Chapter 7
Dynamic Resource and Economy Accounting Model

7.1 Introduction

A demand-driven version of the ECCO-model referred to as Dynamic Resource and Economic Accounting Model (DREAM) is introduced in this chapter to study the energy demand associated with (changing) consumption patterns. In the DREAM-modelling approach a number of the key feedback loops are changed compared to the ECCO-approach to facilitate a switch from a supply-driven model to a demand-driven model.

The main changes as well as the consequences of these changes form the main topics of part two of this thesis. First, section 7.2 lists some of the basic principles of ECCO as a reminder. Moreover, the reasons for developing a demand version are discussed in this section. Basic concepts and model changes are listed in the sections 7.3 and 7.4. Results of a Dutch DREAM model are presented in chapter 7.5. A number of general remarks concerning the DREAM-modelling approach and the Dutch case study are made in chapter 7.6.

7.2 Main Dynamics of ECCO

Compared to the general ECCO-modelling approach, a number of the main dynamic feedback loops are changed in the DREAM modelling approach. In order to highlight the differences between both approaches, the main dynamics of the ECCO-methodology are briefly repeated. The dynamics presented here mainly involve investments in the industrial sector and the total consumption as these two parameters are changed predominantly in shifting from ECCO to DREAM. In the ECCO methodology, all sector’s input in terms of utility (e.g. number of cars) are assumed to be proportional to the capital stock of that sector. As the total output of a sector is equal to the total input of that sector, output is, by definition, also proportional to the capital stock. So, the growth of the output of a sector depends on the growth of...
the capital stock. Capital stock growth rates are determined by the room for investments and play a key role in the growth of the output. Notably, the room for investments in the industry (denoted by $f_{nc}$, i.e. fraction not consumed) is of great importance since it is the balancing term in the ECCO modelling approach. It is limited by consumption activities, and other demands such as contributions to non-industrial capital investments, intermediate deliveries and exports (see figure 7.1). It is, thus, a key indicator as it measures the growth potential of the industrial sector. An example of the allocation mechanism is presented by figure 2.3. To summarise, economic growth, which is indicated by growth of utility output in ECCO, mainly depends on the room for investments in the industrial sector. Thus, the physical growth potentials of the system depend on the allocation of the industrial output over a number of terms.

One of these terms consists of consumption. The growth of the consumption level is directly influenced by the investments in the industrial sector. Albeit indirectly, the allocation of the industrial sector’s output towards consumption is directed from the industrial sector. Hence, the consumption level is mostly set by the production sector. The ECCO-modelling approach is, therefore, based on the assumption that the economy is supply-driven which means that each output creates its demand (theory of Say; in van Ierland et al., 1994).

7.3 A Demand-driven Modelling Approach

This section discusses the reasoning for developing a demand-driven modelling approach. Moreover, the general concepts are outlined in this section.

7.3.1 Arguments for a Demand-driven Modelling Approach

In chapter 1, the ECCO-modelling approach is introduced to study the societal metabolism and the associated energy flows through society in particular (see figure 1.1). It is stressed above that the dynamics of the ECCO-modelling approach are mainly supply-driven. This supply-driven perspective was generally chosen by environmental scientists over the last decades as they tended to emphasize industrial and agricultural production and the associated environmental impacts. In doing so, they followed the traditional approaches of economic historians in whose view lower prices for industrial goods and rising incomes serve as a stimulus for a growing demand for products. [Schuurman, 1997]. More and more, consumers are assumed to play an important role in driving the economy. For instance, the theories of Keynes involve an economy that is demand-driven instead of supply-driven. His general theory, following a macro economic perspective, holds that income and thus consumption decreases as a result of declining investments. In turn, the demand for products declines which subsequently influences negatively total production and employment. Herewith, Keynes disagrees with the theory of Say which holds that
every supply creates its own demand (in: [van Ierland et al., 1994]). In addition, McKendrick [1982] pointed out that the industrial revolution was the result of an increasing demand for consumer goods in eighteenth-century England. Moreover, de Vries [1993] concluded that people began to work harder to accumulate more consumer goods which resulted in higher production levels. Furthermore, Brewer and Porter [1993] argue that the time is ripe for studies of what societies consume instead of what they produce. Pietilä [1997] also advocates the central role of households in the economy and states that households, as a basic economic unit, form the primary base of the economy and all other economic functions should serve as auxiliaries. He puts forward that the whole picture will change if we start looking at production, trade and economic activities from the household point of view. Christensen [1997] stresses that traditionally policies involve the impact of the production process during the whole cycle and therefore the impacts from existing lifestyles are ignored. Moreover, consumption pattern related lifestyles must be changed towards consumption of goods and services which are produced in more environmentally friendly ways. Noorman and Schoot Uiterkamp [1998] argue that households influence environmental conditions directly through the consumption of energy, the use of materials and the generation of waste. In addition, households influence environmental conditions indirectly implying that the goods and services consumed are also associated by the use of energy and materials and the generation of waste. The notion of using consumer activity as starting point to study environmental impacts economic activity is also outlined in Biesiot and Moll [1995], Duchin [1995], RIVM [1997], Biesiot and Noorman [1998], and Noorman and Kamminga [1998].

Ehrlich and Holdren [1971] also acknowledge the relationship between population (consumers), consumption and environmental stress and introduced an equivalent of the following simple relationship which is referred to as the IPAT-equation:

\[
\text{Impact} = \text{Population} \times \text{Affluence} \times \text{Technology} \tag{7.1}
\]

In equation (7.1), the increment of stress on the environment is the result of population change, per capita consumption change, and technology change.

Biesiot and Noorman [1998] link consumer activities, centred around households, to, among others, energy inputs and outputs in the economy and to the associated environmental impacts. Hence, all inputs and outputs in the production sector, with the exception of those involving exports, can be assigned to consumption by households as most output finally ends up in either domestic or foreign consumer goods and services. Taking the prominent role of households into regard, the societal metabolism concept described in chapter 1 and illustrated by figure 1.1 can be changed into figure 7.2. Figure 7.2 illustrates the way the impact of economic activity are attributed to consumption by households.
The concepts presented above are conceptualised in a research program called HOMES (HOuseholds Metabolism Effectively Sustainable) that was initiated to study the physical throughput of energy and materials through households [Noorman et al., 1998]. The aim of this program is to develop and apply the concepts, operational approaches, methodologies and instruments relevant for the diagnoses, evaluation, and change options of household metabolic rates in the Netherlands [ibid]. Or more specifically, it addresses the relationships between trends in consumption and the consequences for spatial and environmental quality, for socio-cultural aspects and for natural resources. In this way, the program takes the consumption side of economic activities as a starting point to study the relationship between economic activity and the environment. The program relies on the notion that consumer activities (centred around households) can be linked through integral assessments and life cycle analysis to the complex patterns of inputs and outputs of the economy and to the associated environmental loadings [ibid]. Households are considered as basic consumption units.

Within the HOMES-research program, measuring the consumption patterns in terms of energy is utilised as a mean towards understanding how to direct them towards sustainable objectives. The demand for natural resources (energy in particular) is not only determined by the number of households and the consumption per household but is also a function of biophysical, economic, technological, spatial and behaviour aspects [Biesiot and Noorman, 1998]. Among others, the dynamics of lifestyles play a key role in these studies.
The energy throughput through households is determined by assessing the energy costs of household expenditures. Assessing the energy content of households expenditures involves a hybrid method of energy analyses that is a mixture of process analyses and input-output analyses [Wilting, 1996]. Process analysis is frequently used to determine the energy intensity of materials and input-output analysis is used to compute the energy intensities at the sectoral level. The input-output methodology was already outlined in chapter 3. The methodologies involved have a quasi-static or semi-dynamic character implying for instance that some energy efficiency improvements which will probably be implemented in the production sectors are taken into account to predict changes in the indirect energy use of households [Noorman and Moll, 1998]. This quasi-static character can be regarded as a shortcoming in studying the long-term consequences of changing consumption patterns as this approach assumes that the system considered is almost in a steady state. In this perspective, the ECCO-modelling approach seems to be appropriate to study consequences of changing consumption patterns at a higher level of aggregation and in a (full) dynamic way. Not only can the consequences of changing consumption patterns be assessed in this way but also the changes in the production can be taken into account.

Therefore, a demand-driven version of ECCO (called DREAM) is developed with which these studies can be performed. In this perspective, Ryan et al. [1998] and Schembri [1998] also developed a more demand-driven modelling approach based on a ECCO-type model as they also note the important role of households and their consumption activity in the economy. Applying the concepts of HOMES to the Energy Accounting approach holds that all the primary fossil energy is extracted from the physical environment in order to produce goods and services to meet the needs, wants and aspirations of the population (or households). The goal of the DREAM-modelling approach is to calculate dynamically the total energy costs of national consumption. As a consequence, the purpose of the DREAM-modelling approach has somewhat shifted away from that of ECCO-models which are developed primarily for studies of production potentials. Besides final domestic consumption, also exports are included in the DREAM-modelling approach. Most of these exports also ultimately end up as consumer goods but are considered separately as it is too complex to assign these exports to foreign or domestic consumption. So in the DREAM-modelling approach, the overall energy costs associated with certain consumption and exports levels are computed by linking them to the primary energy costs of the production of the goods and services involved. This approach also involves an energy accounting approach and in addition it also uses the concepts of input-output analysis. From this perspective, it is not really different from ECCO although several key feedback loops differs in the two approaches. In ECCO, all sectoral outputs were eventually allocated over consumption exports and investments whereas in the DREAM-modelling approach the sectoral output required is based on desired consumption and export levels. The computation of the total
energy costs can best be compared to the derivation of the Leontief inverse (see chapter 3) as the Leontief inverse can, by definition, be used to determine the changing direct and indirect inputs of a changing final demand. The Leontief inverse can only be used in static analyses while the DREAM-modelling approach assesses the energy costs related to consumption and export level in a system dynamic way.

One of the topics of this part of this thesis is to compare from a methodological point of view the results developed with the DREAM-modelling approach with that of the ECCO-modelling approach. The ECCO-modelling approach describes the economy at a macro/meso level. Hence, the DREAM-methodology approach presented here describes also the energy content of household expenditures at macro/meso level in order to be consistent with the ECCO-modelling approach. Changes in household expenditures, therefore, mainly focus here on growing consumption levels. The models and associated results presented in this part are less suitable for assessing the energy costs of (qualitative) shifts in households consumption patterns. Such studies require data availability at a much more detailed level. However, such studies are very interesting for future research.

As stressed above, the demand-driven approach discussed in this chapter involves different balancing terms than the ECCO-model. Compared to the ECCO-approach, some of the key feedback loops are drastically changed in the DREAM-modelling approach (the main changes are outlined in section 7.4). The major feedback loops or influences of the DREAM-modelling approach are described below.

7.3.2 Major Concepts of the DREAM-Modelling Approach

The goal of the DREAM-modelling approach is to determine the energy costs of changing consumption levels in a dynamic way and therefore consumption growth rates are considered to be scenario variables (i.e. these growth rates are set exogenously). Growing consumption levels will result in growing productions levels either domestically or in foreign economies. Capital stock of the production sectors will also have to increase in order to meet those growing consumption levels. In this way, consumption levels determine a desired level of capital stock which determines the amount of capital needed to produce the output required to satisfy the desired demand for consumer goods and services and exports. Differences between the desired capital stock and the existing capital stock set the rate of investments. Thus, investments in the production sector are set by consumption growth rates and act no longer as the balancing term. The amount of industrial output produced domestically that can be allocated to consumer goods now forms the balancing term. Hence, the fraction not consumed (see figure 7.3), which represents the room for investment in the ECCO-methodology, is replaced by a fraction available for domestic consumption. So, the allocation of industrial output produced domestically is no longer balanced by the room for investments but it is balanced by the room for
consumption. In case domestic production does not satisfy the domestic demand, imports balance domestic supply and demand. The key flows and influences of the industrial sectors are presented for the DREAM-modelling approach as well as for the ECCO-approach in figure 7.3.

From the two figures, it can be concluded that one of the most striking differences between both models is the absence of a negative feedback loop in the DREAM-modelling approach. Therefore, the DREAM-model can be considered to be a growth model. Herewith, the DREAM-approach are more consistent with common economic modelling approaches in the sense that the DREAM-approach is also based on extrapolating historical trends. The substantial change in the structure of the DREAM-approach compared to that of the ECCO-approach may have a strong effect on the outcomes of the model as the growth of the production sector no longer appears to be decelerated endogenously. Hence, it is less likely that the production sector will face a severely declining output indicating that the environment may set limits to the industrial growth.

In the DREAM-modelling approach, imports increase if the level of consumption can no longer be met by domestic industrial production. These imports may be regarded as a kind of loans or foreign investments as these imports allow the economy to grow in the sense that these imports do not restrict the investments in the domestic sectors. A number of ECCO models also have the option to include loans (see among others [Crane, 1995; Foran and Crane, 1998]). These loans can among others be used to expand industrial growth. This borrowing feeds into the total debts. Repayments of these debts also include interest rates accrued on the debt [Crane, 1995]. Herewith, these models incorporate the common practice of getting a loan in
order to invest under the assumption that the return on investments exceeds one. However, a number of models (e.g. the Dutch ECCO-model [Noorman, 1995] and the ECCO-model for OECD-Europe as presented in chapter 4) does not have the option to issue loans to increase investments. The reasons for not including loans can be found in the fundamental laws of thermodynamics. In issuing loans capital is created and therefore one might get the impression that energy is ‘created’ too. As a consequence of not issuing loans, scenarios developed with the aid of these models might show less economic growth than observed in reality. The topic of loans complicates the study of determining the all-inclusive energy costs of a number of (consumption) growth paths with the aid of these models. In DREAM, the matter of issuing loans has been dealt with by adjusting the balancing term implying that the additional imports which balance supply and demand can be regarded as a kind of loan as it involves foreign or strange capital.

7.4 Detailed Overview of the DREAM-Modelling Approach

In section 7.3, the main differences between the ECCO and the DREAM-modelling approach are described in more or less general terms. This section presents a more detailed overview of the parameters which are changed in the DREAM-modelling approach compared to the ECCO-modelling approach of OECD-Europe as presented in chapter 4. A complete overview of the DREAM-methodology can be obtained by combining the listing below with the detailed description of the aggregate ECCO-model for OECD-Europe in chapter 4. This section describes a single region model for OECD-Europe. As might be expected the changes mainly involve investments, consumption and the import-export balance. Below, influences are represented by dashed lines and flows by solid lines. The equations changed substantially are listed in Appendix I.

7.4.1 Investments

In the DREAM-modelling approach, the rate of investments of a sector depends on a desired capital stock (\(D_{\text{csut}}[s]\)) implying that investments are demand-driven. Investments are, therefore, determined differently in the DREAM-modelling approach compared to the ECCO-modelling approach. The demand for capital is influenced by

\[
ROI = \sum_{t=0}^{n} \frac{Z_t}{\text{Inv}_{0}(1+r)^t}
\]

In this equation, \(Z_t\) represents the annual average yield of the project, \(\text{Inv}_{0}\) indicates the total investment costs. In addition, \(n\) denotes the life time of the project and \(r\) the discount rate (based on [Bouma, 1988]).
the desired output of a specific sector (\textit{dout}[s]), that is the demand for capital is assumed to be proportional to the amount of output (\textit{cf.} diagram 7.1). The desired output is allocated over the items: exports, total (intermediate) deliveries to sectors (\textit{tintout}[s]), deliveries to the final demand (\textit{del2fc}[s]), and to the rate of capital formation (\textit{del2rcf}[s]). Deliveries to the final demand involve the contribution of that sector to the final consumption by households or government whereas deliveries to the rate of capital formation involve the contribution of a sector’s output to the total investment rate. Intermediate deliveries to sectors are determined by the demand for input in the sector of destination as in each sector the inputs are proportional to the capital stock (\textit{cf. subsection 4.2.1}). The same applies to deliveries to final consumption and to exports as consumers set consumption levels. In addition, the deliveries are also determined by the sectors of destination as growth of the sectors involved regulates the total rate of capital formation and thus the extent of the total deliveries to capital formation.

\begin{itemize}
  \item \textit{Consut[s]} Desired capital stock of sector \textit{s} \\
  \item \textit{Dcsut}[s] Desired capital stock of sector \textit{s} \\
  \item \textit{rcf}[s] Rate of capital formation (investments) of sector \textit{s} \\
  \item \textit{rdc}[s] Rate of capital depreciation of sector \textit{s} \\
  \item \textit{tintout}[s] Total intermediate deliveries of sector \textit{s} to all sectors \\
  \item \textit{del2rcf}[s,a] Deliveries to rate of capital formation of sector \textit{s} \\
  \item \textit{del2fc}[s] Deliveries to final consumption of sector \textit{s} \\
\end{itemize}

Diagram 7.1: Investments

\subsection{7.4.2 Consumption}

The shifts in the balancing term have made the consumption sector more complex than in ECCO. The consumption level (\textit{consut}), which is expressed in terms of utility depends on the the relative population growth (\textit{popf}) and the growth rate of consumption per capita (\textit{grwthconsut}) of which the latter is set exogenously (\textit{cf.} diagram 7.2). The total consumption level is assigned to the sectors of origin by introducing a factor. In other words, the demand for consumption (\textit{dcons}) is coupled to a demand for goods and services in the production sectors. These production
sectors can either be domestic or foreign implying that the consumption level can be met by domestic deliveries or by imports. The ratio of domestic deliveries (\(\text{ctrbincons, incons}\)) to imports (\(\text{ctrbmcons, mcons}\)) needed to meet the consumption level is set exogenously as a starting point. However, it remains to be seen whether this demand for goods and services domestically produced can be met by the output of the associated sector as consumption is the balancing term in the DREAM-modelling approach. In other words, the starting point results in a desired demand for goods and services domestically produced (\(\text{dcons}\)). The room for consumption determines whether or not this desired demand can be completely met by the domestic sectors. The room for consumption is computed in a similar manner as the room for investments in the ECCO-modelling approach which holds that the room for consumption (\(\text{tacons}\)) depends on the output of a sector (\(\text{out}\)) and to the allocation of this output to exports (\(\text{exports}\)), total intermediate deliveries (\(\text{tintout}\)) and investments. The latter is dealt with by introducing an allocation factor called ‘fraction available for consumption (\(\text{fac}\))’ which is similar to the ‘fraction not consumed’ described in section 4.2. The fraction available for consumption depends on the available output (\(\text{out}\)) and on the investments rates required (\(\text{rcf}\)). The room for consumption (\(\text{tacons}\)) is sufficient when it is not smaller than the desired demand for goods and services domestically produced.

\[
\begin{align*}
\text{incons}[s] & : \text{consumption of products stemming from domestic sector } s \\
\text{addimp} & : \text{additional imports required to meet the desired consumption level} \\
\text{dcons}[s] & : \text{desired consumption of products stemming from sector } s \\
\text{consut}[s] & : \text{consumption of products stemming from sector } s \text{ in terms of their utility value} \\
\text{grwthconsut} & : \text{growth of consumption of products stemming from sector } s \text{ in terms of the utility value} \\
\text{mcons}[s] & : \text{imported consumer goods stemming from a foreign sector } s \\
\text{tacons}[s] & : \text{total domestic output available for consumption} \\
\text{fac}[s] & : \text{fraction available for consumption} \\
\text{out}[s] & : \text{domestic output of sector } s \\
\text{exports}[s] & : \text{exports from sector } s \\
\text{tintout}[s] & : \text{total intermediate deliveries of sector } s \text{ to all sectors} \\
\text{rcf}[s] & : \text{Rate of capital}
\end{align*}
\]
In this case, the initial allocation of consumption over imports (mcons) and domestic production (incons) is maintained. When this desired level of consumption exceeds the room for consumption, the additional demand for consumption is met by additional imports (addimp) which holds that consumption is balanced by an increase in imports in the DREAM-modelling approach (see below).

7.4.3 Balance of Trade

The import export balance (impexp-balance) is equal to the differences between the total imports (totimports) and the total exports (totexports) (cf. diagram 7.3). The importance of the import-export balance was already emphasised in chapter 4.5. The import-export balance is even more essential to the DREAM-modelling approach as imports are a balancing term. Consumption and exports which cannot be met by domestic output are met by additional imports (addimp). As mentioned in subsection 7.4.2, these imports are additional to imports of goods and services by the production sectors (imp), imports associated with consumption (mcons), and the imports of primary fuels (pfimports). So, additional imports balance the desired output of sector (dout, see 7.3.1) and the actual output of a sector (out). Exports and imports are linked directly. The level of exports of goods and services is based on a growth rate (GRWTHEXP) which is set exogenously. Besides goods and services (exports), exports also comprise energy sources (pfexports) which depends on the domestic energy supply in that country (see section 4.3).
7.5 Case Study of the Dutch DREAM-model

Results of scenarios developed with the DREAM-model for OECD-Europe are presented throughout chapter 8. In addition, these scenario results are compared to that of corresponding scenarios developed with the ECCO-model of OECD-Europe. Before presenting these scenario results, this subsection presents the case study of developing and applying a DREAM-model for the Netherlands (denoted by NLDREAM). This case study serves to illustrate how the energy costs associated with future consumption growth rates can be studied by using the DREAM-modelling approach. The ECCO-model, which Noorman [1995] developed for the Netherlands (NLECCO), forms the basis of NLDREAM. A number of the basic principles of NLECCO are outlined in chapter 2 and 4. Noorman [1995] presents a detailed overview of NLECCO.

7.5.1 From NLECCO to NLDREAM

Sections 7.3 and 7.4 described the consequences of shifting the model from a supply-driven to a demand-driven perspective. Besides shifting the model’s perspective from supply-driven to demand-driven, a number of other features are changed in NLDREAM compared to NLECCO. This subsection describes these changes briefly. Appendix I presents a detailed overview of these model changes.

Households are included in NLDREAM and direct consumption of goods and services and private transportation. Five types of households are distinguished in NLDREAM: one person households, two persons households, three persons households, four persons households and households with five or more persons. Within the household groups the same age distribution is used as in NLECCO (i.e. young people (19), young adults (20-44), major adults (44-64), and elderly people (>65)) [CBS, 1986,1996].

In NLDREAM, private transportation is included differently in comparison to the procedure in NLECCO. In NLECCO, private transport is influenced by the material standard of living whereas in NLDREAM it is determined by the development in the composition of households. Herewith, NLDREAM uses the aggregate results of the study of Schenk [1998] who describes the private transportation sector at a very detailed level. Schenk calculates the emissions associated with private transport by distinguishing five related subsystems in which the driving forces specific for that module are determined at a detailed level; population module, households, car stock (ownership), kilometres driven per household and car emission module. From these results, average growth rates are derived for the kilometres driven per households type and the car ownership per household type.

Energy conservation is also altered in NLDREAM. In NLECCO, autonomous and additional energy savings are distinguished. Autonomous energy savings are assumed to take place without the requirement of additional investments whereas additional
energy saving require investments implying that additional capital stock must be
developed. In NLECCO, the extent of the additional energy savings depends on the
level of capital stock developed in the energy conservation sector. Moreover, the
introduction of both types of energy savings is set exogenously and is based on
Melman et al. [1990]. In NLDREAM, energy savings are divided in efficiency
improvements and structural changes. Both types of energy savings are set
exogenously. A part of both energy saving options can take place autonomously
whereas the other part of the energy saving options require investments. So unlike
NLECCO in NLDREAM, the extent of additional energy savings set the demand for
the level of capital stock required to enable these energy savings. In many cases, the
energy saving options introduced may not agree with the energy saving options
presented by Melman et al. [1990] as in some other studies (cf. [de Beer et al., 1994;
Hilten, et al., 1996]) other energy savings options are presented. These different
energy saving options will most likely not correspond with the associated capital
requirements presented by Melman et al. [1990]. Despite the possible inconsistencies,
the capital requirements of Melman are still used in order to take into account the
notion that a part of energy savings requires additional investments.

7.5.2 Starting Points of Scenarios

NLDREAM is introduced as a model developed in order to investigate the overall
energy costs associated with household consumption patterns in a system dynamic
way. Four scenarios are developed here to illustrate the potentials of NLDREAM as
well as its limitations. Two of these scenarios are consistent with the European
Coordination scenario (EC) and Global Competition scenario (GC) as developed by
CPB [1996, 1997]. Both scenarios can be considered as two variations on a
‘business-as-usual’ scenario. The former assumes a strong European Community
involvement. The European economy grows considerably together with the Asian
economy while the economy of North America lags behind. The level of technology
develops strongly. Consumption patterns become more immaterial and
environmentally friendly. The GC-scenario involves an economy which grows
globally at a high rate. This scenario also assumes a considerable development in
technology but the developments are mainly market orientated. Consumption patterns
are associated with a high level of product differentiation.

It would be interesting to compare these two ‘business-as-usual’ scenarios with
a sustainable development scenario. Simplifying its concepts, sustainable
development is regarded only from an energy perspective and involves an economy
in which the energy demand is totally met by renewable energy and the energy.
demand does not exceed the 1-1.5 kW per person\textsuperscript{10}. The latter is conceptualised by Dürr [1994] and it is also applied by Biesiot [1998] and Mulder and Biesiot [1998]. The target of 1.5 kW per person to be met in 2050 is based on the maximal amount of renewable energy which can be produced per person if one assumes full global equity in energy service terms (i.e. every person in the world uses the same amount of energy). This target energy demand involves both direct energy use and indirect energy use. In case of the Netherlands, Biesiot [1998] shows that such a long-term sustainability objective requires structural changes in the current consumption patterns and thus in the whole economy. Potential energy savings options alone are insufficient to reduce the current Dutch energy consumption level of about 5-6 kW per person to the target level of 1-1.5 kW per person. Such a ‘sustainable’ scenario cannot be developed with the version of NLDREAM described above since changes in consumption patterns can hardly be studied with the model in its present state because the production sectors are described at a too highly aggregated level (i.e. at a macro level instead of a micro/meso level). Therefore, two ‘semi-green’ scenarios are developed to illustrate the differences between ‘business as usual’ and a transition directed towards a more sustainable future. Both ‘semi-green’ scenarios assume a renewable public electricity supply by the year 2020. In addition, the energy saving options follow the maximum saving potentials as presented by ICARUS-3 [de Beer et al., 1994]. In the first semi green scenario (SG1), consumption and export growth rates are assumed to be similar to the EC-scenario which is consistent with the assumptions of these scenario improvements. In the second semi-green scenario (SG2) are coupled to the growth rates presented in the Divided Europe (DE) scenario. The DE-scenario is also introduced by CPB [1996, 1997] and involves a more pessimistic scenario from a macro-economic point of view implying lower economic growth rates. The basic scenario variables of the four scenarios are listed in table 7.1. The differences in the energy saving potentials between scenarios SG1 and SG2 are the results of differences in structural changes (derived from EC and DE, respectively).

\footnote{The target energy service use of 1-1.5 kW per persons equals a maximal annual energy demand of 30-50 GJ per person.}
Table 7.1: Average annual growth rates and improvements (in %) of driving exogenous factors of the presented scenarios for the period 1995-2020. Thermal energy savings and electricity savings include efficiency improvements as well as structural changes. The observed annual growth rates are also presented for the period 1985-94.

<table>
<thead>
<tr>
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<th>EC</th>
<th>GC</th>
<th>SG1</th>
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<td>6.2</td>
<td>5.0</td>
<td>3.1</td>
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<td>4.9</td>
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<tr>
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<td>3.6</td>
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<td>-</td>
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<td>1.6</td>
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<tr>
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<td>14.8</td>
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<td>16.5</td>
</tr>
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</table>

a Data for 1985-1995 are derived from [CBS, 1987, 1997]. Except, data for export growth rates of transport, market services, and non market services are estimated by combining OECD statistics [1997] with Eurostat statistics [Oosterhaven and van der Linden, 1995; van der Linden, 1999]. Data for the four scenarios are derived from [CPB, 1996, 1997];


c Data for 1985 derived from [Noorman, 1995]; Data for the GC and EC-scenarios are derived from [ECN, 1998]

d Data involve shares instead of growth rates; * Data involve absolute values instead of growth rates

f Data for the year 1985; g Data for the year 2020.
7.5.3 Scenario Results

The growth rates presented in table 7.1 are applied to the year 2050 to develop scenarios which cover the 1985-2050 period. Figure 7.4 shows that the total consumption grows considerably in all scenarios as result of this assumption. For the GC-scenario, the total consumption level is more than eight times as high in 2050 compared to 1985. Even in the case of SG2-scenario, the total consumption level more than doubles in the same time period. The EC-scenario and the SG1-scenario have similar consumption levels and end up with having a level six times as high compared to 1985.

Compared to the consumption level, the total export levels even increase at a much higher rate as shown in figure 7.5 (see scenario assumptions presented in table 7.1). Expanding these rates to the year 2050 results in extreme export levels in the case of scenario GC where the export levels are about 25 times higher in 2050 than in 1985. Also in the case of scenarios EC and SG1, the total export levels are extremely high as they are more than 15 times as high in 2050 as in 1985. Even in 2020, the export levels are about 4-5 times higher for the GC, EC and SG1 scenarios compared to 1985. In addition for scenario GC, total exports are 7 times higher than the consumption level in 2050 whereas they are twice as high in 1985.

In section 7.3, it is argued to assign the energy use in the production sectors to the consumption by households. One can argue whether or not exports should also be assigned to the consumption of households. One can state that most exports end up as consumer goods for foreign households and thus the associated energy costs should be assigned to those households. One can also argue that most of these exports compensate the imports of, among others, energy carriers. Therefore, these exports
can be assigned to Dutch households. However, the latter may involve a kind of snowball effect as increasing exports to balance imports is associated with an increasing output of the production sectors implying growing imports which also have to be balanced.

Figure 7.6 shows the total energy consumption per person whereas figure 7.7 presents the total energy consumption per household. In both cases, the total energy consumption includes the direct energy demand and the energy content of consumer goods and services. The energy content of exports are not taken into account. The energy content of consumption of common goods such as infrastructure, schooling and medical care should be included in the consumption of goods and services. These collective goods and services comprise about 30% of the total consumption of goods and services [van Engelenburg et al., 1991; Kramer et al., 1998].

In figures 7.6 and 7.7, the energy consumption per capita about stabilises for SG2-scenario while it increases considerably in the case of the GC-scenario. The total energy consumption per households more than triples for the GC-scenario between 1985 and 2050 and about doubles for the SG1 and EC-scenarios. Besides the structural changes, the SG1-scenario is associated with a high level of efficiency improvement and a renewable public electricity supply after 2020. These energy savings and renewable public energy supply are exceeded by the consumption growth rates resulting in the increase in the energy use in SG1-scenario. The energy consumption by households only remains about the same for SG2-scenario which involves a lower consumption growth rate (1.7 for SG2 compared to 2.7 for EC and
In 1985, export levels and consumption level were respectively about 2.0 (1985)EJ and 1.0 (1985)EJ compared to the total production of 4.5 (1985)EJ.

Figure 7.8 shows that the total production (in terms of the utility value) increases substantially as a result of the growing consumption levels and especially of the growing export levels. For the GC-scenario and the SG2-scenario, total industrial output increases at an average annual growth rate of about 4.5% and 1.8%, respectively. The scenarios EC and SG1, which have similar export growth rates and consumption growth rates, increase at an average annual growth rate of about 3.5%. In 1985, total export and the total consumption together comprised about 66% of the total output\(^{11}\) in the year 1985 implying that about 34% of the total output is allocated to intermediate deliveries or investments. By 2050, about 80% of all output is allocated to the exports and consumption. This change is the result of the relatively larger contribution of exports.

Figure 7.9 shows the total primary energy demand of the Netherlands. Not only does the primary energy demand result from these developments of the output of the production sectors but it also includes the primary energy demand by households. The production sectors contribute the most to the primary energy demand. For the GC and the SG1-scenario, this contribution increases from about 70% in 1985 to 88% in 2050. For the EC-scenario, the contribution of the production sectors to the primary energy demand is 86% in 1985 and 94% in 2050.

\(^{11}\) In 1985, export levels and consumption level were respectively about 2.0 (1985)EJ and 1.0 (1985)EJ compared to the total production of 4.5 (1985)EJ.
demand increases from 70% to 85% while this contribution remains about the same for scenario SG2. For each scenario, the primary fossil energy demand of the production sectors increases at a lower rate than the total output of the production sectors. These lower growth rates are clearly the result of energy savings. The primary energy demand of production sectors involves average growth rates of 2.2% and 1.4% for the GC and EC-scenarios, respectively. For scenarios the SG1 and SG2, the corresponding growth rates are about 0.6% and -0.5% respectively. Compared to 1985, the primary energy demand is about 45% higher for scenario SG1 in 2050 whereas it is about 30% lower for scenario SG2 in that year.

So in scenario SG1, the fossil primary energy demand is still increasing despite the high level of energy savings and a public electricity supply which is fully based on renewables. Only for scenario SG2, the total primary energy demand decreases slightly as this scenario involves a lower consumption growth rate (1.7%) besides the high level of energy savings and a public electricity supply which is fully based on renewables. For scenarios GC and EC, the fossil primary energy demand is about 4.5 to 2.5 times higher in 2050 than in 1985, respectively.

Figure 7.10 shows that primary fossil energy requirement (in GJ) for producing one kWh of electricity decreases somewhat due to efficiency improvements for scenarios GC and EC. As a result of the public renewable electricity supply, the primary fossil energy becomes zero after 2015 for scenarios SG1 and SG2.

Clearly, the fossil primary energy demand for scenario GC is associated with the highest carbon dioxide emissions while the SG2-scenario is associated with lowest carbon dioxide emissions (see figure 7.11). For each scenario, the carbon dioxide emission change rates are slightly higher.
than that of the fossil primary energy demand which is the result of small changes in the fuel mix. According to the Kyoto (i.e. the Climate Change Conference in 1997) targets, The Netherlands is committed to reduce the CO₂-emission with 6-10% in 2010 compared to the emission level of 1990 [VROM, 1998]. Only in the case of the SG1 and SG2-scenarios, these emission targets are met as these scenario are associated with high energy efficiency improvements and a renewable public electric supply. Although the emission targets of 2010 are met, emissions only decrease slowly after 2010 in case of scenario SG2 as this scenario involves a relatively low consumption growth rate.

Beeldman et al. [1998] investigated in what way the CO₂-emission can be reduced by 32% in 2020 compared to 1990 for the GC-scenario when more energy saving options are used and by so-called ‘backstop’ technologies\(^\text{12}\) are introduced. In principle, backstop technologies should be considered as end-of-pipe technologies and can therefore be regarded as unfavourable. Depending on the way the technology improvements are stimulated, about 55-77% of reducing the CO₂-emission reduction are realised by backstop technologies in order to meet this reduction target. These results illustrate that high consumption levels are almost unavoidably associated with high CO₂-emissions. Hence, substantially reducing the CO₂-emissions necessitates changing consumption patterns. This conclusion corresponds with the findings of Biesiot [1998]. Note that the results in this study, changing consumption patterns mainly concerns lowering consumption growth rates. Changing the consumption package requires a more detailed description of the production sectors in NLDREAM and should be introduced in future versions of the model.

Figure 7.12 shows that the Dutch natural gas reserves are depleted firstly in the GC-scenario. The gas reserves depletion is delayed with about ten years (from 2012 to 2021) for scenario SG2. The natural gas reserves may appear to deplete within a rather short time period.

\(^{12}\) Backstop technology can regarded to be similar to end-of-pipe technology as it also involves dealing with emissions at the sink and not at the source implying that the CO₂-emissions are reduced by ‘putting’ it in a sink other than the air. Beeldman et al. [1998] consider a very broad interpretation of backstop technology by including imports of biomass and imports of electricity derived from nuclear energy and renewables next to CO₂-removal and storage.
However it is assumed here that the contribution of imports to the total domestic supply remains constant after 1990 whereas it may increase in practice.

The depleting gas reserves are associated with an increase in the imports of energy carriers. Figure 7.13 shows the import-export ratio (defined as total imports divided by total exports in which both concern fuels as well as goods and services) increases as result. The year in which the gas reserves are depleted can also derived from figure 7.10 as this year is indicated by a strong increase in the import-export ratio. Therefore, the import-export ratio may be regarded as an indicator for (un)sustainability in the sense that it indicates the dependence on foreign resources. The Netherlands even shift from a net energy exporting country (i.e. import-export ratio is lower than one from 1985 to 1990) to a heavily net energy importing country.

The high dependence on imports is also illustrated by figure 7.14. For the GC-scenario, total imports are about 20 times higher in 2050 than in 1985 implying an annual growth rate of 4.6%. For the SG1 and EC-scenarios, total imports are about ten times higher in 2050 compared to 1985.

7.6 Conclusions

In this chapter, the supply-driven ECCO-modelling approach is changed into the demand-driven DREAM-approach. A dynamic energy accounting approach is developed based on the notion that most production finally ends up in consumer goods and services. The consequences of changing consumption patterns on the overall energy requirements of an economy can be determined by assigning most energy use resulting from economic activity to the consumption of households. Compared to the ECCO-approach, a number of key feedback loops are altered to
facilitate the shift from a supply-driven model to demand. The impact of these changes are studied in chapter 8 in which the results of DREAM are compared with that of ECCO.

The DREAM-model of The Netherlands illustrates that a number of environmental consequences of consumption (i.e. reserve depletion, CO$_2$-emissions and an increasing dependence on foreign resources) can be determined by using the DREAM-approach. Unlike NLECCO, the current version of NLDREAM can be used to study dynamically the energy costs of different consumption growth rates and export growth rates combined with various energy saving potentials. Besides determining the overall energy costs related to consumer activities, NLDREAM offers the possibility to focus on some specific aspects related to consumer activities as all activities are expressed in terms of energy (e.g. fuel use due to private transportation, investments in the services sector, investments in electricity supply, etc). As the current version of NLDREAM involves a rather aggregated level, the energy costs of different aspects related to consumer activity cannot be considered at a detailed level so that the energy costs of changes in consumer packages cannot be studied yet. However, these studies can be carried out when more production sectors are considered.

The results of the GC and EC-scenarios developed with NLDREAM follow the results of the ECN/CPB-studies in the sense that the deviations in the total primary energy demand of the corresponding scenarios are less than 10% in the year 2020 [ECN, 1997-1998; CPB, 1998]. Both scenarios involve a growing primary fossil energy demand as result of consumption and export growth. The results may seem rather straightforward as the energy demand associated with growing consumption and export levels is not restricted by, for instance, adopting the condition that imports and exports should be balanced more in terms of energy or by setting the CO$_2$-emission limits (e.g. consistent with the Kyoto target). In principle, these kind of items can be studied with the aid of NLDREAM but they require some modelling adjustments.

Scenario SG1 showed that despite substantial energy savings potentials and a public renewable electricity supply, relatively high consumption growth rates are still associated by an increasing total energy demand. The results of scenario SG1 and SG2 indicate that a decreasing energy demand can only be realised by lowering the consumption growth rates. However, it should be noted that the consumption patterns are not changed in these scenarios. Changing consumption patterns towards more energy-extensive products will lower the total energy demand. It is not clear whether these changes will result in much more decreasing energy demands. Again, this topic can be studied more properly with DREAM when more sectors are included in the DREAM-modelling approach.