a 1% increase in income results in a 0.63% increase in energy requirement. However, it is conceivable that households with a higher income systematically buy products that cost more per physical unit. For instance, they may pay on average more for one bread or one sofa with the same physical characteristics. Products with a higher price per physical unit may have a lower energy intensity than products with lower prices (see Chapter 2). The consequence of this possible price-income effect is that the real energy requirement elasticity related to income (or expenditure level) can be smaller than the value computed in this chapter.

In order to investigate to what extent our analysis is biased through this effect, we examined the relationship between income and the price per physical unit. On the basis of the household expenditure survey this was only possible for 82 categories, containing homogeneous products like shoes or bread. The other product categories of the expenditure survey are not suitable for this analysis. This because these categories contain products of which many possible variants are possible, like furniture.

For the 82 homogeneous (sub) consumption categories Statistics Netherlands (CBS) supplied data on physical amounts purchased and expenditures, depending on income levels, divided into deciles of quintiles (CBS, 1995). From these data the price per physical unit for the 82 consumption categories per household income level has been derived. The price elasticity of the examined 82 consumption categories together is on average found to be 0.16. This average price income elasticity is extrapolated to all 350 consumption categories, excluding the consumption categories of which the energy requirement is already calculated on a physical basis (house, electricity and natural gas). Than we find a maximal decrease of the elasticity of the energy requirement related to net household income from 0.63

to not lower than somewhere between 0.56 and 0.60[7] (see Figure 4-B1). Because all price - energy requirement relationships are ignored, the estimate made here shows the maximal effect of price income relationships to the total energy requirement. See for more details Vringer and Blok (1997).

This means that for complete consumption patterns only a small effect is found on the energy requirement elasticity related to income of taking into account the price elasticity related to income, while ignoring the price -energy requirement relation

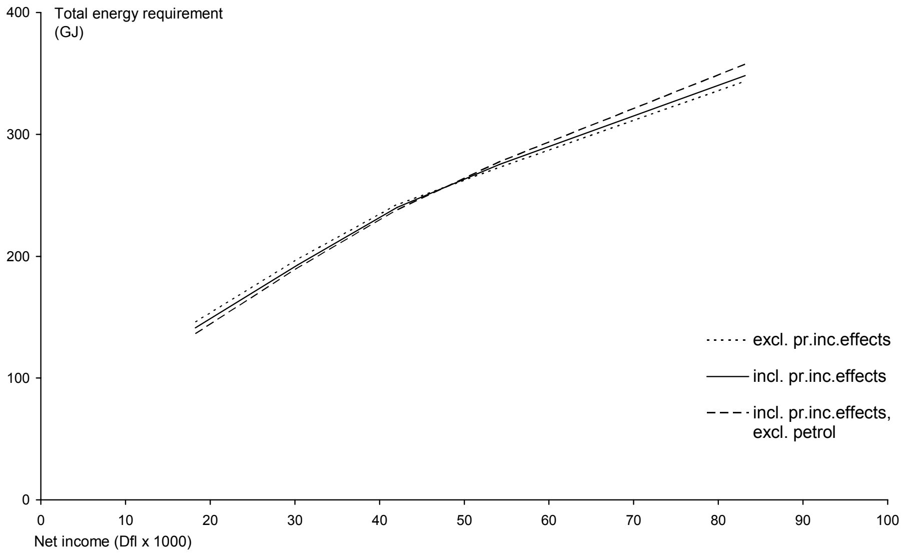

Figure 4B-1 Total energy requirement plotted against net household income, ex- and including the price-income effects and including the price-income effects but leaving out petrol.

7 If the consumption categories which do contain several kinds of petrol are left out the analysis, the elasticity lowers from 0.60 to 0.56.

Chapter 5

Household energy requirement and value patterns[1]

► Abstract

For an effective consumer energy policy it is important to know why some households require more energy than others. The aim of the study described here was to examine whether there is a relationship between the total household energy requirement, on one hand, and value patterns, the motivation to save energy or the problem perception of climate change, on the other. To examine these relationships we held a consumer survey among 2304 respondent households.

We did not find significant differences in the energy requirement of groups of households with different value patterns, taking into account the differences in the socio-economic situation of households. Only for the 'motivation to save energy' we did find that the least motivated group requires 10 GJ more energy than the average and most motivated groups; this is about 4% of the total household energy requirement.

This means that a self-regulating energy policy, solely based on a strategy of internalising environmental responsibility will not be effective in saving energy. There are indications that a social dilemma is one of the reasons why people's consumption patterns do not conform to their value patterns, problem perception or motivation to save energy.

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1 Co-authored by Theo Aalbers, Netherlands Environmental Assessment Agency (MNP-RIVM) and Kornelis Blok, Utrecht University (UU).

1 ► Introduction

To achieve a more sustainable energy system in the future, it is important to reduce or limit the energy requirement of society. Energy consumption cannot only be limited or reduced by improving the energy efficiency, but also by changing consumption patterns. The IPCC (2001) mentions change in consumption patterns as a possible response option to the treat of climate change, while the option of changing consumption patterns is insufficiently exposed. For an efficient consumer energy policy it is important to know how the energy requirement of consumption patterns is established and why some households require more energy than others.

In overviewing the consumption pattern in the Netherlands, Vringer and Blok (1995) found the net household income to be strongly related to the total (direct plus indirect) energy requirement. Other studies also examined the energy requirement for consumption and found relationships between energy requirement and socio-economic characteristics such as income (Weber and Perrels, 2000); Cohen et al., 2005). However, differences in the household energy requirement cannot be solely explained by differences in socio-economic parameters such as income, household size and age. Households in a comparable socio-economic situation vary largely in the total energy requirement (Vringer et al., 1997).

The differences in the total household energy requirement are due to differences in consumer behaviour. There are many studies which use different theories and models to explain (parts of) consumer behaviour (see, for example, Steg and Buijs, 2004); Antonides and Van Raaij, 1997). These studies indicate that there are many factors influencing the actual consumer behaviour. One often mentioned factor is formed by people's values (Antonides and Van Raaij, 1997; Steg and Buijs, 2004; Nordlund and Garvill, 2002; Valette-Florence and Jolibert, 1990; Poortinga et al., 2004). Values can be defined as desirable goals that serve as guiding principles in people's lives (Steg and Buijs, 2004). According to Antonides and Van Raaij (1997) consumers use products and services (means) to realise desirable goals (values) like ambition, independency, comfort, freedom and pleasure. Valette-Florence and Jolibert (1990) analysed the relation between consumption patterns (measured as the purchasing frequency of 140 consumption categories) and values. They found a weak, but not negligible, influence from values on the consumption pattern, independent from socio-economic characteristics. Nordlund and Garvill (2002) quote many studies in which relationships are confirmed between factors such as value orientation and specific pro-environmental behaviours like recycling and buying ecologically produced products. However, pro-environmental behaviour does not have to be relevant to the overall environmental pressure (see also Gatersleben et al., 2002).

The emphasis in this analysis is on the relationship between value patterns and total energy requirement. We chose to examine two other non-socio-economic characteristics as well, which could be expected to influence behaviour more directly than values do. These were: (I) the motivation to save energy and (II) the perception of energy-related societal problems. Motivation is a central concept for consumer behaviour. Antonides and Van Raaij (1997) state that motivation activates and maintains certain behaviour; it also determines the direction and strength of this behaviour. So, if consumers are motivated to save energy, it can be expected that the more consumers are motivated, the less energy they will require. If consumers act as they think about societal problems, those who think that energy-related societal problems, such as climate change, are more important than other problems can be expected to use less energy.

The aim of this study is to examine whether there is a relationship between, on the one hand, the total household energy requirement and, on the other, value patterns, the motivation to save energy or the perception of energy-related societal problems.

In this study, we first describe how we determined the value patterns of consumers and the household energy requirement. Next we examine the relationship between these, taking into account the socio-economic situation of the households. Finally we explore the influence of the perception of energy-related societal problems and the motivation to save energy on the total household energy requirement.

2 ► The consumer survey

To examine the relationship between the total household energy requirement, on one hand, and value patterns and the motivation to save energy or the perception of energy-related societal problems, on the other, we used consumer-specific information of 2304 respondents from the consumer survey (TNS-NIPO, 2003). The respondents filled in five different questionnaires; one for value patterns, two for the consumption patterns, one for their view on societal problems and one for the "motivation to save energy"[2]. Not all 2304 respondents were asked to answer all five questionnaires. There were 2304 respondents who answered the questionnaires on value patterns and both consumption pattern questionnaires. Of these 2304 respondents, 1272 answered the questionnaire about the societal problem perception too and 935 answered the motivation questionnaire too.

To minimise the initial *non-response* we used a panel from the Dutch Institute for Public Opinion and Market Research (TNS-NIPO) for the consumer survey. TNS-NIPO took a random representative sample for Dutch households from a pool of about 80,000 respondents who were invited by TNS-NIPO to register for the panel. The response to our questionnaires was about 80%. After collecting the data we weighted the respondents according to net household income, size of the household, age and education of the breadwinner[3].

3 ► Determination of value patterns

The value patterns of consumers are determined according to the WIN-model[4] from TNS-NIPO (Hessing-Couvret and Reuling, 2002). The WIN-model is based on the value system of Rokeach (1973) and the work of Schwartz and Bilsky (1987).

According to Rokeach, in a value system values are ordered in priority of importance. A value is an enduring belief that a specific mode of conduct or end-state of existence is personally or socially preferable to an opposite or converse mode of conduct or end-state of existence. Rokeach distinguishes 36 values — all socially desirable — into two groups. One group contains 18 instrumental values (modes of conduct) and the other contains 18 terminal values (end states of existence) (see Table 5-1).

2 The motivation questions were borrowed from an ECN questionnaire (see Kets et al., 2003).
3 In this study, the breadwinner is the person in the household with the highest personal income.
4 WIN = Values in the Netherlands (Waarden In Nederland).

Schwartz and Bilsky (1987) found that seven motivational domains, taken from the literature, are organised relevant to one another and can be projected in a value space. Each domain contains a number of accompanying values belonging together (e.g. the motivational domain, ‘security’, includes values of inner harmony, family security, national security and a world at peace).

Table 5-1 The two lists of 18 values each, according to Rokeach (1973). One is with the instrumental values and one is with the terminal values.

	Instrumental values (desired modes of conduct)		**Terminal values** (desired end-states of existence)
1	Ambitious	1	A comfortable life
2	Broadminded	2	A sense of accomplishment
3	Capable	3	A world at peace
4	Cheerful	4	A world of beauty
5	Clean	5	An exciting life
6	Courageous	6	Equality
7	Forgiving	7	Family security
8	Helpful	8	Freedom
9	Honest	9	Happiness
10	Imaginative	10	Inner harmony
11	Independent	11	Mature love
12	Intellectual	12	National security
13	Logical	13	Pleasure
14	Loving	14	Salvation
15	Obedient	15	Self-respect
16	Polite	16	Social recognition
17	Responsible	17	True friendship
18	Self-controlled	18	Wisdom

For this study each respondent had to rank the two lists according to how important the values are for him/herself. The value space was transformed to two dimensions with the help of a principal component analysis (PRINCALS). Finally, Hessing-Couvret and Reuling (2002) made a cluster analysis for the respondents in the value space. They forced an eight-cluster solution and gave names to the clusters, based on the value occurring in each group and other known aspects (see Figure 5-1). In other words, the names mentioned in Figure 5-1 are not based on the perception of the respondents but refer to names taken from Hessing-Couvret and Reuling (2002).

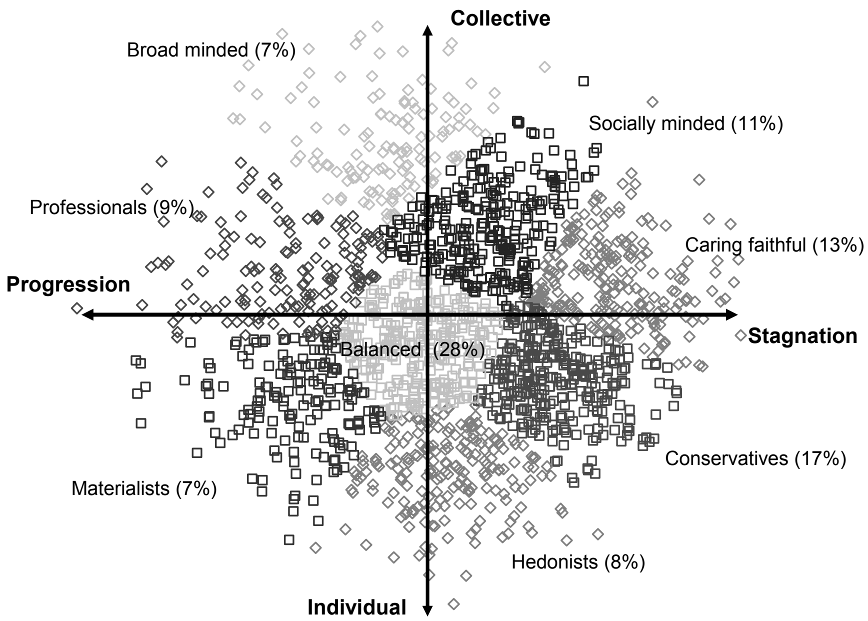

Figure 5-1 The eight value groups positioned in the value space, with two important axes (Hessing-Couvret and Reuling, 2002). The percentages reflect the size of the groups in the Dutch population, each tiny square representing one person.

Figure 5-1 shows the eight value groups in a two-dimensional space. One axis indicates a collective–individual dimension. Expectedly, consumers with a more individualistic value pattern like the Hedonists, Conservatives and Materialists are less focused on such societal problems as climate change than the consumers with a more collective value pattern such as the Broad-minded and Socially-minded. This makes it interesting to compare value groups of consumers with respect to their energy requirements.

4 ► Determination of the energy requirement

If the influence of value patterns, the perception of energy-related societal problems or the motivation to save energy on the total household energy requirement is to be explored, the actual total consumption pattern of a household and the accompanying energy requirement will have to be determined (section 4.1). We wanted to compare the actual energy consumption of a household with a reference; this is the average for households in the same socio-economic circumstances (section 4.2). The determination of the actual consumption pattern and the calculation of the reference energy requirements are described below.

4.1 ► Determining the actual consumption pattern

The emphasis of the information provided by the respondents of the consumer survey is on the consumption categories demanding a considerable amount of energy or money. To avoid the conversion from monetary into physical terms, we collected the information mainly in physical terms. Because the expenditure on durable consumer goods (e.g. cars) for individual consumers may peak in the survey year, we requested information on purchase and possession of these goods. Detailed information was requested on six groups of consumption categories: natural gas, electricity, transport, holidays abroad, the dwelling and food.

To determine the actual consumption pattern, we first made a standard consumption pattern and the accompanying energy requirement. This standard consumption pattern is solely based on the socio-economic situation of the households (see section 4.1.1). We did this using the Household Expenditure Survey (CBS, 2002a). With the help of the detailed responses to our own survey, we adapted this standard consumption pattern to get the actual household energy requirement for the six groups of consumption categories using a method described in sections 4.1.2- 4.1.6. These six groups of consumption categories collectively make up about 75% of the total energy requirement. Finally, the expenditures and accompanying energy requirement for the remaining consumption categories was established, see section 4.1.7.

4.1.1 ► Estimation of the standard consumption pattern

The estimation of the standard consumption pattern and the accompanying energy requirement is based solely on the socio-economic situation of the households. To each household of the consumer survey, we coupled the average expenditure and the accompanying energy requirement of 350 consumption categories of the 10 most similar households from the *household expenditure survey* of 2000 (CBS, 2002a)[5]. To find the 10 most similar households from the expenditure survey, we characterised each household by a vector. We chose the 10 households from the expenditure survey, in which the difference in vector length between their vector and the vector of the household from the consumer survey is the smallest[6]. We based the vector on the socio-economic parameters that 'explain' most of the variance in the energy requirement for most consumption domains[7], using a regression tree analysis[8]. About 65% of the variance in the energy requirement can be explained by all the socio-economic characteristics available in the expenditure survey. The net income is, by far, the most important factor in explaining the variance of the total household energy requirement (about 60%). We selected net income, age of the breadwinner, highest education of the breadwinner and household size[9], normalising

5 The household expenditure survey contains the expenditure of 2395 representative households in the Netherlands in 2000, divided into about 350 consumption categories. Vringer and Blok (1995) gave a detailed description of the survey. The figures of the household expenditure survey figures were adjusted for transport and direct energy requirement according to Vringer et al. (2001) and MONIT (2003). The energy requirement for each consumption category is calculated according to the method described in Vringer and Blok (1995) by using energy intensities for 1996 given by Kok et al. (2001). The energy intensities are indexed to 2000 on the basis of consumer price indexes according to CBS (2002b) and Erkens (2002).

6 In this analysis we chose 10 similar households to calculate the reference consumption pattern. We also made calculations for 5, 25 and 50 similar households. The results were comparable.

7 These are the nine domains used by Vringer et al. (2001), i.e. food, dwelling, housing, clothing, personal care, leisure outdoors, leisure indoors, holidays and labour. Note that the domains do not only consist of the products themselves, but also the required transport of these products from the shop to the dwelling, and the direct energy (natural gas, electricity) required to use these products.

8 In a regression tree analysis the variance in the dependent variable (here, the energy requirement) is minimised by breaking up the data, using every possible binary split on every independent variable (here, many socio-economic parameters). The algorithm split the data into two parts by minimising the sum of the squared deviations from the mean in the separate parts. This splitting or partitioning is then applied to each of the new branches. We used a regression-tree model from S-PLUS.

9 For the consumption survey, comprising 52% men and 48% women, we took the breadwinner or his/her partner. Their ages were strongly correlated (R-square=0.84).

these four dimensions[10]. The weighting factors for the socio-economic variables of the vector we chose to reflect the relative proportions of the separately 'explained' variance on the total energy requirement. The separately explained variances of the total energy requirement of net household income, household size, age and education are 62%, 36%, 15% and 7%, respectively. The difference in vector length between the vectors of two households is then calculated according to equation (1).

$$V^2 = a(I_{hes} - I_{cs})^2 + b(\mathrm{Age}_{hes} - \mathrm{Age}_{cs})^2 + c(HHs_{hes} - HHs_{cs})^2 + d(Ed_{hes} - Ed_{cs})^2 \quad (1)$$

In which:

V	=	weighted difference between the vectors of two households
I	=	normalised net household income
Ed	=	normalised highest education of the breadwinner
HHs	=	normalised household size, in number of persons
Age	=	normalised age of the breadwinner
hes	=	household expenditure survey
cs	=	consumer survey
a, b, c, d	=	weighting factors of 0.51, 0.12, 0.30 and 0.06, respectively

The average consumption pattern according to the expenditure survey and the average standard consumption pattern calculated here are quite comparable. The differences between the expenditure survey of 2000 and the standard consumption pattern calculated here, vary per consumption domain from 2 to 14% of the expenditures and from 0 to 14% of the energy requirement.

4.1.2 ► Natural gas and electricity

We asked the respondents about their payments to the energy companies, and which additional services were included in these payments, e.g. water, cable television and

10 Each dimension is normalised by subtracting the average value from the actual value, and dividing this difference by the standard deviation of the value.

Internet. Next we asked the respondents how much kWh electricity and m^3 natural gas they had used in the past year, based on their most recent annual bill.

► Expenditures

We based the annual expenditure on the monthly payments to the energy companies as reported by the respondents[11]. If applicable, we subtracted the expenditures on additional services, based on average expenditures according to CBS (2002a) and CASEMA (2003). To split the combined bills into the shares for electricity and natural gas (85% of the households has a combined bill), we took the proportion of natural gas and electricity used as reported by the respondents. If the natural gas and electricity consumption in m^3 and kWh was unknown, we took the proportions of the standard consumption pattern (section 4.1.1).

► Energy use

Half the respondents knew their use of natural gas and electricity in kWh and m^3. For all other respondents for whom the physical use of gas, heating or electricity use was unknown[12], we established the energy requirement by using the expenditures on electricity and natural gas, minus the costs for the grid connections plus the eco-tax rebates (Van Maanen, 2003). The resulting expenditures and the kWh electricity and m^3 natural gas used were multiplied by the energy intensities (see Kok et al., 2001).

4.1.3 ► Transport

We asked the respondents how many cars they had, the type and age of the car and the annual distance travelled with this car for private use. We also asked how many kilometres they travelled between home and work and leisure and how they travelled for these purposes.

► Expenditures

We estimated the deprecation and maintenance costs of the car by taking into account its age, catalogue value and type[13]. We based the insurance costs and

11 About 20% of the respondents had to make an estimation.

12 The energy requirement of households that use district heating or a central heating boiler (about 9%) could not be established unambiguously either.

13 For lease cars we took only the depreciation that could be assigned to the private use of the car.

ownership tax of the car on the average insurance costs, according to the type of the car (ANWB, 2003; Belastingdienst, 2003; Consumentenbond, 2003). The calculated fuel costs were based on the reported or estimated fuel use per km, type of fuel, the reported number of kilometres driven and the fuel price (CBS, 2003). The expenditures on train and/or bus were estimated using average distance travelled, the frequency and the bus and train fares (NS, 2003; GVU, 2003).

► Energy use

The energy requirement for fuel was calculated with the energy requirement per litre according to Wilting et al. (1999). The energy requirement for public transport, car maintenance and depreciation was calculated by using energy intensities from Kok et al. (2001).

4.1.4 ► Holidays abroad

We asked respondents who travelled abroad in the past year to tell us for each destination how they travelled and with how many persons. We also asked the kind and comfort level of the accommodation. We asked for detailed descriptions about the three longest holidays, assuming that the fourth and subsequent holidays would be equal to the third, or shortest, holiday.

► Expenditures

The expenditures on holidays abroad were based on the number of participating household members, duration, type and comfort level of the accommodation, mode of transport and destination (country or region). Fares for train, plane and boat were collected from Internet sites of several tour operators. Information on prices for accommodation as found on the Internet and brochures vary largely. Based on information from Aalbers (2004), we assumed an average price of 8 euro per person per night for a camping, 50 euro per night for a double room in a hotel and 450 euro per week for an apartment or holiday home. We indexed the (Dutch) prices for the different country regions with the Big-Mac index (The Economist, 2004) for luxury class accommodation[14].

14 We asked the luxury class respondents about their accommodation. We assumed price differences from very simple, no star (-30%), simple, 1 star (-10%), average, 2 stars (0%), luxury, 3 stars (+20%) to very luxury, 4 or more stars (+40%).

▶ Energy use

The energy requirement for transport between home and final destination for holidays abroad was based on the energy requirement per kilometre (de Paauw, 1995; Essen et al., 2003). Where the car was used for holiday transport, we took the energy requirement per kilometre of the largest car. Extra fuel was taken into account for mobile home use. The energy requirement for the accommodation is based on the energy requirement per person/accommodation per night (see de Paauw, 1995).

4.1.5 ▶ Dwelling

We asked the respondents which type of dwelling they lived in and to tell us about the rent and several physical aspects of their dwelling (e.g. surface area of the living-room and number of rooms).

▶ Expenditures

About 40% of the respondents rent their dwelling, of which 88% knew their rent and 11% estimated it. About 1% did not really know how much rent they paid. For these respondents we took the expenditure and energy requirement according to the standard consumption pattern (section 4.1.1). To make a fair comparison with owner-occupants we calculated the rental value equivalent to the rent. To estimate the rental value for the remaining 60% owner-occupants, we used a model from Statistics Netherlands (CBS) to calculate the gross economic rental value (Sierman, 2003). To calculate the rental value of the dwelling, the model takes the type, age, size, region and a number of facilities like bath and type of heating into account.

▶ Energy use

The calculation of the energy requirement was based on the size and type of dwelling, according to the method used by Vringer and Blok (1993). We took into account the re-calculations made by Kok et al. (2001).

4.1.6 ▶ Food

We asked the respondents about their food consumption, for example, how often they cooked a warm meal at home, what type of meal they ate, what kind of meat they ate and how often they consumed fresh and/or conserved vegetables, and fruit

& dairy products. This information is used to change the ratio between the food consumption categories, available from the standard consumption pattern (section 4.1.1). For example, the number of times a week a household enjoys dessert is assumed to affect the expenditure on custard and porridge. By calculating the expenditure and energy requirement on custard and porridge, we took into account the frequency of eating a desert. If a household consumes more desserts than average, the expenditure on custard and porridge is rised proportionally. The average expenditure on custard and porridge for all households is kept unchanged. Table 5-2 shows which information is known, and which consumption categories this information is assumed to affect. More than 50% of the average expenditure on food is affected in this way.

4.1.7 ► Determining the actual consumption pattern

To establish the actual energy requirement of the actual consumption pattern, we took the estimated standard consumption pattern, as described in section 4.1.1. We replaced the estimated expenditures and accompanying energy requirements of the six groups of consumption categories by the expenditures and accompanying energy requirement for the six categories, as calculated in sections 4.1.2 to 4.1.6. This results in the actual consumption pattern. This replacement resulted in an average rise in the total expenditure of about 5%[15]. For each respondent, we adjusted the expenditures and energy requirement for the remaining categories by multiplying the estimated expenditures and energy requirements for the remaining consumption categories by a factor to meet the initial expenditure plus the average rise of 5%[16]. On average, about 60% of all expenditures and 75% of the total household energy requirement is based on mainly physical information from the consumer survey.

15 Possible causes of this average rise are the high price rise for natural gas and electricity between 2000 (expenditure survey) and 2003 (the year of the consumption survey) and underestimations of the expenditures for these six categories according to the expenditure survey, or overestimations according to the consumer survey.

16 Taking into account the dependency of the average rise with the net income.

Table 5-2 Information from the consumer survey and the consumption categories affected.

Known information from the consumer survey (TNS-NIPO, 2003)	Information assumed to affect the consumption category / categories	Number of consumption categories	Annual expenditure in $euro_{2000}$ per household *
Number of times per week:			
- dinner is cooked at home.	- directly related to ingredients for cooking warm meals at home	46	1008
- dinner is delivered or consumed as take-away, in a restaurant, canteen or cafeteria.	- directly related to restaurants and snack bars etc.	4	633
- no warm meal is consumed.	- kinds of bread and sandwich filling	9	587
- dessert is consumed.	- custard and porridge	1	76
- wine is consumed.	- wine	1	145
- Dutch food is consumed at home.	- potatoes	1	55
- Chinese / Indonesian food is consumed at home.	- rice	1	11
- Italian food is consumed at home.	- pasta	1	11
- fish is consumed.	- fresh fish and frozen fish	2	34
- meat is consumed.	- all types of meat	10	343
- poultry is consumed.	- poultry	1	77
- vegetarian food is consumed.	- eggs and cheese	2	203
- pork is consumed.	- bacon and fresh pork	2	105
- veal and beef are consumed.	- fresh beef and fresh veal	2	77
- ready-to eat food is consumed.	- main course dishes, frozen/canned	1	66
- frozen vegetables are consumed.	- frozen vegetables	1	11
- canned or bottled vegetables are consumed.	- vegetables, canned or bottled	1	39
- fresh vegetables are consumed.	- all fresh vegetables	13	189
- ecologically grown fruit is consumed **.	- all fresh fruit	14	163
- ecologically grown vegetables are consumed **.	- all fresh vegetables	13	198
- ecologically produced meat is consumed **.	- all types of meat	10	342
- dairy products are consumed **.	- milk and yogurt	2	128

* According to the standard consumption pattern (see section 4.1.1).

** Only price differences between regular and ecological products are taken into account. We assume that ecologically grown vegetables are 25% more expensive, fruit 30% more expensive and meat 50% more expensive than traditionally grown vegetables, fruit and meat.

4.2 ► Calculating a reference energy requirement

To compare the energy requirement of a household with other households having the same socio-economic characteristics, we calculated a reference energy requirement. We based the reference energy requirement of a household on the socio-economic situation only. This reference energy requirement is chosen as, in most cases, the socio-economic situation cannot be easily changed by consumers themselves. We calculated the reference energy requirement using a multiple regression analysis. The four socio-economic variables which 'explain' most of the variance in the energy requirement (see above) are taken as independent variables[17]. The reference energy requirement can then be calculated according to equation (2).

$$E_{ref} = \mathrm{C} + (a * I) + (b * HHs) + (d * Age) + (e * Ed) \qquad (2)$$

C	=	Constant
E_{ref}	=	Reference energy requirement
I	=	Net household income, in €
HHs	=	HouseHold size, in number of persons
Age	=	Age of the breadwinner
Ed	=	Highest education of the breadwinner, in education level
a, b, d, e	=	parameters, depending on the reference energy requirement

To calculate a reference energy requirement for the six groups of consumption categories and the total energy requirement, we carried out stepwise regression analyses. The results of these analyses are presented in Table 5-3.

The explained variance of the total energy requirement is about 62%, comparable with the explained variance of the household expenditure survey of 2000 (CBS, 2002a). The explained variance is relatively small for natural gas, electricity, transport, holidays abroad and dwelling.

17 Adding an income elasticity in the equation, to take into account the power relationship between net income and the total energy requirement (see Vringer and Blok (1995), did not improve the models.

Table 5-3 The factors resulting from the stepwise linear regression analyses required for equation (2) to calculate the reference energy requirements and the explained variance for each regression analysis ($p<0.05$, ns = not a significant contribution in Equation (2)).

Reference energy requirement for:	Constant C	Factors a	b	d	e	Explained variance
- Natural gas	2007	0.32	4882	507	ns	0.11
- Electricity	10727	0.19	4682	100	-462	0.23
- Transport	57671	0.90	3489	-556	ns	0.10
- Holidays abroad	-4139	0.72	ns	ns	1703	0.09
- Dwelling	4244	0.05	624	35	114	0.18
- Food	-7775	0.71	2412	159	ns	0.56
- Remaining consumption categories	16921	2.41	-3081	ns	ns	0.59
Total	**46313**	**5.75**	**14853**	**471**	**ns**	**0.62**

5 ► Energy requirement and value patterns, motivation and problem perception

In this section we examine the differences in the energy requirement, which can be related to the values of consumers, their problem perception of energy-related societal problems and their motivation to save energy. To examine the difference in energy requirement, resulting from differences in the perception of energy related societal problems, we took the problem perception of climate change. Each comparison was corrected for the socio-economic situation of the households.

5.1 ► Energy requirement and value patterns

The value groups with a more individually oriented value pattern, e.g. the Hedonists, Conservatives and Materialists, are expected to use more energy, considering their socio-economic situation. Figure 5-2 shows the average energy requirement for all eight value groups, including the standard error of the mean. Two energy requirements are given for each value group: (I) the reference energy requirement, which can be expected in view of the average socio-economic situation of the group of households, and (II) the energy requirement due to the actual consumption pattern.

The differences between the total reference energy requirement and the total actual energy requirement are small; about 0 to 5 GJ (0-2% of the total energy requirement). To examine the significance of the differences between the reference energy requirement and the actual energy requirement, we calculated, for each respondent, the difference between the actual and reference energy requirement (ΔE). Figure 5-3 shows for the total energy requirement the average difference for each value group, including the standard error of the mean. A one-way ANOVA analysis[18] shows that the H0-hypothesis, "ΔE is equal for all value groups", cannot be rejected (95% significance level).

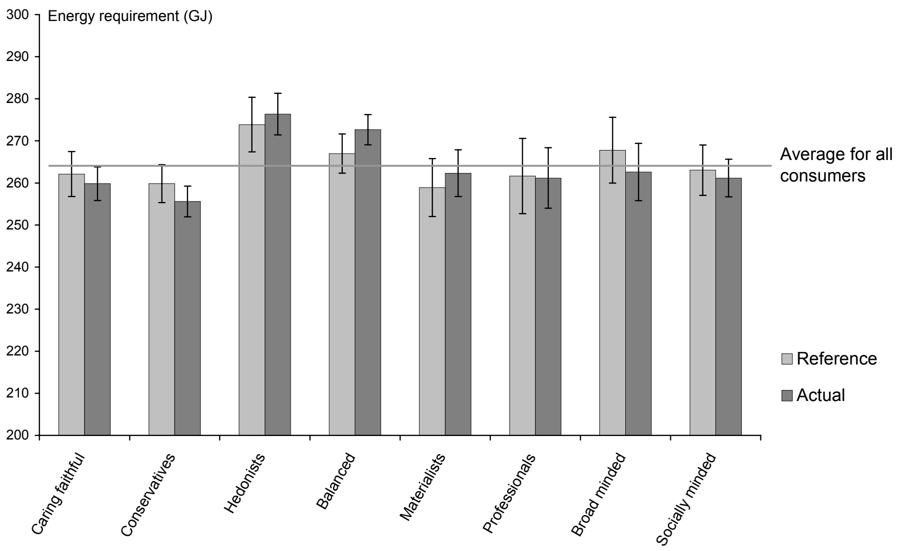

Figure 5-2 The total reference energy requirement and total actual energy requirement for the eight value groups, including the standard deviation of the mean[19]. Note that the vertical scale does not start at zero.

18 One-Way ANOVA is a one-way analysis of variance for a quantitative dependent variable by a single factor (independent) variable. Analysis of variance is used to test the hypothesis that several means are equal (Van der Berken and Voeten, 2002).

19 The standard deviation from the mean is calculated by dividing the standard deviation by the square root of N (here N varies between 190 and 497 depending on the value group). This implies that the error intervals in Figure 5-2 are equal to a reliability interval of about 67%.

Next, we carried out the same analysis for each of the six groups of consumption categories of which the energy requirement is based on individual (mainly physical) information from the households, which are: natural gas, electricity, transport, holidays abroad, the dwelling and food. Also we made an ANOVA analysis for the sum of those groups. The one-way ANOVA analyses for five of the six groups of consumption categories and the sum of these groups show that the H0- hypothesis, "ΔE is equal for all value groups", cannot be rejected (95% significance level). Only for dwellings can the H0-hypothesis be rejected. It is assumable that for at least one value group ΔE for dwellings differs from the others. A closer analysis shows that the Materialists require about 0.7 GJ (7% of the average energy requirement for the dwelling) more energy than average.

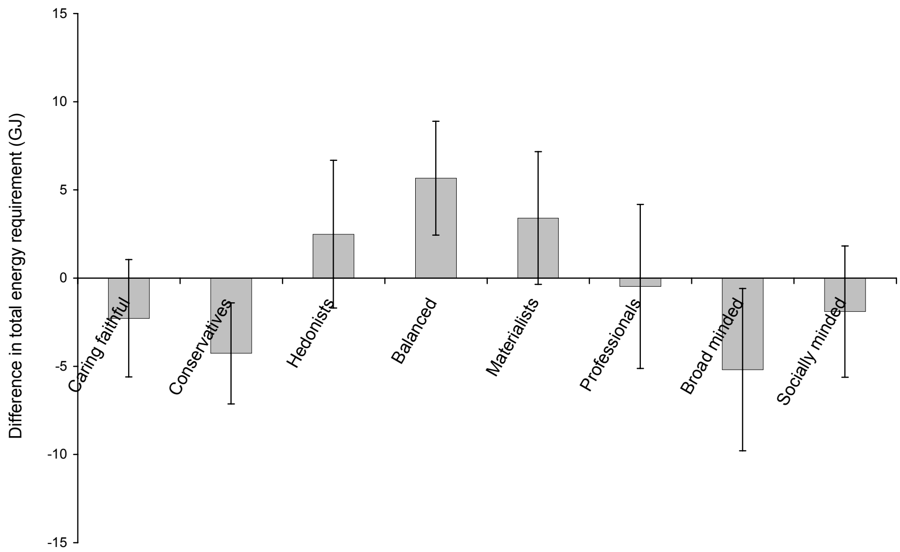

Figure 5-3 The difference between total reference and total actual energy requirement (ΔE) for the eight value groups, including the standard deviation of the mean.

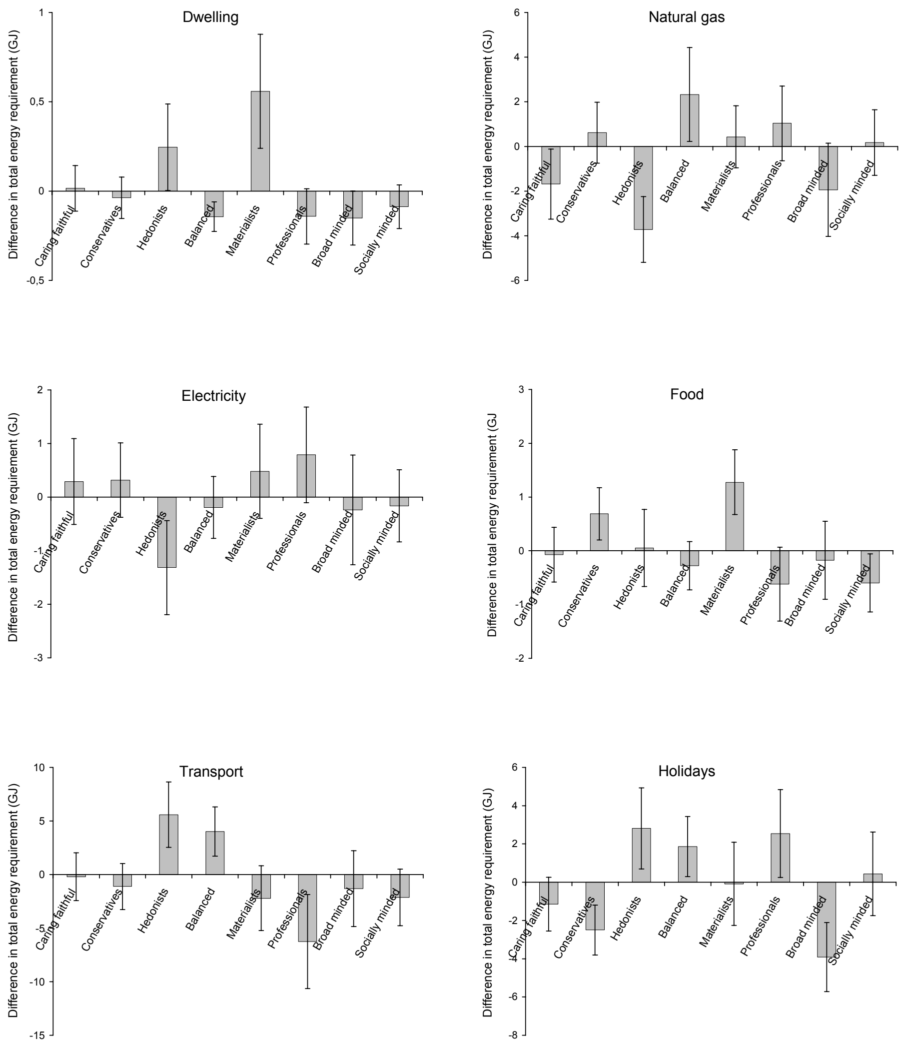

Figure 5-4 For all six groups of consumption categories the difference between reference and actual energy requirement (ΔE) for the eight value groups, including the standard deviation of the mean. Note that the vertical scales differ.

5.2 ► Energy requirement and problem perception for climate change

To obtain the consumer's perception of the importance of the environmental problems, we asked the respondents to rank 16 environmental societal problems in order of importance[20]. We found that climate change was one of the highest ranked environmental problems. We divided the respondents into three groups, one ranking the problem of climate change low (7th in priority or below), one ranking the problem high (at 3rd place or higher) and one with an average problem perception for climate change (at 4th, 5th or 6th place). Figure 5-4 shows the total average energy requirement for the three levels of the perception of the climate change problem.

We expect that consumers who ranked the energy-related problem 'climate change' high would require less energy. The differences between the total reference energy requirement and the total actual energy requirement are small at about 0 to 2 GJ (0-1% of the total energy requirement). To examine the significance of the differences between the reference energy requirement and actual energy requirement, we calculated, for each respondent, the difference between the actual and reference energy requirement (ΔE). A one-way ANOVA analysis shows that the H0-hypothesis, "ΔE is equal for all problem perception levels", cannot be rejected (95% significance level). We found the same result for the energy requirement of the six groups of consumption categories: natural gas, electricity, transport, holidays abroad, dwelling, food, and the sum of those groups.

20 The 16 environmental societal problems which had to be ranked are: (1) improvement in one's direct the living environment, (2) more nature in the Netherlands in future, (3) a better spatial organisation in the Netherlands in future, (4) fewer problems of noise in one's own neighbourhood, (5) no problems in the world of the future caused by the greenhouse effect, (6) no negative influence from genetically modified plants or animals on nature in the world of the future, (7) doing something about over-fertilisation in the Netherlands, (8) pre-existence of animals and plants by less deforestation worldwide in the future , (9) a decrease in the pollution of seas, rivers and lakes in the world of the future, (10) a better existence for the animals on Dutch cattle farms, (11) a decrease in air pollution in the Netherlands, (12) taking the environment into account in Dutch consumption, (13) cleaning polluted soil in the Netherlands, (14) raising the quality of public transport in the Netherlands, (15) more clean drinking water for developing countries in future, (16) reduction of the hole in the ozone layer in future. These 16 environmental societal problems were presented randomly to the respondents.

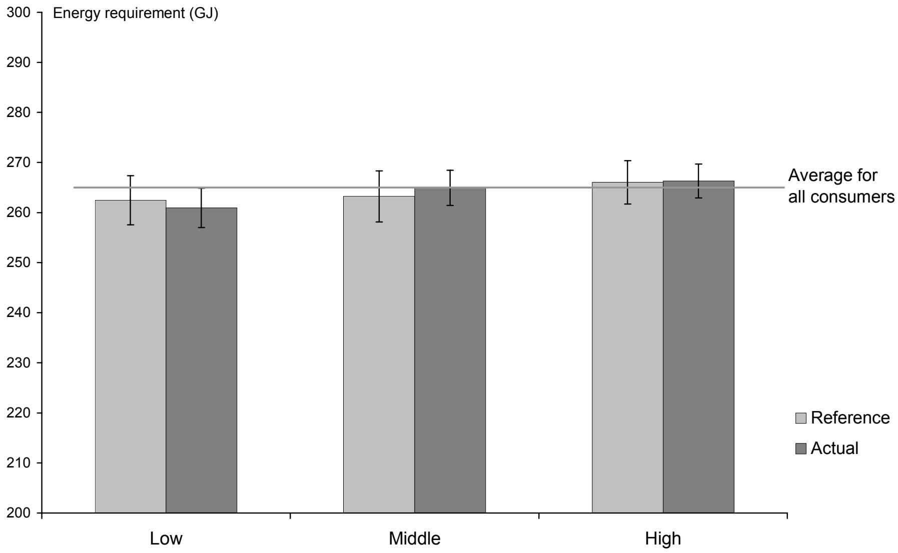

Figure 5-5 The total reference and total actual energy requirement for all three problem perception levels for climate change, including the standard deviation of the mean[21].

5.3 ► Energy requirement and the motivation to save energy

We used data from Kets et al. (2003) to examine the relationship between the energy requirement and the motivation of consumers. The respondents were asked to what extent they were willing to save energy on a 5-point scale, for nine different combinations of costs (higher, the same and less) and comfort (higher, the same and less). Hezemans (2005) made a one-dimensional scale from these nine combinations, which runs from a high willingness to save energy (willing to save energy, even though the costs are higher and the comfort is lower) to a low willingness to save energy (not willing to save energy even though the costs are less and the comfort is higher). We divided the respondents into three groups, one group with the least motivation, one with an average motivation and one with the most

21 N= 402 for the low, 344 for the middle and 526 for the high problem perception level group.

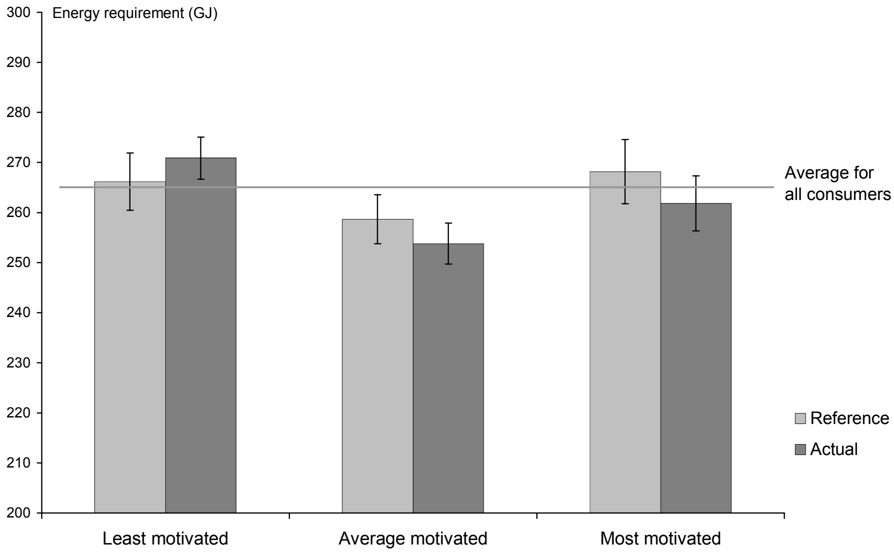

Figure 5-6 The total reference and total actual energy requirement for three different levels of motivation for saving energy, including the standard deviation of the mean[22].

motivation to save energy[23]. Figure 5-6 shows the average energy requirement for all three groups.

We expect consumers highly motivated to save energy to require less energy. The differences between the total reference energy requirement and the total actual energy requirement are about 5 to 6 GJ (i.e. 2% of the total energy requirement). To examine the significance of the differences between the reference and actual energy requirement, we calculated the difference between the actual and reference energy requirement for each respondent (ΔE). A one-way ANOVA analysis shows that the H0-hypothesis can be rejected. It is assumable that for at least one motivation level group ΔE differs from the others (95% significance level). A closer analysis shows

22 N= about 310 for all the three groups.

23 Most motivated: 33% of the respondents with the highest motivation level; least motivated: 33% of the respondents with the lowest motivation level; average motivated: 33% of the respondents between the highest and lowest motivation levels.

that the least motivated group requires about 10 GJ more than the average and most motivated group. Additional, we made one-way ANOVA analyses for the six groups of consumption categories, electricity, natural gas, transport, holidays abroad, dwelling, food, and for the sum of those groups. These analyses show that the H0-hypothesis, "ΔE is equal for all motivation levels", cannot be rejected (95% significance level)[24].

5.4 ► Conclusion

The one-way ANOVA analyses show that the difference between the actual and reference energy requirement (ΔE) is equal for nearly[25] all groups (95% significance level), taking into account the differences in the socio-economic situation of the households. The largest significant difference is found between the total energy requirement for the least motivated and average motivated group, which accounts for about 10 GJ or 4% of the total energy requirement.

6 ► Low- and high-energy households

As we have only found relatively small differences in the energy requirement that can be related to values, the perception of the societal problem of climate change or the motivation to save energy, there is still a large part of the variance in the total household energy requirement unexplained. To examine this unexplained variance here, we compare groups of households with either an extremely low or extremely high total household energy requirement. To define high- and low-energy households we first calculated the difference in energy requirement between the actual and the reference energy requirement. For each income-decile we defined a high-energy group (the 25% of the households with the highest actual energy requirement, compared with their reference energy requirement) and a low-energy group (the 25% of the households with the lowest energy requirement, compared

24 This result is consistent with the findings of Hezemans (2005) for electricity.

25 There are two exceptions: 1) For the value group 'Materialists' is the energy requirement for dwellings about 0.7 GJ (7%) higher than expected (according to the socio-demographic situation). 2) For the total energy requirement, the least motivated group requires about 10 GJ (4%) more than the average and most motivated groups

with their reference energy requirement). We examined the differences between the low- and high-energy households, relating to the societal problem of climate change and the motivation of these households to save energy. As the net income is by far the most important parameter, we made the analyses for two income groups[26]. The average socio-economic situation does not differ within the same income group. We found only a small difference[27] in the urbanisation level; the low-energy households live in a less urbanised area than the high-energy households.

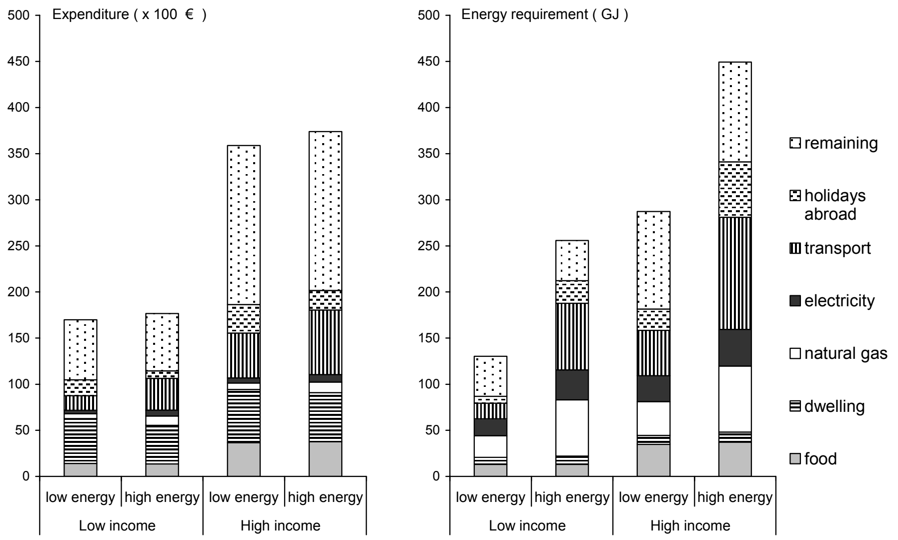

Figure 5-7 Expenditures and energy requirement for low- and high-energy and for low- and high-income households.

Figure 5-7 shows the expenditures and energy requirement for low- and high-energy households, and for low- and high-income groups. The high-energy households require 50% (high-income) to 100% (low-income) more energy than the low-energy

26 We defined the low-income group as the 30% of households with the lowest net household income and the high-income group as the 30% of households with the highest net household income.

27 The urbanisation level differs about 0.5 level on a 5-level scale. This is equal to the difference between a strong and moderate level of urbanisation.

households, while the expenditure is only about 4% higher for the high-energy households.

The high-energy households require two (high-income) to four times (low-income) more energy for *transport* than the low-energy households[28]. The low-income high-energy households more often have a car, while the high-income high-energy households more often have a second car. The high-energy households drive two (high-income) to four times (low-income) more kilometres and use the car more for commuting between home and work. The distance between home and work is about twice as large for the high-energy households as for the low-energy households. Besides commuting between home and work, the high-energy groups also use the car more for daytrips or nights out. More frequently, they motivate their use of the car as being more comfortable or mention a lack of alternatives in which costs are less important.

For *holidays* abroad the high-energy households require two (high-income) to three times (low-income) more energy. The high-energy households travelled about four times more than the low-energy ones. High-energy households require twice the energy of low-energy households for accommodation, while their expenditure on this is 50% lower. Mobile home ownership is higher for the high-energy households.

The high-energy households require 10% (high-income) to 20% (low-income) more energy for the *dwelling*. The high-energy households more often own a dwelling which is relatively older, more often (semi-)detached and 10 to 15% larger.

High-energy households require 70% more energy for *natural gas and electricity* than low-energy households. They also have about 10% more kinds of electrical equipment and more energy-intensive equipment like electrical driers and dishwashers. No differences are found between the low- and high-energy households for the possession of energy-saving light bulbs (compact fluorescent lamps) and the purchase of 'green electricity'. However, most of the households, who report buying green electricity, motivate their choice with arguments that green

28 Remember that doubling the energy requirement for high-income households results in a higher energy requirement than quadrupling the energy requirement for the low-energy households.

electricity helps to diminish the greenhouse effect (60%) and benefits the environment (75%). This means that they are aware of the consequences of using energy.

In comparison with the low-energy households, the high-energy households do not require more energy for food.

The comparison of the low-energy households with the high-energy households did not result in significant differences in the order of importance of the two lists of the 18 values, nor the problem perception of climate change. The motivation to save energy differed slightly. We found a difference of 0.7 on a scale from 9 to 45 (see Hezemans, 2005). This difference is not significant (p=0.05). However, if this difference was significant and if motivation plays a role in saving energy, we expected a much larger difference for households using such a different amount of energy.

7 ► Discussion

We first discuss some of the aspects arising from the consumer survey and the calculated household energy requirement. This is followed by a discussion of the results.

► The consumer survey

- Studies where the relationship between behaviour, on the one hand, and values, motivation, etcetera on the other, are examined with the help of surveys. *Socially acceptable answers* may introduce a bias in the results. Social acceptability can play a role where respondents are ashamed to give an answer that is not socially acceptable. This effect is avoided as much as possible to guarantee anonymity to the respondents; besides they were allowed to fill in the questionnaires at home, without the presence of an interviewer. Furthermore, our questions were also divided over five separate questionnaires and the respondents did not know that the five questionnaires would be combined later on. The time between two questionnaires varied from two weeks to several months. It was impossible for the respondents to deduct our final research questions, which played the greatest role in the two questionnaires on consumption pattern. The absence of any relation between values, problem perception, motivation and total energy requirement (the actual behaviour) underlined that socially acceptable answers do not play any role in this study.

- The consumer survey contains *only data from the breadwinner* or her/his partner, while the consumption pattern concerns the whole household, where more persons can be active. In presenting the results, we implicitly assume that the value pattern, the problem perception of environmental problems and the motivation of the breadwinner or her/his the partner to save energy were comparable with the other household members. However, there is one group available in the dataset where this problem did not occur: the one-person households. For the one-person households we found results which are comparable with those for the whole population.

► The calculated energy requirement

- To calculate the *reference energy requirements* we used a stepwise linear regression analysis. However, for some groups of consumption categories, the explained variance in the energy requirement is fairly small. An alternative reference for the energy requirement might give other results than obtained to date. In our additional analysis, where the standard consumption pattern based on comparable households was chosen as an alternative reference (section 4.1.1)[29], the results of the additional analyses with the alternative references were comparable with the results we found earlier. This happened regardless of the number of similar households (5, 10, 25 or 50) we used to calculate this reference.
- In calculating the *actual total household energy requirement,* about 75% of the total energy requirement is based on individual information on consumption of the respondents. The remaining 25% of the energy requirement is estimated. The remaining consumption categories are based on the average expenditure and energy requirement from the 10 most similar households taken from the household expenditure survey. Because we do not know whether the values, problem perception and motivation to save energy are equally distributed over these 10 households, we cannot draw any conclusions about a possible relation between the energy requirement due to the remaining consumption categories, on the one hand,

29 Disadvantage of taking the estimated consumption pattern as reference is that the estimated consumption pattern is based on only a few (5 to 50) similar households. We do not know whether all value patterns, levels of problem perception and levels of the motivation to save energy are equally distributed over the similar households.

and the value patterns, the motivation to save energy or the perception of the societal problem of climate change, on the other.

► Results

- In their survey, based on just a few questions, Gatersleben et al. (2002) estimated the energy requirement of their respondent households. They also measured the level of pro-environmental behaviour of the respondents. Our results, based on a much more precise estimation of the household energy requirement, are in line with those of Gatersleben et al. (2002), who found that respondents indicating a more pro-environmental behaviour do not necessarily have a lower total energy requirement. Also Hezemans (2005) did not find any relationship between value patterns, the motivation to save energy and the use of electricity. The absence, or at least the presence, of a weak relationship between values, problem perception, motivation and total energy requirement can be explained by the presence of a social dilemma. Antonides and Van Raaij (1997) mention the conflict between thinking in an environmental way and not doing so, due to a conflict between short-term individual interests and collective long-term interests. In the response to the consumer survey we observed that most of the respondents thought that not they, themselves, but others (with an emphasis on the public authorities), should come up with the solution to the most important societal problems, thus supporting the existence of a social dilemma. We also found that both the low- and the high-energy households from the consumer survey think that a climate policy should best be started without further delay. More research will be required to find out why people do not consume according to their values, problem perception, or motivation to save energy. However, this does not answer the question on why comparable households differ so much on their consumption patterns, with a large difference in total energy requirement as result.

8 ► Conclusions

Households in the same socio-economic situation can differ largely in their total energy requirement. Despite a detailed calculation of the energy requirement of individual consumption patterns we could not find that the energy requirements of one of the groups examined for value patterns or problem perception level of climate change significantly differed from the rest, taking into account the differences in the

socio-economic situation of households. Only for the motivation to save energy we did find that the difference between the total energy requirement for the least motivated and average motivated group, amounts about 10 GJ; this is about 4% of the total energy requirement.
We can conclude that the lack of a relation between the total household energy requirement and value patterns of consumers or their problem perception of climate change or their motivation to save energy, will mean that a self-regulating energy policy, solely based on a strategy of internalising environmental responsibility, will not be effective in saving energy. There are indications that the social dilemma is one of the reasons why people do not consume according to their value patterns, problem perception or motivation to save energy.

► Acknowledgements

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Chapter 6

Long-term trends in direct and indirect household energy intensities: a factor in dematerialisation?[1]

► Abstract

Dematerialisation is assumed to contribute significantly to the alleviation of environmental problems. One of the possible causes of dematerialisation is a change in the consumption patterns of households. The aim of this chapter is to analyse changes in the consumption patterns of Dutch households in the period between 1948 and 1996 to discover whether these changes have influenced the energy intensity of society. The rise in consumption has caused the total household energy requirement per capita to increase by an average of 2.4% per year over a period of 48 years (this figure ignores efficiency changes in the supply sectors). In the same period the total energy intensity of households fluctuated but, on average, did rise from 5.6 to 6.3 MJ/Dfl., representing an increase of 0.25% per year. Excluding the direct energy consumption, we find only a slight decline in the indirect energy intensity, namely, from 3.8 to 3.6 MJ/Dfl. (-0.14% per year). No significant trends towards a lower energy intensity were found; neither was there any indication of dematerialisation of the consumption patterns. If governments are to pursue a policy of sustainable development they will have to take into account the fact that dematerialisation of the consumption pattern does not seem to be an autonomous process.

1 This study is a slightly adapted version of Vringer, K. and Blok, K. 'Long-term trends in direct and indirect household energy intensities: a factor in dematerialisation?', *Energy Policy*, 28 (2000): 713-727.

1 ► Introduction

In the past decade various analysts have focused on the phenomenon of dematerialisation. Dematerialisation can be defined as ‘the reduction in the raw material (energy and material) intensity of economic activities, measured as the ratio of energy consumption in physical terms to the gross domestic product (GDP) in deflated constant terms’ (Bernardini and Galli, 1993). There was a reduction in the raw material and/or energy intensity with respect to various materials, e.g. crude steel, copper and zinc, in world regions with a level of GDP per capita higher than US$2000 (Bernardini and Galli, 1993). The reduction was also observed for energy consumption in most countries (Nakicenovic and John, 1991; IEA, 1997).

Dematerialisation is assumed to contribute significantly to the alleviation of environmental problems or to contribute at least to the easing of conflicts between the economy and the environment (Wieringa et al., 1992). If the process of dematerialisation is so important, more should be found out about its underlying causes. Wieringa et al. (1992) suggest some possible causes of dematerialisation:

- changes in the composition of products (more emphasis on quality and design);
- changes in consumption patterns (from material-intensive to labour-intensive products and services);
- technical developments (leading towards more efficient use of energy and materials) and
- changes in the import/export structure (these changes can only cause a regional change in the material intensity, but not a worldwide change).

Not much is known about the importance of each of these factors for dematerialisation at national level. Studies have shown that technical developments play a role in the decrease in energy intensities: the specific energy consumption of many activities in industry, buildings and transport has decreased in many countries (e.g. Schipper and Meyers, 1992; Eichhammer and Mannsbart, 1997; Farla et al., 1997; IEA, 1997; Farla et al., 1998).

In this chapter we focus on one of the other causes: changes in consumption patterns. Consumption patterns of households are to a large extent decisive for the total requirement for goods and services and hence the activity levels of economic sectors. The aim of this chapter then is to examine whether past changes in consumption patterns have influenced the dematerialisation of society. We will limit ourselves to one important resource, energy. The question is therefore whether changes in household consumption patterns have led to decreasing energy intensity in society. We will investigate this by studying the effect that changes in household consumption patterns in the Netherlands have on the life cycle energy requirement (embodied energy) of the products and services consumed by households.

Here, we first describe the method, data sources and the way of calculating the total energy requirement of households. This will be followed by the results concerning general trends, the direct, indirect and total household energy requirements and the energy intensity of household consumption. We will draw some conclusions after discussing the quality of the results.

2 ► Method and data

We start by discussing the definitions of the most important concepts and will follow this with showing how the direct and indirect (cumulative) energy requirements of households are determined. We define:

- *Direct household energy requirement*, as the total primary energy required to produce the energy carriers which households consume (petrol, electricity, natural gas and heat).
- *Indirect household energy requirement*, as the total primary energy required to produce all the other products and services which households consume.
- *Total household energy requirement*, as the sum of the direct and indirect household energy requirements.
- *Energy intensity* of a product, as the total primary energy requirement of the product divided by the consumer price of the product (incl. VAT). The energy intensity is expressed in MJ/Dfl.[2]. In the same way the energy intensity of a group of products or the energy intensity of all household expenditures can be calculated (Vringer and Blok, 1995).

2 All monetary quantities are expressed in Dutch guilders (Dfl.) of 1995. One Dfl. is about 0.45 Euro or 0.6 US$ (1995).

If both the expenditure and the energy intensity of all the consumption categories are known, the total household energy requirements can be calculated according to the following equation:

$$E = \sum_{i=1}^{n} \varepsilon_i * S_i$$

where:

E = total household energy requirement

ε_i = energy intensity of consumption category *i*

n = number of consumption categories

S_i = expenditure on consumption category *i*

To calculate the total energy requirement for a specific year we need to have both expenditure and energy intensity data for that year:

$$E_t = \sum_{i=1}^{n} \varepsilon_{i,t} * S_{i,t}$$

in which the suffix *t* denotes that data are valid for a specific year *t*.

However, we are specifically interested in the changes in the energy requirement caused by a shift in the consumption package. To investigate these changes, we used fixed energy intensities *frozen at the1990 level*. By doing so, we exclude energy intensity changes (probably mainly efficiency improvements) of the supply sectors (industrial, transport and distribution) from the analysis. The energy requirement with energy intensities frozen at the level of 1990, can be calculated according to the following equation:

$$\hat{E}_t = \sum_{i=1}^{n} \varepsilon_{t,1990} * S_{i,t}$$

in which $\hat{E}_t$ is the total energy requirement of households at fixed 1990 energy intensities. The data for the energy intensities of 1990 are available from a previous study (Vringer and Blok, 1995). The sources needed for the annual expenditure data are described in the next section and the expenditures given per household. The total energy requirement can be expressed for all households or per capita[3].

In time-series analysis it is important to correct for climate fluctuations. The household energy requirement for heating (assumed to be 85% of the requirement of natural gas, coal and fuel oil[4], Zonneveld, 1993) is multiplied by a climate correction factor. We calculated this factor by dividing the specific number of degree days for the year concerned by the average annual number of degree days between 1945 and 1993 (Sypkens-Smit, 1993; Farla, 1997).

3 ► Expenditure data

For the time-series of the household expenditure data, we used two sources providing the average expenditure of a Dutch household for two different periods.

For the 1980-1996 period we used the 'Household Expenditure Surveys' as our source for the expenditure data. The Household Expenditure Surveys, compiled annually from 1980 to 1996, are based on annual surveys among a representative sample, and vary from about 1000 to 3000 Dutch households. The published time-series of the expenditure surveys give the average annual total consumption of Dutch households divided into 73 consumption categories[5]. Since 1992 Statistics Netherlands has a new definition of expenditure[6]. We have recalculated the

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3 To make these conversions we used data for the average number of household members as given by Teefelen (1994) and the total number of households as given by CBS (1991) for the years 1960 to 1988 and CBS (1990-1993) and CBS (1992-1997) for the years 1989 to 1996. For the 1948 to 1959 period, no data on the number of households in the Netherlands were available (CBS, 1991, so number of households had to be linearly extrapolated, using the total number of households in the Netherlands in 1947 according to CBS (1994).

4 The climate influence on the (small) consumption of fuel oil is ignored for 1948 to 1955 and 1969 (based on the old classifications) because of lack of information concerning the breakdown between fuel oil and petrol.

5 The expenditure surveys contain about 350 consumption categories, but for the full period from 1980 to 1996 only data for 73 categories were available. The expenditure data are extracted from CBS (1992-1997).

6 According to the definition of expenditure after 1992, subscription fees, examination and licence fees, donations, property taxes and sub tenancy are included in the household expenditure of the expenditure

expenditure according to the expenditure definition from before 1992. To eliminate the influence of price changes, the expenditure according to the annual surveys was converted to constant prices for 1990 by using (CBS, 1985-1997). The consumption categories from the expenditure surveys do not correspond exactly to the consumption categories of the price statistics. If two or more categories of the price statistics correspond to one category from the expenditure surveys, we calculate the price index from several subcategories, taking into account the share of each sub-category. The price index numbers from 1980 to 1985 are valid for households with employees and an income below the wage limit for the compulsory national health insurance. The price index numbers from 1986 to 1996 are valid for the entire population. We ignored this definition difference, assuming the price index numbers from 1980 to 1985 to also be valid for the entire population.

For the period from 1980 to 1996, the expenditures on natural gas and electricity are given not only in monetary units, but also in physical quantities (m^3 natural gas and kWh electricity) (Teefelen, 1994; Pelsers, 1998). We used the latter data to calculate the direct energy requirement using fixed conversion factors from Vringer and Blok (1995). More detailed information on the expenditure surveys can be found in Vringer and Blok (1995) and in Vringer et al. (1997).

For the 1948 to 1988 period we used the ‘Private consumption expenditure and price index numbers for the Netherlands 1921-1939 and 1948-1988’ (CBS, 1991) as our source for expenditure data. This publication is based on the Dutch National Accounts, which, in turn, are based mainly on the statistics for the retail trade sales (Buiten, 1993a). The National Accounts give the annual total consumption (in constant prices) for the Netherlands, divided into 96 consumption categories (CBS, 1991). The price index numbers from CBS (1991) are converted to comparable price index numbers of 1990 with the help of price index numbers from CBS (1985-1997).

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surveys. The household expenditure figures used in this chapter exclude the expenditure of these categories. We made no adjustments for changes in expenditure on medical care due to definition changes.

There are systematic differences between the National Accounts and the expenditure surveys (Buiten, 1993b)[7]. The classification of goods and services also differs for the period before and after 1969. To facilitate a comparison between the time-series from 1948 to 1988 and the time-series from 1980 to 1996, we excluded three categories from the 96 consumption categories in the National Account data that are also excluded from the expenditure survey (see Appendix 6A). In spite of these adjustments, the results based on the National Accounts cannot be compared, pure and simple, with the results based on the expenditure survey. The difference in the total expenditure is still about 10%.

We matched the detailed energy intensity figures from Vringer and Blok (1995) with the categories from the expenditure surveys for both data sources. For the expenditure surveys, this is just straightforward aggregation, based on the 1990 consumption breakdown. The matching for the National Accounts data is described in Appendix 6A.

4 ► Results

We will first discuss the general trends and the development in consumption, followed by total, direct and indirect household energy requirements, given per household and per capita. Finally, the changes in the energy intensity of the total consumption package will be quantified.

In this section, all household energy requirements and energy intensities and their changes exclude effects of energy efficiency improvements in the supply sectors and changes in consumer-product characteristics, i.e. at fixed 1990 energy intensities for each category.

7 The total expenditure according to the expenditure surveys for the years 1988 and 1989 is about 16% lower than the total consumption according to the National Accounts. This 16% can be explained mainly by definition differences (Buiten, 1993b).

4.1 ► General trends

Before attempting to interpret the trends in the energy requirements and energy intensities of households, we will need to overview some general trends. Figure 6-1 shows trends in the population, number of households, total household expenditure, GNP at constant prices (Kattevilder, 1998) and the total Dutch primary energy requirement (CBS).

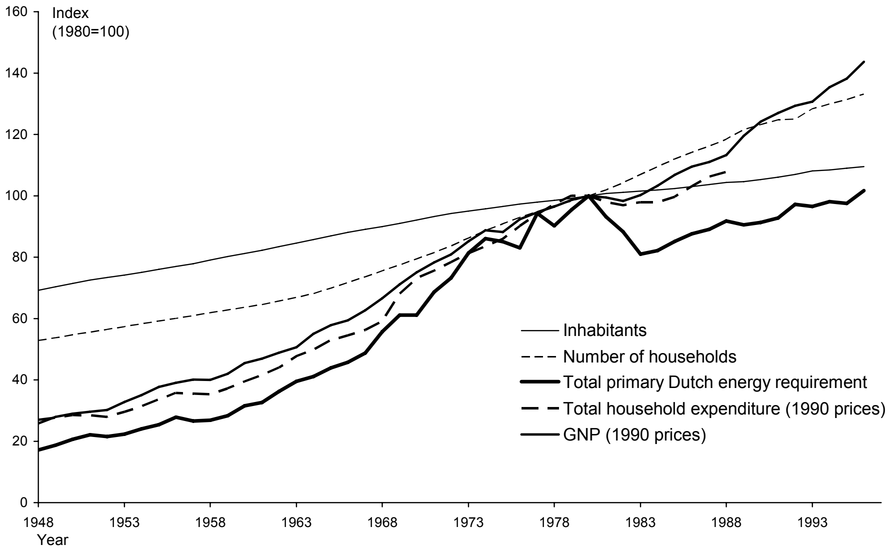

Figure 6-1 Inhabitants, total number of households, total primary Dutch energy demand (CBS)[8], total household expenditure and the GNP in constant guilders for the Netherlands.

Figure 6-1 shows that the number of households grew by a factor of 2.5 (1.9% per year) between 1948 and 1996. In this period the number of inhabitants grew by a factor of 1.6 (0.9% per year). The total household expenditure, converted to constant prices, for all Dutch households grew by about a factor of 4 between 1948 and 1988 (3.4% per year). The total Dutch primary energy requirement also grew rapidly (by a

8 Mind that the total primary Dutch energy demand (according to the conventional definition) is not comparable to the ‘total Dutch household energy requirement’ that will be presented later. For example, Dutch households consume products from abroad, while the Netherlands industry produces for consumers abroad.

factor of 5 between 1948 and 1988, i.e. 4% per year). The growth of the GNP (at constant prices) was about as large as the growth of the total household expenditure.

4.2 ► Development of consumption

In Figure 6-2 the development of the household expenditure per capita is shown for the period from 1948 to 1988, divided into the main consumption categories. The period after 1988 is not shown because of the incompatibility of the main consumption categories of the National Accounts with the expenditure surveys (see also the section, 'Expenditure data').

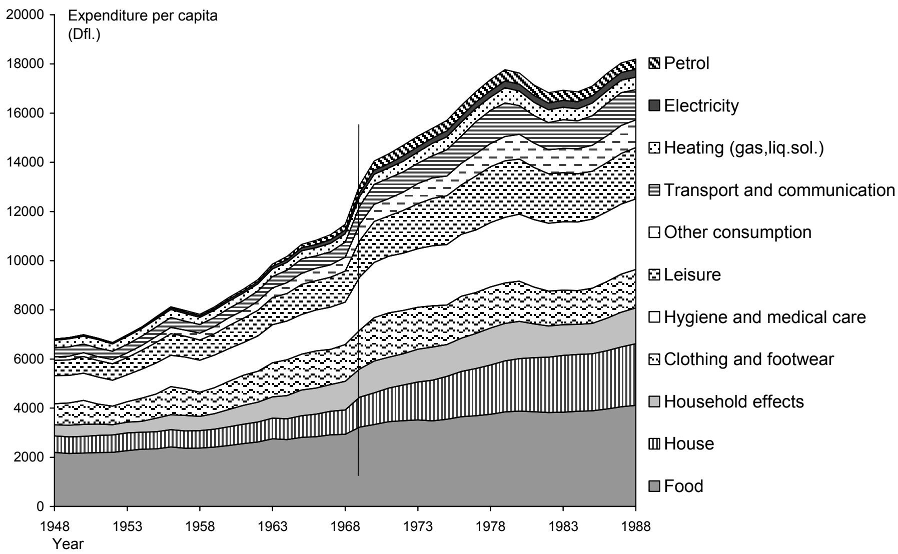

Figure 6-2 Annual expenditure (at 1990 prices) per capita from 1948 to 1988, divided into the main consumption categories. The vertical line marks the start of the new category classification introduced by CBS.

Expenditure per capita at constant prices more than doubled in the period from 1948 to 1988. Expenditure on the direct energy consumption of households (petrol, heating and electricity) varied between 5% and 8% of the total expenditure. Between 1948 and 1988 the average growth rate of household expenditure per capita was 2.4% per year. The growth rate before 1973 (3.1% per year) was more than twice the growth rate from 1973 to 1988 (1.4% per year). Between 1955 and 1973 'petrol' showed the largest growth rate (about 15% per year). The most rapid 'growers' besides 'petrol' (about 7% per year) in the whole 1948 to 1988 period were 'electricity' (about 5% per year) and the 'house' (about 3% per year). The slowest 'growers' were 'heating', 'food' and 'clothing and footwear' (about 1.5% per year).

4.3 ► Total household energy requirement

Here, we will focus on the total household energy requirement per household and per capita. Figures 6-3 and 6-4 show the total average household energy requirement per capita and per Dutch household for the 1948 to 1996 period. The household energy requirement levels for the two expenditure data sources differ by about 10%. The annual household energy requirements from 1980 to 1988 are given for both expenditure sources to check the compatibility of the results based on the expenditure surveys and the National Accounts. The 10% difference in the energy requirement level is about the same for all the years between 1980 and 1988. The definition and classification changes made by Statistics Netherlands in both

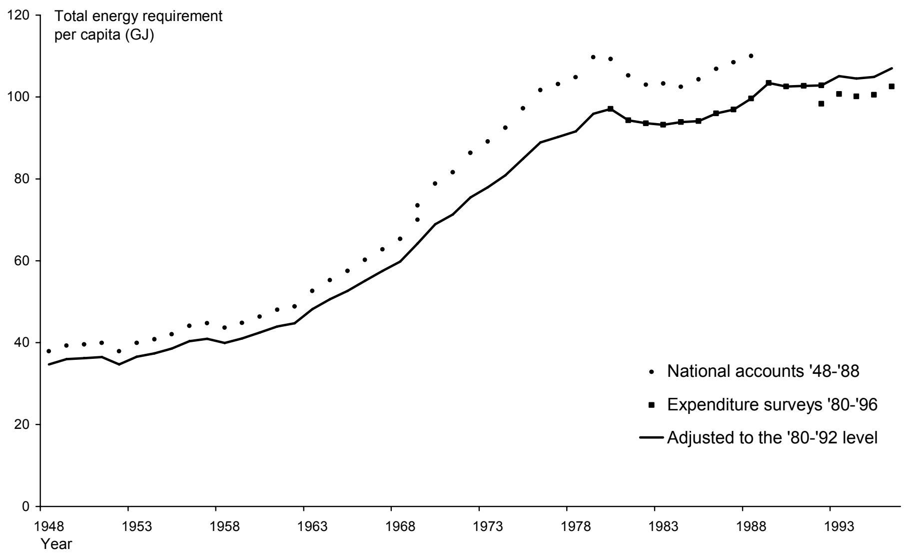

Figure 6-3 The total energy requirement per capita for the period from 1948 to 1996, calculated with fixed energy intensities for 1990.

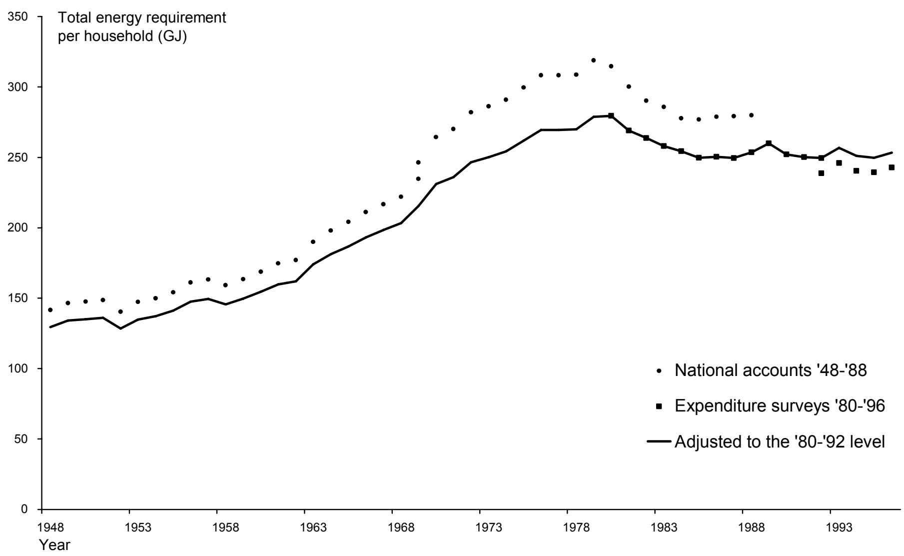

Figure 6-4 The total energy requirement per household for the period between 1948 to 1996, calculated with fixed energy intensities of 1990.

expenditure sources (one in 1969 and one in 1992) also led to differences in the energy requirement level.

We fitted a line in Figures 6-3 and 6-4 for the total time-series from 1948 to 1996 at the 1990 level. Two values of the energy requirement, based on different sources of definitions, could be calculated for three different years (1969, 1980 and 1992). The figures for the 1948 to 1979 period, and the period between 1993 and 1996, are multiplied by such a factor so that a continuous time-series is obtained. We assume the fitted line to be the best approach to describing the effect that changes in the household consumption pattern have on the total household energy requirements in relative terms. Between 1948 and 1996, changes in the household consumption patterns led to an average growth of 3.4% per year in the total energy requirement of Dutch households. This is 1% more than the increase in the energy requirement per capita (on average 2.4% per year) due to the rise in the number of inhabitants.

The total energy requirement per household grew between 1948 and 1979, declined from 1979 to 1985 and stabilised after 1985. The 1% difference in the development of the total energy requirement per household (on average + 1.4% per year) and percapita is due to the decrease in the number of members per household from 3.7 persons per household in 1948 to 2.3 in 1996.

4.4 ► Direct energy requirement

Figure 6-5 shows the cumulative direct household energy requirement per capita, divided into several fuel types for the 1948 and 1988 period. In 1988 the direct household energy requirement per capita was 3.7 times higher than in 1948, a growth of 3.1% per year. Between 1948 and 1963 the direct household energy requirement per capita was quite stable, but grew rapidly between 1963 and 1976 (about 8% per year). Between 1980 and 1985 the direct energy requirement per capita decreased and after 1985 it increased slightly again.

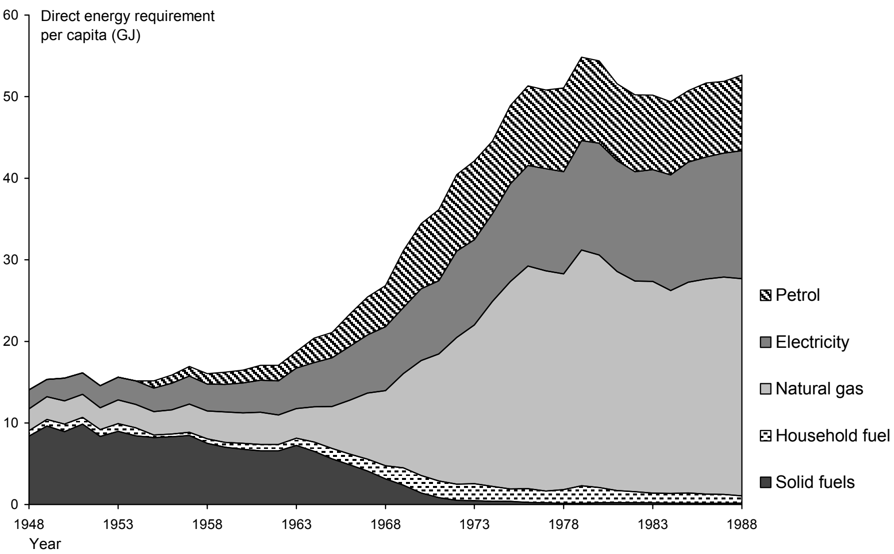

Figure 6-5 Direct energy requirement (in terms of primary energy) by households per capita for the 1948 to 1988 period.

Coal, the most important household fuel in 1948, almost ceased in use in 1973, whereas the use of natural gas grew rapidly from 1966 to 1976. After 1976 the use of natural gas stabilised. The use of petrol grew rapidly from 1964 to 1972 and stabilised after 1972.

Of all the important energy carriers, electricity showed the fastest growth in use by households between 1980 and 1988. Vringer et al. (1997) found these trends to continue for the 1990 to 1995 period: the demand per capita for natural gas and petrol stabilised, while the demand per capita for electricity grew. The driving forces related to growth in the direct energy requirement for both heating the house and electricity consumption will be further examined.

The doubling of the energy requirement per capita for heating seen between 1948 and 1995 represents the net effect of a higher living standard (heating more rooms, a higher average temperature indoors and fewer persons per house) and efficiency improvements (better insulation and more efficient heating equipment). This increase in consumption of fuel for space heat per capita is explained by the following four factors:

- the surface area of the average Dutch house did not change significantly between 1959 and 1995 (Wolbers, 1996).
- the number of household members fell from 3.7 to 2.3, amounting to a rise in available surface area per person of a factor of 1.6 in this period.
- the energy requirement per square metre was halved between 1950 and 1995 due to energy efficiency improvements realised in this period (Nijland and van Delft, 1999).
- the fraction of the heated space in the house increased.

Between 1980 and 1996 the household electricity consumption per capita rose by about 20% (Weegink, 1997). The higher electricity consumption per capita is the net result of a higher penetration and energy efficiency improvements in electrical equipment. Without the energy efficiency improvements realised between 1980 and 1996, the electricity consumption in 1996 per capita would have been about 50% higher (about 7 to 8 GJ) due to a higher penetration of electrical equipment (Boonekamp and Jeeninga, 1999).

4.5 ► Indirect energy requirement

In 1990 about 54% of the total energy requirement of households is indirect (Vringer and Blok, 1995). Figure 6-6 relates to the period, 1948 to 1988, and shows the cumulative direct household energy requirement per capita divided into several consumption categories[9].

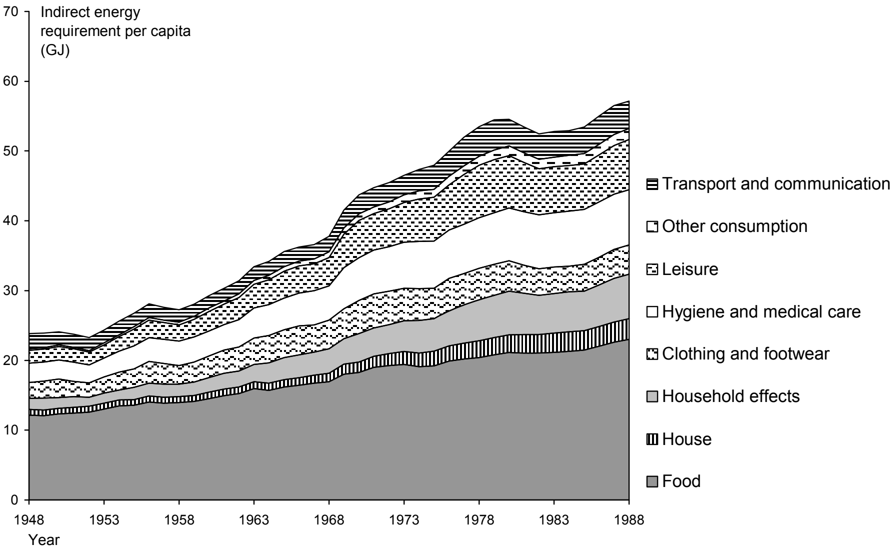

Figure 6-6 Indirect energy requirement per capita divided into main consumption categories, calculated with fixed energy intensities for 1990.

In 1988 the indirect energy requirement per capita was 2.4 times higher than in 1948, a growth of 2.2% per year. The energy requirement grew for all the consumption categories. The energy requirement for food is the largest of all the indirect consumption categories. In 1948 about half the indirect energy requirement was needed for food. Although this share had shrunk by 1988, it was still 40% of the indirect energy requirement. Growth in this category and other categories like 'clothes' and 'transport and communication' was about 1.3 to 1.6% per year. The

9 The period after 1988 is not shown because of the incompatibility of the main consumption categories of the National Accounts and the expenditure surveys (see also the section, 'Expenditure data').

energy requirement for the consumption categories, ‘leisure’, ‘house’ and ‘household effects’ grew by about 3.2% per year.

4.6 ► Energy intensity

Up to now we have reported on the development of the direct and indirect energy requirement in absolute terms. We will now discuss the energy intensity of household consumption, i.e. the energy requirement relative to household expenditure:

$$\varepsilon_{total} = \frac{\hat{E}_{total}}{S_{total}} \qquad \varepsilon_{indirect} = \frac{\hat{E}_{indirect}}{S_{indirect}}$$

In which:

ε_{total} = energy intensity of the total consumption
$\hat{E}_{total}$ = total household energy requirement at fixed energy intensities
S_{total} = total expenditure
$\varepsilon_{indirect}$ = energy intensity, excluding direct energy requirement.
$\hat{E}_{indirect}$ = indirect household energy requirement at fixed energy intensities
$S_{indirect}$ = expenditure, excluding expenditure on direct energy requirement

Figure 6-7 shows the development of the total and indirect energy intensity of household expenditure for the 1948 to 1996 period. In the 1948 to 1996 period the total energy intensity of households fluctuated, but did increase from 5.6 to 6.3 MJ/Dfl. (about 0.25% per year on average). If we exclude the earlier discussed energy efficiency improvements for heating the house and for electrical equipment, the total energy intensity in 1996 would have been at least 25% (about 1.7 MJ/Dfl.) higher.

The changes in the total energy intensity can be explained mainly by changes in the ratio between direct and indirect energy. The energy intensity of energy carriers is typically a factor of 12 higher than the other consumption categories. Hence,

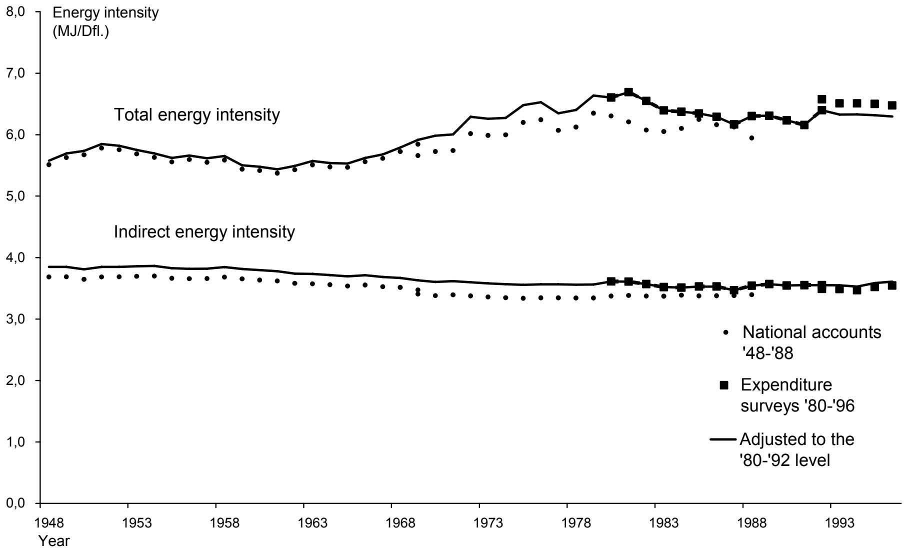

Figure 6-7 Total and indirect energy intensity for the time-series from 1948 to 1996 calculated with fixed energy intensities for the individual consumption categories. The results for both expenditure surveys are given, as well as those adjusted for the level of the 1980 to 1992 period (continuous line).

changes in the ratio have a strong effect on the total energy intensity. The share of the direct energy requirement grew from 1962 to 1975 and shrunk slightly between 1975 and 1991, see Figure 6-8. This development is fairly similar to the development in total energy intensity.

The indirect energy intensity was quite stable from 1948-1996, except for a slight decline in the indirect energy intensity. If the annual energy intensities for the different data sources are adjusted to the indirect energy intensity level for the 1980 to 1992 period, we find a decline of only 0.14% per year. The relative decrease in expenditure on food (which is fairly energy intensive) is the main cause of this reduction. Further examination shows that within the main consumption categories (food, clothing, etc.) themselves, the energy intensities hardly change. These changes play a minor role in the total change in energy intensity.

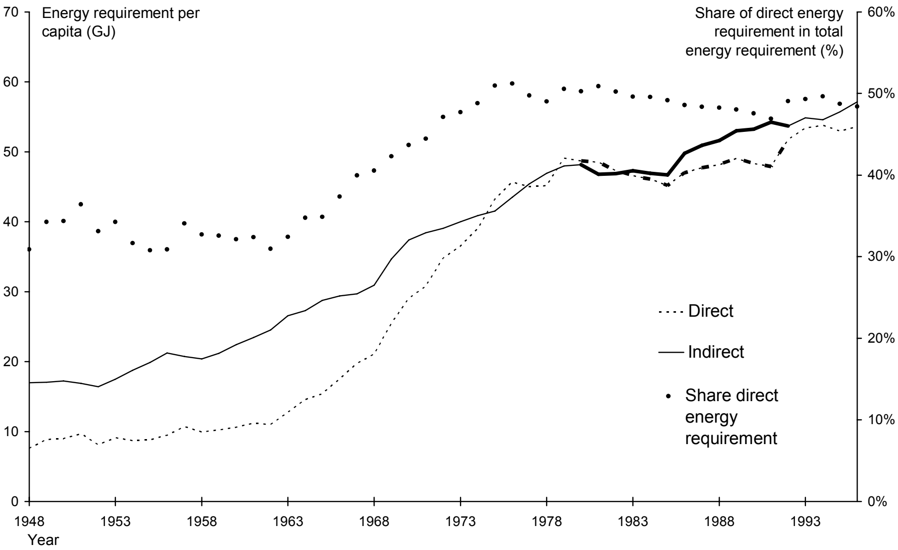

Figure 6-8 Direct and indirect household energy requirement per capita from 1948 to 1996, calculated with fixed energy intensities for 1990. The energy requirement for the periods, 1948 to 1980 and 1992 to 1996, are fitted at the 1980 to 1992 level (indicated in bold), based on the expenditure surveys. The share of direct energy requirement in the total energy requirement is also shown.

5 ▶ Discussion

Several comments should be made with respect to the results, namely that:

(1) the energy requirement resulting from the consumption of several public services and the infrastructure is not included.

(2) the composition of the consumption categories is assumed to be constant.

(3) the results of the time-series from 1948 to 1988 have to be interpreted with extra care.

These aspects will be dealt with below. Furthermore, we will also examine how the energy requirement would have developed if we had refrained from using constant 1990 energy intensities.

(ad 1) The demand on public services (i.e. government expenditure) is excluded from this survey. The share of this collective consumption expenditure varied from

15% of the national final expenditure in 1950 to 20% in 1990 (CBS, 1994). For 1990 we estimated the energy intensity of collective consumption at about half of the energy intensity of household consumption (Vringer and Blok, 1995). Taking this into account we estimated the indirect energy intensity of household consumption and government consumption to have declined by 0.2% per year (instead of 0.14% for households only).

(ad 2) The composition of products in the consumption categories is assumed to be constant, which is a consequence of the assumption that there is a constant energy intensity per category for the whole time-series. Shifts between sorts of products within consumption categories (like a shift from pork to beef in the category 'meat') could not be taken into account because of a lack of data. However, the most important consumption categories are fairly homogeneous (see Appendix 6A), which limits the magnitude of possible errors.

(ad 3) The results of the time-series from 1948 to 1988 which so far are based on data from CBS (1991) have to be interpreted with extra care. The energy intensities used here are based on the expenditure survey for 1990 (Vringer and Blok, 1990). The consumption categories of the National Accounts differ systematically (on average by 16%) from the consumption categories of the expenditure surveys. However, the *relative* changes in the total energy requirement for the overlapping years for both time-series are comparable. This fortifies the assumptions made by coupling the energy intensities to the expenditure according to the National Accounts.

Finally, we will examine the effect of our assumption that the energy intensity of the various consumption categories was kept constant at the 1990 level during the period studied. This means that the energy requirements presented here do not reflect the actual energy requirement, but do reflect what the energy requirement would have been if the energy intensities of the industry, distribution and transport sectors had not changed through the years. In other words, the time-series reflect only those changes in the energy requirement that can be assigned to changes in the consumption patterns of the Dutch households. To obtain an idea of the actual energy requirement of households, we estimated the effect of energy efficiency changes in the supply sectors. For the 1990 to 1995 period, Vringer et al. (1997) calculated a 2% reduction in the household energy requirement due to energy efficiency changes in the supply sectors. For the 1973 to 1988 period, Meyer and Schipper (1992) observed a decline in the average energy intensity for OECD countries. This decline led to a primary energy requirement reduction of around 20% (about 1.2% per year). If we assume that this is also valid for the supply sectors for Dutch households, the actual energy requirement in 1973 would be about 10% higher than if it had been calculated without the influence of energy intensity decrease of the supply sectors. If the energy intensity decrease between 1973 and 1988 is extrapolated to the 1948 to 1973 period, the actual energy requirement in 1948 would be more than 40% higher than the energy requirement calculated at fixed 1990 energy intensities. Figure 6-9 shows the energy requirement per capita for the 1948 to 1996 period, excluding and including the above estimated energy intensity changes of the supply sectors.

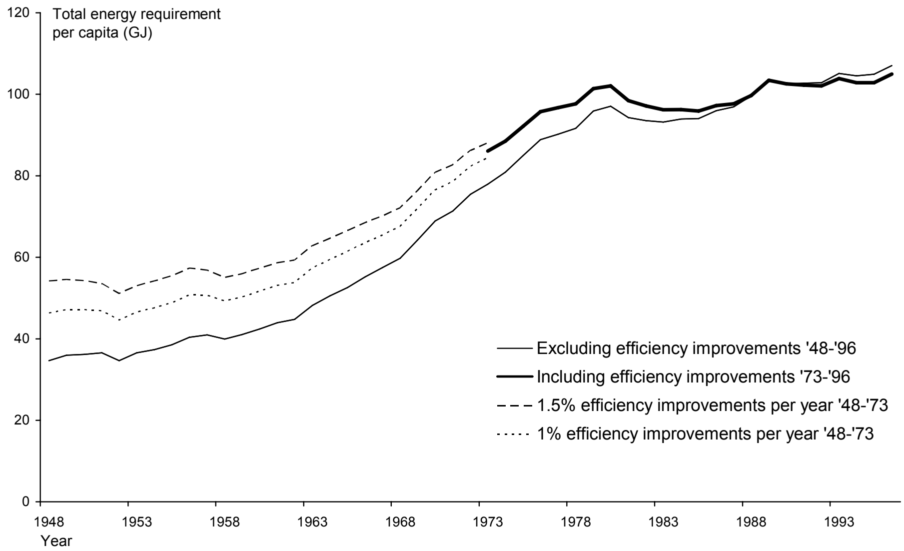

Figure 6-9 Estimate of the total energy requirement per capita for the range in time from 1948 to 1996, excluding energy efficiency improvements in the supply sectors and including an estimation of the energy efficiency improvement in the supply sectors. The extrapolated period (dotted lines) is given for a percentual decrease in the energy intensity of 1% and 1.5%.

6 ► Conclusions

As a result of a rise in consumption, the total household energy requirement per capita grew between 1948 and 1996 by about 2.4% per year (calculated with fixed energy intensities, ignoring efficiency changes in the supply sectors). In this period changes in household consumption patterns led to a growth in the total energy intensity, with some fluctuations, from 5.6 to 6.3 MJ/Dfl. (about 0.25% per year). It is the share of the direct energy requirement in the total household energy requirement that determines the fluctuations in the total household energy intensity. Without energy efficiency improvements for heating and electrical equipment, the growth in the total energy intensity would have been substantially higher.

Between 1948 and 1996 the indirect energy intensity remained almost unchanged, but there was a small decline from 3.8 to 3.6 MJ/Dfl. (about 0.14% per year). The main reason for this reduction is the decrease in the share of the energy requirement for food. We may have overlooked some changes due to insufficient detail in our breakdown (75 to 100 consumption categories), although there is no indication of this. The finding that increasing income does not lead to a lower energy intensity caused by the composition of the consumption pattern is consistent with earlier findings: an analysis for one specific year (1990) showed that the indirect energy intensity of higher income groups was not lower than for lower income groups. But, there was a decline found in the total energy intensity, due mainly to the fact that higher income groups use proportionally less natural gas than lower income groups.
Again it should be stressed that we have considered only changes in the household consumption package; we ignored energy efficiency effects in the production sectors.

No substantial trend to a lower energy intensity was found, indicating that dematerialisation of the Dutch consumption pattern did not occur. If we consider only indirect energy consumption, we find a very slight reduction in energy intensity. In conclusion, the consumption pattern of households in the Netherlands does not show a substantial trend towards a lower energy intensity.

If governments are to pursue sustainable development they will have to take into account that autonomous dematerialisation of the consumption pattern is unlikely to occur. Strong policy may very well be necessary to achieve dematerialisation by means of changes in household consumption patterns.

► Acknowledgements

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Appendix 6A ► Matching consumption categories and energy intensities

Table 6A-1 shows the consumption categories of the National Accounts (CBS, 1991) matched with the consumption categories and energy intensities according to (Vringer and Blok, 1995). A few consumption categories have been added: e.g. banking services', 'insurance services' and 'services not mentioned before’. The energy intensities of the consumption categories added are appraised at 1.0 MJ/Dfl., comparable to other service categories.

We constructed main consumption categories from the 96 consumption categories from the National Accounts (CBS, 1991), taking into account as far as possible the classification of the main consumption categories of the Household Expenditure Surveys. The following consumption categories may be placed under more than one main consumption category, e.g.

- Household effects (a main consumption category) include part of consumption category no. 3411, 'Other articles for household use', which in turn consist of the sub-category no. 3403, 'household utensils', and no. 3408, 'washing machines and refrigerators', as well as part of the sub-category no. 3411, 'other articles for household use'.
- The main consumption category, 'Leisure and education', includes part of the consumption category no. 3411, 'other articles for household use'. This then consists of the sub-consumption categories, no. 3409, 'radio/TV', no. 3410, 'records and cassettes' and half the sub-consumption category, no.3411, 'other articles for household use’.
- Up to 1955 the consumption category, 'Heating', included category no: 4102 'Liquid fuel', which consists of fuel oil and petrol. After 1955 only fuel oil is included in this main consumption category. From the year 1955 on, the expenditure on petrol was known separately and assigned to the main consumption category 'Petrol'. Before 1955 the energy requirement of petrol is included in the main consumption category ‘Heating’.

Table 6A-1 Energy intensities for the consumption categories from the National Accounts, the matched energy intensities and the matched sector number.

Category according to the National Accounts		**Category according to the expenditure surveys**		**Energy intensity**
No.	Name	No.	Name	MJ/Dfl.
	Food			
1101	Rice, groats and oatmeal	110720	Rice	5.7
1102	Noodles/macaroni	110750	Other flour and dry goods	6.9
1103	Tea	113600	Tea	4.3
1104	Coffee	113500	Coffee	3.4
1105	Cocoa	113700	Cocoa	2.6
1106	Chocolate spread	113300	Chocolate paste/butter for bread	4.8
1107	Sugar	113000	Sugar	11.2
1108	Fruit preserves	11250	Preserved Fruit	6.4
1109	Margarine	115000	Margarine	11.0
1110	Edible fat	115110	Fats for frying and deep frying	15.3
1111	Edible oils	115120	Salad oil	26.0
1113	Other groceries	1196	Other food products and beverages	5.4
1201	Standard milk	118000	Milk	6.3
1202	Butter	118500	Butter	6.7
1203	Cheese	118600	Cheese	5.8
1204	Cream and condensed milk	118300	Evaporated milk and Cream	5.4
1205	Skimmed-/butter milk	118400	Other milk products	5.8
1206	Yoghurt	118100	Yoghurt	5.3
1207	Chocolate milk	118400	Other milk products	5.8
1208	Special milk products	118400	Other milk products	5.8
1209	Eggs	118700	Eggs	11.1
1300	Bread	110000	Wholemeal bread	4.0
1401	Potatoes	1110	Potatoes	4.4
1402	Vegetables	1111	Vegetables	8.8
1403	Fruit	1120	Fruit	5.2
1405	Vegetable preserves	11160	Preserved and dried vegetables	9.9
1501	Beef and veal	116000	Beef and veal, fresh	5.7
1502	Pork	116100	Pork, fresh	5.7
1503	Other meat	116520	Other meat products	7.3
1504	Meat preserves/meat prod.	116400	Meat and meat products, frozen	9.3
1505	Poultry (incl. ducks)	117020	Poultry	6.0
1601	Fresh fish	117100	Fish, fresh	5.8
1602	Fish preserves	117340	Preserved fish	12.0
2101	Sugar and chocolate prod.	113130	Sugar products on bread	6.6
2102	Gingerbread	110300	Bread with raisins	4.2
2103	Dutch rusks	110200	Rusks and other sorts of bread	3.9

Table 6A-1 Energy intensities for the consumption categories from the National Accounts, the matched energy intensities and the matched sector number. (Cont.)

Category according to the National Accounts		**Category according to the expenditure surveys**		**Energy intensity**
No.	Name	No.	Name	MJ/Dfl.
2104	Biscuits/cakes/pastry	1105	Cake, biscuits and pastry	3.8
2105	Pastry products	110730	Pastry	4.7
2301	Beer	114110	Beer	3.1
2302	Other alcoholic beverages	11410	Alcoholic beverages	3.0
2303	Non-alcoholic beverages	11400	Non-alcoholic beverages	7.3
2400	Ice cream	119500	Ice cream	4.1
4400	Expenditure in restaurants	1193	Outdoor consumption	4.1
	House			
4300	Gross rent	2200	Rent and rental value	1.2
	Household effects			
3401	Heating equipment	2267	Heating appliances (except central heating)	2.4
3404	Earthenware for hh. use	226300	Pottery and glassware	3.0
3405	Glassware	226300	Pottery and glassware	3.0
3406	Wood products	224000	Dining and livingroom furniture	3.2
3407	Furniture	2240	Furniture	3.4
3411	Other articles for hh. use	2275	Other household appliances and tools	4.0
4801	Flowers and plants	222200	Indoor plants and flowers	15.6
4807	Maintenance services	227800	Repair and maintenance of household appl.	1.1
4815	Service of metal-using craft	221140	Service for maintenance of central heating	1.0
	Clothing and Footwear			
3101	Men's outer garments	3300	Men's clothing	3.0
3102	Ladies outer garments	3306	Women's clothing	2.4
3103	Underwear and nightwear	330500	Night-gowns and underwear	2.8
3104	Rainwear	330000	Men's coats	3.9
3105	Stockings and socks	330750	Ladies tights	2.1
3106	Fashion articles	3340	Other clothing and requisites	3.0
3107	Yarns	3340	Other clothing and requisites	3.0
3108	Woven fabrics	3340	Other clothing and requisites	3.0
3109	Soft furnishings	3340	Other clothing and requisites	3.0
3112	Other textile products	3340	Other clothing and requisites	3.0
3200	Footwear	335	Footwear and finery	1.8
3300	Leather articles	338200	Leather goods etc.	2.8
4813	Shoe repairs	338000	Shoe repairs	2.3

Table 6A-1 Energy intensities for the consumption categories from the National Accounts, the matched energy intensities and the matched sector number. (Cont.)

Category according to the National Accounts		**Category according to the expenditure surveys**		**Energy intensity**
No.	Name	No.	Name	MJ/Dfl.
	Hygiene and Medical Care			
4203	Water	441000	Water	2.4
4803	Cosmetic products	4440	Cosmetics and perfumery	2.5
4804	Detergents	441210	Detergents	6.8
4808	Service of cleaning firms	440230	Window cleaning service etc.	0.1
4809	Household services	4400	Domestic services	0.6
4810	Service hairdr./beauty shops	443000	Hairdresser	1.4
4811	Service of dyers/laundries	440100	Laundry, dry cleaning, dye works	3.0
4700	Medical care	446	Medical care	3.0
4805	Medical/pharm. products	44600	Medicines, wound-dressings and prostheses	1.7
	Leisure and Education			
4500	Entertainment services	5530	Music, singing and theatre	1.9
4802	Paper products	550200	Study books and educational appliances	2.6
4806	Goods/serv. by publishers	550500	Newspaper and weekly papers	5.7
4812	Service of swimming est.	5510	Sports and games	2.6
4814	Service of photographers	554420	Film and photo accessories	1.7
3700	Other durables	226	Household appliances and tools	3.5
3411	Other articles for hh. use	2275	Other household appliances and tools	4.0
2201	Cigars/cigarillos	556000	Cigars	1.2
2202	Cigarettes	556100	Cigarettes	0.9
2203	Cut tobacco	556200	Other tobacco articles	1.3
	Transport			
3500	Bicycles and motorcycles	5574	Mopeds, motor-cycles etc.	2.2
3600	Automobiles	5576	Cars	2.4
4601	Transport services	558430	Cargo services	6.8
4602	Communication	5582	Other transport & communication services	1.9
	Heating			
4101	Solid fuel	2292	Solid fuels	38.5
4102	Liquid fuel	558100	Petrol and motor oils	22.4
4202	Gas	229010	Natural gas	59.1
	Electricity			
4201	Electricity	229110	Electricity	49.4

Table 6A-1 Energy intensities for the consumption categories from the National Accounts, the matched energy intensities and the matched sector number. (Cont.)

Category according to the National Accounts		**Category according to the expenditure surveys**		**Energy intensity**
No.	Name	No.	Name	MJ/Dfl.
	Petrol			
4102	Liquid fuel	558100	Petrol and motor oils	22.4
	Other consumption			
4816	Banking services			1.0
4817	Insurance services			1.0
4818	Services not mentioned before			1.0
4822	Goods not mentioned before			3.5
	Excluded			
4819	Social services			
4820	Contrib. inst. of worship			
4821	Government services			

Chapter 7

Long-term scenarios for the direct and indirect energy requirement of Dutch consumers[1]

► Abstract

Common economic models for the analysis of private consumption generally do not distinguish demographic, economic and technological changes or changes in consumer purchasing behaviour, which are related to different policy fields. This makes common economic models less suitable for the analysis of changes in consumption patterns and the accompanying environmental pressure. The aim of this chapter is to estimate the composition of the whole private consumption for 2030 and the accompanying energy requirement on a detailed level from a consumer's point of view. Besides economic changes the method also distinguishes non-economic driving forces such as technical and demographic changes, and changes in consumer purchasing behaviour.

From our analysis of the effect of two business-as-usual scenarios for the Netherlands, where total private consumption per capita doubles or triples between 1995 and 2030, we estimated the accompanying energy requirement per capita to increase by about 30% to 60% in this period. This means an expected autonomous decrease of 40% in the energy intensity, representing a reduction of 1.5% a year.

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1 This study is a substantially adapted and translated version of Vringer K., Aalbers, Th.G., Drissen, E. Hoevenagel, R., Bertens, C.A.W., Rood, G.A., Ros, J.P.M. and Annema, J.A. 'Nederlandse consumptie en energiegebruik in 2030. Een verkenning op basis van twee lange termijn scenario's' (Consumption and energy requirement for Dutch consumers in 2030. A survey based on two long-term scenarios) National Institute for Public Health and the Environment, Bilthoven, The Netherlands (2001).

Two-thirds of the reduction in the energy intensity is due to changes in both energy efficiency of consumer goods and energy efficiency of the production of the consumer goods. Changes in consumer purchasing behaviour are responsible for the remaining one-third reduction in the energy intensity, expressed in a relatively low growth of the energy-intensive fuels for transport, heating the dwelling and the consumption of hot water. Economic changes and demographic changes hardly affect the energy intensity.

If governments want to achieve at a more sustainable consumption in the future, they will have to take into account that autonomous energy-efficiency improvements and autonomous changes in consumer purchasing behaviour cannot compensate for the effect of the ongoing growth in disposable income.

1 ► Introduction

In the so-called Brundtland Report, the World Commission on Environment and Development of the United Nations states that ‘we must learn to care for the needs of the present generation without compromising the ability of future generations everywhere to meet their own needs’ (WCED, 1987). A (more) sustainable production structure and consumption pattern are necessary to achieve this. Several autonomous trends are threatening this desired aim. One of the threats is the ongoing growth of consumption and the accompanying environmental pressure. From 1948 to 1996 the private consumption per capita for the Netherlands tripled, along with the accompanying total energy requirement (Vringer and Blok, 2000). Almost all this total energy requirement is associated with the emission of greenhouse gases, which are expected to affect the earth’s climate (IPCC, 2001). A further growth in the consumption is expected (CPB, 1996). With an expected economic growth of about 3% a year, the Dutch consumption per capita doubles or triples again between 1995 and 2030 (CPB, 1996; Drissen and Braat, 2002).

To analyse the future environmental pressure of consumption, a fairly detailed description of the whole consumption pattern is a prerequisite. It is also preferable to distinguish the effect of demographic, economic and technological changes, and changes in consumer purchasing behaviour, on the consumption pattern, because each kind of change is related to a different policy field. The Netherlands Bureau for

Economic Policy Analysis (CPB) determined the expected total consumption pattern for 2020, but on a very aggregated level based on an expected production structure (CPB, 1996). To establish future consumption patterns, demographic, technological effects, and effects of changes in consumer purchasing behaviour, were not separately taken into account by the CPB. Economists often use general equilibrium models to analyse future consumption (see Dixon et al., 1982 and Shoven and Whalley, 1992). Most models of this type distinguish a limited number (a few dozens at the maximum) of consumption categories. However, there are exceptions, for example, an Australian model that goes back to Dixon et al. (1982) distinguishing 115 commodities, and the Keller model for the Netherlands that contains 65 commodities (Cornielje and Zeelenberg, 1991). Unfortunately, general equilibrium models in general only take account of 'economic' behaviour (the effect of changes in prices and income on the demand for commodities), whereas we also want to take demographic and technological effects into separate consideration. This makes most of these economic models less suitable for the analysis of changes in the consumption pattern and the accompanying environmental pressure, which is necessary for advising on policy to reduce the future environmental pressure.

The aim of this chapter is to estimate the composition of total private[2] Dutch consumption and the total accompanying energy requirement for 2030 on a detailed level and from a consumer's point of view. The total energy requirement includes all energy that is attributed to private consumption; i.e. all primary energy required for the production of goods and services is allocated to consumers that use these goods and services.

We used a method to estimate a complete future consumption pattern on a detailed level, which derives the expected consumption pattern from driving forces that affect consumer decisions. Apart from economic changes, non-economic driving forces such as technical and demographic changes, and changes in consumer purchasing behaviour, are taken explicitly into account. The method takes the effects of each driving force into separate account with the help of an appropriate approach for each driving force concerned.

2 Private consumption is total consumption less public consumption, e.g. infrastructure, medical care and (other) public services.

We will first describe the method in general and, second, the determination of the expected consumption pattern and the accompanying direct and indirect energy requirement for Dutch consumers in 2030. The estimated private consumption patterns presented here are based on two business-as-usual scenarios for 1995 to 2030, taking only the current policy into account. The analysis thus aims to describe the *autonomous* development of private consumption.

2 ► A method to calculate private consumption patterns

We developed a four-step method to estimate the future private consumption pattern[3] and the accompanying energy requirement. The first step is choosing the scenario context, which is a coherent description of future society. Note that government policies can be part of the scenario cxontext. In the second step the effects of the scenario context on five driving forces are determined. These driving forces are demographic changes, economic changes, changes in consumer purchasing behaviour (e.g. trends, lifestyles etc.), energy-efficiency changes in the consumption phase of consumer goods and energy-efficiency changes in the production phase of consumer goods. Each driving force is related to a different policy field. In the third step the effects of the driving forces on the consumption pattern are determined. The consumption pattern is related to the total primary energy requirement (which is the sum of the direct and indirect energy requirement[4]). This can be regarded as an indicator of environmental pressure. The fourth step results in determination of the energy requirement (see Figure 7-1).

3 A consumption pattern is characterised by the distribution of expenditures among consumption categories. A consumption category is a set of consumer products (goods and services) with the same product characteristics.

4 The direct energy requirement is the total primary energy required for the production of all energy carriers that consumers consume (such as electricity, fuels and natural gas). The indirect energy requirement is the total primary energy required for the production of all the other products and services that consumers consume.

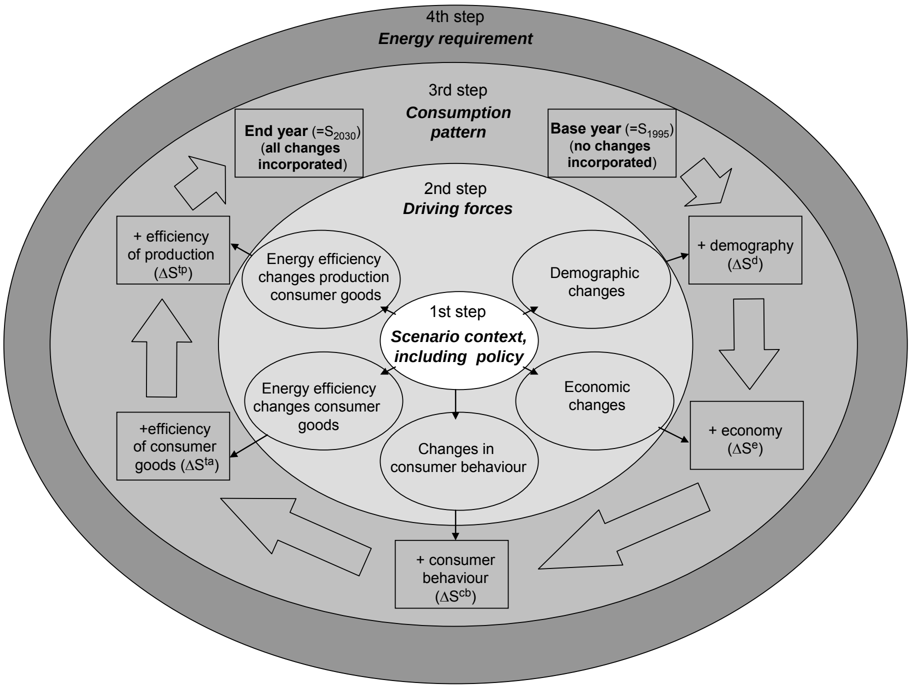

Figure 7-1 The four steps of the method illustrated, along with the five driving forces.

To calculate the future average consumption pattern we have to start with a given consumption pattern in a base year. The effects of the five driving forces are added in succession. Of course, the effects of the driving forces are not independent of each other, so the method checks for consistency with the scenario context. In the following sections we will describe each step of the method in determining the consumption pattern and energy requirement in 2030 for Dutch consumers for two different scenarios.

2.1 ► First step: scenario context

Before a future consumption pattern can be calculated, we need information about possible future developments of the driving forces. Such information can be constructed by forecasting the possible future developments or by constructing scenarios for the future, which describe different, plausible future developments of the driving forces in a consistent way. The use of scenarios is widely accepted for the time span (1995-2030) chosen (IPCC, 2000 and CPB, 1996). We used two long-term scenarios from the Netherlands Bureau for Economic Policy Analysis (CPB, 1996, 1997)[5]:

- Global Competition (GC), with an economic growth of 3¼% a year (CPB, 1996, 1997). Individuals are more concerned about their own (material) interests. Competition and the liberalisation of local and world markets are strong driving forces in this scenario, forming a factor, which leads, inter alia, to great technological progress.
- European Co-ordination (EC), with an economic growth of 2¾ % a year. Individuals take more account of public interests and interests of others (compared to GC). Although there is an ongoing liberalisation of markets in EC, it is not as strong, compared to GC. Cooperation remains an important mechanism for decision making.

The two scenarios provide explicit characteristics of demographic and economic changes but do not give quantitative information on changes in consumer purchasing behaviour and (energy-)efficiency changes, although they give qualitative information about the underlying socio-cultural and technological changes (CPB, 1996). On the basis of this qualitative information, we present a method in the next section to specify the changes in consumer purchasing behaviour.

5 Originally, these two scenarios were developed for1995-2020. Drissen and Braat (2002) made an extrapolation for the period 2020-2030. The scenario context of GC has much in common with the A1 scenario of the IPCC context, whereas the EC context is more or less similar to the B2 context (IPCC, 2000).

2.2 ► Second and third steps: Driving forces and their influence on the consumption pattern

For each driving force we present the net effect on the consumption pattern in 2030. The total consumption in 2030 can be written as:

$$\sum_{y=1}^{z} S_{2030,y} = \sum_{y=1}^{z} (S_{1995,y} + \Delta S_y^d + \Delta S_y^e + \Delta S_y^{cb} + \Delta S_y^{ta} + \Delta S_y^{tp}) \quad (1)$$

where:

$S_{2030,y}$	=	Expenditure on consumption category *y* in the end year 2030;
$S_{1995,y}$	=	Expenditure on consumption category *y* in the base year 1995;
z	=	Number of consumption categories;
$\Delta S^d{}_y$	=	Effect of demographic changes on the expenditure of category *y;*
$\Delta S^e{}_y$	=	Effect of economic changes on the expenditure of category *y;*
$\Delta S^{cb}{}_y$	=	Effect of changes in consumer purchasing behaviour on the expenditure of category *y;*
$\Delta S^{ta}{}_y$	=	Effect of changes in energy efficiency of consumer goods belonging to category *y,* on the expenditure of category *y;*
$\Delta S^{tp}{}_y$	=	Effect of changes in energy efficiency in the production of consumer goods belonging to category *y,* on the expenditure of category *y*.

In this section we will discuss each element of Equation (1).

2.2.1 ► Consumption pattern for the base year

We assumed 1995 as base year for the private consumption pattern because of the availability of data for that year. The consumption pattern (in financial terms) for that year was derived from the Household Expenditure Survey (CBS, 1996). This survey contains the private expenditure pattern of a representative sample of 2069 Dutch households in 1995 consisting of approximately 350 consumption categories.

Note that the total private expenditure is not equal to the disposable income[6]; the differences are mainly due to loans received, and savings and investments made (CBS, 1996).

6 The disposable income is the net income, available for private expenditures and investments (see also Vringer and Blok, 1995).

2.2.2 ► Demographic changes

To estimate the effect of demographic changes we made a static micro-simulation (De Beer, 1998), which is a multiplicative weighing (CBS, 1999) of the individual households from the expenditure survey of 1995. Individual households from the expenditure survey, of which the type is expected to become more (less) common in 2030, are more (less) heavily weighted, when calculating the average consumption pattern. Which household types are expected to become more (less) common in 2030 is derived from the expected future developments of several demographic characteristics, as described by Drissen and Braat (2002).

Table 7-1 The four characteristics of main demographic changes for 1995 and 2030 according to the EC and GC scenarios.

	1995	2030 EC	2030 GC
(1) **Age** (proportion of all Dutch inhabitants of 65 years and older)	13%	22%	24%
(2) **Participation of women on the employment market** (proportion of all Dutch women from 20 to 65 years)	22%	18%	14%
(3) **The number of persons per household** (part of all Dutch households)*			
- 1-person households	31%	36%	46%
- 2-person households	33%	33%	30%
- 3-person households	14%	13%	10%
- 4 or more person households	22%	18%	14%
(4) **Educational level** (proportion of all Dutch inhabitants from 20 to 65 years)			
- Elementary education	16%	9%	7%
- Lower secondary education	28%	23%	21%
- Higher secondary education	38%	42%	43%
- Higher education	19%	27%	29%

* In 1995 the average number of members per household was 2.34, which in 2030 will be 2.19 (EC) or 1.95 (GC) (Drissen and Braat, 2002).

To estimate the effect of demographic changes on the consumption pattern, we concentrate on four main demographic changes mentioned by CBS/CPB (1997), namely, education, households, population and working population. Taking the four main demographic changes into account, we chose four characteristics of these main demographic changes, available in the expenditure survey of 1995 and quantified in the scenario context (see Table 7-1)[7].

The resulting expenditure on consumption category *y,* considering the demographic changes between 1995 and 2030, can be expressed as: $S^d_{1995\text{-}2030,y}$. Now the effect of demographic changes on the expenditure of consumption category *y* can be written as[8]:

$$\Delta S_y^{\ d} = S^d_{1995-2030,y} - S_{1995,y} \qquad (2)$$

Note that the demographic changes not only affect the consumption pattern but also the disposable income per capita.

2.2.3 ► Economic changes

The economic changes as described in the EC and GC scenario form our starting point for the calculation of the consumption pattern. The most important economic characteristics, which may affect the consumption pattern, are the prices and the disposable income. In this chapter, we ignore the effect of changes in relative prices on the consumption pattern because the scenarios that we use do not give prices changes for the consumption categories. We can construct changes in prices on an aggregated level, for example, food products and services. However, on this level we cannot expect substantial substitution effects if prices change, since substantial effects will only occur if goods are close substitutes. Therefore we concentrate on the effect of changes in disposable income on the consumption pattern. The disposable income changes if demographic characteristics such as education level and labour participation change (see previous section). These demographic changes lead to a change in the size, composition and quality of the labour force and, therefore, to a change in labour productivity. In addition to this demographic-related change, labour productivity may also change because of changes in economic

7 One important demographic change is excluded in our analysis, i.e. the growth of the Dutch population, which is expected to increase from 15.5 million to 18.4 (EC) and 17.1 (GC) million people in 2030 (Drissen and Braat, 2002). We excluded the growth of the population because all results are presented per capita.

8 See Appendix 7B for a recapitulation of all symbols used in this chapter.

characteristics such as technology, business organisation or (for labour productivity on a macro level) the sector structure. The economic-related change in labour productivity also leads to a change in disposable income. We will refer to the economic-related change in labour productivity as the change in disposable income due to economic changes.[9] The EC and GC scenarios give only information on the change in income level and expenditure level (see Table 7-2). The economic-related change in income can be obtained by subtracting the demographic-related change in income, which is the sum of the demographic-related change in the expenditure for each consumption category as determined by Equation (2), from the total change in income.

Table 7-2 Development (1995 = 100) of the disposable income and expenditure for the EC and GC scenario (Source: Drissen and Braat, 2002, based on CPB, 1996).

	EC 2030	GC 2030
Disposable income per capita	220	299
Private expenditure on private consumption, per capita	216	277
Total disposable income for all Dutch inhabitants	262	331
Total private expenditure on private consumption for all Dutch inhabitants	258	307

A static micro simulation is not suitable for the calculation of the effect of the economic-related change in disposable income on the consumption pattern. Using this would mean that a few households from the expenditure survey with a relatively high income would be highly determinative in choosing the consumption pattern. This would also lead to problems for specific consumption categories; e.g. detached houses would not be available for a much larger group.

Instead of a static micro-simulation, we used income elasticities for expenditures to estimate the effect of a change in income on the expenditure of a consumption category. We first determined the income elasticity for the nine consumption

9 The economic-related change in labour productivity is dominant in the long term. Note that we ignore the impact of changes in the productivity of other production factors on income: energy, for example, which leads to a change in the energy efficiency. The same applies to changes in consumer purchasing behaviour.

domains using the expenditure survey of 1995 (CBS, 1996). A consumption domain consists of all expenditures made on one kind of activity[10]. The income-expenditure elasticity for consumption domain *x* in 1995 (α_x) is determined by Equation (3):

$$S_{1995,x} = \beta_x * I_{1995}{}^{\alpha_x} \qquad (3)$$

where:

$S_{1995,x}$ = Expenditure on consumption domain *x* in 1995;

I_{1995} = Total disposable income in 1995;

β_x = A constant factor for consumption domain *x;*

α_x = Income elasticity of consumption domain *x*.

Table 7-3 gives the income elasticities for all consumption domains derived from the expenditure survey of 1995 (CBS, 1996).

Table 7-3 Income elasticities (α_x) for the nine consumption domains (CBS, 1996).

Domain	Income elasticity
Food	0.72
Dwelling	0.41
Household effects	0.89
Clothing	1.0
Personal care	0.8
Leisure indoors	0.6
Leisure outdoors	1.2
Holidays	1.4
Employment	1.0

If consumption category *y* belongs to consumption domain *x*, we assume the income-expenditure elasticity for this consumption category (α_y) to be equal to α_x. This implies that we used the same elasticity for all consumption categories

10 For example, domain 'food' does not only consist of food products, but also transport of these products from the shop to the dwelling, natural gas for cooking them and warm water to wash up. See also Appendix 7A for an extended classification.

belonging to one domain, which is not necessarily correct[11]. Assuming that the total disposable income is similar to the total expenditure, the effect of the economic changes on the expenditure of consumption category *y* can be written as:

$$\Delta S_y^e = S_{1995-2030,y}^{d+e} - S_{1995-2030,y}^{d} = S_{1995-2030,y}^{d} * \left[\left(\frac{G^{CPB}}{S^d} \right)^{\alpha_y} - 1 \right] \quad (4)$$

where[12]:

$S^{d+e}_{1995\text{-}2030,y}$	= expenditure on consumption category *y,* concerning the economic changes and demographic changes between 1995 and 2030;
$S^{d}_{1995\text{-}2030,y}$	= expenditure on consumption category *y,* considering the demographic changes between 1995 and 2030;
G^{CPB}	= total expenditure in 2030 according to the CPB scenario;
S^d	= total expenditure in 1995, considering the demographic changes between 1995 and 2030;
α_y	= income elasticity of consumption category *y*.

By calculating ΔS^e_y we used the linear approach of Equation (3)[13]. The total expenditure can now be calculated by adding up the expenditures for each consumption category. The consequence of this method is that the total expenditure calculated here might not be equal to the total expenditure given in the scenario. The sum of ΔS^e_y, as calculated with the linear approach of Equation (3), is about 90% of the total expenditure given by the scenario. There is a difference because the

11 This procedure assumes the elasticity in the short term to equal the elasticity in the long term, which may lead to an additional bias.

12 See Appendix 7B for a recapitulation of all symbols used in this chapter.

13 The error in the expenditure due to this linear approach varies between 0% (household effects) and 9% (holidays) of the expenditure of a consumption domain. See the discussion for the effect on the calculated total energy requirement.

weighted sum of the income elasticities is not equal to one, where the weights are determined by the budget shares of the consumption domains. To equate the calculated total expenditures with the total expenditures from the scenario, we distributed the remaining 10% of the total expenditure proportionally over the consumption domains. We will return to this point in the discussion.

2.2.4 ► Changes in consumer purchasing behaviour

By taking the demographic and economic changes (ΔS^{d}_{y} and ΔS^{e}_{y}) into account we obtained an extrapolation of the consumption pattern for 1995. This means that although the average income and demographic situation has been changed, a specific consumer in 2030 with the same demographic characteristics and the same income level will still consume in the way as he/she did in 1995. However, so far, we have ignored the effects of changes in consumer purchasing behaviour on the consumption pattern, which may be caused by cohort effects, changes in consumers' preferences, trends and technical changes[14]. We used three types of sources, listed below, to explore the effect of changes in consumer purchasing behaviour on the consumption pattern. The second and third types of sources are additional to the first type. The three types are:

a. *Expert sessions* for changes in the expenditure on products and services. For approximately 55% of the total expenditure, the effect on changes in consumer purchasing behaviour was estimated with this source ($\Delta S^{cb}_{y(expert)}$);
b. *Additional research* on changes in expenditure in a few categories requiring a closer analysis. We restricted ourselves to categories, which are, or will probably become, relatively large. For approx. 25% of the total expenditure, the effect on changes in consumer purchasing behaviour was estimated with this source ($\Delta S^{cb}_{y(add)}$);
c. *Energy and transport models* for the changes in expenditure on energy carriers and transport. We used these models because they are quite detailed and because the direct energy requirement covers approximately 50% of the total energy requirement

14 Such changes include the development of e.g. mobile telephones and DVD players. The technical developments mentioned here do not include technological changes concerning the (energy) efficiency.

in 1995. For approximately 15% of the total expenditure, the effect on changes in consumer purchasing behaviour was estimated with this source (=$\Delta S^{cb}_{y(use)}$).

Each source will be discussed below[15].

Expert sessions: we organised four *expert sessions* about 'clothing', 'food', 'dwellings'[16] and 'recreation'[17] for 7 of the 9 consumption domains. Six to ten experts on trends, marketing, sales and technology who work at large retailers, branches of trade, design departments of producers and consumer organisations participated in each session. Before a session started, the participants were extensively informed about the consumption domain concerned (Hoevenagel et al., 2000) as well as about the results of a qualitative literature study on factors and trends that may influence the consumption pattern (Slob et al. (1999); Van der Pijll and Krutwagen (2000); TNO (2000); CREM (2000); Van de Heiligenberg et al. (2000); Vergragt (2000) and Young and Vergragt (2000)). An electronic decision-support system was used to give structure to the sessions.

We asked the experts of each session how consumers would divide the total expenditure over all consumption domains, taking into account the consumption pattern of 1995 and the above-described demographic and economic changes between 1995 and 2030. Taking the new proportions of the consumption domains into account[18], the experts were asked how consumers divide the expenditure among clusters of consumption categories of the relevant domain[19]. We asked the experts to motivate and discuss their vision on possible trends. In most cases consensus on the

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15 About 9% of the total expenditure (responsible for 3% of the total energy requirement) in 1995 was not covered by one of the sources. This concerns expenditure on two domains: labour (excl. the expenditures on petrol), and personal care (excl. the expenditures on natural gas, electricity, medical care and day-care centres), and expenditures not classified in a consumption domain. For these expenditures we assumed no developments in consumer purchasing behaviour (ΔS^{cb}_{y}=0).

16 In this session two consumption domains were discussed: the 'dwelling' and 'household effects'.

17 In this session three consumption domains, 'leisure indoor', 'leisure outdoors' and 'holidays', were discussed.

18 The proportion of the consumption domains in 2030 that the experts expected deviate from the originally presented proportions. Although these deviations differ per session, nearly all the deviations point in the same direction. For calculating the shares of the consumption domains we took the average of the proportions expected in the expert sessions.

19 To offer the experts a limited number of categories, the consumption categories) were clustered according to CBS (1997). Each cluster will require a substantial amount of energy or expenditure (either now or in the future).

trends was obtained. The results are extensively discussed in Hoevenagel et al. (2000).

Additional research was carried out for a few consumption categories, of which the expenditures are already, or are expected to become, relatively large. In looking closer at the dwelling in 2030, we find that the expenditures per capita are expected to be 10% higher due to larger dwellings, 8% (EC) and 17% (GC) higher due to having fewer persons per household and, finally, 20% higher due to having a more luxurious home, all compared with 1995. For medical care and day-care centres additional information from Stokx (2000) and Brink (2000) did not supply arguments to adapt the expenditure on the basis of the demographic and economic changes. An extensive description of the additional research is given by Vringer et al. (2001).

Energy and transport models: for changes in the expenditure due to changes in the use of appliances and transport services, we used three detailed physical-based-energy and transport models to establish consumers' expenditure on the energy carriers (natural gas, electricity, petrol) and transport services. Using these models Feimann et al. (2001), Jeeninga (2000a) and Crommentuijn et al. (1999) calculated the energy required on the basis of the EC and GC scenarios, and taking the current policy up to the year 2000 into account. They distinguish the changes in required activity level and the energy-efficiency changes of the appliances. The energy requirement of the consumption categories concerned can be expressed as:

$$E_y = \frac{P_y}{Ef_a} \qquad (5)$$

where:

E_y = Energy requirement of consumption category *y* for an energy carrier or transport service (in required energy units);

P_y = Activity level for consumption category *y* (in units such as distance travelled or kg washed clothes);

Ef_a = Energy efficiency of the relevant appliance *a* (in units per required energy unit).

Changes in the required activity level (ΔP_y) are the result of changes in purchasing behaviour. We assumed that since changes in price of the energy carrier or transport service (Pr_y) and changes in energy efficiency (Ef_a) are not a result of changes in purchasing behaviour, they are, therefore, kept constant. Now the changes in expenditure on energy carriers and transport services due to changes in the use of appliances ($\Delta S^{cb}_{y(use)}$) can be written as[20]:

$$\Delta S^{cb}_{y(use)} = \Pr_y * \Delta E^{cb}_{y(use)} = \frac{\Delta P_y}{Ef_a} * \Pr_y \qquad (6)$$

Then the effect of changes in consumer purchasing behaviour on the expenditure on a consumption category *y* can be expressed as:

$$\Delta S_y^{cb} = \Delta S^{cb}_{y(\text{expert})} + \Delta S^{cb}_{y(add)} + \Delta S^{cb}_{y(use)} \qquad (7)$$

In Appendix 7A, the effects are quantified of changes in consumer purchasing behaviour on the consumption pattern.

After taking into account all the changes in consumer purchasing behaviour, we needed to increase the expenditures on all consumption categories by 2% (EC) and 7% (GC) to get the total expenditure level given by the scenario.

2.2.5 ► (Energy-) efficiency changes of consumer goods

The three energy and transport models (Feimann et al., 2001; Jeeninga, 2000a and Crommentuijn et al., 1999) also specify the changes in the energy requirement due to changes in the (energy) efficiency of consumer goods (ΔE^{ta}_y). Activity level (P_y) and price (Pr_y) changes are not due to efficiency changes, so both are kept constant (see Equation (5). The effects of efficiency changes of the appliance concerned, *a* (ΔEf_a), on the expenditure on energy carriers and transport services belonging to consumption category *y* (ΔS^{ta}_y) can be written as:

$$\Delta S^{ta}_y = \Pr_y * \Delta E^{ta}_y = \frac{P_y}{\Delta Ef_a} * \Pr_y \qquad (8)$$

20 See Appendix 7B for a recapitulation of all symbols used in this chapter.

The results on the expenditure of the consumption categories concerned (=ΔS^{ta}_{y}) are described in detail in Vringer et al. (2001).

After taking into account the efficiency changes of consumer goods, we increased the expenditures on all consumption categories by 2% (EC) and 1% (GC) to get the total expenditure given by the scenario.

2.2.6 ▶ Efficiency changes in the production of consumer goods

Because in most cases the expenditure on energy paid by the supplying sectors is of minor importance on the consumer price[21], we assumed that energy-efficiency changes within the supplying sectors do not affect the consumption prices. Therefore the changes do not affect the consumption pattern, but they do have an effect on the energy requirement of the consumption pattern. So, the influence of these changes in efficiency will be discussed in the next section. The assumption mentioned above implies:

$$\Delta S^{tp}_{y} = 0 \qquad (9)$$

2.3 ▶ Fourth step: Total energy requirement due to private consumption

Now that the expected consumption pattern of 2030 is determined, the total energy requirement for private consumption can be calculated. If both the expenditure and the energy intensity[22] of all the consumption categories are known, the total energy requirement for consumption in 2030 can be calculated according to:

21 The average energy intensity of consumer goods and services (excl. direct energy requirement) was about 8 MJ/€ for 1995 (Vringer et al., 1997). The price paid by the supply sectors for one MJ is less than 0.01€/MJ (CBS, 2002). An annual energy-efficiency improvement of 0.9% (RIVM, 1997) reduces the energy costs with 35% between 1995 and 2030. Energy-efficiency improvements in the production of consumer goods will then reduce the consumer price on average by less than 5%.

22 The energy intensity of a consumption category is defined as the total primary energy requirement for that category divided by the consumer price of the product (incl. VAT and other taxes) given in MJ/€.

$$E_{2030} = \sum_{y=1}^{z} \varepsilon_{2030,y} * S_{2030,y} \qquad (10)$$

where:

E_{2030}	=	total primary energy requirement for private consumption in 2030;
$\varepsilon_{2030,y}$	=	energy intensity of consumption category *y* in 2030;
z	=	number of consumption categories and
$S_{2030,y}$	=	expenditure on consumption category *y* in 2030.

The energy intensity of a group of products and the energy intensity of the total consumption pattern can be calculated similarly. We used the energy intensities from Vringer and Blok (1995) and Vringer et al. (1997)[23] based on a hybrid energy analysis method. This hybrid method combines two methods for determining the cumulative energy requirement of goods and services: process analysis and input-output analysis (see Van Engelenburg et al. (1994).

2.3.1 ► Efficiency changes in the production of consumer goods

Energy-efficiency changes in the production of consumer goods will affect the energy intensities of consumption categories. The effects of these changes in energy efficiency on the energy intensity can be described as:

$$\varepsilon_{2030,y} = \varepsilon_{1995,y} + \Delta\varepsilon^{tp}_{1995-2030,y} \qquad (11)$$

where:

$\varepsilon_{2030,y}$	=	energy intensity of consumption category *y* in 2030
$\varepsilon_{1995,y}$	=	energy intensity of consumption category *y* in 1995
$\Delta\varepsilon^{tp}_{1995-2030,y}$	=	change in the energy intensity of consumption category *y* between 1995 and 2030 due to changes in efficiency in the production of consumer goods

23 These energy intensities are based on figures of 1990 (See Vringer and Blok, 1995), but indexed for the inflation between 1990 and 1995. The energy-efficiency developments of the supply sectors between 1990 and 1995 are taken into account by reducing all results for the energy requirement and energy intensities (Table 7-4) by 2% (See Vringer et al., 1997 and the discussion).

Analogue to Equation (5) we calculated $\Delta\varepsilon^{tp}_{1995\text{-}2030}$, assuming that the changes in energy efficiency in the production of the goods belonging to consumption category *y* (ΔEf_y) equals the changes in energy efficiency of the consumption domain *x,* to which consumption category *y* belongs (ΔEf_x). We also assumed that the activity level of the sectors (that produce goods for the relevant consumption domain *x* (P_x) and the expenditure on consumption category *y* (S_y), will only slightly change if the efficiency in the production of consumer goods changes. We ignored the minor changes in P_x and S_y, in which case we can state that:

$$\Delta\varepsilon^{tp}_{1995-2030,y} = \frac{\Delta E^{tp}_{y}}{S_y} = \frac{\left(\dfrac{P_x}{\Delta Ef_x}\right)}{S_y} \qquad (12)$$

where[24]:

ΔE^{tp}_{y} = the change in energy requirement of consumption category *y* due to efficiency changes in the production of consumer goods.

S_y = expenditure on consumption category *y*

Analogous to Vringer et al. (1997), ΔEf_x is estimated by weighing the changes in energy efficiency of the relevant supply sectors. Weighing was based on the share of the supply sectors had in the total energy requirement necessary for that consumption domain. This share is taken from Biesiot et al. (1995). The expected annual efficiency improvements for the supply sectors are derived from RIVM (1997)[25]. These improvements hold for the period between 1995 and 2020. We assumed that these annual improvements would also hold for the period between 2020 and 2030.

24 See Appendix 7B for a recapitulation of all symbols used in this chapter.

25 RIVM (1997) gives an average annual energy-efficiency improvement of 0.9%. For retail and (public) services the improvements are somewhat higher (approx. 1.1% per year) than for the industry (approx. 0.7% per year).

The energy requirement of an average consumer in 2030 can now be described as:

$$E_{2030} = \sum_{y=1}^{350} \{ (\varepsilon_{1995,y} + \Delta\varepsilon^{tp}_{1995-2030,y}) * [(S_{1995,y} + \Delta S^{d}_{y} + \Delta S^{e}_{y} + \Delta S^{cb}_{y} + \Delta S^{ta}_{y} + \Delta S^{tp}_{y}) * c] \} \tag{13}$$

where c is a correction factor to retain the total expenditure level per capita given by the scenario context[26].

3 ► Consumption pattern and energy requirement for 2030

First we present the expected effects of all driving forces on the consumption pattern in 1995 and 2030 in monetary units, as described in the previous sections. This is followed by the expected energy requirement of this consumption pattern. Finally, we will discuss the development in the total energy requirement due to consumption from 1948 to 2030 and the change in the total energy intensity. All results are presented per capita, while the monetary values are converted from Dutch guilders (Dfl., 1995) to Euros. One Dfl. is 0.45 Euro. In 1995 one Euro (€) was about equivalent to 0.90 Dollar (US$).

3.1 ► Consumption patterns for 1995 and 2030

In the scenarios, the total private expenditure level is expected to increase from about € 8700 per capita to € 19,200 (+120%, EC scenario) and € 24,400 (+ 180%, GC scenario) between 1995 and 2030. Figure 7-2 gives the expenditures for each consumption domain for 1995 and 2030, and for EC and GC as calculated with Equation (1).

26 See Appendix 7B for a recapitulation of all symbols used in this chapter.

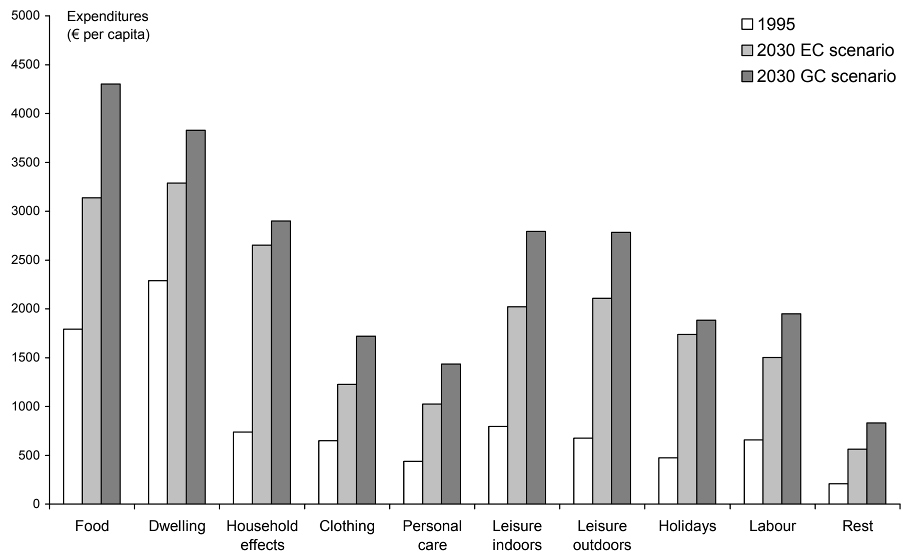

Figure 7-2 Annual expenditures (in €) on private consumption per capita for each consumption domain for 1995 and 2030 in the EC and the GC scenarios (1995 euro).

The expenditure increases for each consumption domain. For the more luxury domains of household effects, leisure and holidays, there is a more than average growth, whereas the growth for the more basic domains – food and the dwelling – is less than average. The distribution of the expenditures over the domains differs slightly between the two scenarios.

3.2 ► Energy requirement for private consumption, 1995 - 2030

The total primary energy requirement for private consumption is expected to increase between 1995 and 2030 from about 101 GJ per capita to 131 GJ in EC (+30%) and to 160 GJ in GC (+ 58%). If the expected growth of the Dutch population is taken into account, the energy requirement for the total Dutch private consumption increases by 54% in EC and 74% in GC between 1995 and 2030. However, the CO_2 emissions due to private consumption for the Dutch population increase by 40% (EC) and 55% (GC). The lower growth is due to expected changes in the Dutch energy supply system, of which the CO_2 intensity (CO_2 emission per acquired unit primary energy) is about 10% lower in 2030 than in 1995 (Van Wee et al., 2000).

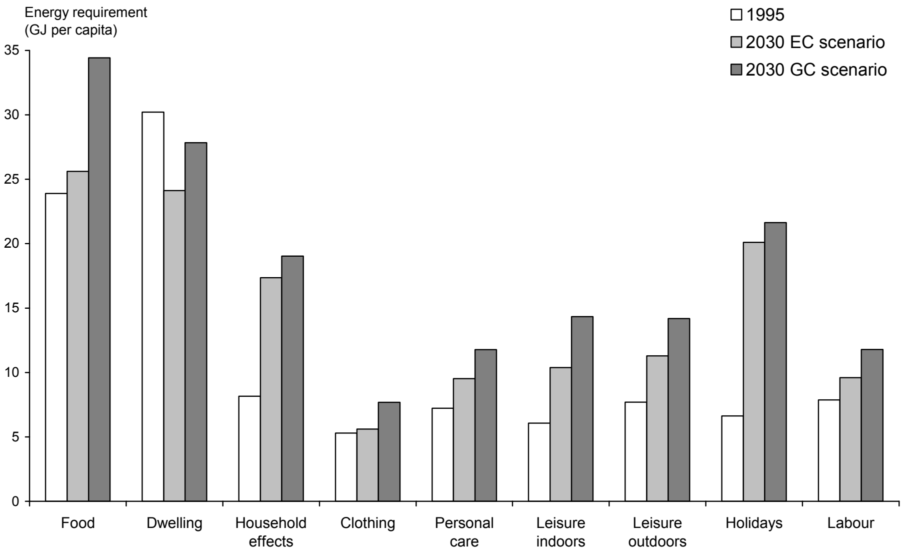

Figure 7-3 Annual energy requirements for private consumption per capita for each consumption domain in 1995 and 2030, for the EC and GC scenario.

Figure 7-3 shows the energy requirement in both scenarios for each consumption domain per capita for 1995 and 2030, as calculated with Equation (13).

The energy requirement for almost all consumption domains increases due to the increase in the disposable income. Note that the energy requirement for the consumption domains ‘household effects’ and ‘holidays’ become relatively much more important. The energy requirement for the dwelling is the only consumption domain with an expected decrease in energy requirement. This is due to the current Dutch energy policy, which focuses on the building of energy-efficient new dwellings and the retrofit of existing dwellings (see also Crommentuijn et al., 1999).

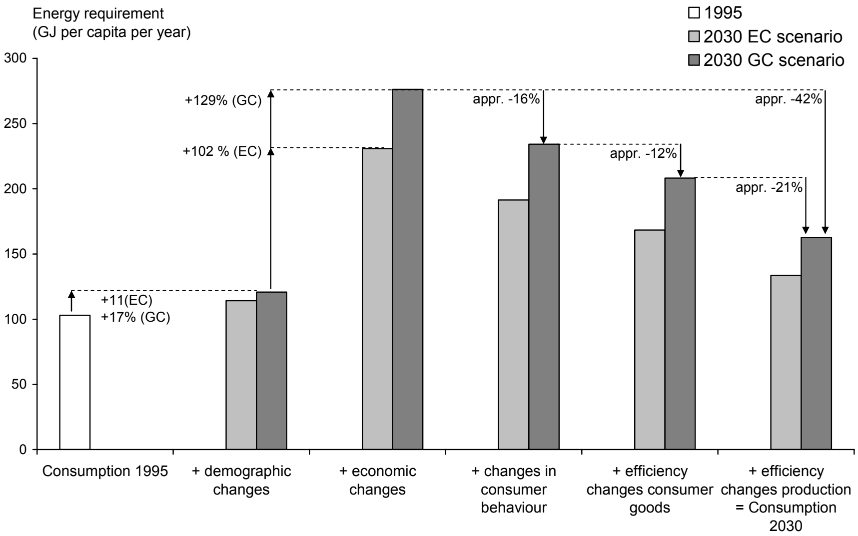

Figure 7-4 Energy requirement for private consumption per driving force and per capita in the years 1995 and 2030 for the EC and GC scenario.

3.3 ► Effects of the separate driving forces on the energy requirement

Figure 7-4 shows the expected effects for the energy requirement for each driving force[27]. Demographic changes lead to an increase of 11% in the energy requirement in EC and 17% in GC; economic changes lead to an increase of 102% (EC) and 129% (GC) per capita. Changes in consumer purchasing behaviour reduce the energy requirement by about 16%, efficiency changes of consumer goods by about 12% and efficiency changes in the production of consumer goods by about 21% for both scenarios. The reduction of the energy requirement caused by changes in consumer purchasing behaviour is mainly expressed in a relatively low growth of

27 Note that in this figure the expenditure levels for each column (except for '1995' and 'demographic changes') are retained at the same income level. The difference in the energy requirement between the two columns, excluding the columns for '1995' and 'demographic changes', then represents the difference in energy intensity.

the energy intensive fuels for transport, heating the dwelling and hot water. The total energy requirement in 2030 is still higher than in 1995.

3.4 ► Dematerialisation in past and future

It is interesting to show how the developments in the energy requirement in the past decades relate to future developments. In Figure 7-5 we present the expected energy requirement between 1995 and 2030, as well as the realised energy requirement between 1950 and 1995 according to Ros et al. (2000)[28] (see also Vringer and Blok, 2000).

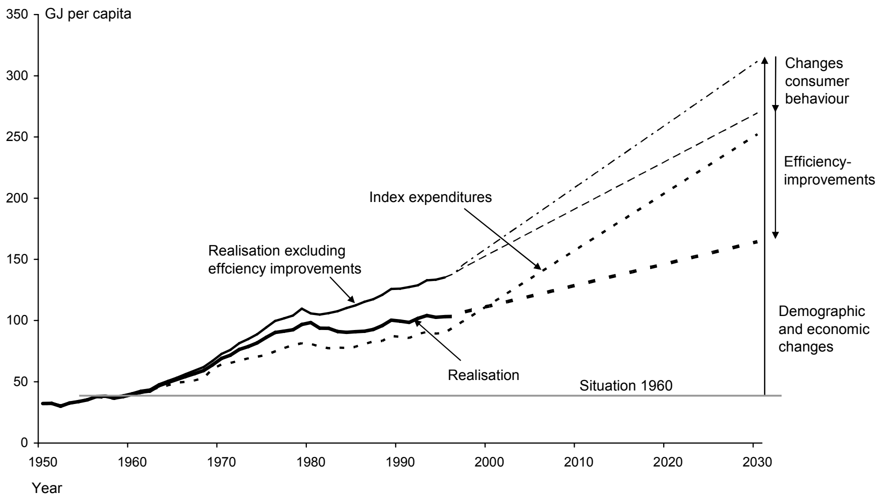

Figure 7-5 Total energy requirement per capita for the period between 1950 and 1995, and the expected energy requirement for the period from 1995 to 2030 for GC scenario. Note that for the 1995-2030 period, we calculated only the energy requirement for 2030 and not the energy requirements in the intermediate years.

28 The realised energy requirement for 1950 to 1995 is based on Ros et al. (2000), but we have subtracted the energy requirement for public consumption, which is about 15% of the total energy requirement (Ros et al., 2000). Public consumption concerns medical care, infrastructure and other public services.

Between 1950 and 1995 the total Dutch energy requirement per capita tripled from about 30 to about 100 GJ per capita, which is an annual growth of 2.6%. Between 1995 and 2030 the energy requirement per capita is expected to increase from about 100 GJ to 130 GJ in EC (+30%, annual +0.8%) and 155 GJ in GC (+60%, annual +1.3%).

Figure 7-5 also shows the expected growth of expenditures between 1995 and 2030 to be much larger than the expected growth of the energy requirement, which is due to a reduction in the energy intensity. The energy intensity of consumption can be seen as an indicator of the requirement of materials per consumption unit. Bernardini and Galli (1993) define a reduction of the energy intensity as a form of dematerialisation. Dematerialisation (here, delinking the energy requirement from consumption) is assumed to contribute significantly to the alleviation of environmental problems (Wieringa et al., 1992).

Between 1948 and 1980, the energy intensity of Dutch private consumption increased by 10 to 15%, which was due to an increasing share of direct energy requirement. A slight dematerialisation of Dutch consumption seems to have started between 1980 and 1995 (Vringer and Blok, 2000). This dematerialisation is expected to increase up to 2030. Between 1995 and 2030 the Dutch private consumption is expected to dematerialise by about 40% (-1.5% per year), mainly because of changes in consumer purchasing behaviour and efficiency changes (see Table 7-4).

A reduction in the share of direct energy requirement in the total energy requirement from about 50% in 1995 to one-third in 2030 is responsible for 40% of the total dematerialisation. The dematerialisation found for the period between 1995 and 2030 is about the same for all consumption domains, except holidays (-18%) and leisure indoors (-33%) and leisure outdoors (-54%).

Table 7-4 Energy intensities in MJ/€ for 1995 and 2030 according to the EC and GC scenarios, and the influence from the five driving forces on this energy intensity.[29]

	EC scenario (MJ/€)	GC scenario (MJ/€)
Energy intensity in 1995	**11.6**	**11.6**
+ demographic changes	11.3	11.4
+ economic changes	11.8	11.1
+ changes in consumer purchasing behaviour	9.7	9.4
+ efficiency changes in consumer goods	8.5	8.3
+ efficiency changes in the production of consumer goods **= Expected energy intensity 2030**	**6.8**	**6.6**

4 ► Discussion

Several comments should be made on the method; the uncertainty of the results and the consistency of the possible consumption pattern for 2030 calculated here.

4.1 ► Method

The method is not fully matured and must be regarded as a first step to quantifying future consumption patterns. The influences of the five driving forces on the energy requirement of the possible future consumption patterns can be distinguished with this method. Economic changes have the largest influence, followed by energy-efficiency changes in the production phase of consumer goods and the influence of demographic changes. Energy-efficiency changes in the consumption phase have the smallest influence, although this influence is still substantial. Notwithstanding the large effort to examine changes in consumer purchasing behaviour, they have a limited influence on the total energy requirement. However, the changes in consumer purchasing behaviour cannot be ignored. The expert sessions are important for the underlying details; and the experts substantially adapted the size of

29 The 1995 energy intensity is based on the energy requirement of 1990 according to Vringer and Blok (1995). We indexed the 1995 intensity to € and took efficiency developments of the supply sectors into account for the 1990-1995 period by reducing the energy intensity by 2% (see Vringer et al. 1997)

the specific consumption categories and ultimately confirmed the consumption pattern used for our calculations.

4.2 ► Consistency

For a possible future consumption pattern, consistency has, ideally, to be maintained for all relevant aspects of the scenario context and for boundary conditions, which are connected with this scenario context. Examples of boundary conditions which may affect the future consumption pattern are: the total expenditure, consumer's time, the supply and demand of goods and required space (see also Rood et al., 2001). In this chapter only one, important, boundary condition is taken into account for determining the future consumption pattern: the total expenditure level per capita has to be equal to the expenditure level per capita given by the scenario context. We ignored other boundary conditions such as:

- consistency between the consumption pattern estimated and the structure of the supply sectors,
- an equilibrium between the supply and demand of labour and
- consistency in the time expenditure of consumers.

These boundary conditions are not discussed in this study. The development of a consistent method, taking more boundary conditions into account, is recommended. Rood et al. (2001) took the first step.

4.3 ► Uncertainties

To establish the energy requirement for the possible future consumption pattern in 2030, several assumptions had to be made. These assumptions influence the uncertainty in the calculation of the energy requirement and the consistency of the consumption pattern. *Uncertainty* can be divided into two types: unreliability and structural uncertainty (Van Asselt, 2000). *Structural uncertainty* can hardly be quantified and is the result of uncertainties about the future developments of, for example, economy or demography. To capture the effects of this type of uncertainty, we used two scenarios that are comparable with the A1 and B2 scenarios of IPCC (2000). However, these scenarios do not reflect the most extreme possible situations. The A2 (low growth) and B1 ('green' growth) scenarios of the IPCC reflect more extreme possible situations.

Unreliability results from the impossibility of measuring and from inaccuracy, which can be quantified (Van Asselt, 2000). The main sources of unreliability on the total energy requirement are:

- The unreliability of the total energy requirement for 1995, due to the unreliability in the expenditure, is about 1%. It is plausible that by taking into account the demographic changes, the introduced unreliability is smaller than 1%.
- The maximum unreliability of the income elasticities for the consumption domains from the expenditure survey (CBS, 1996) varies between 2% to 5% with a reliability interval of 95%.
- By calculating the energy requirement of 2030, the introduced maximum reliability is less than 1%. This is done assuming for the most energy-intensive domains (food, holidays and household effects)- a maximum value for the income elasticity and – for the lowest energy-intensive domains (labour, personal care and leisure indoors) – a minimum value for the income elasticity.
- As mentioned earlier, we used a linear approach for Equation (3). The effect of this approach on the relative share of each domain has a maximum effect of 0.8% on the total expenditure. Taking the energy intensities of each domain into account, the maximum structural unreliability, introduced by using the linear approach of Equation (3), is less than 1% of the total energy requirement.
- As mentioned previously, we distributed 10% of the total expenditure proportionally over the consumption domains when we calculated the influence of the economic changes. If we had distributed these 10% with the help of income elasticities, the total energy requirement would have been less than 1% higher. Therefore, the maximum structural unreliability, introduced by a proportional distribution is less than 1%.
- After taking into account the changes in consumer purchasing behaviour and the efficiency changes of consumer goods, we increased the expenditures on all consumption categories by 2% (EC) / 7% (GC) and 2% (EC) / 1% (GC), respectively, to equal the total expenditure at the level given by the scenario. The unreliability introduced in this way is not larger than the unreliability introduced by the proportional distribution of 10% of the total expenditure, when calculating the influence of the economic changes (see above). The maximum unreliability introduced by this proportional distribution is then less than 1%.
- Despite the elaborated information given to the experts and the careful selection of them, the number of experts assessing the changes in consumer purchasing

behaviour is small. However, the information of the experts makes the extrapolated consumption pattern (taking only the demographic and economic influences into account) more consistent and coherent. In most cases consensus on the possible trends determined was obtained. The influence of these experts on the total energy requirement was about 5%. It is very plausible that the maximum unreliability due to the small number of experts is less than 5%.

- The models we used to estimate the energy requirement for electricity and transport both have an estimated unreliability of about 10% (Jeeninga, 2000b; Annema, 2000). The model we used for fuels for heating the dwelling and hot water (mainly natural gas) has an unreliability of about 15-20% (Crommentuijn et al., 1999). Therefore the unreliability of the results for electricity, transport and natural gas on the total energy requirement comes to 1%, 1% and 2%, respectively.
- The unreliability of the efficiency improvements of the supply sectors is not given by RIVM (1997). If this unreliability is comparable with the energy and transport models (10%), the unreliability of the total energy requirement due to the unreliability of efficiency improvements of the supplying sectors comes to 2%.
- In calculating the effects of changes in the economy, we used the same income-expenditure elasticity of 1995 for all consumption categories within one consumption domain. Furthermore, we assumed the short-term elasticity to be equal to the long-term elasticity. It is plausible that the errors caused by these assumptions are mitigated by our analysis of changes in consumer purchasing behaviour. Therefore this approach mainly affects the shares of changes in the economy and changes in consumer purchasing behaviour in the total energy requirement, but will hardly affect the total energy requirement.

It is plausible that the unreliabilities mentioned above are independent and random. In this case, the impossibility of measuring and inaccuracy lead for a given scenario context to a maximum unreliability in the total energy requirement in 2030 of about 10%.

5 ► Conclusions

In this chapter we determined the effect of long-term changes in the consumption pattern on the energy requirement due to consumption. The impact of important driving forces can be distinguished and quantified. All five distinguished driving forces have a substantial influence on the energy requirement, where economic changes have the largest influence.

We used this method to estimate the total primary energy requirement for consumption per capita in the year 2030 for two business-as-usual scenarios. Between 1995 and 2030 private consumption increases by 120% (EC scenario) and 180% (GC scenario) per capita. The required primary energy is expected to increase by 30% (EC) and 60% (GC) per capita. This is an annual growth of 0.8% and 1.3% per capita, respectively. The relative shares of the consumption domains of food, dwelling and clothing decrease, while the relative shares of the domains: household effects, holidays, leisure indoor and leisure outdoors increase. The energy requirement for the dwelling is the only domain that is expected to decrease in absolute terms. The indirect energy requirement becomes more important, with its share increasing from about one-half in 1995 to two-thirds in 2030.

In 1995 the energy intensity of private consumption is 11.6 MJ per €, decreasing the next 35 years by 40% (-1.5% per year). This expected reduction indicates that consumption will be relative de-linked from the energy requirement for consumption (dematerialisation). Two-thirds of the reduction in the energy intensity is due to changes in energy efficiency of consumer goods and changes in energy efficiency of the production of the consumer goods. A third driving force, changes in consumer purchasing behaviour is responsible for the remaining one-third reduction in the energy intensity. This is caused by a relatively low growth of the energy intensive fuels for transport, heating the dwelling and the production of hot water. The driving forces ‘economic changes’ and ‘demographic changes’ hardly affect the energy intensity.

The expected dematerialisation between private consumption and the energy requirement does not lead to an absolute reduction in the required primary energy or the accompanying CO_2 emissions due to private consumption. This is because of the growth of expenditures for consumption, particularly because the disposable income grows. Thus, if governments aim at a more sustainable consumption, they have to take into account that the autonomous dematerialisation is not expected to compensate for the negative effects of the ongoing growth in disposable income caused by economic growth.

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Appendix 7A ► Effects of changes in consumer purchasing behaviour on the consumption pattern

Table 7A-1 quantifies the effects on the expenditures (ΔS^{cb}_{y}) due to changes in consumer purchasing behaviour estimated for the EC scenario. Table 7A-1 also specifies the source used to establish these effects. The total expenditure after taking the changes in consumer purchasing behaviour into account is about 2% too high, compared with the expenditure level according to the scenario context.

Table 7A-1 Expenditures (in € of 1995 per capita) for 1995 and 2030 EC, and excluding and including changes in consumer purchasing behaviour (ΔS^{cb}_{y}), if only the demographic (ΔS^{d}_{y}) and economic changes (ΔS^{e}_{y}) are taken into account.

	1995	2030	2030	Source behaviour
	Basic year	Democraphic + economic change		
		Excl.	Incl.	
		behaviour		
Total expenditure	**8,707**	**19,262**	**18,894**	
Food	**1,791**	**3,642**	**3,055**	
Purchase	103	220	128	
- Public transport	6	13	6	model
- Cycle, moped	9	18	8	model
- Car	88	188	102	model
- Delivery	1	2	12	experts
Preparation	120	255	221	
- Electrical appliances (like food processors and kitchen utensils)	21	46	39	experts
- Refrigerators, deep-freezers	13	26	22	experts
- Cookers	3	8	6	experts
- Natural gas	6	11	6	model
- Electricity	31	65	74	model
- Other	46	99	74	experts

Table 7A-1 Expenditures in € of 1995 per capita… (Cont.)

	1995	2030	2030	Source behaviour
	Basic year	Democraphic + economic change		
		Excl. behaviour	Incl. behaviour	
Food products	1,269	2,525	1,553	
- Potatoes, pastry and rice	33	62	42	experts
- Fresh vegetables	67	142	96	experts
- Fresh fruit	63	132	90	experts
- Preserved vegetables and fruit	30	59	40	experts
- Meat (beef, veal and horse meat)	39	77	35	experts
- Meat (pork, sausages)	175	329	151	experts
- Fish and poultry	55	109	50	experts
- Milk and milk products and eggs	182	359	159	experts
- Ready-to-use meals	16	34	105	experts
- Delivered meals	31	68	210	experts
- Bread and sandwich filling	110	209	96	experts
- Rusks and other sorts of bread	17	37	17	experts
- Cakes, biscuits, candies and sugar	126	252	116	experts
- Peanuts and nuts	12	26	12	experts
- Non-alcoholic Beverages	67	128	70	experts
- Alcoholic beverages	127	269	148	experts
- Coffee and tea	47	91	50	experts
- Other (like margarine and oil)	72	142	65	experts
Dining out / consumption outdoors	299	641	1,154	
- French fries, rolls, ice-cream and snacks	58	118	224	experts
- Restaurant	67	153	283	experts
- Café	53	110	170	experts
- Other	120	260	476	experts
Dwelling	**2,287**	**3,972**	**3,360**	
Rent and rental value	1,727	2,940	2,379	
- Rent	689	1,144	949	additional research
- Rental value	1,038	1,796	1,430	additional research
Taxes, insurance, maintenance, installations	336	566	701	
- Taxes	171	284	352	experts
- Fixed equipment	7	13	16	experts

Table 7A-1 Expenditures in € of 1995 per capita… (Cont.)

	1995	2030	2030	Source behaviour
	Basic year	**Democraphic + economic change**		
		Excl.	Incl.	
		behaviour		
- Maintenance fixed equipment	58	100	124	experts
- Rented office equipment	10	18	22	experts
- Other	90	151	187	experts
Heating and lighting	224	466	280	
- Natural gas and other fuels	175	373	191	model
- Electricity	44	81	81	model
- Solid and liquid fuels	5	12	9	experts
Household effects	**737**	**1733**	**2482**	
Purchase	22	53	55	
- Public transport	1	3	1	model
- Bike, moped	1	3	4	model
- Car	19	46	47	model
- Delivery	0	0	3	experts
Furniture and furnishing	513	1,190	1,551	
- Furnishing	146	342	395	experts
- Bedding and household linnen	35	79	91	experts
- Furniture	171	373	537	experts
- Plants and flowers	51	121	162	experts
- Garden	77	191	256	experts
- Other	33	84	109	experts
Maintenance	202	491	877	
- Domestic services, window cleaning services	55	152	368	experts
- Electrical appliances	26	55	145	experts
- Repairs and rental of appliances	6	14	57	experts
- Other	115	269	307	experts
Clothing	**649**	**1,565**	**1,187**	
Purchase	23	57	39	
- Public transport	1	3	1	model
- Bike, moped	2	4	3	model
- Car	19	48	32	model
- Delivery	0	0	3	experts

Table 7A-1 Expenditures in € of 1995 per capita… (Cont.)

	1995	2030	2030	Source behaviour
	Basic year	**Democraphic + economic change**		
		Excl. behaviour	Incl.	
Maintenance	78	173	106	
- Electrical appliances (like irons and sewing machines)	14	29	14	experts
- Sewing & knitting needles, and needlework tools	2	3	2	experts
- Electricity	10	22	20	model
- Repairs	8	19	8	experts
- Laundry, dry-cleaning	5	14	22	experts
- Detergents	25	56	28	experts
- Requisites, haberdashery	14	31	13	experts
Clothes and shoes	548	1,335	1,042	
- Outer wear	349	852	655	experts
- Underwear	29	74	57	experts
- Sportwear	15	37	28	experts
- Other	13	31	21	experts
- Clothes	1	2	1	experts
- Rental of clothes	2	4	7	experts
- Finery	47	117	79	experts
- Shoes	82	196	172	experts
- Sport shoes	9	19	17	experts
- Rental of footwear	1	3	5	experts
Personal care	**438**	**1,033**	**997**	
Energy	51	118	83	
- Electricity	12	39	37	model
- Natural gas	39	79	46	model
Products and services	259	583	583	
- Nursery, babysitting etc.	38	97	97	additional research
- Other e.g. water, toilet articles and other services	222	486	486	-
Medical care	127	331	331	additional research

Table 7A-1 Expenditures in € of 1995 per capita… (Cont.)

	1995	2030	2030	Source behaviour
	Basic year	**Democraphic + economic change**		
		Excl.	Incl.	
		behaviour		
Leisure indoors	**794**	**1,510**	**1,962**	
Purchase	11	22	64	
- Public transport	0	1	0	model
- Bike, moped	1	1	4	model
- Car	10	19	58	model
- Delivery	0	0	1	experts
Various products	783	1,488	1,898	
- Electricity	21	47	69	model
- Education and courses	12	21	24	experts
- Computer and stationery	65	124	166	experts
- Journals, periodicals and magazines	128	256	229	experts
- Other	57	100	117	experts
- Smoking	89	156	95	experts
- Telephones and postal expenses	158	308	514	experts
- Radio, television, video, audio and photo equipment	196	373	531	experts
- Pets	56	103	152	experts
Leisure outdoors	**675**	**1,851**	**2,087**	
Materials	23	66	185	
- Sport	12	34	95	experts
- Other	10	32	90	experts
Entrance and course fees	170	463	579	
- Sport	66	175	241	experts
- Course fees and contributions	62	169	205	experts
- Entrance fees	39	112	126	experts
- Other	3	6	7	experts
- Public transport	36	105	37	model
- Bike, moped	23	60	128	model
- Car	419	1,145	1,101	model
- Delivery	3	11	58	experts

Table 7A-1 Expenditures in € of 1995 per capita… (Cont.)

	1995	2030	2030	Source behaviour
	Basic year	**Democraphic + economic change**		
		Excl. behaviour	Incl. behaviour	
Holidays	**473**	**1,769**	**1,714**	
Holidays abroad	346	1,423	1,166	
- Organised holiday trips	172	715	580	experts & additional research
- Other holiday costs	174	708	586	experts & additional research
Holidays in the Netherlands	58	150	326	
- Organised holiday trips	21	49	107	experts
- Other holiday costs	37	100	218	experts
Other	68	197	223	
- Camping equipment	25	67	76	experts
- Other	43	130	147	experts
Labour	**657**	**1,647**	**1,510**	
Education	140	346	346	-
Mobility	517	1,302	1,164	model
Other	**207**	**539**	**539**	-

Appendix 7B ► Symbols used in chapter 7

I_{1995} = Total disposable income in 1995

S_{1995} = Total private expenditure in 1995

S_y = Expenditure on consumption category *y*

$S_{y(use)}$ = Expenditure on consumption category *y* for an energy carrier or transport service.

$S_{1995,y}$ = Expenditure on consumption category *y* in 1995

$S_{1995,x}$ = Expenditure on consumption domain *x* in 1995

$S_{2030,y}$ = Expenditure on consumption category *y* in 2030

$S^{d}_{1995\text{-}2030,y}$ = Expenditure on consumption category *y,* considering the demographic changes between 1995 and 2030

$S^{d+e}_{1995\text{-}2030,y}$ = Expenditure on consumption category *y,* considering the economic changes and demographic changes between 1995 and 2030

ΔS^{d}_{y} = Effect of demographic changes on the expenditure of category *y*

ΔS^{d} = Effect of demographic changes on the total private expenditure

ΔS^{e}_{y} = Effect of economic changes on the expenditure of category *y*

ΔS^{cb}_{y} = Effect of changes in consumer purchasing behaviour on the expenditure of category *y*

$\Delta S^{cb}_{y(expert)}$ = Effect of changes in consumer purchasing behaviour on the expenditure of category y, established with expert sessions.

$\Delta S^{cb}_{y(add)}$ = Effect of changes in consumer purchasing behaviour on the expenditure of category y, established with additional information.

$\Delta S^{cb}_{y(use)}$ = Effect of changes in consumer purchasing behaviour on the expenditure of category y, established with energy and transport models

ΔS^{ta}_{y} = Effect of changes in energy efficiency of consumer goods belonging to category *y,* on the expenditure of category *y*

ΔS^{tp}_{y} = Effect of changes in energy efficiency on the production of consumer goods belonging to category *y,* on the expenditure of category *y*.

E_y = Energy requirement of consumption category *y*

$\Delta E^{cb}_{y(use)}$ = Effect of changes in consumer purchasing behaviour on the energy requirement of category y, established with energy and transport models

ΔE^{ta}_{y} = Effects of changes in the energy efficiency of consumer goods on the energy requirement of consumption category *y*

ΔE^{tp}_{y}	=	Effect of changes in energy-efficiency changes of the production of consumer goods on the energy requirement of consumption category y
Ef_a	=	Energy efficiency of relevant appliance *a*
ΔEf_a	=	Energy efficiency change of relevant appliance *a*
ΔEf_y	=	Changes in energy efficiency of the production of the goods belonging to consumption category *y*.
ΔEf_x	=	Changes in energy efficiency of the production of the goods belonging to consumption domain *x*.
P_y	=	Activity level for consumption category *y* (in units such as distance travelled or kg washed clothes)
ΔP_y	=	Changes in activity level for consumption category *y*
P_x	=	Activity level of the sectors, producing goods for the relevant consumption domain *x* (in units such as numbers of consumer goods produced)
Pr_y	=	Price of the energy carrier or transport service for consumption category *y*
$\varepsilon_{2030,y}$	=	Energy intensity of consumption category *y* in 2030
$\varepsilon_{1995,y}$	=	Energy intensity of consumption category *y* in 1995
$\Delta\varepsilon^{tp}_{1995\text{-}2030,y}$	=	Change in the energy intensity of consumption category *y* between 1995 and 2030 due to changes in efficiency in the production of consumer goods.
G^{CPB}	=	The total expenditure in 2030 according to the CPB scenario
α_x	=	Income elasticity of consumption domain *x*
α_y	=	Income elasticity of consumption category *y*
β_x	=	A constant factor for consumption domain *x*
c	=	Correction factor to retain the total expenditure level per capita given by the scenario context
z	=	Number of consumption categories

Summary

1 Introduction

Humans in households use energy for their activities. This use is both direct, for example electricity and natural gas, but also indirect, for the production, transport and trade of other goods and services. The availability of energy allows many people in industrialised countries to enjoy a consumption level with unprecedented comfort and mobility. The World Energy Assessment concludes that today's energy system is not sustainable. This is due to environmental, economic and geopolitical concerns, all having implications far into the future. A sustainable energy system is important for keeping the major benefits of the use of energy in the future. There are various ways to achieve a more sustainable energy system, but the change of consumption patterns is an under-explored option. Since changes in consumption patterns can lead to a reduction or limitation in the energy requirement of society, thus contributing to a more sustainable world, the analyses presented in this thesis should be helpful in exploring the feasibility of this option.

The main objective of this thesis is to gain insight into the energy requirement associated with household consumption patterns, with a focus on (I) the quantification of the energy requirement of the present consumption pattern and its components, (II) differences in the energy requirement between groups of households and, (III) the development of the average consumption pattern in the past and future. Insight into the energy requirement associated with household consumption patterns is necessary before an answer can be given to the question on how the energy requirement caused by consumption can be decreased by changing consumption patterns.

The energy requirement of society was examined here from the household perspective. In fact, in the end all products and services produced within an economic system are meant for consumption, mainly by households. Determining the energy requirement associated with consumption patterns and the differences between consumption patterns required an alternative cross-section of the economy as opposed to the traditional sector-by-sector approach. All energy required by society has been allocated to the products consumed by consumers, living mainly in households. A fast and accurate method was needed for analysing the primary energy requirement of many individual consumption categories.

2 ► Determining the primary energy requirement of consumption patterns

Chapter 2 proposes a hybrid method to analyse the primary energy requirement for the various consumption categories. There are two common ways to calculate the energy requirement of a consumer good. The first is input-output analysis, which is not very accurate but does allow one to rapidly calculate the energy requirement of all consumer goods. The second is process analysis, which is very accurate but requires a lot of input data. The hybrid method for energy analysis as presented in Chapter 2 combines the accuracy of process analysis with the speed of input-output analysis.

This hybrid method for energy analysis was found to be suitable for rapidly calculating the direct and indirect energy requirement associated with the purchase and use of large numbers of consumer goods. The method detects differences between consumption categories, even if they are produced by the same economic sector. For individual products, of which the price level deviates from the mean price, the use of input–output analysis for parts of the calculations can cause errors. However, on average, the calculated energy requirement will be correct. Although the error margins for individual products can be reduced by using more process data, more effort will be needed to make analyses.

3 ► The energy requirement of cut flowers and consumer options to reduce it

We first applied the hybrid method for energy analysis to one component of the consumption pattern: cut flowers. In 1990, an average Dutch household purchased one or more bouquets of flowers for €88[1] at a frequency of 11 times throughout the year; this came to a total of about 250 flowers. Together these flowers required about 2.2 GJ, or about 1% of the total primary household energy requirement. The energy intensity of flowers is among the highest of all non-energy household purchases: on average about 25 MJ/€. The high energy intensity of cut flowers makes it interesting to take a closer look at less energy-intensive alternatives.

The aim of Chapter 3 is to examine how households can reduce their primary energy requirement for the decorative and gift functions provided so far by cut flowers, taking the financial costs into account. First, the cumulative primary energy requirement for 37 of the most common cut flowers grown in the Netherlands was determined as a function of the season of purchase. The energy requirement and energy intensity varied considerably per month of purchase and per type of flower. Large variations were found in the energy requirement per flower, ranging from 3 to 195 MJ. The functionality of cut flowers was then elaborated, as this is relevant to the degree to which alternatives are feasible. After this, several options for the reduction of the energy required were worked out. A distinction was made between replacements by other types of products of the same category and other types of products with a comparable function. All reduction options can be applied nowadays by households. Examples are: replacing flowers as a gift by other articles, using flowering indoor plants instead of cut-flowers and buying less energy-intensive flowers like flowers from abroad, less energy-intensive species and flowers in summertime.

1 In the various chapters of this thesis, monetary results have been provided in currencies for various years, both in Dutch guilders (Dfl.) and Euros. In this summary all monetary results have been converted to the Euro-equivalent of the 1995 guilders (using the exchange rate at the guilder-Euro conversion: €1 = Dfl 2.20371). Further, we used the conversion factor: 1 Dfl_{1990} = 1.14 Dfl_{1995}, from the website of Statistics Netherlands (www.cbs.nl).

The analysis in Chapter 3 suggests that if all the consumer energy reduction options discussed here are applied to a substantial extent, the cumulative energy requirement for flowers and their substitutes for Dutch households can be halved. The findings in Chapter 3 can certainly not be extrapolated to other consumption categories, be it only because of the extremely high energy intensity of cut flowers. This analysis shows a variety of options that together have substantial potential for reducing the primary energy requirement. However, it is this variety that makes achieving this potential difficult.

4 ► The direct and indirect energy requirements of Dutch households

Chapter 4 aims to overview the total energy requirements of Dutch households and the energy requirement of about 350 consumption categories, including an outline of the influence of several important variables determining the total energy requirement of consumption: net household income, household expenditure, age and number of household members. In realising this aim, the energy intensities of all 350 consumption categories were determined using the hybrid method for energy analysis (see Chapter 2). Next, the energy requirements of Dutch households were calculated by combining the 350 energy intensities with expenditure data from 2767 households. Data were collected by National Statistics in the Household Expenditure Survey of 1990.

We found large differences in the energy intensities between the 350 consumption categories, varying from about 2 MJ/€ for services (for instance repairs, hiring a cab, the nursery) to about 111 MJ/€ for natural gas. The average energy intensity for the energy carriers was found to be about 88 MJ/€, while the average energy intensity for all other products and services was found to be about 7 MJ/€. The average energy intensity for the whole consumption pattern in 1990 amounted to about 12 MJ/€.

The total average energy requirement in the Netherlands in 1990 was found to be 240 GJ per household, or 99 GJ per capita, of which 54% was indirect (see Figure S-1). Among the analysed socio-economic variables, the net income was found to have the most important relationship with the total energy requirement. The elasticity of the energy requirement with respect to income came to 0.63. There is, however, a considerable spread in energy requirement within a particular income class (standard deviation about 20%). A one-person household requires about 45 GJ less energy than a multiple-person household with the same income level. No differences in the total energy requirement were found between households from different age groups.

The important relationship between income and total energy requirement suggests that, with further increases in income levels, the average household energy requirement will probably rise as well. However, the large differences between the energy intensities of the various consumption categories indicate that the total household energy requirement can be reduced by changing the consumption pattern. The substantial spread in the total energy requirement of households within the same income class also supports this.

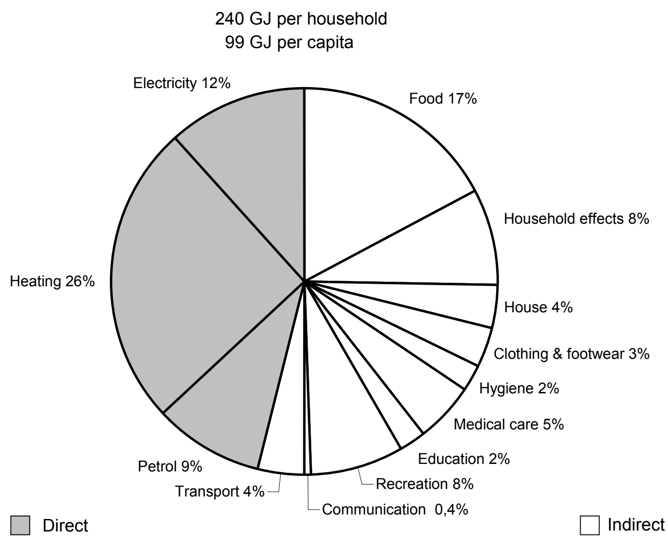

Figure S-1 The average total (direct plus indirect) energy requirement per household or capita in 1990, split up into main consumption categories.

5 ► Household energy requirement and value patterns

As mentioned above, the net income was found to have the most important relationship with the total energy requirement. But the net income cannot explain all the variance in the total energy requirement, not even in combination with other socio-economic parameters such as household size, education level and age. For an efficient consumer energy policy it is important to know why some households require more energy than others.

The differences in the total household energy requirement can be described as differences in consumer behaviour. Many studies indicate that many factors influence the actual consumption behaviour. One often mentioned factor possibly influencing consumer behaviour is people's value pattern. The aim of Chapter 5 is to examine whether there is a relationship between the total household energy requirement and value patterns. Besides value patterns, two other non-socio-economic characteristics were examined as well; these could be expected to influence behaviour more directly than values do. These were: (I) the motivation to save energy and (II) the perception of energy-related societal problems.

These relationships were examined via a survey on consumption among 2304 household respondents. The actual total consumption pattern and the accompanying energy requirement for the respondent households were determined from this survey. To compare the energy requirement of a specific household with the energy requirement of other households having the same socio-economic characteristics, a reference energy requirement was calculated. The reference energy requirement depends only on the socio-economic characteristics.

Despite a detailed calculation of the energy requirement of individual consumption patterns, we could not find that the energy requirements of one of the groups examined for value patterns or problem perception level of climate change significantly differed from the rest. Here we took into account the differences in the socio-economic situation of households. Only for the motivation to save energy we did find that the least motivated group requires 10 GJ more energy than the average and most motivated groups; this is about 4% of the total energy requirement. The lack of a relationship between the total household energy requirement and values, as well as the perception of the climate change problem or the motivation to save energy, means that an energy policy solely based on a strategy of internalising environmental responsibility will not be effective in saving energy. There are indications that a social dilemma is one of the reasons why people do not consume according to their value patterns, problem perception or motivation to save energy.

6 ► Long-term trends in direct and indirect household energy intensities

More knowledge about developments in consumption patterns in the past may improve our understanding of the ways consumption patterns could develop in the future. The aim of this chapter is to analyse consumption patterns of Dutch households in the past, so as to discover changes in the average consumption pattern and its energy intensity.

To determine the direct and indirect (cumulative) energy requirements of household expenditure, Dutch household consumption data were used for the period from 1948 to 1996. Because we are specifically interested in the changes in the energy requirement caused by changes in consumer behaviour, energy intensities frozen at the 1990 level were used to calculate the energy requirement. In doing so, energy intensity changes (for instance, those caused by efficiency improvements) of the supplying sectors (industrial, transport and distribution) were excluded from the analysis. Also, the resulting energy requirement was corrected for climate fluctuations.

As a result of a rise in consumption level the total household energy requirement per capita in the Netherlands grew between 1948 and 1996 by about 2.4% per year (see Figure S-2). In this period changes in household consumption patterns led to a net growth in the total energy intensity, from 12 to 14 MJ/€ (about 0.25% per year), with some fluctuations. The share of the direct energy requirement in the total household energy requirement is the main determinant of both the fluctuations and the net growth. Without energy efficiency improvements for heating the house and for electrical equipment, the growth of the total energy intensity would have been substantial higher. Between 1948 and 1996 the indirect energy intensity only

declined slightly from 8.4 to 7.9 MJ/€ (about 0.14% per year). The main reason for this reduction was the decrease in the share of the energy requirement for food.
Thus it can be concluded that the average consumption pattern of households in the Netherlands in the past five decades did not show a substantial development towards a lower energy intensity. This indicates that a change to a consumption pattern with a lower energy intensity did not occur in the Netherlands.

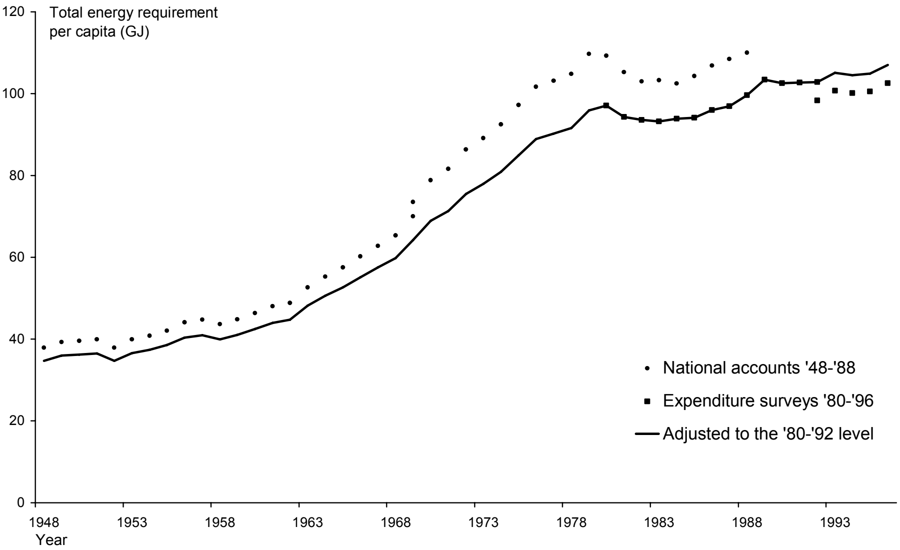

Figure S-2 The total energy requirement per capita for 1948 to 1996, calculated with fixed energy intensities of 1990. Different data sources were used. The solid line shows the adjusted energy requirement, to one common level.

7 ► Long-term scenarios for the direct and indirect energy requirement of Dutch consumers

Besides knowledge about changes in consumption patterns in the past, it is also important to have information on possible autonomous future changes in the consumption pattern and the accompanying energy requirement. The aim of Chapter 7 is to estimate the composition of the consumption pattern in 2030 and the accompanying energy requirement, distinguishing the effects of the most important forces which can have influence on the consumption pattern.

A method was developed to be able to estimate a complete future consumption pattern on a detailed level. The method derives the expected consumption pattern from driving forces that affect consumer decisions. Apart from economic changes, non-economic driving forces such as technical and demographic changes, and changes in consumer purchasing behaviour, were taken explicitly into account. The method takes the effects of each driving force separately into account with the help of an appropriate approach for each driving force concerned.

The total primary energy requirement for consumption per capita was estimated for the year 2030 for two business-as-usual scenarios (European Co-ordination - EC and Global Competition - GC). In these scenarios, between 1995 and 2030 private consumption increases by 120% (EC) and 180% (GC) per capita, while the required primary energy is expected to increase by 30% and 60%, respectively. This is an annual growth of 0.8% and 1.3% of the energy requirement per capita, respectively. The relative shares of the consumption domains food, dwelling and clothing decrease while the relative shares of the domains household effects, holidays, leisure indoor and leisure outdoors increase. The energy requirement for the dwelling is the only domain that is expected to decrease in absolute terms. The indirect energy requirement becomes more important; its share increases from about 50% in 1995 to two-thirds in 2030. In the two scenarios the total energy intensity of the consumption pattern will decrease by 40% (-1.5% per year). This expected reduction indicates a relative de-linking of consumption from the energy requirement for consumption.

Two-thirds of the reduction in the energy intensity between 1995 and 2030 is due to changes in energy efficiency of consumer goods and changes in energy efficiency of the production of the consumer goods. A third driving force, formed by changes in consumer purchasing behaviour, is responsible for the remaining one-third reduction in the energy intensity caused by a relatively low growth in the energy intensive fuels for transport, heating the dwelling and the production of hot water. The driving forces, ‘economic changes’ and ‘demographic changes’, hardly affect the energy intensity.

The decreasing energy intensity for the 1995-2030 period contrasts with the nearly stable energy intensity found in Chapter 6 for the period between 1948 and 1996. This difference can partially be explained by the exclusion of the efficiency improvements in the supplying sectors in Chapter 6 and the inclusion of these improvements in Chapter 7. The rest of the explanation can be found in the relatively low growth in the direct energy requirement between 1995 and 2030 and the relative high growth in the direct energy requirement between 1962 and 1975. After 1975 the energy intensity already started to decrease slightly, due to a decrease in the share of the direct energy requirement.

According to the two analysed scenarios the reduction in energy intensity does not lead to an absolute reduction in the required primary energy caused by private consumption. This is due to the expected growth of expenditures for consumption, particularly because the net income grows.

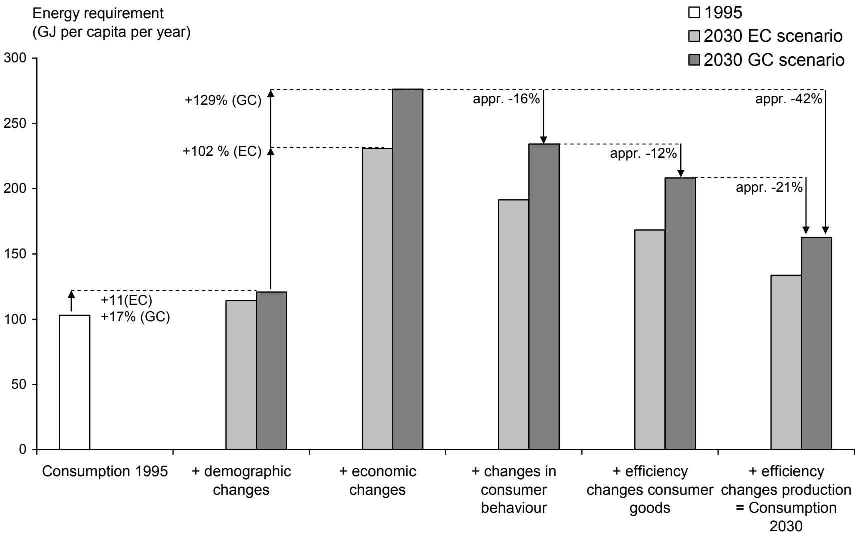

Figure S-3 Energy requirement for private consumption per driving force and per capita in the years 1995 and 2030 for the EC and GC scenario.

8 ► Final comments

The analyses in this thesis should be helpful in exploring the feasibility of the option to reduce or limit the energy requirement of society by changing consumption patterns.

The results in the Chapters 3 and 4 indicate that changing consumption patterns can reduce or limit the energy requirement of society. There are large differences between the energy intensities of consumption categories. Also the spread in energy requirement of households within the same socio-economic situation was found to be large.

However, the results in the Chapters 6 and 7 indicate that a change in consumption patterns (to reduce or limit the energy requirement of society), will not occur autonomously. No substantial trend towards a less energy intensive consumption pattern has been found for the past decades (excluding efficiency improvements in industry and retail). Chapter 7 suggests that, in the future, an autonomous substantial reduction of the energy intensity will occur, but the ongoing economic growth will still lead to a higher household energy requirement.

These findings are combined with the lack of any influence of values, problem perception and motivation on the household energy requirement, as found in Chapter 5. Then, it is clear that it will not be easy to reduce household energy requirements. A really strong policy that solves the social dilemma aspect of the problem, for instance, via pricing or regulation, will be necessary to achieve a reduction in the energy requirement of society through changes in household consumption patterns.

► Samenvatting

1 ► Inleiding

Door te consumeren verbruiken mensen energie. Er wordt niet alleen direct energie verbruikt in de vorm van aardgas, elektriciteit of benzine, maar er wordt ook indirect energie verbruikt voor de productie, transport en handel van de geconsumeerde goederen en diensten. Dit verbruik van energie maakt voor veel mensen in de geïndustrialiseerde wereld een consumptieniveau mogelijk met veel comfort en mobiliteit. De World Energy Assessment concludeert dat de hedendaagse energievoorziening niet duurzaam is. Overgang naar een duurzaam energiesysteem is belangrijk om de grote voordelen van het gebruik van energie in de toekomst veilig te stellen. Daarom wordt er veel aandacht besteed aan alternatieve energiebronnen als zon- en windenergie en een verhoging van de energie-efficiëntie. Daarnaast kunnen wijzigingen in ons consumptiepatroon leiden tot een lager energieverbruik. Deze mogelijkheid wordt echter veelal onderbelicht. Vóórdat de vraag kan worden beantwoord *hoe* ons energieverbruik teruggedrongen kan worden door consumptiepatronen te wijzigen, moet er meer inzicht zijn in het energieverbruik dat nodig is voor onze consumptie.

In energiestudies wordt het energieverbruik van de samenleving vaak toegerekend aan de verschillende economische sectoren (zoals landbouw, industrie of handel). In dit proefschrift is voor een alternatieve benadering gekozen. Het energieverbruik van de samenleving wordt vanuit het perspectief van huishoudelijke consumptie bekeken. Uiteindelijk worden alle producten en diensten die in een samenleving zijn geproduceerd direct of indirect geconsumeerd, voornamelijk door mensen die in huishoudelijk verband leven. Daarom is in dit proefschrift alle energie die door de economische sectoren wordt gebruikt, toegerekend aan de geconsumeerde producten en diensten.

Het hoofddoel van dit proefschrift is inzicht te krijgen in het energieverbruik, dat nodig is voor huishoudelijke consumptie. Daarbij ligt de nadruk op: (I) het kwantificeren van het energieverbruik dat nodig is voor huishoudelijke consumptie, (II) het kwantificeren van de verschillen in het energieverbruik tussen groepen huishoudens en (III) het analyseren van ontwikkelingen in dit energieverbruik, zowel voor het verleden als voor de toekomst.

2 ► Het bepalen van het primaire energieverbruik van consumptie patronen

Om het energieverbruik van de economische sectoren toe te rekenen aan de geconsumeerde producten en diensten is een methode nodig om het primaire energieverbruik van deze producten en diensten te berekenen. Deze energieanalyse moet aan de ene kant natuurlijk voldoende nauwkeurig zijn, en aan de andere kant niet te tijdrovend zijn vanwege het grote aantal door te rekenen consumptiecategorieën. In hoofdstuk 2 wordt een hybride energieanalysemethode gepresenteerd. Met deze methode is in hoofdstuk 4 het primaire energieverbruik berekend van 350 consumptiecategorieën[1]. Samen vormen deze 350 consumptiecategorieën het totale consumptiepatroon.

Er zijn twee principieel verschillende methoden waarmee het energieverbruik van een product of dienst vastgesteld kan worden. De eerste methode is input-output analyse welke niet erg nauwkeurig is, maar waarmee snel een analyse gemaakt kan worden voor alle consumptiegoederen. De tweede methode is proces-analyse. Deze is erg nauwkeurig maar vraagt om veel gegevens en is daardoor erg tijdrovend. Met de hybride energieanalysemethode, zoals in hoofdstuk 2 wordt behandeld, worden de belangrijke onderdelen van de levenscyclus van het te analyseren product met proces-analyse berekend, terwijl de minder belangrijke onderdelen met input-output

1 Het primaire energieverbruik van een product of dienst is de totale hoeveelheid energie die nodig is voor de gehele levenscyclus van het product, inclusief de energie die nodig is om de daarvoor benodigde energiedragers te verkrijgen. Het totale primaire energieverbruik ten behoeve van consumptie omvat alle primaire energie die nodig is voor alle geconsumeerde diensten en producten, inclusief energiedragers, inclusief de energie die nodig is om de energiedragers te verkrijgen.

analyse worden berekend. Zo wordt de snelheid van input-output analyse gecombineerd met de accuratesse van proces-analyse.

De hybride energieanalysemethode blijkt bruikbaar te zijn voor het berekenen van het primaire energieverbruik dat nodig is voor de levenscyclus van een groot aantal consumptiegoederen. De methode onderscheidt verschillen in energie-intensiteit tussen consumptiegoederen, ook als deze binnen dezelfde economische sector zijn geproduceerd.

3 ► Het energieverbruik voor snijbloemen en mogelijkheden voor consumenten om dit energieverbruik te reduceren

Om de mogelijkheden voor consumenten om energie te besparen te illustreren is de hybride energieanalysemethode toegepast op snijbloemen. In het jaar 1990 kocht een gemiddeld Nederlands huishouden circa 250 snijbloemen, voor totaal €88[2]. Voor de productie van deze 250 bloemen was ongeveer 2,2 GJ nodig, wat overeen komt met 1% van het totale (directe plus indirecte) primaire energieverbruik voor consumptie. De energie-intensiteit[3] van snijbloemen is hoog, gemiddeld 25 MJ/€. Deze hoge energie-intensiteit maakt het aantrekkelijk om minder energie-intensieve alternatieven voor snijbloemen te onderzoeken.

Daartoe is eerst het primaire energieverbruik berekend dat nodig is voor de hele levenscyclus van 37 van de meest in Nederland geteelde bloemen. De hoeveelheid benodigde energie is sterk afhankelijk van de maand van aankoop en het type

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2 In de verschillende hoofdstukken van dit proefschrift zijn de monetaire eenheden niet geïndexeerd naar één jaar en gegeven in zowel guldens (Dfl.) als euro's (€). In deze samenvatting zijn alle monetaire eenheden omgerekend naar euro-equivalenten van guldens van 1995. Daarbij is gebruik gemaakt van de omrekeningsfactor van guldens naar euro's: €1 = Dfl 2,20371. Om guldens van 1990 om te rekenen van 1990 naar 1995 is de conversiefactor 1 Dfl_{1990} = 1,14 Dfl_{1995} gebruikt, afkomstig van de website van het Centraal Bureau van de Statistiek (www.cbs.nl).

3 Energie-intensiteit staat voor de benodigde hoeveelheid energie (MJ) per besteedde monetaire eenheid (€).

snijbloem. Het energieverbruik van de onderzochte bloemen varieert van 3 tot 195 MJ per stuk.

Vervolgens zijn verschillende reductie-opties voor het energieverbruik uitgewerkt, waarbij de bloemen worden vervangen door andere bloemen of door een ander product met een vergelijkbare toepassing. Het extra energieverbruik dat nodig is voor de alternatieve producten is meegenomen in de analyse. Voorbeelden van de onderzochte energiereductie opties zijn: het vervangen van bloemen als cadeau door minder energie-intensieve cadeaus zoals wijn; voor decoratie een bloeiende kamerplant gebruiken in plaats van snijbloemen; minder energie-intensieve bloemen kopen zoals bloemen afkomstig uit warme landen; minder energie-intensieve soorten kopen en de aankoop van relatief meer snijbloemen in de zomer en minder in de winter.

De analyse in dit hoofdstuk toont aan dat met behulp van de doorgerekende energie reductieopties het energieverbruik voor bloemen met 50% gereduceerd kan worden. De kosten en functie van de alternatieven zijn vergelijkbaar met de kosten en functie van de oorspronkelijke 250 bloemen. Opgemerkt moet worden dat het voor de consument lastig is op het moment van aankoop alle opties tegen elkaar af te wegen. Het hier berekende potentieel zal daardoor moeilijk behaald kunnen worden.

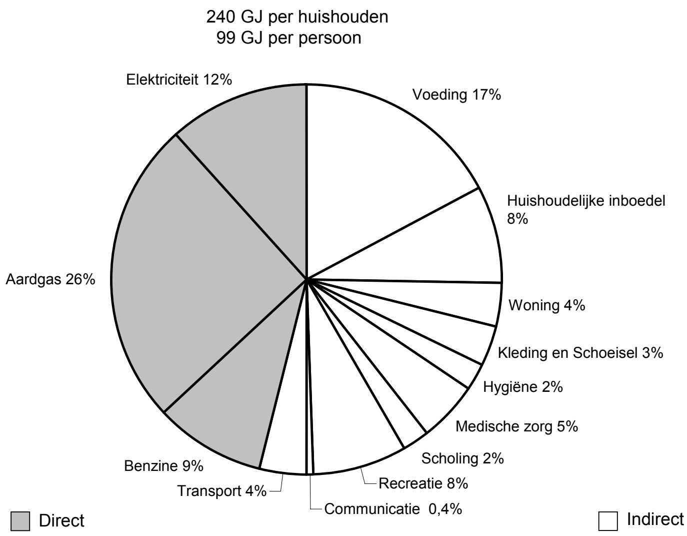
4 ► Het directe en indirecte energieverbruik van Nederlandse huishoudens

Het doel van hoofdstuk 4 is een overzicht te krijgen van het totale energieverbruik van Nederlandse huishoudens voor alle consumptiecategorieën, inclusief een overzicht van de invloed die een aantal belangrijke huishoudkenmerken op dit energieverbruik hebben. De onderzochte kenmerken zijn het totale netto inkomen, de totale bestedingen, de leeftijd van de hoofdkostwinner en de grootte van het huishouden. Als eerste is de energie-intensiteit van 350 consumptiecategorieën bepaald met behulp van de hybride energieanalysemethode (zie hoofdstuk 2). Vervolgens is voor zo’n 2800 Nederlandse huishoudens waarvan het uitgavenpatroon bekend is, het energieverbruik berekend. Dit is gedaan door de besteding van ieder huishouden aan een consumptiecategorie te vermenigvuldigen met de bijbehorende energie-intensiteit. De bestedingsdata zijn afkomstig van het budgetonderzoek van 1990 van het Centraal Bureau voor de Statistiek (CBS).

Er zijn grote verschillen gevonden tussen de energie-intensiteiten van de 350 consumptiecategorieën. Voor produkten en diensten variëert de energie-intensiteit van circa 2 MJ/€ voor diverse soorten diensten (zoals reparatie en onderhoud-services, taxivervoer en kinderopvang) tot 25 MJ/€ voor snijbloemen. De gemiddelde energie-intensiteit van alle producten en diensten bedraagt ongeveer 7 MJ/€. De gemiddelde energie-intensiteit van de energiedragers (zoals aardgas, elektriciteit en benzine) bedraagt 88 MJ/€, waarvan aardgas de hoogste energie-intensiteit heeft, 111 MJ/€. De gemiddelde energie-intensiteit voor het totale consumptiepatroon bedroeg in 1990 circa 12 MJ/€.

In 1990 was voor de consumptie van een gemiddeld Nederlands huishouden ongeveer 240 GJ nodig. Dit staat gelijk aan 99 GJ per persoon. Circa 54% van het totale energieverbruik was indirect (zie Figuur S-1). Het netto inkomen is nauw gerelateerd aan het energieverbruik. Er is een energie - inkomens elasticiteit gevonden van 0,63. Dat wil zeggen: bij een inkomensstijging van 1% stijgt het energieverbruik met 0,63%. Echter, binnen dezelfde inkomensklasse verschilt het energieverbruik nog aanzienlijk (de standaarddeviatie bedraagt ongeveer 20%). Daarnaast blijkt dat bij hetzelfde inkomensniveau, éénpersoons huishoudens ongeveer 45 GJ minder energie verbruiken dan meerpersoons huishoudens. De leeftijd van de hoofdkostwinner heeft geen invloed op het energieverbruik.

De in hoofdstuk 4 gevonden relatie tussen inkomen en het totale energieverbruik betekent dat een stijging in het gemiddelde inkomen onder gelijkblijvende omstandigheden zal leiden tot een stijging in het gemiddelde energieverbruik. Echter, de grote verschillen in de energie-intensiteiten van de 350 consumptie-categorieën geven aan dat een wijziging in het consumptiepatroon mogelijk kan leiden tot een reductie van het energieverbruik.



Figuur S-1 Het gemiddelde totale (directe plus indirecte) energieverbruik voor een huishouden of persoon in 1990, opgesplitst in hoofd-consumptiecategorieën.

5 ► Huishoudelijk energieverbruik en waardepatronen

Zoals in de vorige paragraaf reeds is opgemerkt heeft het totale energieverbruik ten behoeve van consumptie een nauwe relatie met het netto inkomen van consumenten. Echter, het netto inkomen kan niet alle variantie in het energieverbruik verklaren. Zelfs als de invloed van andere sociaal-economische parameters als huishoudgrootte, opleidingsniveau en leeftijd wordt meegerekend, blijven er aanzienlijke onverklaarde verschillen in het totale energieverbruik bestaan. Voor het ontwikkelen van het energiebeleid is het belangrijk te weten waarom sommige huishoudens meer of minder energie verbruiken dan anderen, die in een vergelijkbare sociaal-economische situatie verkeren.

In principe kunnen de verschillen in het totale energieverbruik nodig voor consumptie, toegeschreven worden aan verschillen in consumentengedrag. Vele studies noemen een groot aantal factoren, welke het consumentengedrag kunnen beïnvloeden. Eén veelgenoemde factor die mogelijk invloed heeft op het consumentengedrag is het waardepatroon van individuen. In het waardepatroon van een individu zijn waarden (zoals bijvoorbeeld: ambitie, eerlijkheid, een comfortabel leven, verantwoordelijkheid) in volgorde van persoonlijk geacht belang gerangschikt. Doel van hoofdstuk 5 is te onderzoeken of er een relatie aanwezig is tussen het totale huishoudelijke energieverbruik en het waardepatroon. Naast waardepatronen zijn twee andere niet-sociaal-economsiche karakteristieken onderzocht, waarvan te verwachten is dat zij het gedrag van mensen directer beïnvloeden dan dat waarden doen. Dit zijn (I) de motivatie om energie te besparen en (II) de mate van belang die wordt gehecht aan energie gerelateerde maatschappelijke vraagstukken.

In het kader van dit onderzoek is een enquête gehouden onder 2300 huishoudens. Op basis van deze enquête is voor elk huishouden het consumptiepatroon en het daarbij behorende energieverbruik vastgesteld. Na correctie voor verschillen die veroorzaakt worden door de sociaal-economische situatie blijken er geen significante verschillen in het energieverbruik te bestaan tussen verschillende waardegroepen[4]. Evenzo zijn er geen verschillen gevonden in energieverbruik tussen groepen die een verschillend belang hechten aan het klimaatprobleem. Enkel voor de mate van de ‘motivatie om energie te besparen’ blijkt dat de minst gemotiveerde groep circa 4% meer energie verbruikt dan de gemiddeld en hoog gemotiveerde groepen.

Geconcludeerd kan worden dat een relevante invloed van waarden van individuen, de mate van belang die wordt gehecht aan het klimaatprobleem en hun motivatie om energie te besparen, op hun energieverbruik ontbreekt. Het lijkt voor consumenten lastig te zijn het consumptiepatroon aan te passen en zo het energieverbruik te verlagen. Er zijn indicaties dat een sociaal dilemma één van de redenen is waarom dit lastig is. Een op consumenten georiënteerd energiebeleid zal het sociale dilemma moeten oplossen, bijvoorbeeld door prijsmaatregelen te nemen of met regelgeving.

4 Een waardegroep is een groep van individuen die een overeenkomend waardepatroon hebben.

6 ► Lange termijn trends in de directe en indirecte energie-intensiteit van huishoudelijke consumptie

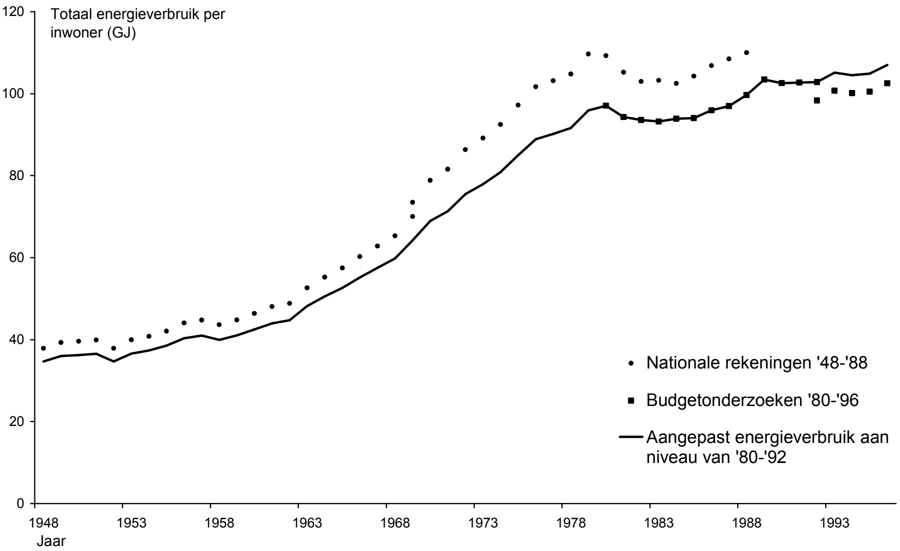
Kennis over de ontwikkeling van consumptiepatronen in het verleden kan bijdragen aan meer inzicht in de toekomstige ontwikkeling van ons consumptiepatroon. Doel van hoofdstuk 6 is de ontwikkelingen van het gemiddelde huishoudelijke consumptiepatroon, de daarvoor nodige energie en de gemiddelde energie-intensiteit over de afgelopen decennia te analyseren.

Voor de berekening van het directe en indirecte primaire energieverbruik dat nodig is voor de huishoudelijke consumptie, is gebruik gemaakt van gegevens over het gemiddelde bestedingspatroon van Nederlandse huishoudens, in de periode van 1948 tot en met 1996. Het onderzoek is gericht op het analyseren van veranderingen in het energieverbruik als gevolg van veranderingen in het consumptiepatroon. Daarom zijn veranderingen in het energieverbruik als gevolg van bijvoorbeeld het gebruik van meer of minder efficiënte technieken door de toeleverende sectoren (industrie, transport en handel) niet in de berekeningen meegenomen. Het energieverbruik, zoals berekend in dit hoofdstuk, is gecorrigeerd voor schommelingen in de gemiddelde jaartemperatuur.

In de periode van 1948 tot 1996 is het energieverbruik per hoofd van de bevolking gestegen met 2,4% per jaar (zie Figuur S-2). Deze stijging is het gevolg van de stijging van het gemiddelde consumptieniveau.

Als gevolg van veranderingen in de samenstelling van het geconsumeerde pakket goederen, diensten en energiedragers is tussen 1965 en 1975 de gemiddelde hoeveelheid energie per besteede euro (energie-intensiteit) gestegen en tussen 1975 en 1996 gedaald. De netto stijging tussen 1948 en 1996 bedraagt 0,25% per jaar. Een verandering van het relatieve aandeel van het directe energieverbruik in het totale energieverbruik is de belangrijkste oorzaak van deze trends.

Geconcludeerd kan worden dat in de periode van 1948 tot 1996 het energieverbruik per hoofd van de bevolking aanzienlijk is toegenomen als gevolg van de stijging van het gemiddelde consumptieniveau. Daarbij hebben veranderingen in de samenstelling van het geconsumeerde pakket goederen, diensten en energiedragers dit energieverbruik nauwelijks beïnvloed in deze periode.



Figuur S-2 Het totale energieverbruik per hoofd van de bevolking van 1948 tot 1996, exclusief de invloed van efficiëntieveranderingen in de toeleverende sectoren. Er zijn verschillende databronnen gebruikt. De doorgetrokken lijn geeft het aangepaste energieverbruik aan als deze bonnen gecorrigeerd worden naar één gemeenschappelijk niveau.

7 ► Lange termijn scenario's voor het directe en indirecte energieverbruik van Nederlandse consumenten

Naast kennis over de invloed van de wijzigingen van ons consumptiepatroon op het energieverbruik over de afgelopen decennia, is het van belang meer inzicht te krijgen in mogelijke toekomstige ontwikkelingen in het gemiddelde consumptiepatroon en de daarvoor benodigde energie. Het doel van hoofdstuk 7 is een inschatting te maken van het consumptiepatroon voor het jaar 2030 en de daarvoor benodigde energie, waarbij de invloeden van een aantal belangrijke factoren ('drijvende krachten') op dit consumptiepatroon van elkaar worden onderscheiden.

De volgende drijvende krachten worden meegenomen: economische veranderingen (inkomensniveau), niet-economische veranderingen zoals technische en demografische veranderingen (denk aan efficiëntie van apparaten en huishoudgrootte), en veranderingen in het consumentengedrag (wijzigingen van voorkeuren). Er wordt een model gepresenteerd waarmee een mogelijk toekomstig consumptiepatroon berekend kan worden. Het model neemt de effecten van iedere drijvende kracht afzonderlijk mee, waarbij per drijvende kracht het effect op het energieverbruik gekwantificeerd wordt.

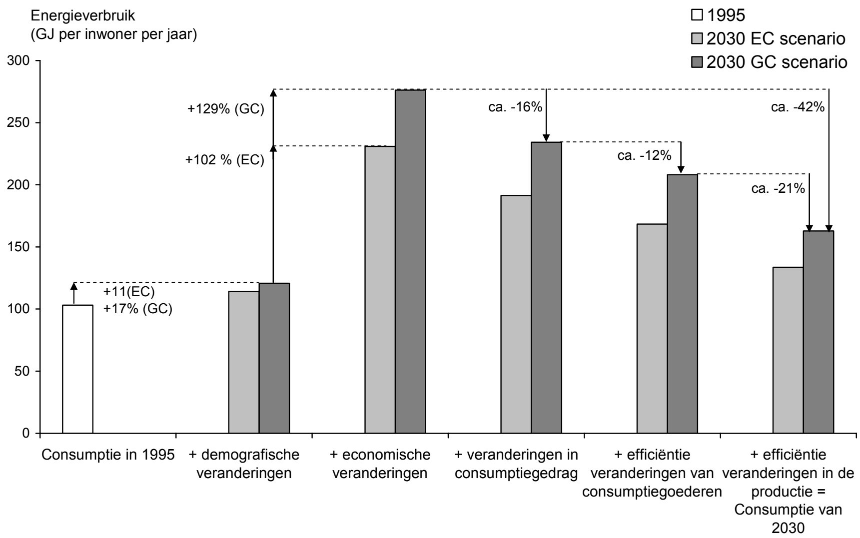
Het totale energieverbruik als gevolg van consumptie is voor het jaar 2030 ingeschat op basis van twee Business-As-Usual scenario's: (I) European Co-ordination (EC) en (II) Global Competition (GC). Volgens deze scenario's zal tussen 1995 en 2030 de consumptie per hoofd van de bevolking toenemen met respectievelijk 120% (EC) en 180% (GC). Uit de berekeningen blijkt dat het daarvoor benodigde primaire energieverbruik ten opzichte van 1995 stijgt met respectievelijk 30% (0,8%/jaar) en 60% (1,3%/jaar). Het relatieve aandeel van het energieverbruik voor 'voeden', 'woning' en 'kleding' zal afnemen, terwijl het relatieve aandeel voor 'wonen', 'vakantie', 'vrijetijdsbesteding binnenshuis' en 'vrijetijdsbesteding buitenshuis' zal toenemen. Alleen voor de woning wordt verwacht dat de benodigde energie ook in absolute zin zal afnemen, omdat de Nederlandse overheid energie-efficiëntie eisen stelt aan nieuw te bouwen woningen.

Het aandeel van het indirecte energieverbruik in het totale energieverbruik zal toenemen van ruim 50% nu naar circa 65% in 2030. De energie-intensiteit van het totale consumptiepatroon zal met circa 40% afnemen (-1,5%/jaar). Gezien de dalende energie-intensiteit, het stijgende inkomen en het stijgende energieverbruik is er sprake van een relatieve ontkoppeling tussen consumptie en het daarvoor benodigde energieverbruik.

Tweederde van de reductie van de energie-intensiteit tussen 1995 en 2030 is toe te schrijven aan efficiëntieverbeteringen van consumentengoederen zelf en efficiëntie-verbeteringen in de productie van deze goederen. Een derde drijvende kracht, veranderingen in de voorkeur van consumenten, is verantwoordelijk voor de rest van de afname van de energie-intensiteit. Deze afname wordt veroorzaakt door een relatief lage groei van transport, de verwarming van de woning en warmwater. Economische veranderingen (het inkomensniveau) en demografische veranderingen (de huishoudgrootte) hebben nauwelijks effect op de energie-intensiteit.
De verwachte afname van de energie-intensiteit voor de periode tussen 1995 en 2030 is een voortzetting van de lichte daling van de energie-intensiteit die al vanaf

1975 is ingezet, als gevolg van een afname van het aandeel direct in het totale energieverbruik (zie hoofdstuk 6). Tussen 1962 en 1975 is het directe energieverbruik juist relatief toegenomen.

Voor de twee geanalyseerde scenario's leidt de reductie van de energie-intensiteit niet tot een verlaging van het energieverbruik ten behoeve van consumptie in absolute zin. Dit is het gevolg van de verwachte groei in de consumptieve bestedingen.



Figuur S-3 Energieverbruik per hoofd van de bevolking ten behoeve van consumptie bij verschillende combinaties van drijvende krachten voor 1995 en 2030, voor het EC en GC scenario.

8 ► Tot slot

De analyse in dit proefschrift is bedoeld om meer zicht te krijgen in de mogelijkheden om het energieverbruik van de samenleving te reduceren of te beperken door het veranderen van consumptiepatronen.

De resultaten van de hoofdstukken 3 en 4 geven aan dat veranderingen in consumptiepatronen ons energieverbruik kunnen verminderen. Er zijn grote verschillen in de energie-intensiteit van consumptiecategorieën gevonden. Ook zijn er grote verschillen gemeten in het totale energieverbruik van huishoudens die in dezelfde sociaal-economische omstandigheden verkeren.

De resultaten van hoofdstuk 6 geven aan dat autonome veranderingen in het consumptiepatroon in het verleden tot een hoger energieverbruik hebben geleid. In de afgelopen decennia hebben veranderingen in de samenstelling van het geconsumeerde pakket goederen, diensten en energiedragers het energieverbruik nauwelijks beïnvloed. Uit hoofdstuk 7 blijkt dat zonder beleidswijziging naar verwachting in de toekomst een aanzienlijke verlaging van de energie-intensiteit zal plaatsvinden. Maar door de voortgaande economische groei zal het totale energieverbruik voor huishoudelijke consumptie toch verder toenemen.

Tot slot blijkt uit hoofdstuk 5 dat het energieverbruik ten behoeve van consumptie niet wordt beïnvloed door de waarden van individuen, de mate van belang die wordt gehecht aan het klimaatprobleem en de motivatie om energie te besparen. Het lijkt voor consumenten lastig te zijn het consumptiepatroon aan te passen en zo het energieverbruik te verlagen. Er zijn indicaties dat een sociaal dilemma één van de redenen is waarom dit lastig is. Een op consumenten georiënteerd energiebeleid zal het sociale dilemma moeten oplossen, bijvoorbeeld door prijsmaatregelen te nemen of met regelgeving.

► Curriculum Vitae

Kees Vringer was born in Groningen, The Netherlands in 1966. In 1983 he graduated from secondary school in Groningen. In 1989 he completed his training for secondary-school teacher at Ubbo Emmius in Groningen, receiving a BSc. Kees continued his study in chemistry, receiving his MSc from the University of Groningen in 1991, with a master's thesis on energy-saving potentials for several industrial and trade sectors. He started his career that same year at his alma mater, doing research on energy-saving potentials for households. From 1992 to 1998 he was employed as researcher at the Department of Science, Technology and Society at the Utrecht University. There he carried out several studies on the direct and indirect energy requirement of households and consumption patterns. Since 1998 he has been working at the Netherlands Environmental Assessment Agency (MNP), which until recently functioned as a division of the National Institute for Public Health and the Environment (RIVM). MNP advises the Dutch government on environmental and sustainability issues. Kees Vringer continued his work on consumption patterns, consumer behaviour and the related energy requirement at MNP, contributing to MNP's Environmental Balances and the 5th Environmental Outlook, as well as several scientific articles.

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