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INTEGRATED EVALUATION OF ENERGY CONSERVATION OPTIONS AND INSTRUMENTS

A COUNTRY COMPARISON

CO-ORDINATOR

THE NETHERLANDS ENERGY RESEARCH FOUNDATION ECN

A.K. van Harmelen
M.A. Uyterlinde

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Abstract

The main objective of the study was to provide insight in the driving forces for energy conservation and their relation with conservation policy instruments and to investigate the present and future situation regarding energy conservation in different countries in terms of differences and common challenges.

The results give rise to the following recommendations regarding national and EU policies. R&D policies should particularly pay attention to the energy services and branches with a relatively small technical energy conservation potential available at the moment, in particular those for which the share in total consumption is large or is projected to grow. In households, energy services such as drying, miscellaneous electric household appliances (audio-video, hobby, personal care, sleeping etc.) and washing should have priority in order to reduce households energy consumption in the long run. For the manufacturing sector, the technical saving potential in the subsectors Chemicals, Metal products and Building materials should be enlarged. Feedstocks comprise a substantial share of the industrial energy consumption. Research is required on complex integrated process improvements, substitution of materials, possibilities for recycling and utilisation of residuals and waste in industrial processes.

Energy conservation policy should close the gap between realised energy savings and technically available potential, prioritising those energy services and manufacturing branches which require a large share of the energy consumption, now or in the future. In households, for hot water, cooking and cooling a large gap between technical potential and realisation is calculated. Furthermore, heating is important since it covers a large share. This ‘efficiency gap’ is smaller in the manufacturing sector where the investors are more rational. Therefore R&D policies on the development of new technologies are more important for this sector. The case studies indicate that for households the availability of profitable saving technologies is not an important barrier for energy conservation. Much more important barriers are the competitive disadvantages of new entrants, bifurcation effects due to low replacement rates, strong competition and decreasing effectiveness of new technologies after substantial savings. Therefore, the savings induced by general financial and behavioural instruments are limited, as relative competitive advantages are not addressed. Hence, most impact can be expected from combinations of instruments addressing different barriers simultaneously, policies focusing on specific technologies and from regulation which may overrule existing barriers.

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ECN (NL)	Toon van Harmelen, Martine Uyterlinde, Harm Jeeninga, Mariam Motahari, Wilma Pellekaan and Frits van Oostvoorn
ACE (UK)	Joanne Wade and Victoria Wiltshire
Ecoplan (CH)	Felix Walter, Andy Muller and Renger van Nieuwkoop
IDAE (ES)	Carlos García Barquero and Francisca Rivero García
LiU (SE)	Mats Söderström and Björn Rolfsman
SEO (NL)	Jan Willem Velthuijsen, Aldo Paape and Dorita Sleur
SRC (DK)	Kirsten Dyhr-Mikkelsen and Bo Pedersen
VTT (FI)	Seppo Karkkainen, Eero Tamminen and Aulis Ranne

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EXECUTIVE SUMMARY

The main objective of the study was to provide insight in the driving forces for energy conservation and their relation with conservation policy instruments and to investigate the present and future situation regarding energy conservation in different countries in terms of differences and common challenges.

The most obvious finding of the national review is that the information which is presently collected and reported is insufficient to guide policy transfer. Also, the study of policies, when carried out using varying baselines, assumptions and methodologies, does not assist the process. However, the range of promising policies identified by the work should provide scope for action in all Member States, allowing the particulars of national situations to be accounted for without the opportunity for improvement being lost. Reducing policies to short summaries may be necessary to facilitate the development of an overview. However, the most productive type of information to transfer between countries may be much more detailed and qualitative. The project, like much other recent work, has highlighted the lack of understanding which energy researchers and policy makers have about human behaviour.

The comparative process would be improved by the application of common techniques and methodologies across all countries. Therefore, quantitative case studies were conducted using a common methodology (the dynamic energy conservation model REDUCE) and comparable, consistent scenarios for households (Denmark, Finland, the Netherlands, Switzerland and United Kingdom) and the manufacturing sector (Spain, Sweden and the Netherlands).

The household energy consumption in the year 2020 is expected to remain more or less constant at 1994 level, for all countries except the Netherlands and Finland. Energy savings have a substantial contribution of 15% to 25% of the baseline consumption. Technical saving potentials are around 50% of the baseline. Energy consumption of the manufacturing sector is expected to rise considerably up to 2020. The saving technologies can limit the projected growth of 53% to 42% in Spain, 63% to 44% in the Netherlands and 82% to 77% in Sweden. Technically feasible saving potentials are not much larger than the implemented savings. For both sectors, country differences are rooted primarily in the present and projected structure and present efficiency of energy consumption (services or sectors).

The results give rise to the following recommendations regarding national and EU policies. R&D policies should particularly pay attention to the energy services and branches with a relatively small technical energy conservation potential available at the moment, in particular those for which the share in total consumption is large or is projected to grow. In households, energy services such as drying, miscellaneous electric household appliances (audio-video, hobby, personal care, sleeping etc.) and washing should have priority in order to reduce households energy consumption in the long run. For the manufacturing sector, the technical saving potential in the subsectors Chemicals, Metal products and Building materials should be enlarged. Feedstocks comprise a substantial share of the industrial energy consumption. Research is required on complex integrated process improvements, substitution of materials, possibilities for recycling and utilisation of residuals and waste in industrial processes.

R&D policies should also address technology specific barriers for market introduction of the current Best Available Technologies to make them competitive with presently used technologies. This is crucial for achieving long term energy efficiency improvements.

Energy conservation policy should close the gap between realised energy savings and technically available potential, prioritising those energy services and manufacturing branches which require a large share of the energy consumption, now or in the future. In households, for hot water, cooking and cooling a large gap between technical potential and realisation is calculated. Furthermore, heating is important since it covers a large share. This ‘efficiency gap’ is smaller in the manufacturing sector where the investors are more rational. Therefore R&D policies on the development of new technologies are more important for this sector.

The case studies indicate that, in particular in households, the availability of profitable saving technologies is not directly a barrier for energy conservation. Much more important barriers are the competitive disadvantages of new entrants, bifurcation effects due to low replacement rates, strong competition and decreasing effectiveness of new technologies after substantial savings. Therefore, the savings induced by general financial and behavioural instruments are limited, since relative competitive advantages are not addressed. Hence, the most impact can be expected from combinations of instruments addressing different barriers simultaneously, policies focusing on specific technologies and, finally, from regulation because it overrules existing barriers.

GLOSSARY

BAT	Best Available Technology
CHP	Combined Heat and Power, or co-generation
CO_2	Carbon dioxide
DSM	Demand Side Management
EPS	Energy Performance Standard
EU	the European Union
GJ	Gigajoule
hh	household
IRR	Internal Rate of Return
kWh	kilowatt-hour
PbP	Payback period
PJ	Petajoule
SME	Small and medium sized enterprises
TPF	Third Party Financing
U value	measure of thermal efficiency (W/m^2K)
VA	Voluntary Agreement
VAT	Value Added Tax

CH	Switzerland
DK	Denmark
ES	Spain
FI	Finland
NL	The Netherlands
SW	Sweden
UK	United Kingdom

1. INTRODUCTION

The Joule III project ‘Method for integrated evaluation of benefits, costs, and effects of programmes for promoting energy conservation’ consisted of two phases, which were documented in a Phase I and a Phase II report. The Final Report is a synthesis report of these two reports. The objectives of the project are described in chapter 2.

The first phase consisted of a review of the present situation regarding energy consumption and energy conservation policies and studies in seven EU countries. A summary of the analysis of the present situation is given in chapter 3, while the extended report can be found in the Phase I report. Also, specific analyses were made of three subjects, viz. the impact of market liberalisation on energy conservation, environmental surcharges and a survey on investment decisions on energy conservation options in industry in the selected countries. This survey aimed at identifying the behavioural aspects of decisions as a reason for conservation potentials not being achieved and policies not being effective. The findings of these three analyses are also reported in the Phase I report.

The main subject of the second phase was to conduct, on the basis of Phase I material, for each country a quantitative case study using a common methodology and comparable, consistent scenario assumptions. The case studies focus on the interaction of technological parameters of energy conservation options and investment behaviour in relation with policy instruments. The applied methodology is described in chapter 4. The scenario assumptions, partly based on Phase I material, are presented in chapter 5. The results of the case studies for the seven countries, viz. Denmark, Finland, Netherlands, Spain, Sweden, Switzerland and United Kingdom are presented and discussed in chapter 6. All material stems from the national reports of the involved institutes. The Final Report concludes with Conclusions and Recommendations regarding the research content in chapter 7.

2. OBJECTIVES

The Joule III project ‘Method for integrated evaluation of benefits, costs, and effects of programmes for promoting energy conservation’ had the following objectives:

- To review the present situation in seven European countries with respect to energy consumption, the level of energy efficiency, energy conservation policy instruments used and (types of) energy conservation studies applied.
- To provide a robust methodology for integrated assessment of benefits and costs of different policy instruments applicable for different countries and the Commission.
- To conduct comparable case studies in seven different countries for two sectors, viz. households and manufacturing sector, in order to provide insight in driving forces for energy conservation and their relation with conservation policy instruments and to investigate the present and future situation regarding energy conservation in different countries in terms of differences, common challenges and scope for common activities (households is specified for Denmark, Finland, the Netherlands, Switzerland and the United Kingdom and the manufacturing sector for the Netherlands, Spain and Sweden).
- To use, discuss, evaluate, modify and disseminate the REDUCE energy conservation evaluation model.
- To formulate recommendations for the EU Community policies as well as for national governments on policies and programmes to promote energy conservation, in particular the complex economic, financial and behavioural instruments in contrast with the often applied regulatory instruments.

3. PRESENT SITUATION

3.1 Introduction

Throughout the European Union there is an increasing emphasis on the use of market forces to deliver energy efficiency improvements wherever possible. The strong movements towards deregulation and liberalisation of energy markets in Western countries are an incentive for reconsidering policies that support energy conservation measures. Furthermore, as energy prices are expected to remain low, it is recognised that, in certain cases, policy assistance to improve the functioning of the market will be necessary.

An evaluation of successful energy conservation policies in different European countries provides the opportunity to learn from a wide range of experience. A review of conservation studies gives an indication of the attention paid to different types of policies, but also of the basis for (transferred) new policy. In this respect it is also relevant to analyse the extent to which success is influenced by country-specific elements such as the economic background, dependency on imported fuels, climatic conditions, energy intensity, level of energy prices and taxes, emissions of greenhouse gases etc.

In this chapter, a selection of policies and programmes, judged to be successful, from Denmark, Finland, the Netherlands, Sweden, Switzerland, Spain, and the United Kingdom, are briefly characterised and compared. After that, a number of recent conservation studies from the above countries are investigated, to obtain insights into the research directions taken in policy preparation and design. The analysis is based on reports written by authors participating in the project, who have provided detailed information on their own national situation. See Annex A for more information.

The remainder of this section provides an outline of the chapter. Section 3.2 develops a methodology for characterising policy effectiveness, and uses this to compare the policy instruments and programmes reviewed in the national reports against the aim of reducing carbon dioxide emissions. The cost-effectiveness of the policies is also considered. Section 3.3 describes the results of a qualitative analysis of approaches and assumptions used in recent conservation studies executed in the countries involved. Special attention is paid to the choice of methodology in relation to the objective of the study. Section 3.4 is a discussion of issues raised by the assessment results. In Section 3.5, conclusions are drawn concerning the possibility of policy transfer from one country to another, and areas where further work would be beneficial.

3.2 Successful policies and programmes

Policy initiatives throughout Europe have been aimed at a variety of economic, social and environmental goals. These may have covered a range of market failures, market barriers and non market issues. One aim of this work has been to identify some of the most successful national policies, which may be collected together into a policy toolbox for use by the Commission and national governments when considering how to overcome specific market failures and barriers in the future. This use of a toolbox to assist a market transformation process is consistent with the Commission's present approach to energy efficiency policy (e.g. Bertoldi 1996).

Each of the project partners reviewed in detail five policies or programmes which had been implemented in their country. These were chosen, from an initial basic characterisation of a wide range of implemented policies, to cover a range of types of instrument which appeared to show some degree of promise. The policy choice was also intended to ensure that comparisons of similar policies, implemented in different countries, could take place. In addition, a brief review of international policy initiatives was provided by one of the project partners.

3.2.1 Assessment methodology

As part of the in-depth review of national policies, a comparative assessment was carried out. The programme assessments available to the authors of the national reports were insufficiently detailed to allow the construction of national cost-benefit curves (many of the costs and benefits involved are not translated into monetary values). Whilst some of the costs and benefits could be quantified, including these numbers in the presentation of the overall results could have resulted in an over-emphasis on these aspects of the policy's effect, when they may not be the most important. Therefore an alternative comparison method has been used, in which each option is assessed against a series of criteria, and the results are presented in symbolic rather than numeric form. This also avoids any tendency for the reader to simply sum the different assessments to produce an overall rating. This approach has been used in other studies for the Commission, and also in individual countries (e.g. Martin and Michaelis 1992; Wade 1995).

Thus, in each of the national reports, the policies chosen for detailed analysis were assessed against a set of common criteria, including reducing CO_2 emissions, and cost-effectiveness from a variety of perspectives. For the first of these criteria, each policy is awarded a rating: +++, ++, +, 0, -. These signify the following (based ideally on what the policy is actually expected to achieve, relative to baseline projections, not what it theoretically could achieve):

+++ = results in a reduction in annual national emissions of > = 5%
++ = results in emissions reductions of < 5% but > = 1%
+ = results in emissions reductions of < 1% but > = 0.05%
0 = results in emissions reductions of < 0.05%
- = results in an increase in annual emissions

If a policy has only been applied, as a pilot phase, to a small proportion of the possible end-users (for example a domestic insulation programme which has only been implemented in one town), the above rating is calculated against emission reduction targets of an appropriate scale. This scaling of the effects is necessary to compare policies fairly: otherwise small-scale but very effective initiatives would not perform as well as larger scale yet less effective programmes. Note that the comparison of policies with differing scales of application is particularly difficult: this issue is discussed further below.

Partners were asked to assess cost-effectiveness from three perspectives: customer; utility; and total resource cost. At this point any non monetary costs and benefits will be excluded from these analyses (this issue is being considered in another part of the project).

For this criterion, it is perhaps more appropriate not to split down levels of positive effects, since information on total costs where a number of organisations or individuals contribute to the financing of a programme can be very difficult to find. Therefore, the ratings given here are:

⌉ = cost-effective
.. = no effect
⌋ = not cost-effective

Note also that the degree to which costs and benefits are quantified may vary between countries, and thus the ratings given may not be directly comparable. A different set of symbols has been used to indicate that the level of detail in the assessment for this criterion is different to that for the previous one.

In addition to the above criteria, the impact on primary energy demand was assessed. This was included to allow consideration of, for example, the possible energy security implications of CO_2 reducing fuel switching programmes. However, little variation from the CO_2 reduction assessments was found for the selected policies, so this aspect has not been taken into consideration.

3.2.2 Selected assessment results

Exhibit 3.1 illustrates the results for the fiscal policies considered. Similar tables can be constructed for regulatory, educational and institutional initiatives.

Exhibit 3.1 *Assessment results for fiscal policies and programmes*

		Assessment against criteria			
		CO_2 emiss.	Cost effectiveness		
Fiscal Policy	Country	reduction	Consumer	Utility	TRC
Taxes	Sweden	++			⌉
	Netherlands	++	..	..	⌉
	Denmark	+++			..
	Finland	+++	?	..	⌉
Rebates	Spain	0			⌉
Grants/	Sweden	+			-
Subsidies	Spain	0/+/++	..	..	⌉
	Netherlands	+	⌉	..	⌉
Loans	UK	0/+	⌉	..	?
	Netherlands	+	⌉	..	⌉
TPF	Spain	+			⌉
Tariffs for CHP	Netherlands	+++	⌉	⌉ /..	⌉

The assessments provide an initial list of policies and programmes which appear to have been successful. However, the results must be treated with caution: the assessments are in many cases based on very few data, they may reflect differences in the interpretation of the criteria used, and the information available varies between countries, as assessment methods and comprehensiveness vary. Therefore the results must not be seen as directly comparable.

There are some policy approaches, for example taxes, which appear to be successful in all countries where they were assessed. Note, however, the difficulty of separating the impact of a tax policy from that of other underlying economic and social factors. All the assessments had the benefit of surveyed demand elasticity values but all admitted the difficulty of determining actual impacts relative to a business as usual pathway.

Other fiscal mechanisms, such as rebates, grants, loans and so on, although effective to some extent, appear to have less impact than taxation. However, this may be simply because they have been implemented on a smaller scale (in terms of investment levels). This is supported by the example of Spain, where grants and subsidies have been one of the main policy instruments: in some cases here such policies appear to be as effective as taxation in other countries. The impacts of these fiscal policies, in terms of total investment levels and energy use avoided by the technologies installed, tend to be well documented.

Building regulations are also widely considered to be an effective policy instrument, in terms of their impact on energy use and CO_2 emissions. The information available tends to be based on theoretical calculations of the impact of the standards, and rarely includes actual measurements of energy consumption.

A combination of investment subsidies and a supporting tariff structure to promote the development of CHP capacity has proved to be effective in the Netherlands, and the use of regulation to support the development of CHP in Spain appears to be highly effective. Note that the subsidies in the Netherlands have been discontinued as there is now concern that increased CHP would lead to overcapacity in the electricity generation industry, and therefore that continuing subsidies for investment in own generation would have an adverse impact on the electricity sector.

Assessments of the effectiveness of educational policies differ between countries. This is due in part to the differing nature and scale of the programmes implemented, but also it reflects the difficulty in identifying the full impacts of an educational approach. Whilst specific, targeted information and advice can often be seen to have an immediate positive impact (as reflected in the assessment of the UK's Best Practice Programme, for example), the effects of more general (national media) campaigns can only be estimated, and it is likely that different experts will include differing sets of impacts and varying timescales in this estimating process.

Programmes which aim to adjust the institutional structures and cultures governing the markets for energy and energy efficiency are almost universally judged to be effective. The nature of these programmes varies between countries, and this doubtless reflects differing decision-making and government cultures. It is perhaps in this area where particular effort should be made to transfer the knowledge gained from successful approaches from one country to another.

3.3 Energy efficiency studies

There are several reasons for reviewing the conservation studies recently conducted in the participating countries. First, we note that the introduction of a policy often is preceded by a study of its expected effectiveness. Therefore the review is a method to learn more about the (intended) energy efficiency policies in a country and the basis for policy transfer. The extent to which studies and methods correspond to national policies may give an indication of the basis for (transferred) new policy. Ongoing research may already be addressing some of the existing barriers to policy implementation. Second, many energy conservation studies aim at identifying sectoral conservation potentials, and thus indicate the scope for energy conservation in a country. Finally, a review of the methodologies used in the different countries might provide scope for transfer of methodologies that appear suited for energy conservation studies.

Transferability depends on the characteristics that countries have in common. Although not described in this chapter, the characterisation of national energy contexts in terms of the energy supply mix, energy intensities by sector, energy prices and the environmental situation was an important first step to gather information explaining country differences. Together with the identification of sectoral energy conservation levels from recent studies, this provided an impression of the current situation regarding energy conservation in the participating countries.

3.3.1 Characterisation methodology

The analysis has been performed in a qualitative way, by arranging the described studies into the previously defined categories described below, and thus attempting to compare methodologies and emphases between the different countries. Exhibit 3.2 illustrates this approach for one of the countries.

- *Methodology. Bottom-up* approach, taking the engineer's point of view, with explicit consideration of energy technology properties for deriving conclusions on national policies, or *top-down* approach, treating energy demand (and thus implicitly energy conservation technologies and behaviour) as a function of economic production and energy prices.
- *Objective or evaluation criterion*. This characteristic was included to give an indication of the goals of the models or studies. Naturally the goal and the methodology of a study are closely related.
- *Scope.* National, regional or local (municipality).
- *Sectors.* Some studies concentrate on one sector while others include all or take an overall approach.
- *Horizon.* The distinction is between short term (<10 years), medium term (10-25 years) and long term (>25 years).
- *Energy carrier*. Some studies focus on one energy carrier, for example electricity, others include all energy carriers.
- *Options.* Options are technological possibilities to save energy. There is a difference between supply and demand options. Supply options concern an increase of efficiency of the generation of energy. Demand options are options that decrease the useful energy demand, such as insulation.
- *Instruments.* Four groups of instruments were distinguished, as for the review of policies: fiscal; regulatory; institutional and educational.

In addition, the bottom-up and top-down methodologies were further characterised by the following classification.

For bottom-up approaches:
1. *Evaluation*. The term evaluation denotes a static study, focused on techno-economic aspects of options for energy conservation (micro-economic approach).
2. *Simulation*. Simulation models investigate the effects of assumed penetration values of energy conservation options, often based on expert judgements of exogenous model parameters.
3. *Optimisation*. Energy supply models calculate the least-cost mix of energy supply technologies under (national) energy demand and price assumptions, and possibly emission constraints. When studying energy conservation, aggregated conservation potentials and their marginal costs can be included. Given the properties of optimisation models, it is only possible to study *national* cost-effectiveness of aggregated energy conservation options and potentials. No information is obtained about consumer behaviour in their markets, market penetration rates of options, and effects of policy instruments on this penetration.

For top-down models:
4. *Macro-economic*. These models do consider market barriers and consumer behaviour such as price responses in an aggregated way by means of (cross) price elasticities and income elasticities.
5. *General equilibrium*. This type of model explicitly takes into account the interactions between markets, and determines a situation of economic equilibrium through changes in relative prices.

Exhibit 3.2 *Example of Structured Comparison of Energy Conservation Studies*

Methodology		#	Objective/ Evaluation crit.	Scope	Sectors	Horizon	Energy carrier	Options	Instru-ments
Spain									
Bottom-up	optimisation								
	simulation	1	'market segments for energy conser-vation'	national	all	short	-	various	fiscal
	evaluation	7	estimating conser-vation potentials, inventory of possibilities for energy saving	national, regional	all or sectoral (industry, households services)	short	all, elec. natural gas, biomass	various, cogene-ration, boilers	fiscal or various
Top-down	equilibrium								
	macro-econ.								
Combi-nations		2	evaluation & pre-paration of DSM programmes/ con-servation and efficiency plan	national	households all	short/medium term	elec., all	various	DSM, educa-tional

The relation between energy and economic actors is the strong point of top-down models. However, they are not able to analyse at the level of individual efficiency technologies.

Finally, *combinations* of the model types listed above are a separate category. The studies in this category can also consist of a comprehensive analysis based on a number of models or on other studies.

3.3.2 Selected comparison results

The different national reports listed a total of over 60 studies. The first point to make is that we found a great variety in approaches and underlying assumptions. Even within one country, comparing results calculated in different studies appears to be a risky enterprise. The assumptions made regarding GDP growth and fuel prices directly affect the model results. In addition, the choice of the baseline scenario is very important because the (cost-)effectiveness of conservation options and policies is determined in comparison to a 'Business as usual' situation. These observations imply that comparison of results between different countries is even harder because of differences in the energy and environmental situations, and therefore should be made with great care. An attempt, however, is made in Section 3.3.3.

A comparison of the methodologies and time horizons chosen, as well as the sectors studied in the participating countries is less sensitive and gives additional information regarding the attention different countries pay to energy efficiency.

There seems to be a preference for bottom-up approaches for the study of energy conservation (see *Exhibit 3.3*). Bottom-up models and methods can incorporate more technological detail, and therefore are suitable for evaluating technological saving options and estimating conservation potentials. Evaluation approaches are frequently used in short term studies, focusing on identification and implementation of conservation options. Simulation studies are often a medium or long term preparation of policy targets and strategies. Within the bottom-up approach, there is a preference for simulation and evaluation methods. This is partly due to the fact that cost-optimisation models take an integrated approach, not specifically aimed at energy conservation.

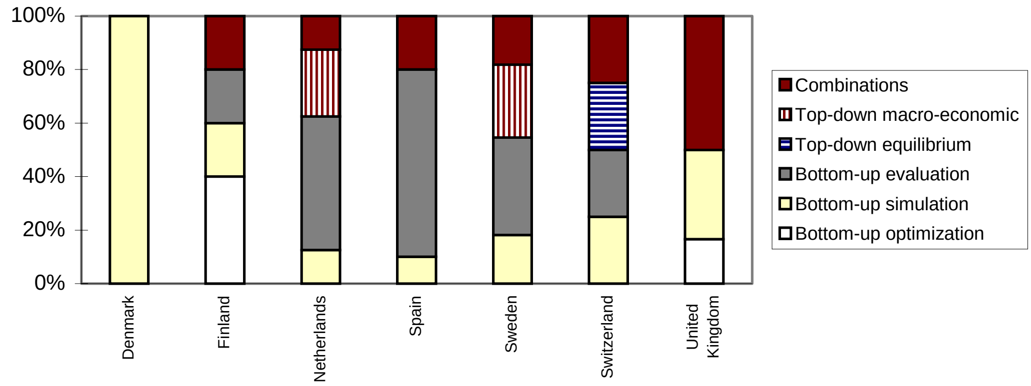

Exhibit 3.3 *Methodologies used in the different countries*

Even if top-down macro-economic models are used, these are often combined with energy supply models. This can be explained by the technology-oriented nature of most conservation studies. The human dimensions of energy use seem to be disregarded in many studies. This may be ascribed to the fact that it is hard to represent human behaviour mathematically. Finland and Sweden do report the use of sociological and empirical methods.

In most countries there is a balance between short and long term studies. In general, the short term studies provide a framework for designing policies for implementation, while medium term studies set policy targets. In addition, studies considering policies to reduce greenhouse gases have a long term horizon. Almost all Spanish studies have a short term horizon. This could be explained by the fact that many studies investigate the role of a particular technology or energy carrier in a specific sector.

It is worth noticing that in most studies where only one energy carrier is considered, electricity is the carrier. Two factors may contribute to this focus on electricity. First, producers and distributors of electricity may have an economic interest in electricity savings, and regulation of electricity demand. Therefore they carry out energy conservation studies to support DSM programmes. Second, the prices of electricity are substantially higher than the prices of other energy carriers. As a result there is a financial incentive to investigate saving of electricity.

3.3.3 Policy instruments studied: some remarks

Studies are usually conducted to inform policy design or policy preparation. Therefore an analysis of the type of policy instruments studied should give an indication of the policies currently being considered in the different countries. A relationship exists between methodology and type of instrument studied. The different methodologies are complementary and each particularly suited for studying specific (types of) policy instruments. Financial measures such as subsidies and taxes are often analysed in top-down studies. Bottom-up approaches are used to investigate regulatory measures and fiscal measures aiming at specific technologies. Educational and DSM measures are mainly analysed in evaluation studies.

One step further is to take into account the conclusions of the studies regarding the effectiveness of different policy instruments. However, the remarks made in Section 3.3.2 regarding the comparability of model results do apply here.

Energy or carbon taxes are studied in all countries except Spain. In Switzerland many different studies consider fuel and CO_2 taxes, which are judged effective in the long term. Road fuel taxation is identified to be effective in Switzerland and the UK. In a Dutch study, an energy tax applied to all economic sectors has a particularly large impact on fossil fuel and electricity demand in industry. The fiscal instruments studied in Spain concern subsidies and grants. This is noteworthy because Spain is the only country where (additional) taxes to encourage conserving behaviour are not applied at all. This is coherent with the fact that partial subsidies for projects have been one of the main instruments used in Spain to promote energy efficiency over the last decade.

DSM programs are prepared by studies in Finland, Denmark and Spain. In Denmark, energy audits, advice on energy efficiency (for new constructions or investments), and information campaigns to influence customer behaviour are identified as successful policies for the residential and commercial sectors.

Educational instruments are proposed in Spain, Sweden, Switzerland, and the United Kingdom. In the UK, one of the studies identifies information campaigns and education to be a key part of an effective strategy in the domestic appliance sector.

Regulatory instruments are studied in the UK, the Netherlands, Switzerland and Sweden. In Switzerland it concerns building and vehicle standards that, together with a tax on gasoline and subsidies on renewables, slow the increase of electricity consumption and achieve a decrease in fossil fuel consumption. Institutional instruments are hardly mentioned. In the Netherlands bottom-up studies are carried out as a preparation for the negotiations regarding voluntary agreements.

Although the authors of the national reports have been asked to aim at a variety of recent conservation studies of importance, it must be noted that part of the observed country differences may stem from the selections made by the authors. Keeping this in mind, the following country preferences can be identified. Denmark focuses on DSM studies, which may be caused by the Danish Integrated Planning legislation. Since 1994, this legislation requires a collective integrated resource supply plan to be produced every second year. In Spain most studies are addressing (short term) market evaluations of specific technologies. Other country preferences for sectors and fuels can be ascribed to the energy intensity of the sector in question, and to the natural resources and import dependency of the countries involved.

3.4 Discussion

The results from the policy and study comparisons raise a series of issues which deserve further investigation.

3.4.1 Geographical boundaries of the study

As already mentioned, the basic energy and economic situation in a country will significantly influence the applicability of any given policy in that country. These differing policy drivers will, to some extent, be reflected in the commitments each nation has made to controlling emissions of CO_2. For example, Denmark's original commitment to *reduce* emissions by 20% relative to 1988 levels by the year 2005 can be contrasted with Spain's agreement to limit *growth* in emissions to 25% of 1990 levels by 2000 (CEC 1994). Such differences in focus will affect both the types of initiative needed and the programmes which will be considered acceptable in different countries.

In the review of studies, the consideration of energy taxes was noted in all participating countries other than Spain. This raises the issue of the geographical boundaries of the present work. A full investigation of the reasons why Spain is not considering taxes, and is more interested than other countries in the use of grants and loans can perhaps only be undertaken with the consideration of other southern European countries.

3.4.2 Theoretically promising areas not reflected in current practice

Energy taxes are seen as a highly effective fiscal instrument, particularly for their impact on CO_2 emissions. Results of conservation studies in many countries support this conclusion. At the moment taxes are being used only in a small number of countries, but taxes are being studied in all countries except Spain, indicating that there might be a basis for transfer.

Taxes for domestic users receive mixed reactions. In the Netherlands, for example, the small user tax has met with little opposition (possibly due to comparatively low base fuel prices) but in some European Member States the situation is very different. For example, in the UK there is very strong resistance to the idea of increasing taxes on domestic energy use. Also, taxes are hardly being applied in industry, where they can pose a potential competition disadvantage with other countries. It is often argued that environmental or other taxes can only be applied 'properly' in industry when applied simultaneously in all EU countries.

Thus, whilst in theory this is a very effective mechanism for reducing energy use, there are problems associated with the introduction of this type of policy across Europe. However, the success of tax policies in countries where this type of initiative is acceptable highlights the need for continued effort in this area in within the EU. Whilst opposition from some Member States remains strong, efforts should be made to enable those which do wish to use this tool to do so effectively within the framework of the developing European energy markets.

Institutional instruments, such as technology procurement and voluntary agreements, are also judged to be effective. In the studies surveyed, institutional instruments were hardly mentioned, presumably because these are not very suitable for incorporating in a model. However, research would be required to investigate the effect of differing decision-making and government cultures on the design of the programmes.

Any emphasis on the transfer of present success stories should not be at the expense of investigation of as yet untried or controversial alternatives.

3.4.3 Quality and availability of information

National cost benefit curves for policy actions cannot be constructed as insufficient information is available. The lack of information about costs of programmes, and investment levels they produce, also limits the comparisons which can be made between the assessments. A tax policy which costs the government relatively little to administer but results in large flows of money from consumers to government is perhaps inherently more likely to produce greater results than one which involves far smaller financial transfers. The impacts of such differences can not be deduced from the information available.

The measurement of cost effectiveness also raises an issue about the definition of total resource costs. All partners were asked to include only quantified costs, and therefore to exclude environmental externalities. However, it is possible that in some countries a greater range of costs and benefits (other than environmental externalities) are quantified than in others. This may account for the generally more favourable results from some countries and the more cautious assessments from others.

Several authors report that availability of data on realised conservation measures and technical conservation options is a problem. The data available may be of not very recent date, indicating the need for statistical surveys. A related problem, experienced in assessing policy effectiveness was the confidentiality of the results of evaluations carried out by private companies and utilities.

The feasibility of improving the level of information available, and the time and expense which would be involved in such an exercise require careful thought. Alternative methods of comparing policies may be possible, and this issue is considered in the concluding section of this chapter.

3.4.4 Methodologies and assumptions

As mentioned previously, the comparability of study results is, even within a country, a delicate matter. The assumptions and the choice of a baseline scenario greatly affect the results. The goal of the study also plays a role. Studies differ in their stated aims, and therefore calculate different variables and reach different conclusions. For cross-national comparisons, there is an additional difficulty in the differing national contexts and cultures. An important observation is that for almost every study, specific national approaches and models have been used. It is remarkable that the international conservation model MURE has not been mentioned once. Such a diversity of tools hampers comparison of studies, results and experiences and thus transfer of knowledge.

Similar remarks apply to the comparative policy assessment. The quality of initial assessments on which the national authors have based their work will vary within and between countries. It is at times difficult to ascertain whether the impacts described for a policy are relative to a business-as-usual scenario or are simply a measure of the difference in energy use before and after the policy implementation. This reinforces the need to treat these assessments as preliminary only.

One aspect of the policy assessment methodology used in this study which requires further thought is the comparison of policies implemented on differing geographical or financial scales. Whilst adjusting target reductions to suit the scale of the policy allows a rough consistency to be introduced into the comparison process, the application of a local or small scale programme on a larger level is unlikely to result in a directly comparable scaling up of effects, and therefore alternative comparison methods need to be sought.

3.5 Conclusions for further work

It was pointed out that the large majority of energy conservation studies mentioned by the partners in the different countries, concerns country specific approaches and models. Of course, such a diversity of tools hampers transfer of knowledge and experiences in general and comparison of results of studies in particular.

Although it is clear that experiences in different EU Member States with different policy measures can be beneficial to other Member States, a basic influence on the possible success of any policy or programme will be the fundamental drivers of energy policy in a given country. For example, the lack of indigenous fossil fuels in Sweden has had a major impact on energy policy there, as has a high level of concern for the natural environment. This implies that transfer of success policies and instruments from one state to another should be considered with care and studied in comparable case studies. This calls for a common approach to investigate the effectiveness of policy instruments in different countries.

One very basic problem that most policy instruments have in common is that, although some instruments are more sensitive than others, in most cases the effectiveness of a policy measure is determined by the attitude and behaviour of the economic actor that has to be stimulated to implement energy conservation. Studies provide only crude information on the aspect of behaviour with respect to policy instruments.

For instance, macro-economic models include ‘aggregated behaviour’, based on time series of data of the past, in the form of energy price (cross) elasticities and income elasticities, implicitly assuming that the attitude of energy consumers and investors will not change in the next years. Although some forecast can be made of energy demand in different sectors, the options which are in effect realising the energy conservation are not known. On the other hand, bottom-up evaluation models start with the technically feasible options and take into account thresholds or discount rates while using payback or other profitability criteria, reflecting the investors reluctance or barriers to invest. This is a rather crude way of dealing with the behavioural aspects of energy conservation instruments.

Therefore, Phase II was devoted to the international application of a new integrated conservation model REDUCE. It is a dynamic energy conservation model that calculates market penetration of energy conservation options based on the evaluation of costs and benefits of conservation policy instruments. The model takes into account economic, social and behavioural aspects of penetration of energy conservation technology in different market niches and the effects of policy measures upon the penetration. Competition and interaction of options is endogenously included in the model. Finally, the resulting (saving of) energy end-use is calculated.

The study does not provide forecasts but merely an investigation into the driving forces of energy conservation, given the presently available conservation options on the market, in relation to different energy conservation policy instruments in a consistent multi-country approach. With this approach, an exploration of strategies for the application of policy instruments is conducted.

4. METHODOLOGY

4.1 Introduction

In the last decade the international dimension of the greenhouse effect and of sustainable development has paved the way for an international and more structural approach to energy conservation. Now it becomes apparent that although a wide range of internationally applied energy demand models exists (SEEM, MEDEE, MIDAS etc.), it is not always easy to incorporate energy conservation activities in these models in an appropriate way.

Econometric models such as SEEM and MIDAS treat energy demand (and thus energy conservation) as a function of economic production and energy prices. These models do consider market barriers, consumer behaviour and responses to prices in an aggregated way by means of (cross) price elasticities and income elasticities, but they are not able to analyse at technology level. Furthermore, calculation of elasticities is based on long time series of data, implicitly assuming unchanged technological and policy environment. In simulation models such as MEDEE relationships are typically fixed without description of conservation behaviour of consumers.

Besides these international modelling activities, many national energy conservation models have been developed, but in most cases these are very detailed and country specific. Often only conservation experts are able to run these models, because they are very complicated, being designed for assessing local, desegregated energy conservation options and potentials. Most existing tools are primarily focused on techno-economic aspects of options for energy conservation (micro-economic approach). Up to now, most close to an internationally applicable energy conservation model is MURE, developed by EU-DG XII, which is in fact a sophisticated detailed database of energy conservation options that takes into account both technological data, e.g. efficiency, capacity, and type of energy carrier, and economic data, e.g. investment costs, variable costs, and lifetime for simulating effects on energy demand. With MURE, a static micro-economic evaluation can be performed but hardly any conclusions can be drawn about market penetration of options.

Given the complex field of energy conservation and the many approaches for modelling and understanding different aspects of conservation, it is impossible to combine all these modelling activities into one energy conservation model. However, scope exists for an international energy conservation model which can provide a basis for international communication, research activities, and policy making in the field of energy conservation. The main reason for the development of the energy conservation model REDUCE (Reduction of Energy Demand by Utilisation of Conservation of Energy) is to provide national results that are comparable in an international (EU) context. This allows for assessing common aspects as well as understanding country-specific characteristics of energy conservation across the EU. This way, REDUCE tries to provide a common ‘language’ and framework for transfer between countries of know-how of different aspects of energy conservation, viz. options, potentials, costs, market penetration and policy instruments.

International application depends on finding a balance between country specific and more general aspects. Both types of aspects have been represented in REDUCE. In modelling terms: the balance between flexibility (of data requirements and structure) and structure (clear formats and consistent equations) has been taken into account. Furthermore, the current state of the art in software has been used to support the user in using and understanding the model.

Summarising, the main objective of REDUCE is the evaluation of the effectiveness of economical, financial, institutional, and regulatory measures for improving the rational use of energy in end-use sectors. Not only the technical scope and ranking according to a range of criteria for investments in energy savings is assessed, but also the market dynamics of energy saving options are considered, on the short term (immediate policy actions and implementation) and longer term (strategic policy considerations). The latter are particularly important with respect to equipment with a long lifetime such as insulation in buildings, networks etc.

4.2 General approach

The REDUCE model can be characterised as a bottom-up approach, taking into account all techno-economic aspects of energy conservation options. However, market barriers and consumer behaviour with respect to conservation options are taken into account without using elasticities. Therefore, impacts over time of policy instruments influencing market barriers, consumer behaviour and benefit-cost ratios can be assessed given certain technological conditions and dynamic interactions of different conservation options and policy instruments. A schematic representation of the framework is given in Exhibit 4.5 .

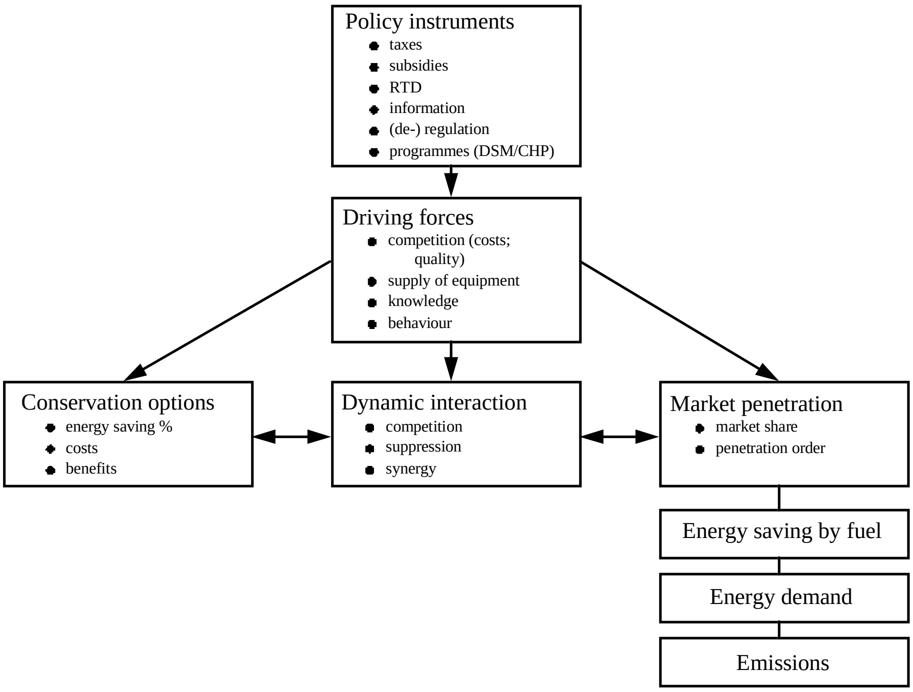

Exhibit 4.4 *Schematic overview of the analytic framework for evaluation of energy conservation policies*

The dynamics of market penetration of conservation options are influenced by a number of diverse and complex factors. These factors can be divided into three categories, such as (1) properties of conservation options, (2) dynamic interaction between these options, and (3) driving forces for penetration of options, which will be discussed in the following paragraphs.

Conservation options

A conservation option can be characterised by its direct investment costs and operation and maintenance costs, its potential energy saving effect (usually expressed as a percentage of energy consumption) and technical aspects which determine the market niche for possible application of a particular option. Like in MURE, a large database on conservation options is starting point for the analysis.

Dynamic interaction
Dynamic interaction between conservation options can take several forms. Certain conservation options are *competing* for application in the same energy service market, for instance a heat pump and a high efficiency boiler compete for heat supply in households. They have to share the market. Penetration of competing options can be more or less 'permanent' (options such as wall insulation that stays in place for a very long period), which implies that a conquered market share will not be lost to a competing option. In that case the market share can only increase. Penetration of options can also be ‘temporary’. This applies to options such as heating systems which are frequently replaced, implying that the market share can increase but also decrease. This is a typical example of crowding out.

Conservation options in energy supply interact with options in energy end-use. High savings in end-use decrease attractiveness of supply savings and vice versa. This second form of interaction is not a competition between alternative options but *suppression* of complementary options. An interesting example of suppression of complementary options concerns energy conservation and fuel switch. The fuel price has a large influence on the profitability and therefore also on the market penetration of conservation options. But, if cost differences become large, the market will respond with fuel switch towards the cheaper fuel, herewith reducing the economically attractive saving potential. Therefore, fuel switch is taken into account. This point is often neglected in conservation studies.

A third, less known form of interaction is *synergy* of options: the installation of a certain option makes the application of a second option possible. For example, replacement of serial heat supply by parallel heat supply in multi family houses in Eastern European countries is a condition for applying thermostats.

In the remainder of this paper, the last two forms of interaction are often summarised by the term *interference* of options. One could say that suppression of options is a negative type of interference, while synergy of options has a more positive meaning.

Interaction of options is modelled by means of two simple concepts: groups and penetration order. Options in a group compete with each other on the basis of crowding out. Depending on the type of options in a group, permanent penetration and temporary penetration can occur. Furthermore, supply and demand groups have been distinguished to model interaction of options. Calculations are conducted for each year. It is a reasonable assumption that each supply option to be installed will be introduced in a situation where on average a percentage of end-use saving equal to that of the previous year has been reached. When the percentage of end-use savings is high, the energy demand to be reduced by a new supply option will be low, and the profitability of the supply option will also be low.

Driving forces
The driving forces for implementation of conservation options are highly important for understanding market penetration of dynamically interacting conservation options. These driving forces are a schematic representation of consumer behaviour with respect to conservation options. In other words, what makes options attractive? The economic attractiveness (cost-effectiveness, rates of return, payback periods etc.) is an important driving force. But also technology supply constraints, limited knowledge about a technology, and socio-psychological aspects of consumers and options can play a role in the (rate of) uptake of options by a market. Obviously, many energy conservation frameworks avoid these hardly quantifiable driving forces and assume exogenously specified restrictions instead. However, driving forces are the bottle-neck for evaluating policy instruments, since most instruments place incentives through one or more driving factors.

Market penetration
Although market penetration of options is very complex, especially concerning driving forces, and hard to project, experts agree that market introduction of a new technology tends to follow an S-

shaped curve. This gradual penetration of technology accounts for some general, commonly accepted ideas in technology dynamics. According to Fisher and Pry, the stages of technology development, viz. demonstration technology, mass production, and saturation of the market are reflected by this S-curve. Apart from these supply oriented stages, social, economic, and psychological driving forces play a role in determining the slope of the curve. Fisher-Pry and others have assessed curves for several technologies which penetrated the market in the past, thereby also quantifying these driving forces. In our approach, this driving force factor is split up in two factors, one determined by socio-psychological and other factors, the other determined by economic profitability, measured by means of Internal Rate of Return. In this way, the penetration speed factor is not fixed for a technology, but can vary under different economical circumstances. When profitability increases, the penetration speed increases too.

Two different approaches can be used to deal with penetration speed. First, one can try to estimate the penetration speed factor with the help of statistical analysis of data time series and surveys. Second, as in techno-economic assessments of national strategies for the longer term, penetration speed factors can be varied but are being kept equal for each conservation technology. In that case, options are compared and ranked in a sophisticated way as in cost-optimisation models.

This new approach, related to for instance the approach used in the renewable energy evaluation model SAFIRE (Energy for a Sustainable Development, UK) leads to more differentiated technology projections than those produced by the more static economic evaluation.

Policy instruments

The main objective of developing REDUCE is to analyse the expected realised energy conservation and its costs or benefits as induced by certain policy instruments. Furthermore, the interaction of different policies must be analysed. A number of policy instruments are mentioned in the box ‘Policy instruments’ in Exhibit 4.4. The arrow from this box indicates that most policy instruments influence the conditions under which driving forces induce certain behaviour. Different policy instruments can act upon one or more different driving forces. The driving forces affected by a type of instrument have to be identified and quantified in terms of marginal changes in market penetration speed. It is extremely important to distinguish the differences and overlap between policy instruments.

The instruments mentioned in Exhibit 4.4 are all taken into account in REDUCE. Emphasis is put on economic and financial instruments, since the economic driving forces are studied in most detail and are relatively easy to quantify.

Energy demand

A reference energy demand projection, without additional energy conservation options and policies, is an important starting point for the analysis. The relationship with economic developments must be clearly specified. Special attention has to be given to the split into different fuels, since the fuel type has a large influence on profitability and thus penetration of conservation options.

4.3 Model description

4.3.1 Economic evaluation

One of the classical ways of performing an economic evaluation of project investments makes use of the Internal Rate of Return (IRR). The IRR can be interpreted as the interest percentage one could receive when the money for investment is not invested, but put on the bank during the period of the economic lifetime.

The internal rate of return IRR is derived from the following standard formula:

$$\sum_{t=1}^{lt} \frac{CashIn}{(1 + IRR)^t} - CashOut = 0$$

with:

CashOut: the additional investment for installing an option
CashIn: the annual benefit of an option
lt: the lifetime of an option

Other methods for performing an economic evaluation of project investments are the Payback Period (PBP) and the Net Present Value (NPV). The Payback Period focuses on risk, minimising the period for return. The total benefits are not directly taken into account: if the lifetime is long, the payback period becomes also longer, although total benefits may be very high. This aspect is particularly considered by the Net Present Value method. This method focuses on absolute benefits, herewith giving an advantage to large projects above small projects. The Internal Rate of Return has not that property, since it expresses benefits in the form of a profitability percentage. In this case, the absolute benefits are not considered.

An advantage of the IRR above the Payback Period is that it is independent of the economic lifetime. The advantage of the IRR above the Net Present Value is that it is independent on the magnitude of the investment. So, small and large projects with different lifetimes can be compared. A disadvantage of IRR compared to the Net Present Value is that negative additional investments result together with benefits in a infinitely high IRR, regardless of the size of the benefits.

The expression above is the static way of calculating the internal rate of return. Unlike other models in this field, REDUCE is completely based on dynamics and for every year in the period under study, the IRR is calculated. The IRR changes over time because annual benefits can vary over time. They consist of saved fuel expenses minus the options' variable costs. First, the fuel prices vary over time. Second, the saved amount of energy after applying an option will decrease if other options are applied meanwhile. This interference of options has been explained in the previous section.

From the IRR, the market share and a behavioural factor, the market penetration of conservation options is calculated.

REDUCE is based on a large database of energy saving options. Options are defined with respect to a reference technology. The attractiveness of options is expressed in their respective IRR and thus market penetration and energy saving potentials are determined.

4.3.2 Market penetration

Energy saving is defined as reduction of projected energy demand. Calculation of this reduction is based upon a market penetration model. The penetration of a single energy saving option in its own market is supposed to happen conform an S-curve.

This S-curve is described cf. Fisher and Pry in the following differential equation:

$$\begin{cases} \ast P / \ast t = S \cdot P(t) \cdot (1 - P(t)) \\ P(t_0) = P_0 \end{cases}$$

The increase in penetration percentage P depends on the actual penetration or market share and the share that is left to be penetrated (1-P). Exactly when half of the market is penetrated, penetration speed is at its highest.

The constant S is in the basic Fisher Pry curve a calibration constant. In REDUCE this constant is used to reflect the driving forces for market penetration of energy saving options: economic attractiveness in terms of IRR and behavioural aspects as discussed earlier. Behaviour is quantified by the parameter α. So an additional equation is:

$$S = \alpha \cdot IRR$$

The complete above differential equation is approximated by a difference equation:

$$\begin{cases} P(t+1) = P(t) + \alpha \cdot IRR \cdot P(t) \cdot (1 - P(t)) \\ P(t_0) = P_0 \end{cases}$$

With a well specified α the penetration in time can be calculated iteratively. In Exhibit 4.5 three different curves are presented with different S and with different initial penetration. Two observations can be made:

- S, being α and IRR, represents the penetration speed: sensitivity of behaviour for economic incentives,
- the start share P_0 affects the initial penetration speed.

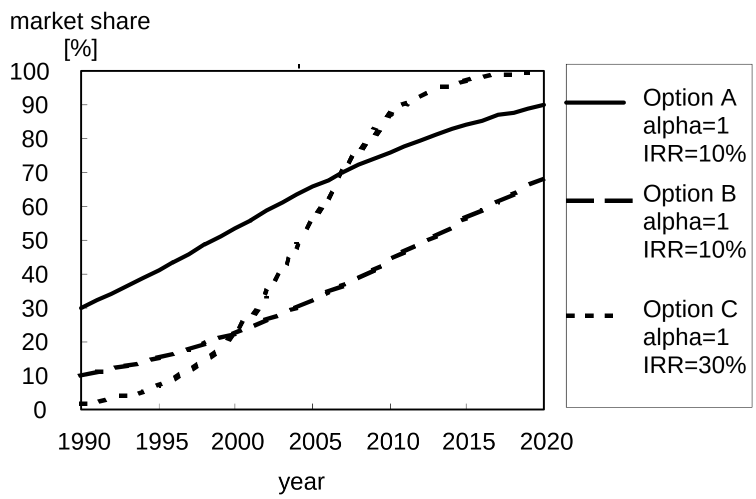

Exhibit 4.5 *Market penetration of three single options in separate market groups*

4.3.3 Competition between options

With the S-curve concept, market penetration of options can be calculated iteratively. However, it is not as simple as that. In the market of energy conservation, a number of options compete with each other as in any market. The ‘market’ is to be divided by different options if these options deliver to the same market. Moreover, internal rates of return are affected by penetrations of other options.

Permanent options

Once an option has penetrated on a certain share of the market, this market share will not be lost to another option. Examples of this kind of options are wall insulation and roof insulation. As a result of the competition, a particular option can not conquer the part of the market which has not installed this single option, but it can only conquer that part of the market which has no options at all.

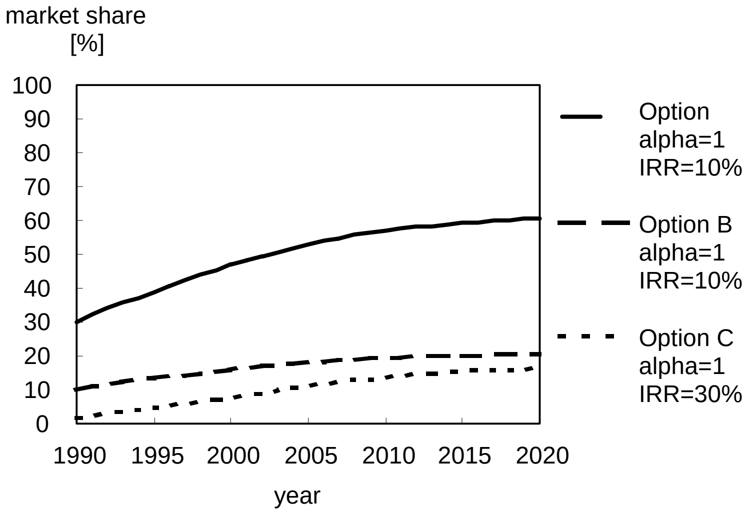

Exhibit 4.6 *Market penetration of three competing permanent options in one market group*

Temporary competing options

It is also possible that options can replace one another. For instance compact fluorescent lamps or double glassing only last for their lifetime and then will be replaced. In the case of more than one option in the same market, the influence of an option’s penetration share is weighed with the other options’ shares, and multiplied with their penetration speed.

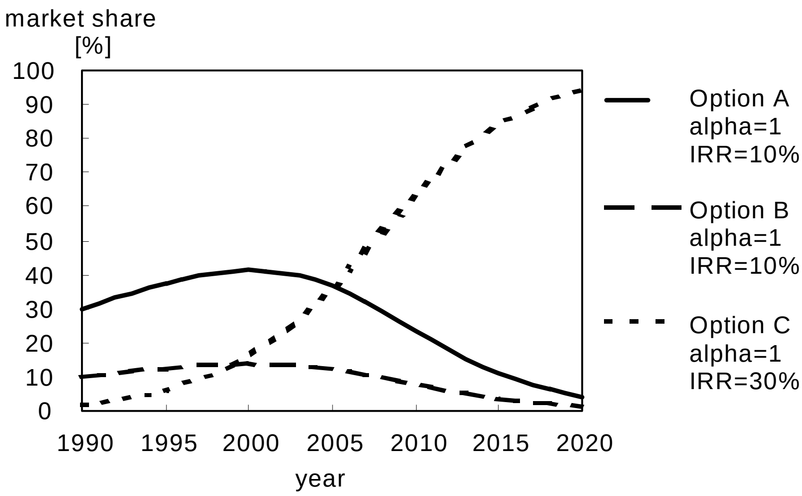

Exhibit 4.7 *Market penetration of three competing temporary options in one market group*

So, options must be specified to follow permanent or temporary penetration patterns because different penetration curves apply for each type of options. Furthermore, it has to be specified which options exclude or compete with each other and which options can be applied at the same time. For this purpose options are allocated to groups. Within a group, options compete with each other.

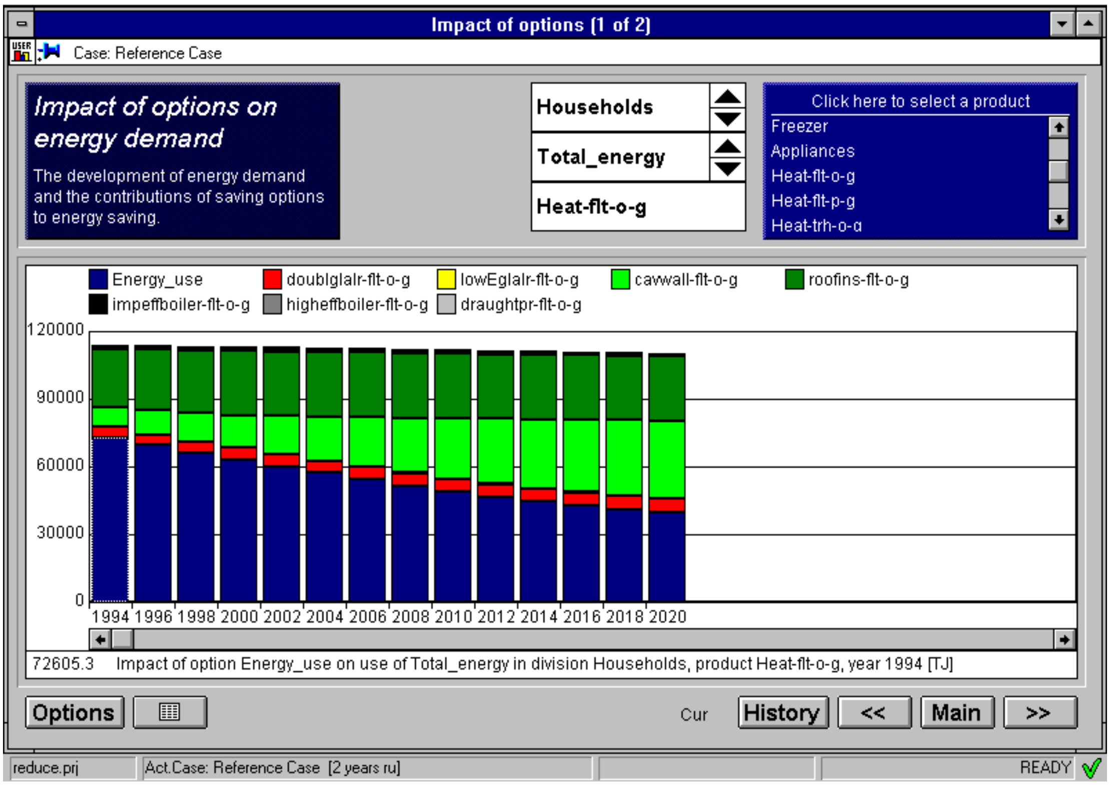

Exhibit 4.8 *REDUCE screen on the impact of energy saving options on the energy demand*

4.3.4 Interference of options

Options are being characterised as supply or demand options. Supply options are by definition temporary. This concerns efficient boilers for heating, insulation of heating pipes, etc. Demand options concerning heating are for instance insulation of walls, double glazing, etc.

Supply and demand options are distinguished to model interference of options. This is illustrated by the following example. Wall insulation and heat pumps can both be applied in the same house to save energy for heating. Suppose that one house is already provided with wall insulation and another is not. Then in both houses application of a heat pump will cost the same but the return in terms of a lower energy bill will differ. In other words, the IRR of the heat pump depends on the question whether wall insulation is applied or not.

For calculating the interference of supply and demand options, it is necessary to introduce the *demand effectiveness* and *supply effectiveness* for a product - energy carrier combination. The demand effectiveness is the remaining fraction of the energy demand after subtracting the saved fractions reached by already existing supply saving options. The reverse holds for supply-effectiveness. These parameters are calculated yearly for all product - energy carrier combinations.

The energy demand is the product of both supply- and demand-effectiveness and the projected energy demand.

The difference between the projected energy demand and the energy demand is the energy saving. The energy saving is smaller than the sum of savings of demand options and supply options due to interference of demand and supply options. The effectiveness based on the penetration of options in the previous year is included in calculating the annual benefits and thus the IRR of an option for each year. In time, penetration depends on the penetration in the previous year and the IRR in each year.

4.3.5 Overview

Exhibit 4.9 gives a schematic overview of the REDUCE model. The issues discussed in the previous section, viz. economic evaluation, market penetration, competition and interference of options, their relations and the relations with different types of policy instruments are presented schematically. See Annex E for a more detailed calculation scheme and overview of the structure of REDUCE.

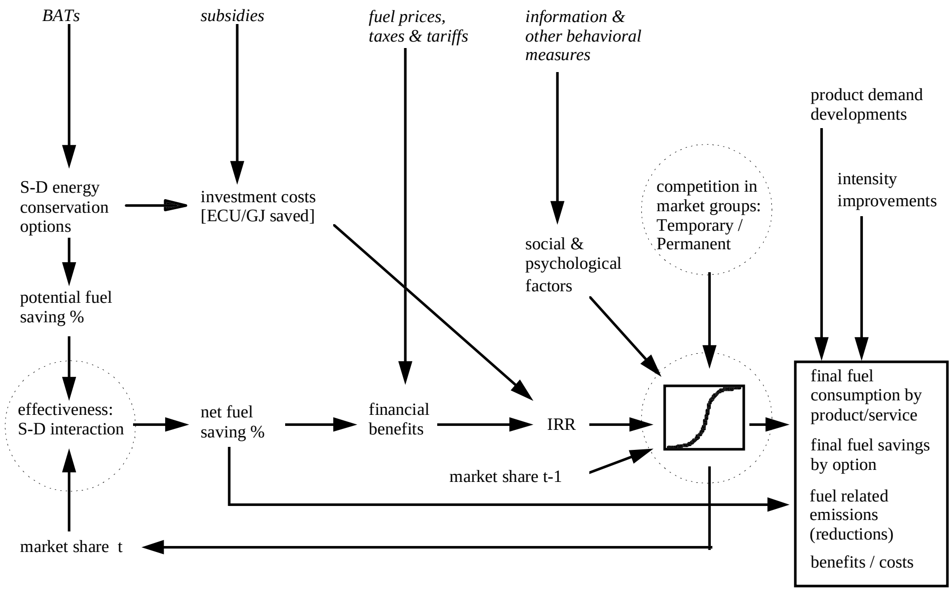

Exhibit 4.9 *Schematic overview of the REDUCE model (in italic policy relevant parameters; within the circles important model mechanisms)*

5. ASSUMPTIONS

5.1 Reference scenario

5.1.1 Baseline development

Definitions

Before presenting the scenario assumptions on economic growth resulting in volume growth and changes in the economic structure, a few conceptual issues have to be settled first. First, a definition of 'baseline developments' has to be given. What are considered to be baseline developments when these have to be used in a bottom-up conservation model such as REDUCE? This is schematically illustrated below in Exhibit 5.1.

The basic underlying issue is that energy consumption and energy conservation is an ongoing process, metaphorically speaking a train moving on a track. The modelling work has to start at a certain point, the baseyear, where the modeller has to jump on the running train. In the baseyear, already energy conservation options are installed and saving energy. At first, only the energy consumption in the baseyear is known from the statistics, so taking into account all current energy conservation. This energy consumption is called in the report the Actual energy consumption. This in contrast with the energy consumption corrected for energy conservation reached by conservation equipment installed in the baseyear. This (higher) energy consumption is referred to as Energy Use Without Savings (EUWS).

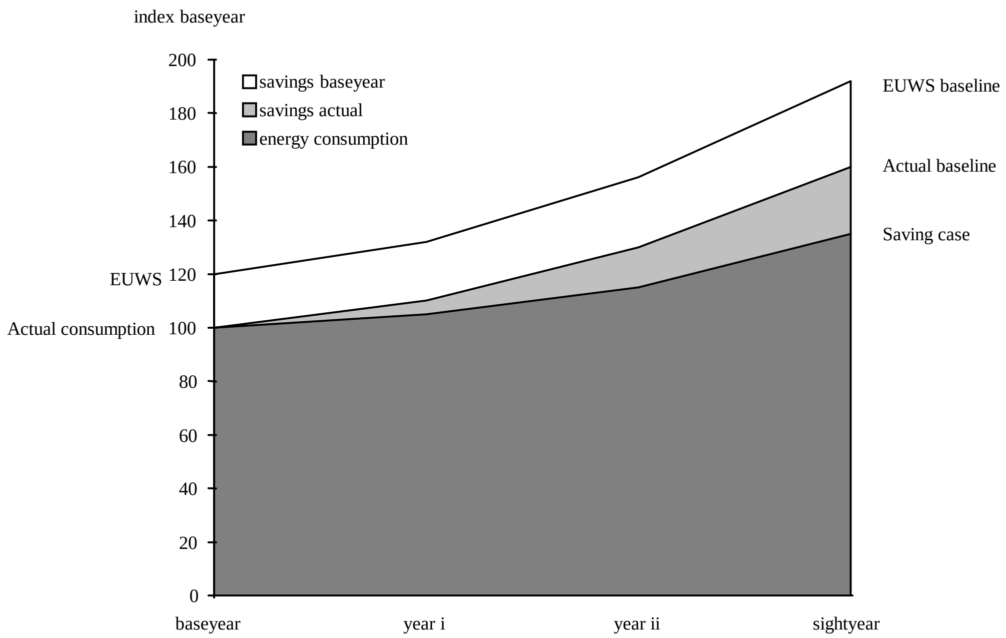

Exhibit 5.1 *Schematic illustration of the concept of different types of baselines as a reference for the saving impact of the penetration of attractive energy savings*

When a growth path is applied to develop a baseline, this growth path can be applied on both the EUWS and the Actual energy consumption in the baseyear. The difference between these two in the baseyear, notably the energy saved in the baseyear, will grow proportionally to both baselines. This can be interpreted as a volume growth of the baseyear energy savings proportional to the volume growth of energy consumption. In other words, the baseyear situation is considered to be a status quo.

The EUWS baseline is important for the explicit specification for energy conservation options in the baseyear and the (proportional) correction for this energy conservation in the years after. The Actual baseline is taken as the baseline which is interesting as a doing nothing case with a baseyear perspective. Also, energy conservation after the baseyear should be viewed with reference to the Actual baseline, hence considering energy conservation additional to the baseyear situation.

Assumptions
Baselines as specified in the previous paragraph are hardly available. Most of the available energy scenarios do include volume growth and structural changes but unfortunately also (implicit) developments in energy efficiency and energy conservation and are therefore not immediately applicable as a baseline in REDUCE. Some expert modifications had to be made in all cases for all countries.

Furthermore, always the dilemma arises around national and international comparability of scenarios. In most cases, the national scenarios have been taken as a basis for baseline development because these scenarios have been specified and developed in great detail and are often accompanied by national energy conservation studies which are both an advantage for accurate modelling of energy conservation. However, as has been said before, this hampers comparability between countries.
Two sectors have been specified for REDUCE, viz. households for Denmark, Finland, the Netherlands, Switzerland and the United Kingdom and the manufacturing sector for the Netherlands, Spain and Sweden.

The baseline developments represent a low to moderate growth of 0.5% to 1% per annum of household energy consumption up to the year 2020. Exceptions are the Netherlands and Finland with a high growth of 2% annually. In general, this volume growth of household energy consumption is a result of a growth in the number of households, a decreasing number of persons per household and income growth. Only the last factor is directly linked with economic growth projections. Especially in Denmark (0.25% per year) and to a lesser extent Switzerland (0.5% per year) the low annual growth raises the question whether the baseline includes developments in energy conservation. This is not necessarily a problem if the specification of conservation options is consistent with the baseline, as will be shown later on.

Of course, baseline developments for the manufacturing sector are more directly related to economic growth projections. Besides economic growth projections, the baseline development of energy consumption is influenced by changes in the economic sector structure. All three countries have different baseline developments for the manufacturing sector. In the case of the Netherlands the annual growth of the baseline is 1.9%, in the Swedish case 2.4% and for Spain 1.7%. The baseline for Spain projects a decline of the share of energy intensive sectors, whereas the baseline for Swedish manufacturing includes a relative increase of energy intensive sectors.

5.1.2 Energy price projections

Definitions
In order to use comparable energy end-user prices for all countries, which is an important requirement for arriving at comparable results from a price sensitive model such as REDUCE, it is necessary to use a common calculation method for making country specific end-user price projections. Exhibit 5.2 illustrates the approach used.

At present, a wide variety of end-user price levels exists in the different countries, although world energy prices are thought to be more or less similar. When looking at the different aspects behind end-user prices it becomes clear where these differences could stem from. Besides the energy production and transportation costs (including a profit reflected by the world market price level), a margin for coverage of distribution costs (and attached profit) is applied. In the case of electricity, production costs are included in this margin, which are highly country specific, depending on the fuel mix used, the distribution of production and demand during the day and the year and the state of the generation sector. On top of this part of the end-user price that reflects merely costs and profit, taxes are applied. Both Value Added Tax (VAT, only relevant for households) and excise tax are country specific.

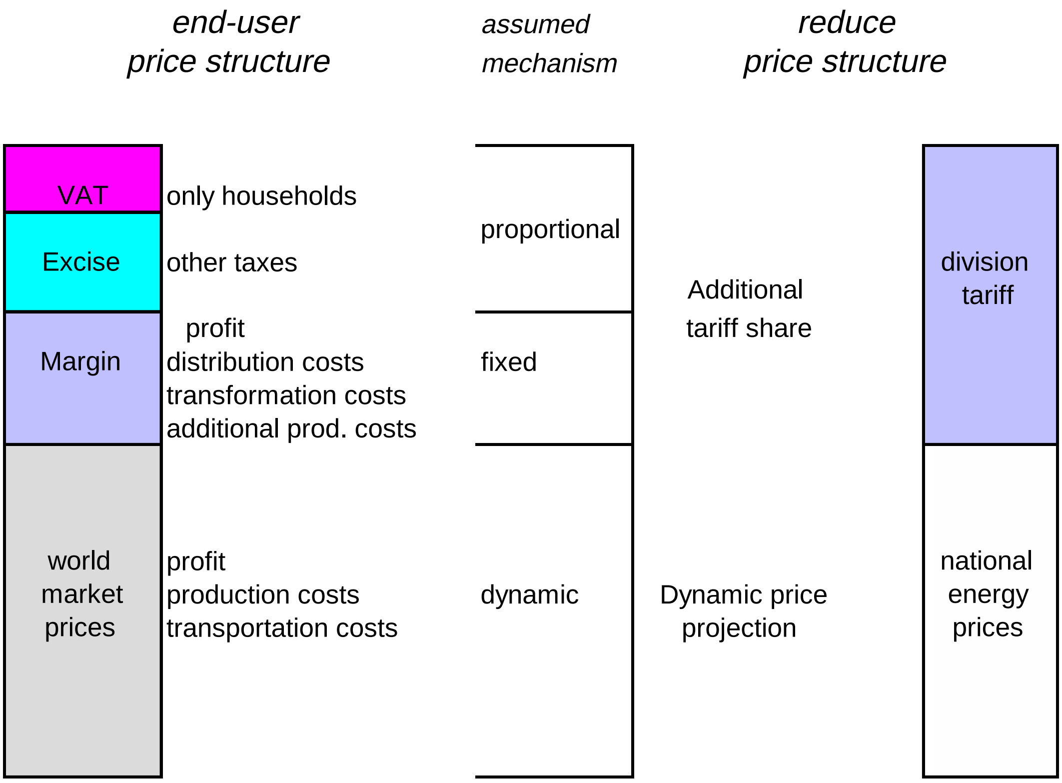

Exhibit 5.2 *Schematic overview of the end-user price structure and the calculation method used for end-user price projections which are used in REDUCE*

Given this simplified end-user price structure, assumptions can be made about future developments of the different parts of the end-user price. Projections of world market energy prices are common for all countries. The margin is assumed to be constant in the end-user price projection. The tax share in the price remains constant in the projection, so the tax quantity is proportional to the price projection.

The main advantage is that these simple assumptions can be applied consistently for the different countries, resulting in more or less consistent end-user price scenarios without losing country specific information (the price structure in the baseyear).

Projections

The world market price projections for primary energy sources are depicted in Exhibit 5.3 and are stemming from ‘European macroeconomic projections for baseline scenario’ developed for ‘Evaluation of EU policy and measures for Kyoto targets, Analyses made by using Primes for EC Joule (DG XII)’ by Capros et al. From the year 1995, coal prices are projected to grow 0.6% annually, crude oil prices 2.6% and natural gas prices 2.4% per year.

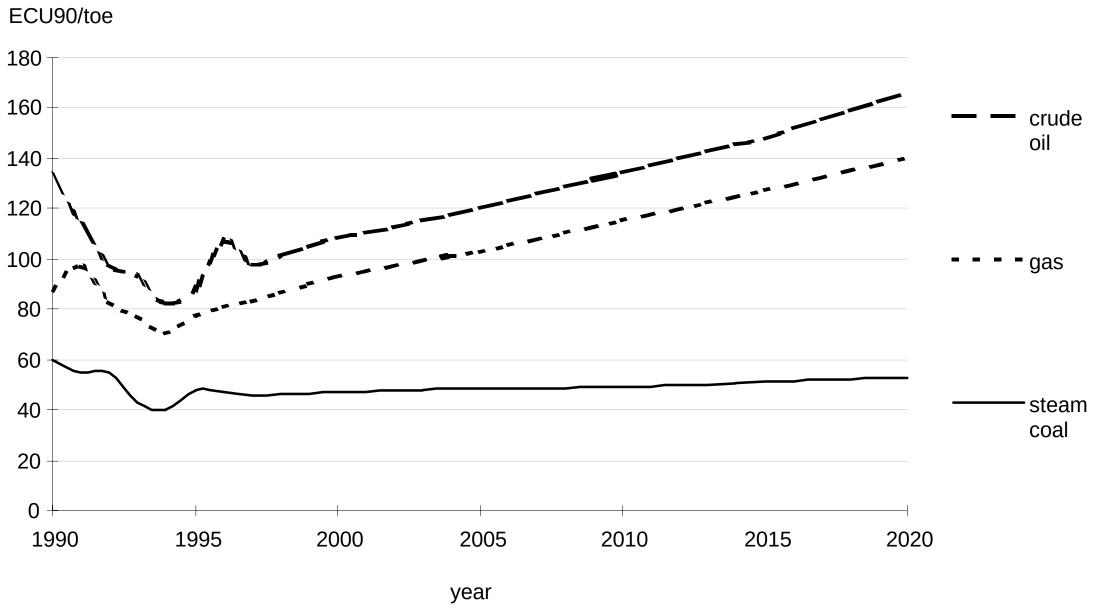

Exhibit 5.3 *Projections of world market energy prices*

The end-user prices of the year 1994 and the projected end-user prices for the year 2020 of the main energy carriers for households and the manufacturing sector are respectively shown in Exhibit 5.4 and.Exhibit 5.5. End-user prices of all energy carriers are increasing less than world market energy prices. Country differences from the baseyear 1994 are more or less preserved in the end-user projections. If the tax is the main explanatory factor for price differences in the baseyear, the 2020 price difference will be proportionally higher. If the margin is the main source for price differences in the baseyear, the price difference will remain similar up to 2020. In all cases, price developments concern a mixture of these two mechanisms.

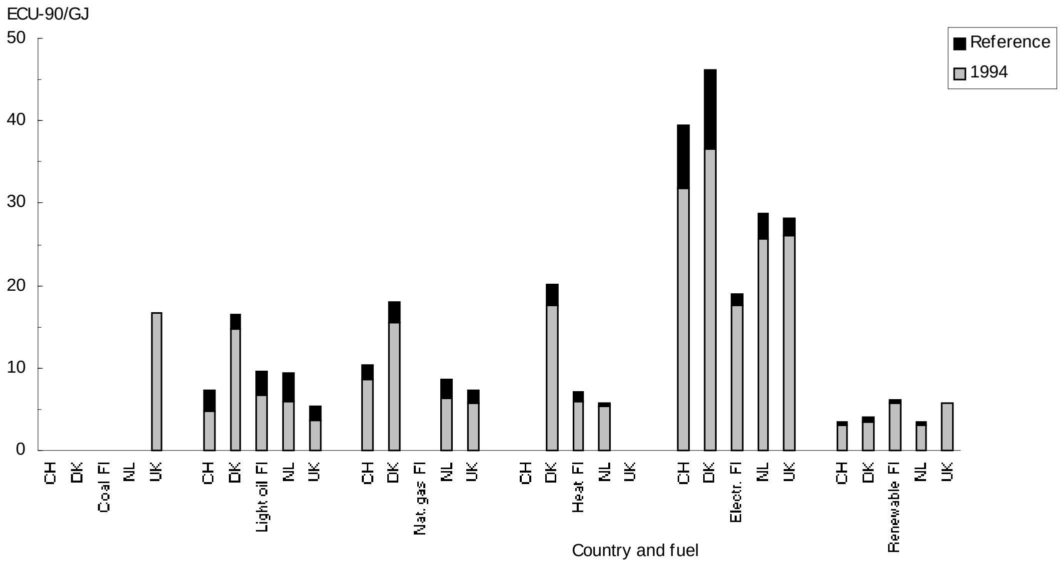

Exhibit 5.4 *Energy end-user prices for households in 1994 and projected prices for the year 2020 in the Reference scenario for the relevant countries*

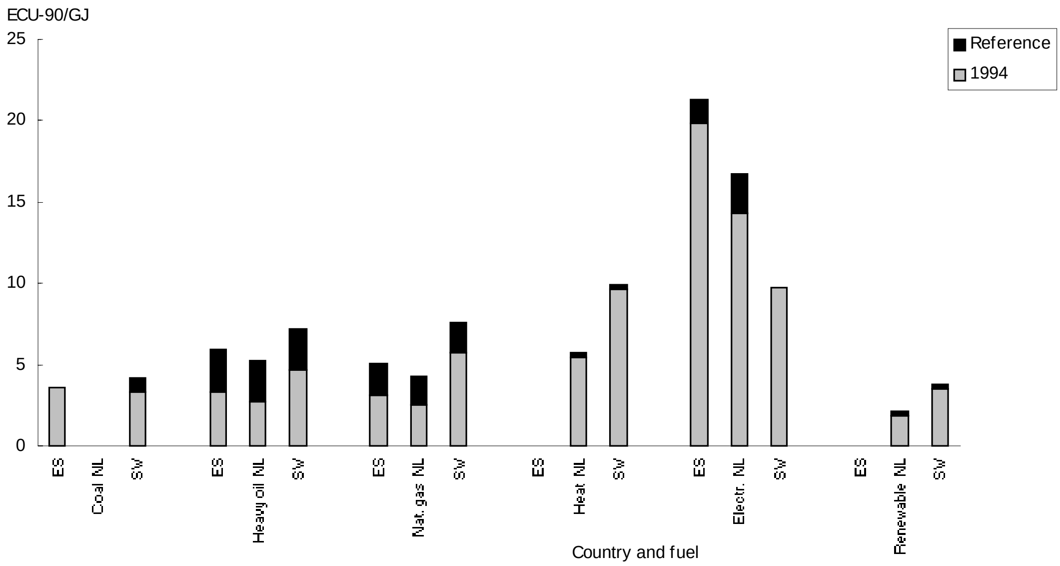

Exhibit 5.5 *Energy end-user prices for the manufacturing sector in 1994 and projected prices for the year 2020 in the Reference scenario for the relevant countries*

For households, the highest increases (about 50%) are shown by light oil prices with an annual growth rate of about 1.5%. The only exception is Denmark which already has a relatively high light oil price. Coal prices remain almost constant (due to the almost flat world market price development) and renewable (mainly wood) prices as well while natural gas prices increase with about one fifth. It is interesting that the countries with the highest electricity price (Switzerland and Denmark) show the highest price increase (25%). Other countries project lower price increases of 8% to 13% over the period up to 2020.

For the manufacturing sector, energy prices are expected to grow more than for households when it concerns the primary energy carriers because the projected world market price increases are influencing a larger part of the end-user price. For instance heavy oil prices will increase with 50% to almost 100%, gas prices a little less. Electricity prices will increase only a little.

5.1.3 Behavioural parameters

As has become clear from the chapter on methodology, the future market penetration of an energy conservation option depends on the present market share, the IRR of this option and a penetration speed factor α, representing behavioural factors concerning the willingness to make additional investments in return for new efficient technology. Empirical data for α are not available in the special format as defined in REDUCE. More general data on investment behaviour is available but still scarce. In Phase I, a survey in the manufacturing sector was devoted to this particular subject.

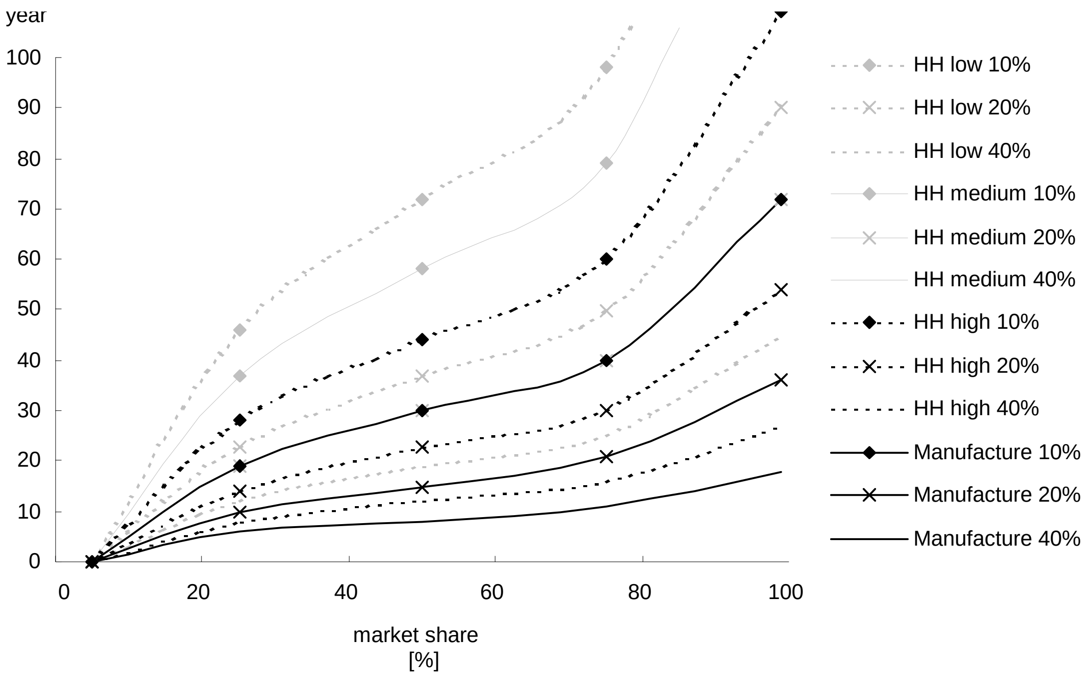

Exhibit 5.6 *Combinations of market penetration time (years) and market share of options as a function of the Internal Rate of Return for different sensitivity categories (penetration speed α) in households (HH) and manufacturing sector (Manufacture)*

For the case studies, in which REDUCE is run for seven countries, a more straightforward approach has been chosen, more in the style of 'what-if'-scenario-approach. Four different penetration speed α values have been selected to model four categories of behaviour which have a different sensitivity for cost-effectiveness and economic profitability of new energy conservation options of which three are for households and one for manufacturing. The time options need to completely conquer a market is presented for each sensitivity category and different values of IRR in Exhibit 5.6. For instance very profitable options (40% IRR) in the manufacturing sector need in REDUCE about 20 years to cover the full market. Hardly profitable options (10% IRR) will need about 70 years. In households, all three sensitivity categories are less willing to invest than in the manufacturing sector. The highly sensitive category approximates the market penetration speeds of the manufacturing sector, the low sensitive category needs more than twice as much time for options with a comparable IRR.

For households, the national experts have chosen a sensitivity category which fits in their opinion best with the country situation. They also based their choice on analysis of energy price (cross) elasticities of the countries. The choice for each country is presented in Exhibit 5.7.

Exhibit 5.7 *Sensitivity categories for the sector households as used in the national cases of REDUCE*

Sensitivity category	National case study
Households high	Denmark, Finland, Switzerland
Households medium	United Kingdom
Households low	Netherlands

5.2 Policy cases

5.2.1 Introduction

Besides the Reference case, in which the market penetration and effects of energy conservation options under the projected demand, sector and price conditions will be studied, the following cases are being distinguished:

- subsidy
- surcharges
- enhanced
- harmonisation
- technical.

The first three cases concern three types of policy instruments applied for energy conservation policies, the last two cases investigate the robustness of the national conservation potentials for EU tax harmonisation and the presence of technical potential in the REDUCE model as a benchmark for the other case results.

For all cases except the technical case, the policy measure applied is introduced according to a linear path from 1997 up to the year 2000.

5.2.2 Subsidy case

In this case, a grant or subsidy of 30% of the investment costs (additional to the Reference option) is given to a selection of five energy conservation technologies which are promising. This means that the technology should be the most efficient in its market, its IRR should be not too low (at least positive) and the penetration of the option remains low (a limited market share). The subsidy is given from the baseyear to the year 2005.

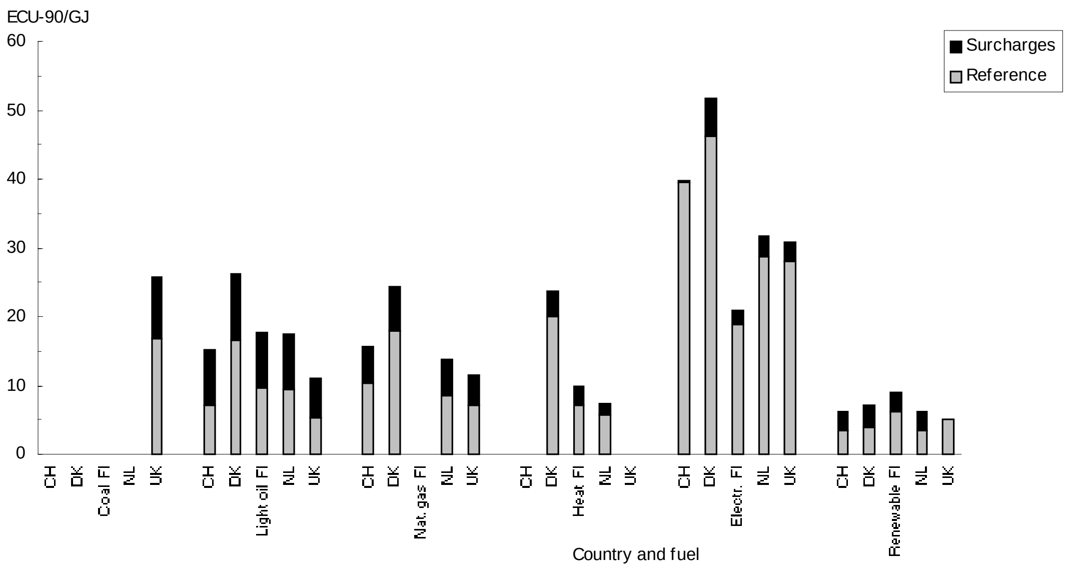

Exhibit 5.8 *Environmental surcharges additional to the Reference energy end-user prices in households in the year 2020 as applied in the Surcharge case for the relevant countries*

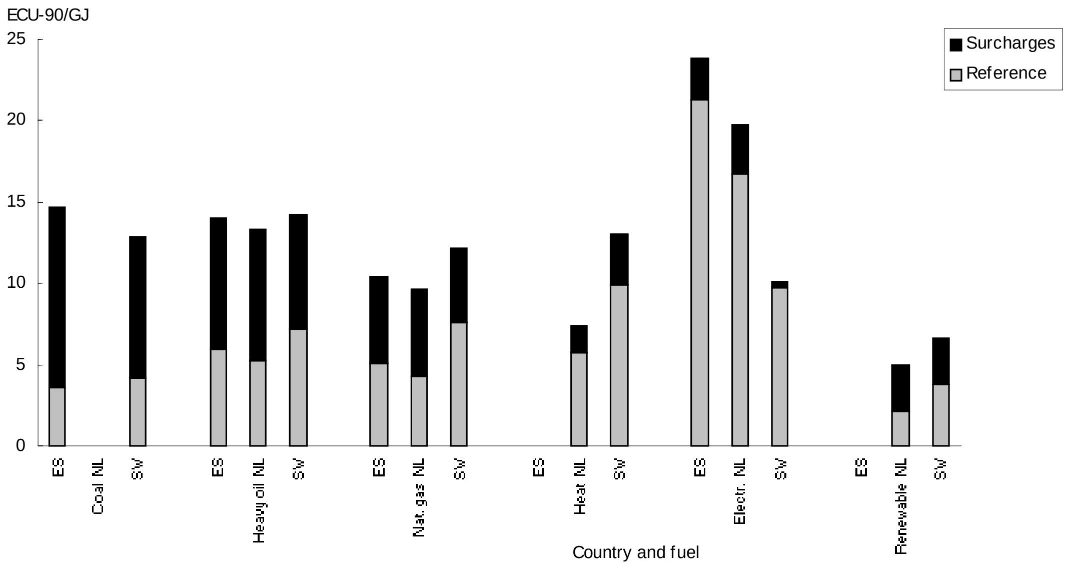

Exhibit 5.9 *Environmental surcharges additional to the Reference energy end-user prices in the manufacturing sector in the year 2020 as applied in the Surcharge case for the relevant countries*

5.2.3 Surcharges case

Based on empirical research conducted in Phase I of the study, Ecoplan collected data on environmental surcharges internalised in energy end-user prices for different sectors (see Annex D). Due to a lack of reliable, comparable national data, for most countries similar surcharges are used for similar fuels, except for electricity and heat, which are calculated on the basis of the fuel mix of the electricity or heat generation system in each country. The surcharges applied for households and manufacturing are graphically presented in respectively Exhibit 5.8 and Exhibit 5.9

For households, prices of the fossil fuels are influenced substantially (about 50% growth for gas and up to 100% growth for light oil) by the surcharges. Secondary energy carriers remain relatively unaffected by surcharges. The relative price levels of different energy carriers have not changed much.

In the manufacturing sector, the influence of a surcharge is much higher because the end-user prices are relatively lower. Coal and heavy oil prices come to a similar high level (double or triple the original price), gas becomes the most attractive commercial fuel, next to heat.

5.2.4 Enhanced case

The case with enhanced sensitivity consists of running the household cases for all countries with an equal penetration speed factor α similar to that of the manufacturing sector. This case is developed for two reasons. First, the results give an impression of the sensitivity of the model for increases of α and indicates the sensitivity of options in REDUCE for policy measures influencing the investment behaviour through psycho-social measures such as information campaigns, energy conservation awareness etc. Second, it forms a basis for comparison of national results since all countries use the same α.

5.2.5 Harmonisation case

In the harmonisation case, the end-user prices are modified in such a way that all countries have a similar tax regime (VAT and excise tax). This represents a first step of liberalised EU energy markets. It means that some countries such as Denmark which have relatively high taxes on energy, will lower their taxes and thus end-user prices. Other countries, such as United Kingdom, will have to increase their taxes and end-user prices. For both the manufacturing and the household sector the present taxes for the relevant countries and the unweighted average EU tax is depicted in Exhibit 5.10 and. Exhibit 5.11.

In households, for instance the Danish electricity price becomes almost 50% cheaper. Except for the Netherlands and Denmark, other countries will have to increase their taxes and end-user prices of most energy carriers. For instance in the United Kingdom, the electricity and natural gas prices will rise with 15% and light oil prices with 40%, in Switzerland the natural gas prices with 15% and the light oil prices with almost 60%. In manufacturing, differences in present tax levels of countries are much smaller for the relevant countries. This is probably due to the forces of market competition in the manufacturing sector, which leaves less space for governmental price policy. The effects of the application of an average EU tax are in most cases in the order of 10% of the end-user price.

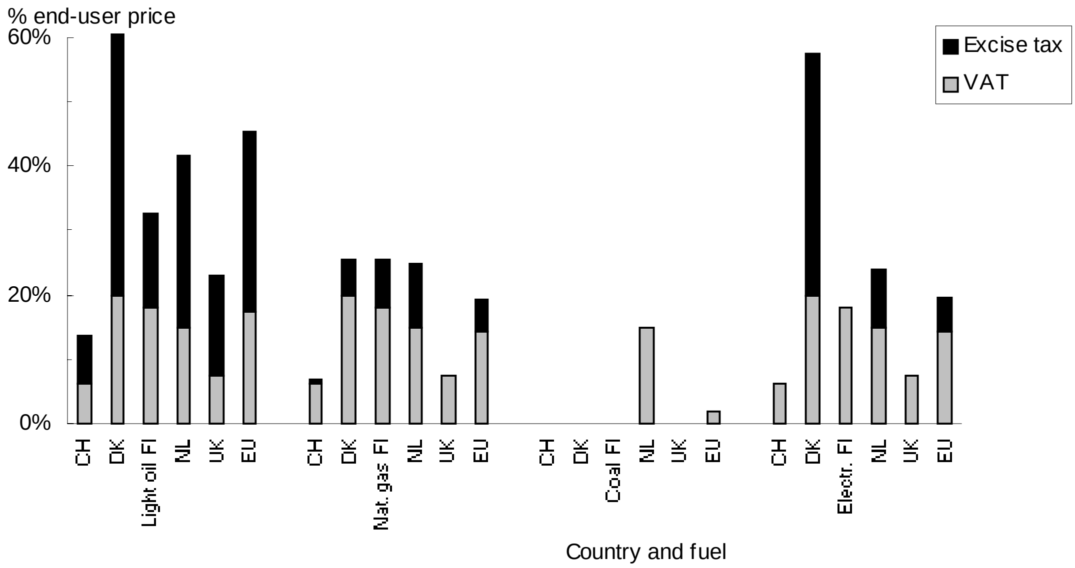

Exhibit 5.10 *Energy end-user taxes for households in 1996 for the relevant countries and the EU (unweighted average) values which are applied by the countries in the Harmonisation case*

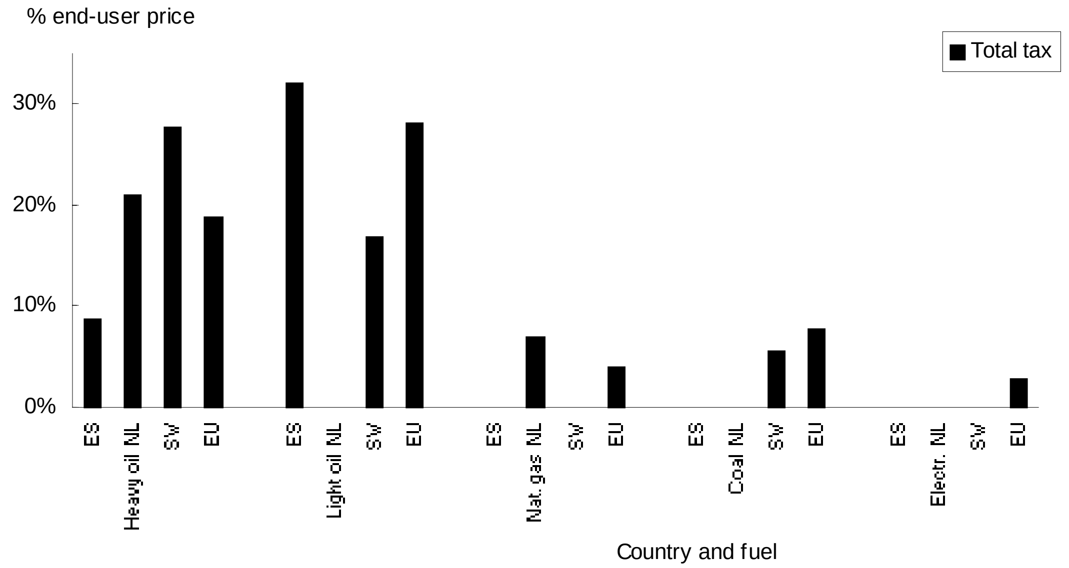

Exhibit 5.11 *Energy end-user tax for the manufacturing sector in 1996 for the relevant countries and the EU (unweighted average) values which are applied by the countries in the Harmonisation case*

5.2.6 Technical case

This case will show the technically available energy conservation potential present in the REDUCE versions of each countries, and the effects on the energy demand it will have, regardless of costs, energy prices and investment behaviour. It functions as a reflection on comparability to the modellers and experts who specified the national REDUCE versions, it puts the country comparison of other case results in perspective and it indicates possibilities for energy conservation which are technically feasible but policy makers only can dream of (designing policy measures for).

6. RESULTS

6.1 Households

6.1.1 Reference case

The Reference case shows the energy saving potential which is expected to be reached due to increases of market shares of energy conservation options which are profitable at the projected energy end-user prices. At the present stage of development of REDUCE, it is not possible to state that the energy savings penetrating in the Reference case reflect an autonomous development without present or additional policy measures. For a large part, present conservation policies in the form of standards, building codes and energy taxes are implicitly included in the model specification. The Reference case provides a ‘what-if’-scenario approach that indicates which options provide profitable energy saving potential given the competition and interaction of options and the energy carrier price developments and moreover, the general barriers existing in the sector households with respect to investment in energy conservation options as reflected by the market stages of technologies.

It is useful to illustrate the results of the Reference case in comparison with the baseline development and the Technical case (see Exhibit 6.1). The baseline development includes no additional energy savings with respect to the baseyear, the so called ‘frozen technologies’-approach, but it does take into account volume growth of the sector and changes in the structure of the sector. In other words, the different energy services can grow at different speeds and the energy service itself can also change over time. For instance, new houses can have different heating characteristics (smaller windows, larger living rooms etc.) which gives a different energy intensity value to the service ‘heating of houses’. These baseline developments are the result of the scenario analysis and should be consistent with each other, the energy price projections and the options specified in the model. The energy saving potential in the Technical case consists of the maximum energy saving which can be reached by all available technically feasible energy conservation options regardless of present market shares or profitability.

The baseline values for the year 2020 as an index of the baseyear energy consumption, which are presented in Exhibit 6.1 by the black bars, are quite different for the six countries. Finland and the Netherlands assume a high growth of the energy consumption (2% annually), United Kingdom projects a moderate growth (0.9% annually) and Switzerland and Denmark forecast a growth of respectively 0.57% and 0.24% per year. Switzerland and Denmark have included in their projections some energy saving effects, which explains the difference with the other countries. This will be analysed in detail later.

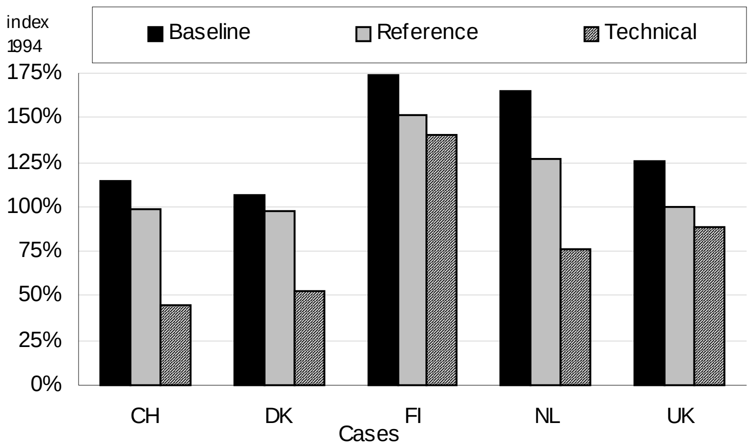

Exhibit 6.1 *Projected household energy consumption for the year 2020 according to the Actual baseline (Baseline), the Reference case (Reference) and the Technical case (Technical), for relevant countries expressed as index of 1994 energy consumption*

The light grey bars show the energy consumption for the Reference case, so including profitable energy savings. All countries except the Netherlands and Finland calculate an energy consumption similar to the baseyear consumption. The Netherlands and Finland have a much higher Reference energy consumption, partly due to a higher volume growth and increasing energy intensity (Netherlands). For Finland applies that a limited set of conservation options was specified in REDUCE, which resulted in low relative savings expressed as a percentage of the baseline.

Exhibit 6.2 shows the purposes of energy consumption or the type of energy services as a share of total household energy consumption in the baseyear in each country. Of course, the overall structure of energy services is similar in the countries. The major part of energy consumption in households is required for heating (62% to 75%), followed by hot water (13% to 23%) and the other services (each 5% or less). The differences between the countries are not easy to explain. They can be rooted in different relative levels of energy services, for instance due to differences in income, lifestyle, living space etc. Another explanation is a difference in relative efficiency of energy services, eventually caused by differences in fuel mix, supply and conservation technologies and differences in demand factors such as climate, house type, window sizes etc.

Exhibit 6.3 gives an impression of the aggregate of the level and efficiency of energy services for the different countries by presentation of the specific energy consumption per energy service per household. It also illustrates the fuel mix per energy service in the baseyear for the different countries.

Considering the country differences in lifestyle, income, energy prices, fuel mix etc. it is striking that specific energy consumption values for households are so similar. Nevertheless, relative differences per type of energy service are sometimes substantial, especially in the service categories which consume little energy.

Energy consumption for heating ranges from 50 GJ per household (United Kingdom and the Netherlands) to 66 GJ per household in Finland. The latter can be (partially) explained by climatic circumstances, the first by the presence of gas heating systems with a, compared to other fossil fuels, high efficiency. Relative high specific consumption for Switzerland is probably related to many large detached single family houses and few multi-family terraced houses. Differences in energy consumption for hot water are probably due to most arbitrary definitions for making a distinction between fuel consumption for heating and hot water. The sum of hot water and heating is more reliable than the figures for hot water alone, for which the ranking of countries is completely different than the ranking for heating.

Heating and hot water is supplied by conversion of all types of fuels, ranging from natural gas in the Netherlands and United Kingdom to light oil in Switzerland, renewables (wood) in Finland, Denmark and Switzerland and district heat in Finland and Denmark. Since the share of heating and hot water is the largest of all energy services for households, the fuel mix used for heating and hot water dominates the total average fuel mix for households.

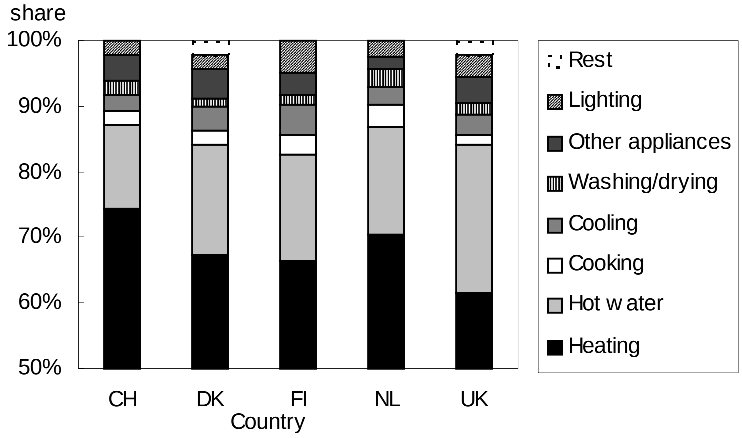

Exhibit 6.2 *Relative shares of energy services contributing to Actual energy consumption of households in the baseyear 1994 for relevant countries*

Energy consumption for cooking is partly related to the fuel and technology type used. For instance electric cooking and micro-waves are from an end-user perspective more efficient than gas fired cooking. Therefore, the relatively high energy demand for the Netherlands cooking seems to be logical. Most important though is the lifestyle with respect to cooking and, related to that, cooling which influences the demand for cooking per household. To put an example: do persons have time and the attitude to shop and to cook a haute cuisine dinner every day... or do they merely heat up fast food from the freezer which is filled once a month?

The main country differences in the energy demand for washing and drying are caused by the demand for drying. In reality, the demand differs substantially per country, but this is exaggerated by the fact that some countries did not distinguish drying separately due to a lack of reliable data and included drying in the category ‘other appliances’. This is partly also an explanation of some high values concerning appliances for some countries. Also, differences in use of energy intensive appliances such as for instance sauna and solarium can have a substantial impact.

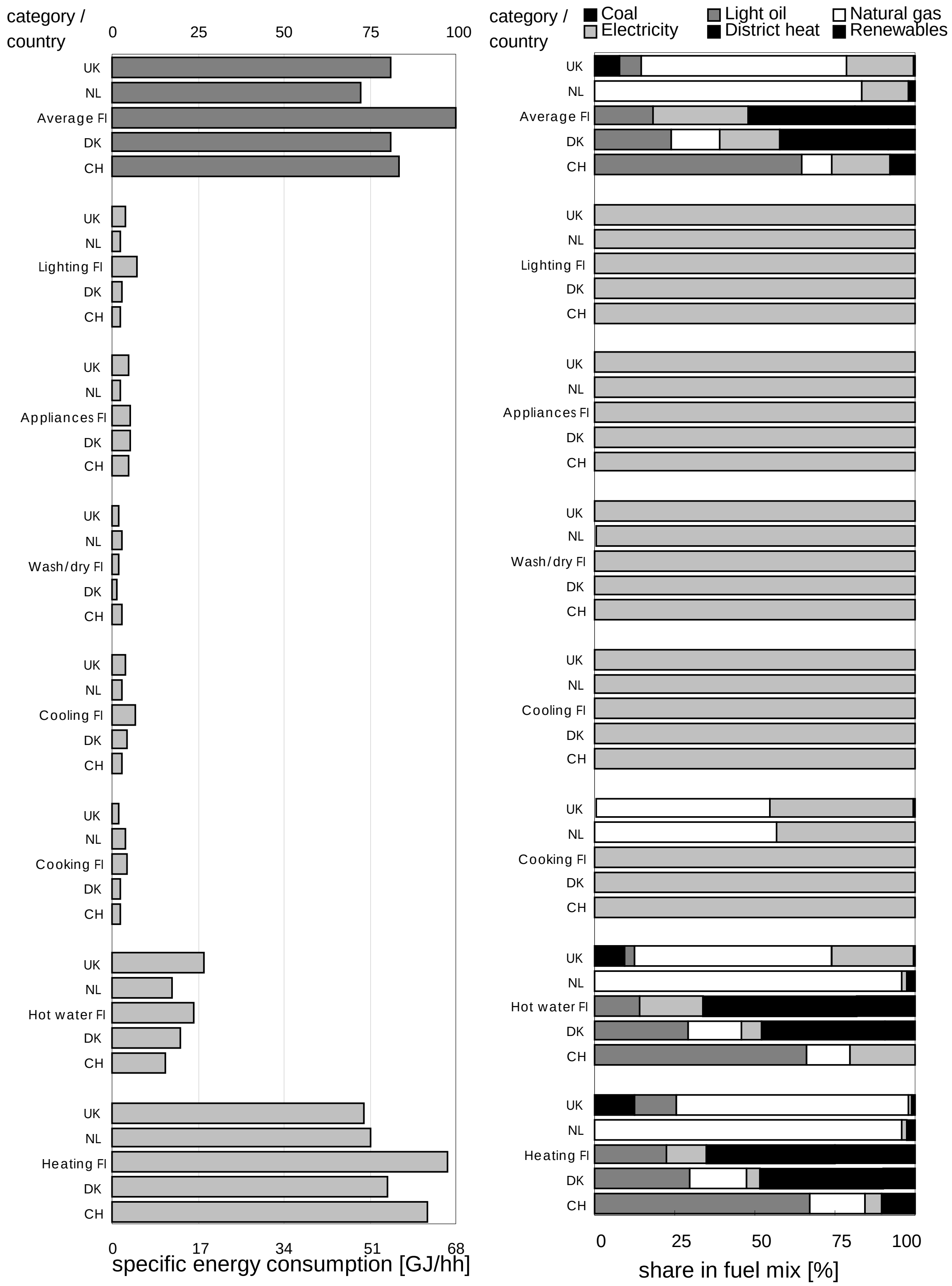

Exhibit 6.3 *For each energy service in households, the specific energy consumption and the fuel mix for the baseyear, for relevant countries*

The demand for lighting is partly related to climate (see the high values for Finland) but also lifestyle, living space etc.

Of course, the present specific energy consumption for each energy service is also influenced by the presently already implemented energy conservation options and these differ also from country to country. This will be discussed along with the projected energy savings in

The total average specific energy consumption per household is, as has been said, not so different in the five countries. Netherlands' households are the least energy intensive, Finnish households the most energy intensive.

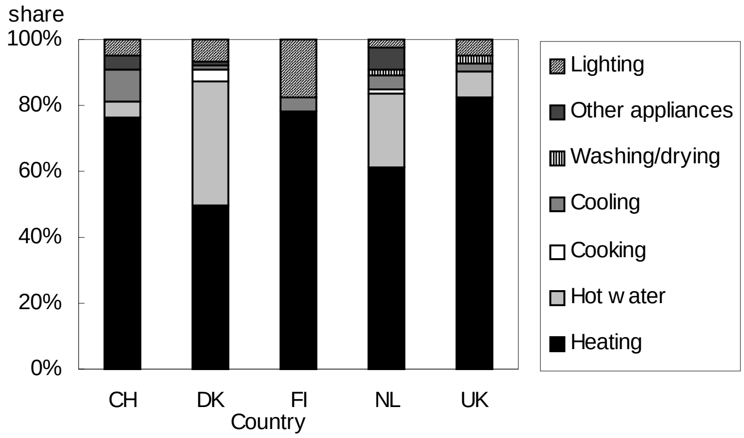

Exhibit 6.4 *Relative energy savings by energy service in the Reference case for the year 2020 for relevant countries*

Since the structure of household energy consumption is roughly similar in the different countries, the relative energy savings by energy service are similar in the different countries too. Exhibit 6.4 shows the shares of savings of energy services in the total energy saving reached in the Reference case in the year 2020. Savings in heating have the highest share (50% to 80%) followed by savings in hot water (5% to 38%). Savings in other service categories are much smaller, viz. smaller than 5% for almost all categories and countries. The dispersion of values is much larger than the dispersion of shares of energy services in energy consumption of households. This is only partly due to the lack of options specified in some energy service categories, which distorts the relative shares. Therefore, a more detailed analysis is required of the relative growth, energy intensity changes and specified saving potentials for each energy service category for each country. These are shown in Exhibit 6.5.

The left graph in Exhibit 6.5 presents for each energy service category the scenario assumptions for each country on volume growth, energy intensity change and the resulting growth in energy demand. All growth values are percentages of the baseyear energy consumption for each energy service category.

The graph on the right-hand side of Exhibit 6.5 gives three different types of energy saving potential for each energy service category for each country. The saving potential presented by the white bars, indicated by '1994', is the saving potential already realised in the baseyear. It concerns options such as fluorescent light bulbs, wall insulation, double glazing etc. which already have a (substantial) market share in the baseyear. This saving potential is partly arbitrary since it depends on the definition of the reference energy demand technology. However, it is essential to define a reference as a homogeneous set of existing and identifiable technologies with present market shares because the market share is an important driving factor. But in some cases it requires detailed data which are not available.

The saving potential realised in the Reference case expressed as index of the Actual baseline energy consumption for the year 2020 is presented by the black bars. It concerns presently applied saving options which have increased their market share and new technologies which have penetrated the market. The grey bars indicate the energy saving potential which is technically feasible and available additional to the Reference case but was not realised due to all kinds of barriers in the area of profitability, behaviour, supply problems or market saturation. One of the reasons, apart from the ones discussed below, for country differences between saving potentials of Reference or Technical cases is the sometimes incomplete specification of the set of options.

The two graphs in Exhibit 6.5 present in a nutshell the energy scenario information and present and future energy savings by energy service category. One important relation between these two concerns the energy intensity change and the Reference energy saving potential. A change in energy intensity indicates a change in the character of the energy service. For instance, due to the decreasing number of persons per household, the demand per household for cooking, cooling and lighting could decrease as well. When the demand *per household* decreases, the energy intensity decreases which results in a lowered impact of a specific investment in a conservation option. For instance, investing in an efficient cooker saves less energy if the cooker is used less because of a lower number of persons per household. Therefore, a decrease in energy intensity has not only an constraining impact on the potential which can be technically saved, it also results in a lower profitability and therefore a slower penetration of the saving option. Sometimes an energy intensity decrease has been used in REDUCE to specify the penetration of a package of energy conservation options in an aggregated way. A lack of data can be a reason for this, but it is not a recommended method because the penetration of options is not dependent anymore on costs and market shares but is just fixed based on expert judgement.

The combined result of the two graphs in on energy scenarios and future energy saving potentials is the energy consumption by energy service category. The 2020 energy consumption, expressed as index of the baseyear, is presented by energy service in Exhibit 6.6.

Heating

For heating, most countries foresee a rather limited volume growth of energy demand up to the year 2020. In the Netherlands, a substantial increase of energy intensity is projected as a result of an increase of living space and the share of detached single family houses. Such a development might be expected for all countries, given the increasing income projections for all countries. Nevertheless, Switzerland and United Kingdom have neglected this development and Denmark and Finland have actually projected a decrease in energy intensity. In these last two countries it concerns an aggregated way of specifying energy conservation options, not a change in the character of heating of houses. This is illustrated by the relatively low Technical saving potential for heating specified in the model of the two countries.

When looking at the saving potentials implemented in the baseyear, only the Netherlands and United Kingdom have explicitly specified a complete set of presently penetrated energy conservation options. In comparison with the other energy services it is clear that present savings are the largest in the energy service heating. The countries with a limited potential for 1994 have implicitly included present conservation options in the specific energy demand. The effect is that one of the driving forces behind market penetration of conservation options, viz. the present market share, is underestimated in these cases. It can be seen in the results for Denmark, Switzerland and Finland that the Reference saving potentials are limited. This is due to the fact that most explicitly specified options are new (future) technologies which have to start from scratch and therefore have a hard time entering the market, even despite relative high energy prices such as in Denmark. In contrast, conservation options in the Netherlands and United Kingdom (with low energy prices) have a much larger impact. The Reference energy saving potential in the United Kingdom is the largest (up to half the Actual baseline in the year 2020) since the technical efficiency of buildings is relatively low compared to those of other countries. In particular cavity wall insulation has presently a small market share which can grow strongly up to the year 2020.

The result of both scenario assumptions and energy saving potentials is the energy consumption for heating in the year 2020. In terms of 1994 energy consumption, it will increase with 10% in the Netherlands and 5% in Switzerland and decrease in the other countries (5% in Finland, 10% in Denmark and 50% in the United Kingdom). Realisation of the technically feasible energy saving potential would lead to energy consumption of 40% to 50% of the baseyear energy consumption. The main part of the energy saving potential exists in existing houses.

Due to the large share of the energy service category heating in total household energy demand, the pattern of changes in energy intensity, volume and energy demand and the energy saving potentials for the total household energy demand is similar to that of heating. This underlines the importance of energy conservation in heating for the total household energy conservation policies. Therefore, a market example for the Netherlands on heating will be discussed on the level of conservation options in chapter 6.1.3.

Hot water

All countries expect a moderate volume growth of the demand for hot water, except the Netherlands and Finland that projects almost 50% growth. Only the Netherlands foresees an increase in the hot water demand per household as a result of an increase of showering and bathing (energy intensity increase). The United Kingdom projects no change in behaviour related to hot water demand, Switzerland, Finland and Denmark foresee a decrease in hot water demand per household as a result of a decrease of the number of persons per household. For Switzerland, this is not a satisfactory explanation since the resulting total energy demand for hot water is decreasing. For the other countries, total energy demand for hot water is on the baseyear level or increasing.

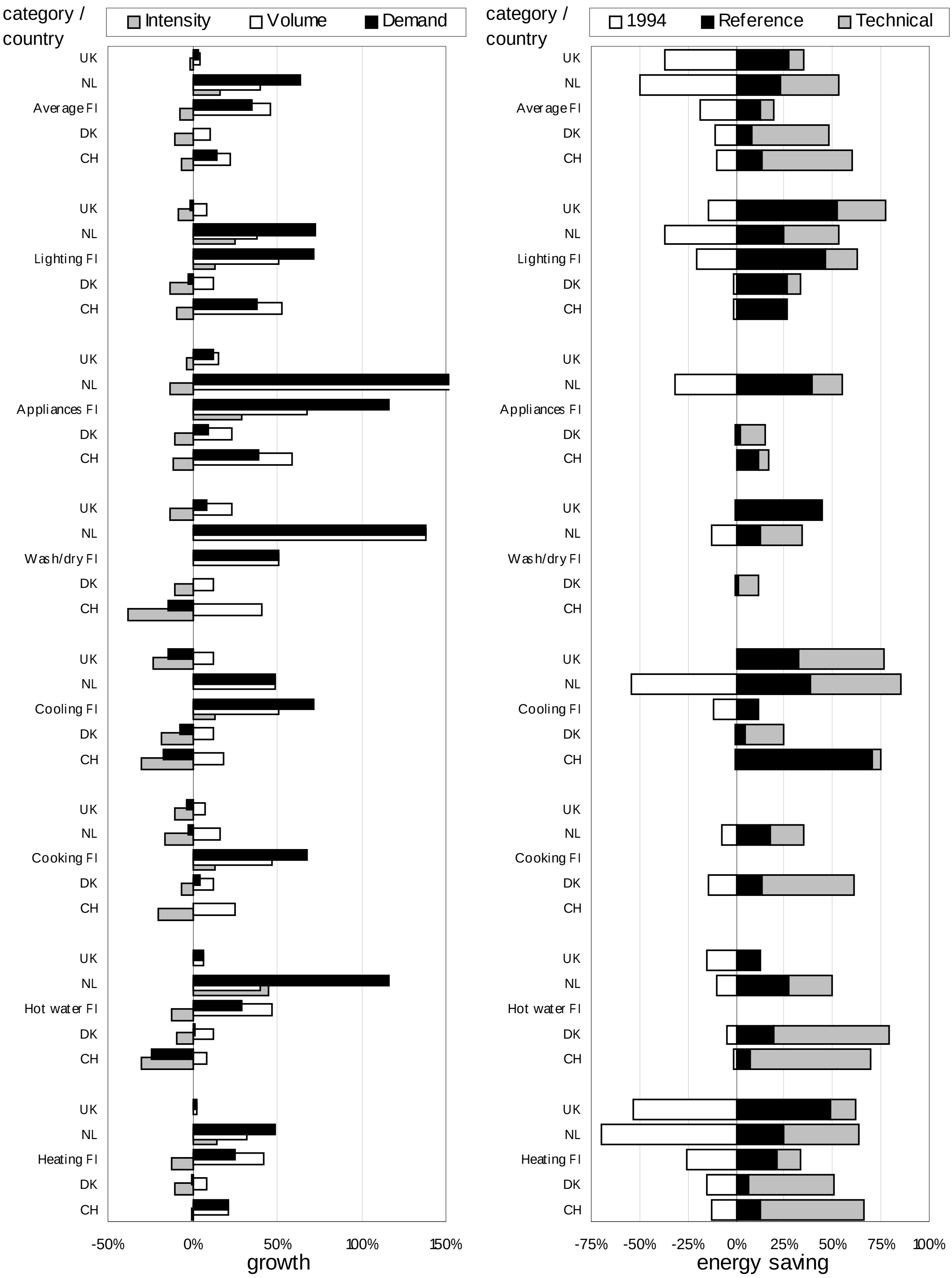

Exhibit 6.5 *For each energy service in households for the year 2020, the projected growth of energy demand baseline as a result of volume and intensity changes of the energy service expressed as a percentage of the energy consumption of the baseyear 1994 and energy savings in the baseyear 1994 and in 2020 in the Reference case and the Technical case, expressed as a percentage of the Actual baseline energy consumption for the year 2020, all for relevant countries*

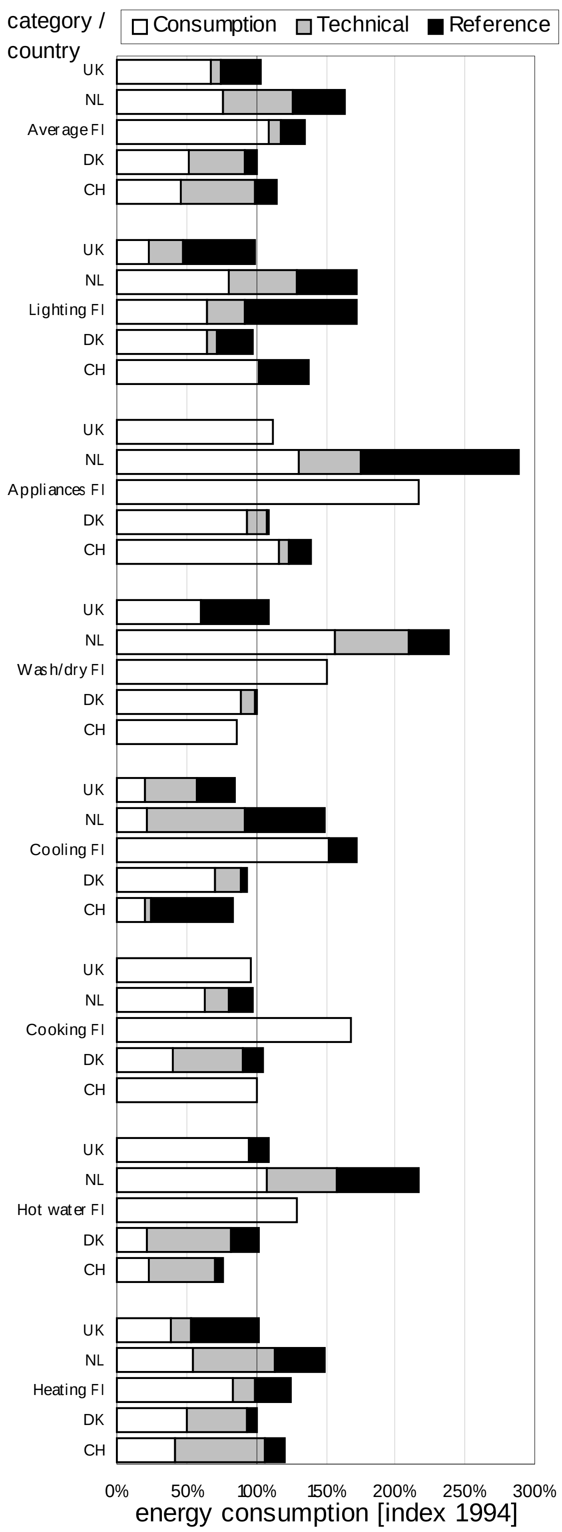

Exhibit 6.6 *For each energy service in households for the year 2020, the projected growth of the energy demand baseline, energy savings in the Reference case and the Technical case, expressed as a percentage of the energy consumption of the baseyear 1994, all for relevant countries*

In the baseyear, the efficient water heater (on gas or electricity), water reducing shower and to a lesser extent the water reducing tap already have a substantial market share in the Netherlands. In the Reference case, these options increase their market share. Reduction of waterpipe losses is profitable but has only a small present market share. Solar boilers are not specified, which explains the relative limited technical saving potential in the Netherlands compared to that of Denmark and Switzerland. Solar boilers, however, are not profitable in the Reference case. For Denmark also water reducing showers are specified but they have a smaller impact than in the Netherlands because they are only technically feasible on the small part of the market which has individual central heating. In Switzerland, electric heatpumps are modelled for hot water supply and take half the market of hot water supply on electricity. In the United Kingdom, hot water tankings and pipe lags have a very large market share. Saving potential in the Reference case consists of efficient water heaters covering almost the complete market. Other options are not specified. Finland did not specify any energy conservation option for hot water.

In terms of baseyear energy consumption, energy demand for hot water is foreseen to increase in the Netherlands (50%) and Finland (25%) and to decrease in the other countries (10% to 30%). It is not clear due to the application of different definitions whether implementation of the technical saving potential could lead to a further decrease of the energy consumption down to 50% of the 1994 energy consumption.

Cooking

All countries except Finland foresee a decrease in demand for cooking per household (a decrease in energy intensity) due to the decrease in the average number of persons per household or in other words the increasing number households consisting of 1 person. Also an increase in volume is projected due to an increased number of households, resulting in a more or less constant energy demand for cooking. For the Netherlands also a shift from cooking on gas towards cooking on electricity is foreseen. It concerns an increase in conventional electric stoves, ovens but also microwaves, which require, from an end-user point-of-view, less energy. For the other countries, except Finland, this type of fuel switch is not relevant or not taken into account (United Kingdom).

Energy saving options for cooking are only specified in the Danish and Dutch models. Effective hardware can save 25% electricity and has a substantial contribution in the Reference case. Induction cooking is slightly profitable and can save in theory about 50% electricity, but at present it has a low market share and thus difficulty of penetrating the market. This explains the Danish technical potential. For the Netherlands, different types of options are specified, viz. new and efficient stoves on gas and electricity and new and efficient micro-waves. The Reference potential consists of a majority of new cooking appliances and a small market share for the efficient types. The technical potential consists of a complete market of efficient cooking appliances.

Relative to 1994 energy consumption for cooking, energy demand after energy savings is expected to remain stable (Switzerland and United Kingdom) or decrease with about 5% (Denmark) to 20% (the Netherlands). Application of the technical energy saving potential would lead to reductions of energy demand down to 40% of the baseyear energy consumption.

Cooling & freezing
For all countries, an increase of the volume of cooling and freezing is expected, mainly due to growth of the number of households. Three countries, viz. United Kingdom, Denmark and Switzerland foresee a substantial decrease in the energy intensity of cooling and freezing due to the decrease of the average number of persons per household. For the Netherlands, an unchanged energy intensity is assumed, since the fridges and freezers are in operation whether they are half or completely filled. In other words, the decrease of the average number of persons per household does not affect the energy intensity of cooling. The resulting energy demand for cooling is therefore projected to increase in the Netherlands and Finland and to decrease in the other countries. This decrease may be too optimistic.

Two conservation options are specified for cooling and freezing in the United Kingdom model, viz. efficient (75% saving) and vacuum insulated (88% saving) fridges and freezers. The efficient models cover in 2020 about 40% of the market, the vacuum insulated models are less profitable than the efficient models. For the Netherlands, the overall picture is the same, although four types are modelled for fridges and respectively freezers: new (35% and 49% saving), efficient (49% and 68% saving), advanced (79% and 85% saving) and vacuum insulated (90% and 92% saving). By this different categorisation, in 2020 the efficient fridges cover the complete market for cooling and the efficient and advanced freezers share the market for freezing. The database for Switzerland only includes one highly efficient option which saves 75% and almost completely covers the market since it is reasonably profitable. This seems a too simple and optimistic approach. In the Danish model different types of fridges and freezers are modelled (box fridge and combi fridge) which have a technical potential of only 25%. In the Reference case only a limited part of the market is covered by the more efficient models (which are profitable) since they are bounded by the expert to make the result more realistic. This can be regarded as a conservative approach.

The energy demand for cooling and freezing in the year 2020 is foreseen to decrease with respect to 1994 energy consumption with about 10% (Denmark, Netherlands and Switzerland) up to 45% (United Kingdom), except in Finland (50% growth). Implementation of the technical energy saving potential would lead to reductions of energy demand for cooling down to 20% of 1994 energy consumption.

Washing and drying
The volume growth of the demand for washing and drying is considerable in Switzerland, the Netherlands and Finland, mainly reflecting the rapidly growing demand for drying. The projection for the United Kingdom is more conservative. The Danish model does not explicitly distinguish dryers. In the Danish, Swiss and British models, the energy intensities for washing and drying decrease as a result of the decreasing number of persons per household. The energy intensity projections for the Netherlands and Finland are assumed to remain constant which seems less likely. Like with cooling, the Swiss energy demand for washing and drying is decreasing which seems not very probable. One explanation would be that this is a way to model energy conservation in an aggregated way, since no conservation options have been specified. Energy demands of other countries remain almost or completely constant (United Kingdom and Denmark) or grow considerably (Finland and the Netherlands).

Two separate conservation options are specified in the United Kingdom model, viz. efficient (40% saving) and advanced (70% saving) washing machines and dryers. The efficient models cover the major part of the market. The Netherlands' model includes efficient (20% saving) and advanced (60% saving) washing machines and also hot fill options. The efficient and the advanced (conventional and hot fill) washing machines are all very profitable, but the efficient type takes the largest share of the market since it already has a substantial market share. In the market for drying, the efficient dryer (10% saving) is the most profitable although the advanced type saves more energy (35%). For the dryer types on natural gas applies the same. For both the dryers on natural gas and the hot fill washing machines applies that they save less energy from an end-user point-of-view which is reflected in the limited technical saving potential. In the Danish model, only modest saving options for washing are included, in the other countries' models no saving options have been specified.

The energy demand for drying in the year 2020 is expected to increase with maximum 80%, expressed as a percentage of 1994 energy consumption. Even the technical available saving potential can not counterbalance the growth in this demand category. The energy demand for washing is foreseen to decrease with 10% to 40%. Application of the technical energy saving potential would lead to reductions of energy demand for washing down to 60% of the 1994 energy consumption.

Other appliances

Other appliances is a very heterogeneous category of different household appliances such as mixers, shavers, vacuum cleaners, hair dryers, dish washers, televisions, videos, computers, water beds, etc. Nevertheless, a few general things can be said about this category. First, a strong increase of the volume of the demand for these appliances is expected for the year 2020 in all countries. Generally, it seems logical to project a decrease in energy intensity as a result of a decrease of the average operation time or usage of all these appliances, since it is in many cases not useful to use appliances at the same time. For instance the radio, compact disk, computer and television will generally not be used at the same time by one person. Nevertheless, this effect is on average smaller than the projected volume growth and thus resulting in a strong growth of the energy demand for other appliances.

Only the Dutch model has specified for many appliances separate options of the types new, efficient and advanced. For almost each appliance, all options are very profitable. The Reference energy saving potential consists in most cases of a major part due to efficient types and a small market share of the advanced type, which is just as profitable but enters the market only in the year 2000 and has to proof itself in a market which is already covered by the existing products. The additional potential which is saved in the Technical case is about 20% electricity.

For the year 2020 an increase in energy demand for other appliances is expected with respect to the baseyear energy consumption of 10% (Switzerland, Denmark) to 75% (Netherlands). Finland even projects a more than doubling of 1994 energy consumption for lighting. Even the technical available saving potential can not counterbalance the growth in this demand category.

Lighting

In all countries the volume of the demand for lighting is expected to grow up to the year 2020 due to increasing living space and number of households. For the Netherlands and Finland, an increase of the amount of lumen per light point (energy intensity) is expected. The other countries foresee a decrease in of the energy intensity. Result of these developments is that the energy demand for lighting is projected to grow in the Netherlands, Finland but also Switzerland, while it is expected to decrease with respect to baseyear in the United Kingdom and Denmark.

In the Dutch model, different tranches of fluorescent bulbs have been specified for different categories of operation hours. In this way the market for lighting has been differentiated into submarkets. Penetration of fluorescent bulbs in the submarkets with low operation hours are not or hardly profitable and have a low market share in the year 2020. This explains that the saving potential of the Reference case is only half that of the Technical case. This result is similar to that of the Danish and Swiss cases, but in these models a less sophisticated approach of constraining the penetration of fluorescent bulbs was chosen. The British and Finnish database include only one option that saves 80% electricity and is slightly profitable resulting in a market share of two third in 2020. This seems a rather simple way of specifying the savings on lighting and results in a too optimistic electricity saving.

In terms of 1994 energy consumption, energy demand for lighting is expected to grow with 30% in the Netherlands, remain constant for Switzerland and Finland and strongly decrease in Denmark and

United Kingdom. Implementation of the technical saving potential could lead to a further decrease of the energy consumption down to approximately 60% of the 1994 energy consumption.

Summarising

The analysis of the results concerning scenario projections and energy savings up to the year 2020 for the different countries leads to the following general conclusions:

- Present and future volumes and energy intensities of energy services in households are in general strongly lifestyle related. Demand for heating is also related to climate, type of building, fuel mix and related technologies and past conservation policies.
- Therefore, developments in volume and energy intensity of the energy services in households differ by type of energy service and country.
- Technical saving potentials for energy services in households differ not so much between countries since most options are available on the EU market. Conservation options for heating are an exception to this due to the country specific character of heating and building types and the long lifetime of many technical measures in the building stock..
- The characteristics of the market for heating dominate the structure of energy services for households since heating covers a large share of 65% to 75% of the energy demand for households.
- Therefore, energy saving potentials in households are also dominated by those on energy demand for heating and also hot water.
- Energy service with a smaller share of around 5% in the energy consumption can differ more than a factor two between countries which is not related to differences in efficiency but volume due to lifestyle differences.
- Country differences in energy pricing and energy intensities are not of large influence on the Reference energy saving potential. The market stage of conservation options is much more decisive, just as the replacement rate of existing devices.
- The comparability of the results for the different countries can be improved by further harmonisation of the scenario assumptions and conservation options database.

More concrete, the present situation and projected developments for energy services in households in the different countries can be characterised as follows:

- Demand projections for United Kingdom and Denmark are for the energy services in households (without the rest category 'undefined') constant up to 2020, but it probably includes already substantial energy savings. The demand projection for Switzerland is increasing moderately, for the Netherlands and Finland they are growing strongly.
- For all countries except the Netherlands, energy intensities are projected to decrease moderately. For the Netherlands, energy intensity increases for heating, hot water and lighting more than counterbalances intensity decreases for other energy services.
- Energy demand for appliances and drying is expected to grow strongly despite energy intensity decreases. Energy demand for lighting is projected to grow substantially in most countries. Energy demand for washing, cooling and cooking remains more or less stable up to 2020. Energy demand for heating grows moderately according to the scenarios of most countries and dominates the growth of total energy demand for households.

Energy saving potentials in households for the different countries in 2020 can be described as follows:

- Energy savings have a substantial contribution in the Reference case for the year 2020 from 10% to 25% of the baseline consumption. The lower number is biased by energy savings which are included implicitly in the baseline development. Technical saving potentials are around 50% of the baseline energy demand in 2020.
- Energy saving potentials in 2020 in the Reference case are for lighting approximately 25% (Technical 50%), for cooling 30% (80%), for cooking 15% (60%), for appliances 30% (50%), for washing 15% (35%) and for hot water around 20% (65%) of the baseline energy demand for the particular energy service. The country differences are not so large.

- Energy saving options for heating contribute in the Reference case in 2020 about 10% to 50% depending on the country. The extreme figure of 50% energy saving applies for the United Kingdom which has only started with particularly cavity wall insulation. Technical potentials depend not much on the country and are estimated to be about 65% of the energy demand baseline. The main part of the energy saving potential exists in existing houses.

The combined result of energy service projections and energy saving potentials in terms of energy consumption for the different countries in the year 2020 is as follows:

- Total household energy consumption in the year 2020, relative to 1994 energy consumption, energy demand after energy savings is expected to remain more or less constant for all countries except the Netherlands and Finland.
- However, an increase in energy demand is expected for the energy services other appliances (10% to 40%) and drying (up to 80%). Even the technical available saving potential can not counterbalance the growth in these demand categories.
- The energy demand is foreseen to decrease for washing (10% to 40%), cooling (10% to 45%) and cooking (5% to 35%). Application of the technical energy saving potential would lead to reductions of energy demand for washing down to 60%, for cooling down to 20% and cooking down to 40%.
- Energy demand for lighting is expected to grow with 30% in the Netherlands, to remain constant for Switzerland and Finland and strongly decrease in Denmark and United Kingdom. Implementation of the technical saving potential could lead to a further decrease of the energy consumption down to about 60% of the 1994 energy consumption.
- Energy demand for hot water is foreseen to increase in the Netherlands (50%) and Finland (25%) and to decrease in the other countries (10% to 30%). It is not clear due to the application of different definitions whether implementation of the technical saving potential could lead to a further decrease of the energy consumption down to 50% of the 1994 energy consumption.
- Energy consumption for heating will increase with 10% in the Netherlands and 5% in Switzerland and decrease in the other countries (5% to 50%). Realisation of the technically feasible energy saving potential would lead to energy consumption of 40% to 50% of the baseyear energy consumption.

Concerning the REDUCE model, the following remarks can be made:

- The energy saving potential as calculated by REDUCE is sensitive for explicit specification of energy saving options since the market share in the baseyear is an important factor for determining the market share in years after. Also, explicit specification of submarkets with different techno-economic characteristics (for instance operation hours) is important to reach realistic results.
- At the present stage of development of REDUCE, the Reference case does not reflect an autonomous development without present or additional policy measures, partly because present conservation policies are implicitly included in the model specification. More importantly, barriers for energy conservation options are specified for the sector as a whole, not taking into account technology specific barriers or competitive advantages other than the market stage and profitability.
- The long term results are not heavily influenced by differences in the general value of the penetration speed factor α due to slow replacement (long lifetime) and heavy competition of technologies. Technology specific differences in α are important.
- Conservation options concerning fuel switch from electricity to a primary fuel are underestimated with respect to their saving potential since the conversion losses for electricity are not explicitly taken into account.

6.1.2 Policy cases

The previous section described for each country the baseline developments of energy demand for different energy services in households and the impacts of energy savings in the Reference case. Barriers for energy conservation options are specified for the sector as a whole, not taking into account technology specific barriers or competitive advantages other than the market stage or profitability. Therefore the Reference case provides a 'what-if'-scenario approach that indicates which options attain profitable energy savings given the competition and interaction of options and the energy carrier price developments and moreover, the general barriers existing in the sector households with respect to investment in energy conservation options as reflected by the market stages of technologies. The Reference case is not a 'doing nothing' case.

Nevertheless, the Reference case can provide a basis for the investigation of the role of additional policy measures, since the effect of certain types of measures can be calculated under the assumption that technology specific barriers or advantages are not affected by the policy measure to a different extent.

Exhibit 6.7 shows for all countries the energy saving potentials in households expressed as a percentage of the Actual baseline energy consumption in the year 2020 for the Policy cases in combination with the Reference and Technical case which were already discussed in the previous section. Exhibit 6.8 shows for the same cases and countries the impact of the energy savings on the energy demand which is expressed as an index of the baseyear energy consumption. The results in both exhibits will be discussed by case in the next paragraphs.

Subsidy case

In this case, a grant or subsidy of 30% of the investment costs (additional to the Reference technology) is given during a 10 year period to a selection of five energy conservation technologies which are most promising. This means that the technology should be the most efficient in its market, its IRR should be not too low and nevertheless the market share of the option remains low.

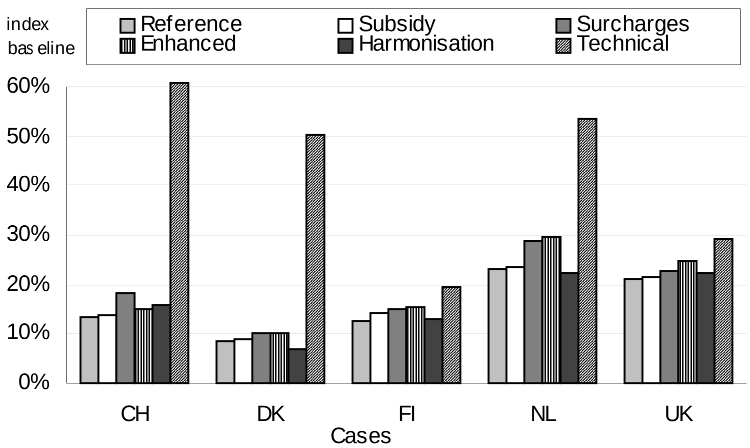

Exhibit 6.7 *Energy savings in households in different cases expressed as a percentage of Actual energy consumption in the year 2020 for relevant countries*

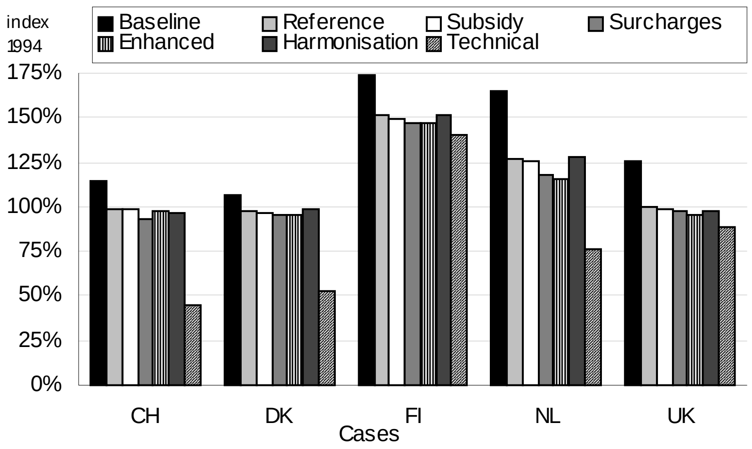

Exhibit 6.8 *Projected energy consumption in households in different cases expressed as index of the Actual energy consumption in the baseyear 1994 for relevant countries*

The result of the subsidy case, like any other policy case, should be viewed in comparison with the Reference case in order to assess what additional savings can be induced by a particular policy. It is clear from Exhibit 6.7 that the subsidy given to five promising energy conservation options does not lead to substantial increases of the realised energy saving potential, viewed from a sector perspective. There are several reasons for this. The main reason is that the energy saving options which are subsidised only cover a part of the total available energy saving potential in the sector. Furthermore, the contribution of the energy service category in which the options are active only cover a limited share of the total energy consumption of the sector households.

But what happens at the level of options? Thirty percent investment grant results in an increase of the profitability of the investment (IRR) from an investors point-of-view. The IRR will increase relatively the most if the IRR is low without grant. The increase in IRR is also dependent on the lifetime of the option. The increase becomes larger if the lifetime is shorter. This makes sense because the investment costs are more important for a short term investment where the benefits cover only a few years.

The highest relative increase in IRR leads to the highest relative increase in market penetration in REDUCE. A doubling of the IRR results in a doubling of the penetration speed of an option. This means that the time to reach a certain market share reduces to approximately 50% (under the assumption that the grant is applied for the complete period).

It is possible that a grant also leads to an indirect competitive advantage of an option, for instance that it receives more attention of the investors than other options which are not subsidised. This implies an option specific relative increase of the penetration speed factor α. This side-effect has not been taken into account since data are not available at this moment.

To illustrate the effect of a 30% investment grant on the penetration of an option, Exhibit 6.9 shows the market penetration of a highly efficient boiler for heating in households with and without grant. The example is taken from the Netherlands subsidy case. The grant is only given for a period, resulting in a temporarily increased penetration speed. However, even after the grant period, the subsidised boiler increases its advantage in market share because it is already in a more favourable market stage (the more steep part of the S-curve). Hence, it seems sensible to use grants for a market introduction of new technologies to overcome the first hard barriers for market introduction. This is confirmed in the next paragraph where the financial part of the subsidy instrument will be discussed.

When an arrangement for subsidy of a certain technology exists, the question is who is going to collect the grant. Exhibit 6.9 gives two examples in the form of two baselines. In case of a permanent option (wall insulation) only the new investors will apply for a grant, so the market share increase over the subsidy period will be implemented completely with subsidy. In fact the baseline is horizontal in this case. In the example, it means that a group of 'free riders' exists that also would have invested in the option if the grant had not been available but nevertheless collects the grant. This group is equal to the increase of market share over the subsidy period in the case without a subsidy. In the example this is a limited group due to the relatively low profitability and thus market penetration speed of the option.

This group is not so small if the option is a boiler with a lifetime of 15 years. The annual replacement is considerable: the graph shows that over the subsidy period of 10 years two third of the boilers in operation in 1995 is replaced (baseline replacement). These investors are considered to invest also without a grant again in a highly efficient boiler. This is an additional, very large group of free riders.
Furthermore, the total sum of subsidies can reach substantial values. The total capital required in the example for subsidising efficient boilers amounts to 50 to 200 million ECU over the period depending on the share of free riders.

What does this mean in terms of economic efficiency? If we compare the sum of subsidies over the subsidy period and the annual revenues in terms of avoided fuel costs after the period, the break-even point is reached after about 3 years in case of a permanent option with a low share of free riders. In case of the boiler, with much more free riders collecting the grant, the break-even point is reached after 10 years, so the year 2015, which is a questionable performance. Of course, in both cases the higher efficiency and additional avoided fuel costs are expected to last after the break-even point until the market saturation. That is, if the option is profitable without subsidy, thus has net benefits. This could be considered from a government perspective as a multiplier effect on the investment. This illustrates again that subsidies should be applied in the early stages of market penetration of new technology. It also illustrates that the designer of a subsidy policy should have reliable information in these early stages to assess which option is (going to be) profitable and will be accepted in the market.

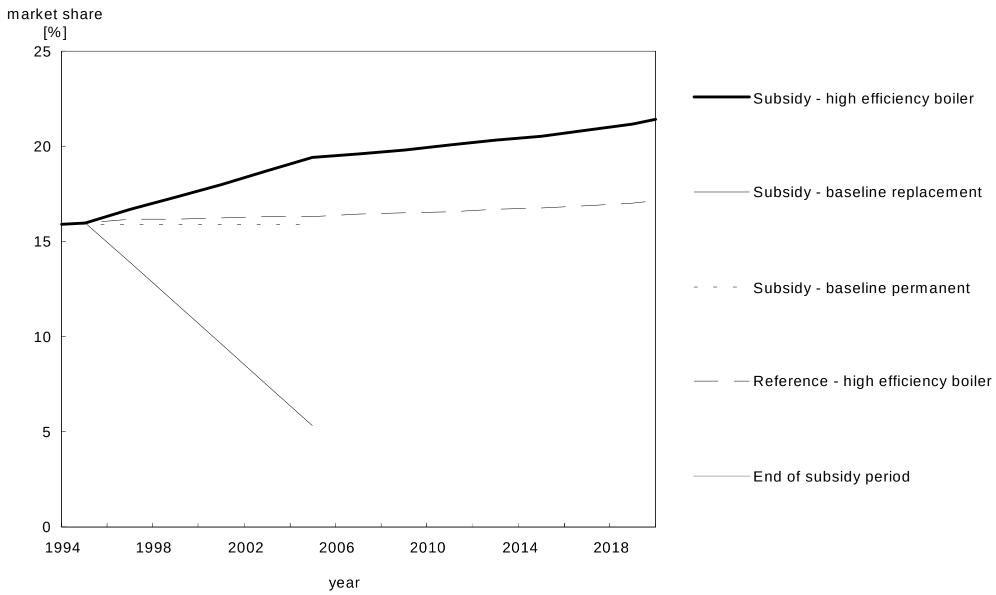

Exhibit 6.9 *Effect of subsidy on the market share of high efficiency boilers, and the market groups which potentially collect the grant*

It is concluded that subsidies on energy conservation technology can be an effective instrument for stimulating energy efficiency if:

- the option has net benefits without subsidy,
- the option has a low market share and needs to overcome the barriers of market introduction,
- the lifetime is not too short (about 10 years).

The last two conditions are necessary to reduce the share of free riders collecting the subsidy and to increase the market multiplier effect of the government subsidy. However, subsidy requires large government funds which indicate that this policy instrument should be applied scarcely for specific technologies only.

Surcharges case

For households, prices of fossil fuels are influenced substantially (compared to the Reference case about 50% higher for gas and up to 100% higher for light oil) by the environmental surcharges. Secondary energy carriers remain relatively unaffected by surcharges. This means that the fuel mix used in the countries is important for understanding responses to surcharges in household energy consumption. The relative price levels of different energy carriers have not changed much.

If we look at the weighted price increases due to the surcharges, the highest price increases (about 45%) are viewed in the Netherlands and Switzerland. United Kingdom and Finland follow with 35% increase and Denmark has the lowest price increase of 25% compared with the reference price scenario. This is partly due to the fuel mix: Netherlands and Switzerland have a low electricity share and a high gas or oil share, Denmark and Finland have a high share of district heat. Partly, the present price level plays a role, for example for Denmark which already has high taxes and thus prices, which leads to relatively smaller price increases due to surcharges.

Obviously, as a result of higher energy prices, the energy savings in households in the surcharge cases are for all countries higher than in the Reference cases. The highest energy savings additional to the Reference case are reached by the Netherlands and Switzerland (8% and 7% of the Reference energy consumption). Only limited reductions of 2% to 3% of the Reference energy consumption are reached in Finland (2.8%), United Kingdom (2.2%) and Denmark (1.8%). The order of countries is completely in line with the price increases induced by the surcharges in the countries.

Nevertheless, the energy savings are relatively limited compared to the high price increases due to the surcharges. Apparently the price sensitivity is limited in households or, in other words, the price elasticity is low which is realistic. However, the elasticities of the energy demands in the different countries as viewed in response to the surcharges are in some of the models lower than expected. For the Netherlands households, which is known as being relatively insensitive for energy price rises, the ratio of energy demand decrease and energy price increase is low and comparable with energy price elasticities. However, all other countries are known for larger price sensitivities but show in contrast with this lower elasticities than the Dutch case. This is even more striking if one recalls that the Dutch assumptions include a relatively low penetration speed α compared with the other models to reflect for this lower price sensitivity.

The explanation for a low elasticity must be sought in a relative inflexibility of the country models as they have been specified in the present project. First, the number of conservation options is sometimes relatively limited. This can be in the ‘broad’ sense when conservation options are not specified for all services and a large category ‘unknown’ exists, or in the sense of ‘depth’ when only very conventional options have been specified which save not more than a few percent of the Reference energy consumption. This is the case for Finland and the United Kingdom, as shown by their limited energy conservation Technical energy saving potential. Second, energy savings can be implicitly modelled by energy intensity decreases of energy services, for instance due to a lack of data. This is the case for Switzerland and Denmark.

Enhanced case
The case with enhanced sensitivity consists of running the household cases for all countries with an equal penetration speed factor α similar to that of the manufacturing sector. This case is developed for two reasons. First, the results give an impression of the sensitivity of the model for increases of α and indicates the sensitivity of options in REDUCE for policy measures influencing the investment behaviour through measures such as information campaigns, energy conservation awareness campaigns etc. Second, it forms a basis for comparison of national results since all countries use the same α.

The enhanced case shows energy savings additional to the Reference case for all countries, which is logical because the penetration speed α is for all countries higher than in the Reference case. However, the increases in penetration speed α are not equal for all countries and therefore different results are expected in comparison with the Reference case. In chapter 4.1.3 the country values of α are explained. For the Netherlands, the penetration speed α is 2.5 times higher than in the Reference case, which is the highest relative increase. Therefore, the highest decrease of energy consumption (9% of the Reference energy consumption) can be viewed in the Dutch case. The lowest increase of a factor 1.5 is applied for Denmark, Finland and Switzerland. For these countries, a small decrease of energy consumption can be seen (2 to 3% of the Reference energy consumption). The result for the United Kingdom (4% reduction of Reference energy consumption) is in between the two groups as expected from the factor of 2 which has been applied on the Reference penetration speed factor α. So, the results seem consistent but the energy savings additional to the Reference case are in general limited.

Main reason for this is that the barriers for energy conservation options are specified for the sector as a whole, not taking into account technology specific barriers or competitive advantages other than the market stage and profitability. For instance an option such as double glazing is popular and covers a large market share not only because it is profitable but also because it provides a higher comfort and better noise protection than conventional single glazing. This means that in fact the market penetration speed factor α should be higher for double glazing than for single glazing. However, on this subject quantitative data by technology are not available. Technology specific increases of α, simulating for instance labelling or technology commercials, are expected to have a (relatively) larger impact.

Harmonisation case
In the harmonisation case, the end-user prices are modified in such a way that all countries have a similar tax regime (VAT and excise tax). This might represent a first step towards more liberalised EU energy markets. It means that some countries such as Denmark which have relatively high taxes on energy, will have to lower their taxes and thus end-user prices. For instance Danish electricity prices for households will decline almost 50%. Except for the Netherlands and Denmark, other countries will have to rise their taxes and end-user prices of most energy carriers. For instance in the United Kingdom, the electricity and natural gas prices will rise with 15% and light oil prices with 40%, in Switzerland the natural gas prices with 15% and the light oil prices with almost 60%.

In line with these end-user price rises or falls we see in Exhibit 6.7 and Exhibit 6.8 limited increases and decreases of the energy saving potentials compared with the Reference case. The energy consumption in Denmark, the Netherlands and Finland is a little higher than in the Reference case, the energy consumption in Switzerland and the United Kingdom is a little lower. As already was assessed, the energy consumption in households is relatively insensitive for price changes and the effect of harmonised taxes in the EU in households is therefore also limited.

Case Combination
A sensitivity analysis for the Dutch case has been executed in order to test the flexibility of the REDUCE model and to assess the interaction of policy instruments for stimulation of energy

conservation. Therefore, a combined case, including both the surcharges and the enhanced penetration speed factor α, has been executed. The resulting energy saving of 35% of the baseline is surprisingly high. This is equal to 16% reduction of the Reference energy consumption, and is almost the sum of the energy savings in the separate cases with respect to the Reference case. This finding is interesting: the REDUCE model shows that the large Technical energy saving potential as it is known today can be expected to be implemented for a substantial part if a combination of types of stimulating policy instruments is used. Vice versa, the implementation of energy savings is limited when induced by only a single type of instrument.

6.1.3 Market example: individual central heating

To give a more clear insight in the model behaviour, it is necessary to present some results at saving technology level. Because it is not feasible to present results for all specific options (100 to 200 options per country model), an example will be given of the market for individual central heating in the Netherlands, which covers more than 50% of the energy demand for households. Exhibit 6.10 presents the market shares of all options active in the market for individual central heating in the Reference case. It concerns several market groups of technologies. The supply and demand groups influence each others effectiveness. For instance, the energy saving and profitability of a highly efficient boiler is lower in a situation where insulation has reduced the heat demand than in a situation without insulation and vice versa. Within technology groups, such as wall insulation, glass in the living room, glass in other rooms and heaters, options compete directly with each other and have to share the market.

The bold lines in Exhibit 6.10 present the market shares of the options in the group heaters. The upper bold line presents the decreasing market share of the reference boiler. This share is decreasing due to the increasing market shares of the other options, viz. the improved boiler (10% energy saving) and to a lesser extend the highly efficient boiler (17% energy saving). Both options are slightly profitable but hardly better than the reference boiler. Therefore, market penetration of these new options is far from spectacular. The improved boiler makes the most progress due to a little higher Internal Rate of return and a higher market share in the baseyear.

In the market group for wall insulation, highly profitable cavity wall, which can save 25% of the energy demand for heating, increases its in 1994 already high market share up to the point of market saturation. A small share of exterior insulated houses (can save 35% of energy demand) can not be reached by this option since it concerns permanent options. An increase of the conservation level of wall insulation up to 35% is not possible with the present housing stock.

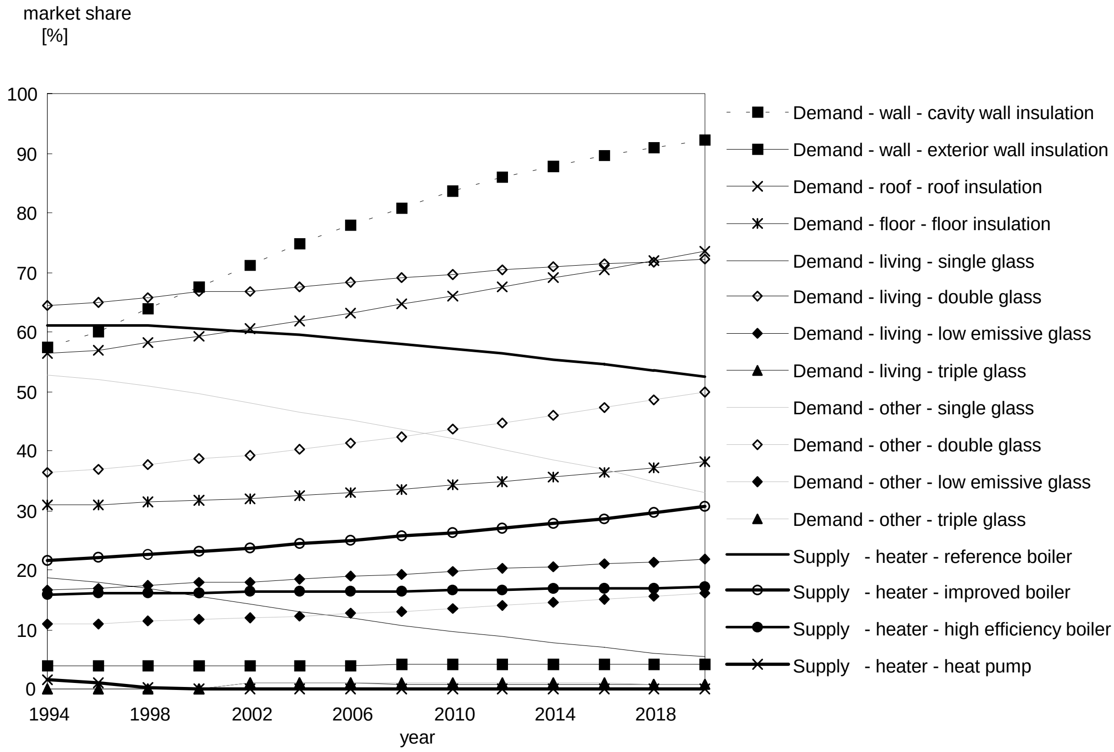

Exhibit 6.10 *Penetration of options in time in the market Individual Central Heating in the Netherlands' Reference case*

The two thin lines without a marker show the development downwards of the market shares of single glass, the lower (solid) line for living rooms and the upper (dashed) line for other rooms. Due to market saturation, the market share of single glass for living rooms is decreasing not as fast as that for other rooms, although it is 'threatened' by more competitive options (the IRR of the same conservation option is higher in better heated living rooms than in other rooms). The options which push single glass out of the market are double glass (7%-11% saving of heat demand) and to a lesser extent low emissive glass (10%-15% energy saving). Although double glass is slightly less profitable than low emissive glass, double glass has a competitive advantage by its present large market share. Therefore, double glass catches in 2020 the largest parts of the market for living rooms (75%) and other rooms (50%). This is again an illustration of the feature that new technology has to be not as good but significantly better than the present technology. Double glass 'withholds' low emissive and triple glass from conquering the market and the policy maker from getting the technical potential being implemented.

Roof and floor insulation are slightly profitable and have considerable market shares which increase with time. Roof insulation, which can save a very substantial 15% of the heat demand, is projected to be implemented in three quarter of the houses with individual central heating in 2020.

As was described in the previous section, the energy savings in the Surcharges case additional to the Reference case are limited. Therefore it is useful to examine at option level the model response to surcharges and to compare it with the Technical case. Exhibit 6.11 gives for each option an overview of the main characteristics (energy saving and IRR) and the market share and energy saving in the Reference, Surcharges and Technical case.

The table illustrates three messages. First, it can be seen that for a few important conservation options (large energy saving characteristic of cavity wall insulation, roof insulation and double glass in living rooms) the stage of market saturation is reached in 2020. That leaves little scope for additional surcharges induced energy savings by these options.

Second, surcharges give an incentive to all options in the market for individual central heating, which means that all options improve their profitability. So, in the Surcharges case the relative profitability stays similar as in the Reference case. The whole set of options penetrates somewhat faster into the market, but reaches then the point of market saturation. Then, differences in profitability between options have to induce relative competitive advantages to obtain further energy saving. It is often the case, like for example with the electric heatpump, that the profitability of the highly advanced and efficient option is lower than that of a more conventional efficient technology, such as the improved boiler, resulting in a relatively small market share for the advanced technology which embodies the high (technical) energy saving potential.

Third, the many options on the demand side of heating have reduced and will reduce the heating demand substantially which gradually decreases the effectiveness of energy savings and thus the profitability of investments in heaters even more. In the theoretical situation without this suppression, the IRRs of boilers are much higher (given between brackets) and even the heat pump starts to become profitable. This decreasing effectiveness of energy conservation options when more severe energy savings are reached result in higher marginal costs which makes it increasingly difficult to save energy.

These three issues, viz. market saturation of conventional options and the difficult market introduction of new advanced options, the need for option specific instead of general incentives and suppression of the effectiveness of (investments in) energy savings when more severe conservation targets have to be reached, explain why energy savings induced by price changes are not so large as expected. The market developments of conservation options are quite robust and are difficult to change into a direction of stronger energy conservation. This indicates that, besides financial instruments, regulatory instruments (voluntary or not) have to play a role as well in order to attain further efficiency improvements. In fact, present market shares of many options in the market for individual central heating have been reached as a result of a combination of subsidies and regulation (building codes and environmental and efficiency standards).

Group	Options	Saving [%]	IRR [%] Ref 2020	IRR [%] Sur 2020	Market share [%] 1994	Market share [%] Ref 2020	Market share [%] Sur 2020	Market share [%] Tech 2020	Saving [% Product baseline] Ref 2020	Saving [% Product baseline] Sur 2020	Saving [% Product baseline] Tech 2020
Demand	*effectiveness*								*0,94*	*0,93*	*0,84*
wall	cavity wall insulation	25	31	50	60	92	95	96	14%	14%	12%
	exterior wall insulation	35	3	7	4	4	4	4	0%	0%	0%
roof	roof insulation	15	9	16	57	74	83	100	4%	6%	9%
floor	floor insulation	7	5	9	31	38	48	100	1%	2%	7%
living	single glass	0	0	0	18	5	2	0	0%	0%	0%
	double glass	11	16	27	65	72	74	0	1%	1%	-12%
	low emissive glass	15	18	29	17	22	24	0	1%	2%	-4%
	triple glass	17	9	17	0	1	1	100	0%	0%	26%
other	single glass	0	0	0	52	33	19	0	0%	0%	0%
	double glass	7	10	18	37	50	60	0	2%	3%	-4%
	low emissive glass	10	11	20	11	16	20	0	1%	1%	-2%
	triple glass	11	5	11	0	1	1	100	0%	0%	17%
	Total demand								**24%**	**30%**	**48%**
Supply	*effectiveness*								*0,45*	*0,40*	*0,24*
heaters	reference boiler	0	0	0	61	52 (26)	37 (9)	0	0%	0%	0%
	improved boiler	10	7 (22)	14 (37)	22	31 (50)	42 (66)	0	1%	3%	-4%
	high efficiency boiler	17	4 (16)	9 (28)	16	17 (23)	21 (25)	100	0%	1%	22%
	heat pump	75	-99 (-6)	-99 (23)	1	0	0	0	-1%	-1%	-1%
	Total supply								**0%**	**3%**	**17%**
Total	*effectiveness*								*0,95*	*0,94*	*0,87*
	Total saving								**24%**	**33%**	**65%**

Exhibit 6.11 *Overview of characteristics (energy demand saving and IRR), market shares and savings for each option in the market Individual Central Heating for the Netherlands Reference case, Surcharge case and Technical case*

6.2 Manufacturing

6.2.1 Reference case

Three countries have specified their Manufacturing sector in REDUCE, namely Spain (ES), Sweden (SW), and the Netherlands (NL). These countries have a relatively large and energy-intensive industry. In this section, we will start with comparing the results in the Reference case first to the baseline development, and secondly to the maximally achievable technical potential. After that, the Policy cases will be compared to the Reference case in Section 5.2.2.

The Reference case serves as a basis for comparing specific policy cases, because it shows the energy saving potential which can be reached by increases of market shares of energy conservation options that are profitable at the projected energy end-user prices. As explained in Section 5.1.1, this saving potential should not be regarded as a ‘no policy’ autonomous development.

In the baseline development, no additional energy savings are assumed after the baseyear, so the state of the technology is considered ‘frozen’ at the level of 1994. The volume growth and changes in the structure of the sector are however taken into account. In other words, the different subsectors and products can grow at different rates. These baseline developments result from the scenario analysis and should be consistent with the energy price projections. All countries have chosen a rather optimistic scenario, which obviously has great impact on the model outcomes.

Finally, the Technical case intends to show the energy saving potential consisting of the maximum of savings achievable by all available, technically feasible, energy conservation options, regardless of present market shares or profitability.

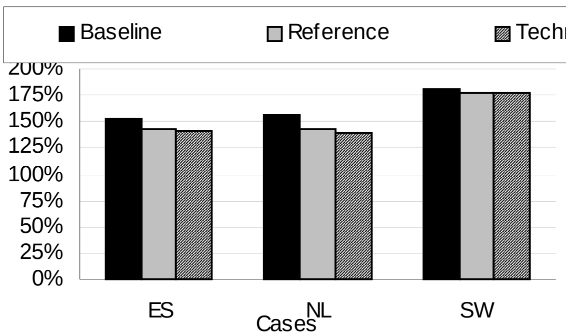

Exhibit 6.12 *Projected energy consumption in the manufacturing sector for the year 2020 according to the Actual baseline (Baseline), the Reference case (Reference) and the Technical case (Technical), for relevant countries expressed as index of 1994 energy consumption*

Exhibit 6.12 compares the Reference case to the baseline development and the Technical case. The baseline ‘frozen technology’ values for the year 2020 as an index of the baseyear energy consumption are represented by the black bars. These bars depict the differences in energy demand growth projections between the countries. Sweden assumes the highest growth of energy consumption (2.4% annually), due to the expectation of a relatively high growth of energy intensive subsectors such as the basic metal and the chemical industry. The growth may also be due to growth of specific products within these subsectors. The growth figures in the Netherlands, presume that energy demand grows proportionally with the physical growth rate (resulting in an average of 1.9% annually) which is lower than the economic growth rate and thus includes some dematerialisation. Spain projects a moderate physical growth (1.7% annually).

The grey bars show the energy consumption for the Reference case. In the manufacturing sector, the difference between energy consumption in the Reference case and in the Technical case is not as large as in the Household models. This could mean that investors in the manufacturing sector are more rational than household members, so that a large part of the technical potential is actually utilised. In REDUCE, this rationality is reflected in a higher value of the penetration speed α for the manufacturing sector. All three countries have assumed the same penetration speed. For Spain the remark should be made that the technical potential case has been simulated by raising the prices of the different energy carriers. Since the barriers for energy conservation were not taken away, the results of this case as presented here will not reflect the complete technical potential. In addition, no measures are considered which may be introduced on the market after 1998, thus limiting the technical potential.

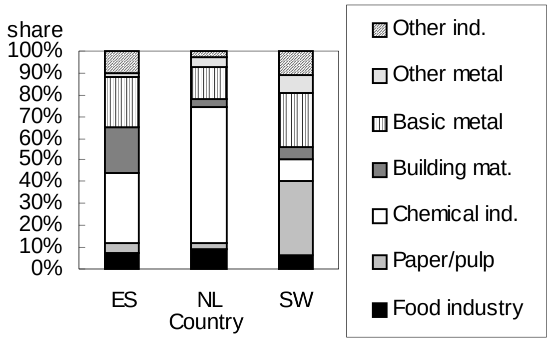

Exhibit 6.13 *Relative shares of divisions contributing to energy consumption of the manufacturing sector in the baseyear 1994 for relevant countries*

Sweden has taken a different approach in specifying the technological options, due to limited availability of data. For each energy service, one aggregate option is described, implying that there is no competition between different technologies. A major drawback of this philosophy is that almost all options have a market share of 100% in 2020, due to the absence of competition, and that therefore the Technical potential is just slightly larger than the energy savings achieved in the Reference case. In addition, any technologies to be introduced after the baseyear are not taken into account.

Analysis at the subsector level ('division' in REDUCE) shows that in some subsectors the technically feasible savings are considerably larger than the savings reached in the Reference case. This will be described in more detail later, see also Exhibit 6.17.

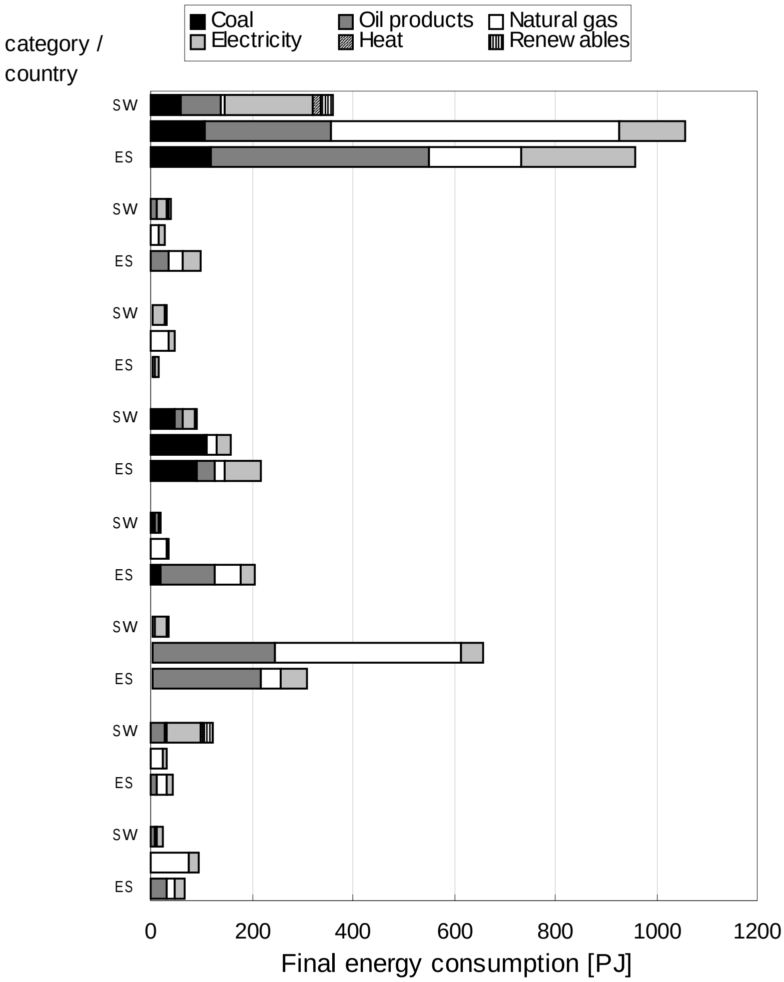

Exhibit 6.14 *Final energy consumption on site by division and fuel in the baseyear, for relevant countries*

In Exhibit 6.13 the distribution of the energy consumption over the various divisions is shown. This shows the relative importance of an industrial sector for the energy consumption in the manufacturing sector per country. In Spain, the share of the most energy-intensive industries, basic metal and chemical industry in the energy consumption is 55%, and the production of building materials is more important than in the other countries. In the Netherlands, the chemical industry alone accounted for 62% of the total industrial energy consumption in 1994, which includes non-energetic use of energy carriers, mainly oil products. The basic metal also takes a considerable share of the energy consumption. In Sweden the most energy intensive sectors are the paper and pulp industry and the basic metal (steel production).
Exhibit 6.14 illustrates the energy consumption by fuel for the three different countries. The share of electricity in the fuel mix is around 50% in Sweden, due to the supply of cheap nuclear power in this country. On the other hand, natural gas is hardly used in Sweden, while it is a very important energy carrier in the Netherlands, where it has a share of 50% in the sectoral energy consumption. Natural gas in the Netherlands also includes heat, which is almost entirely generated on the basis of natural gas. The Netherlands has the highest share of fossil fuel consumption. Spain has the highest consumption of oil products (50%), with also a 20% share of natural gas in the fuel mix. Hard coal is mainly used in the basic metal industry in the different countries. Exhibit 6.14 also illustrates the differences between subsectors in share in the final energy consumption in the manufacturing sector in a country.

Although the total energy consumption in the manufacturing sector is by far the lowest in Sweden, the energy intensity of the Swedish manufacturing sector is almost as large as that of the Dutch industry, see Exhibit 6.15. Spain has a lower final energy intensity.

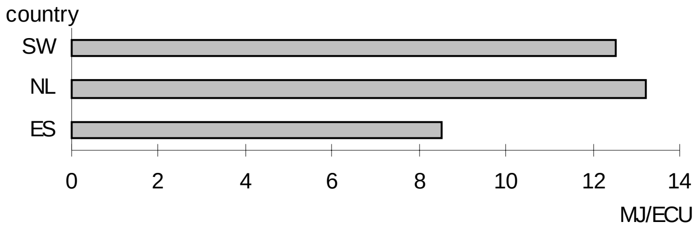

Exhibit 6.15 *Final energy intensity for the sector manufacturing (including construction) in the baseyear 1994 for relevant countries*

The current energy intensity is also influenced by the conservation technologies already implemented, which differ from country to country. This will be discussed along with the projected energy savings in Exhibit 6.17.

To some extent, the structure of energy consumption in the manufacturing sector visible in Exhibit 6.13 is reflected in the relative energy savings per division.Exhibit 6.16 shows the shares of savings of divisions in the total energy saving reached in the Reference case in the year 2020. However, some differences are worth noticing. In Spain, the contribution of the savings in the Building Materials division is remarkably large, indicating a considerable saving potential. On the other hand, the saving potential in the Chemical Industry is only 10%, which might imply that a lot of energy conservation measures have already been taken in the past. For the Netherlands the largest share of savings are reached in the Chemical industry, which is also the largest energy consuming division. However, compared to the size of the sector, the savings achieved are relatively small, see Exhibit 6.17. In Sweden, it is remarkable that hardly any savings are achieved in the Basic Metal industry, which takes 25% of the manufacturing energy consumption. Unfortunately, this is mainly caused by a lack of options specified. A more detailed analysis of the specification of relative growth and saving potentials in the divisions will shed more light on the causes of the differences.

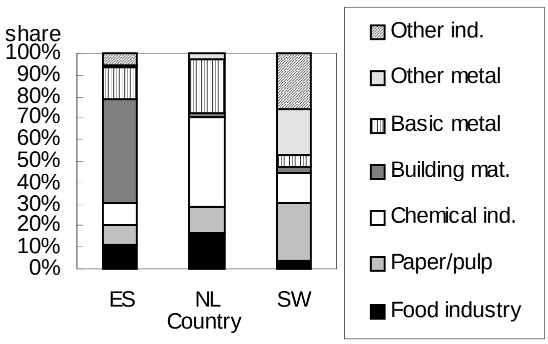

Exhibit 6.16 *Relative energy savings by division in the Reference case for the year 2020 for relevant countries*

The two graphs in Exhibit 6.17 present an overview of the energy scenario information and present and future energy saving potentials by division. In the left graph, the scenario assumptions on volume growth are presented for each division in the three countries. Energy intensity changes have not been specified for manufacturing sectors, because this requires detailed data on 'product' level, which was not available in the considered countries. As a result, the products manufactured in the subsectors are assumed not to change over the years.

The growth values are expressed as percentages of the base year energy consumption for each division.

The graph on the right-hand side of Exhibit 6.17 gives three different types of energy saving potential for all divisions in each country. The white bars, indicated by ‘1994’, present the saving potential already realised in the base year. It concerns options such as pinch optimisation of heat flows in industrial processes, waste heat recovery and thermal insulation measures, which already have a substantial market share in the base year. This saving potential is partly arbitrary since it depends on the definition of the reference energy demand technology. However, it is essential to define a reference as a homogenous set of technologies with realistic market shares, because this market share is an important driving factor.

Sometimes, a slightly different approach has been taken, due to limited availability of data. Both reference and options have been defined as a weighted average of a mix of technologies and options. Sweden has specified all options this way, and in The Netherlands this approach has been chosen a few times for sub-sectors with many small companies where for instance thermal insulation measures have been combined into one option.

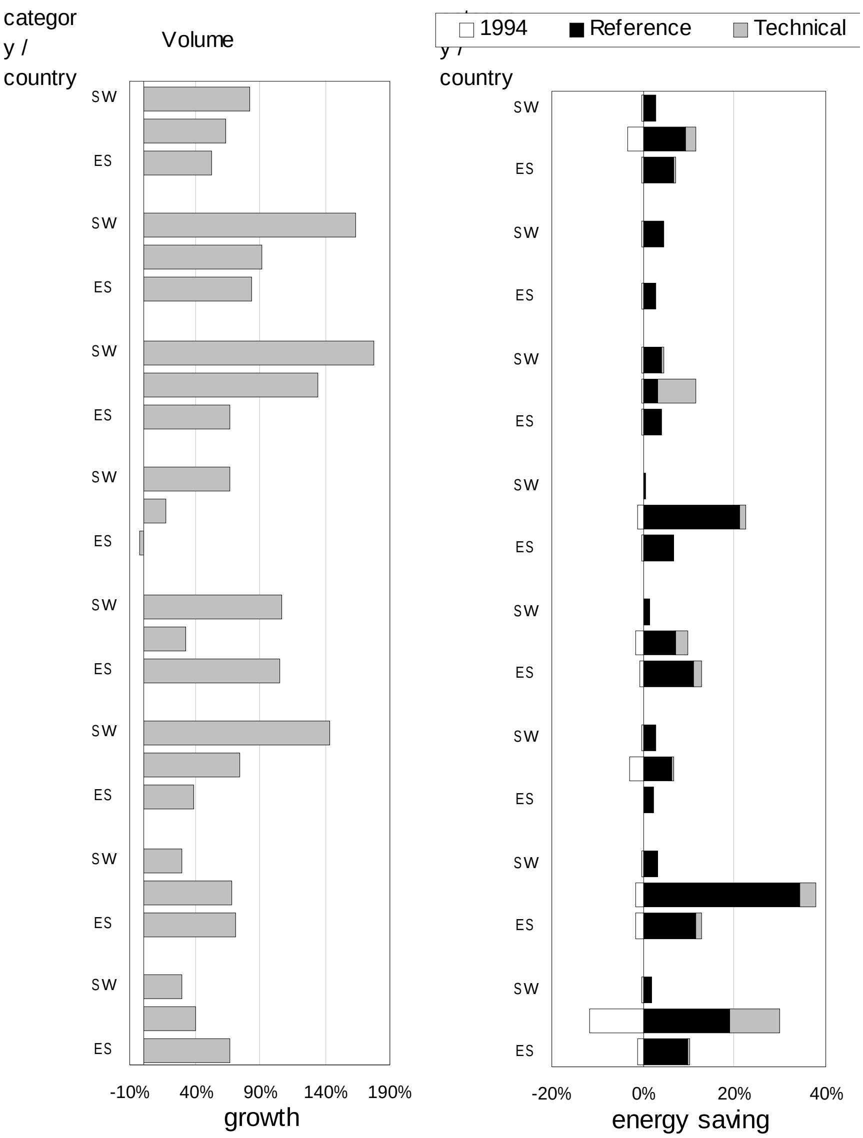

Exhibit 6.17 *Left graph: For each division in the manufacturing sector for the year 2020, the projected volume growth of energy demand baseline expressed as a percentage of the energy consumption of the baseyear 1994. Right graph: Energy savings in the baseyear 1994 and in 2020 in the Reference case and the Technical case, expressed as a percentage of the Actual baseline energy consumption for the year 2020, all for relevant countries*

Another drawback in the cases of Sweden and Spain is that endogenous competition between technologies is not possible. However, the interaction between supply and demand options still plays a role. All options have been specified in separate groups, and do not have to compete in the market with similar technologies. This way, almost all options penetrate the entire market, unless their IRR is negative. Consequently, the energy saving potential in the Reference case is almost equal to the technical potential. Information on the market success of specific technologies is not obtained. These remarks should be kept in mind when analysing the model results.

The saving potential realised in the Reference case expressed as index of the Actual baseline energy consumption for the year 2020 is presented by the black bars in Exhibit 6.17. It concerns currently applied saving options which have increased their market share and new technologies which have penetrated the market. The grey bars indicate the energy saving potential which is technically feasible and available additional to the Reference case but was not realised due to various barriers in the area of profitability, behaviour, supply problems or market saturation.

Food industry

For the Food industry, Spain projects the largest energy demand growth of 67%, the Netherlands assumes 40% growth, and the most moderate growth rate is 30% in Sweden. In the Netherlands the growth is a weighted average of the physical growth projections for different 'products'. The production in dairy and sugar industries is expected to shrink, while some growth is expected in the starch, oils and beer industries. Other subsectors, such as meat and fodder are not expected to grow. In all countries, the baseline energy consumption is assumed to grow at the same rate as the physical production. The food industry contains a large number of subsectors. The total energy consumption is less than 10% of the industrial energy consumption in all considered countries. Exhibit 6.18 gives the structure of the subsector as shares in the sectoral energy consumption for Spain and the Netherlands. For Sweden these figures have not been specified.

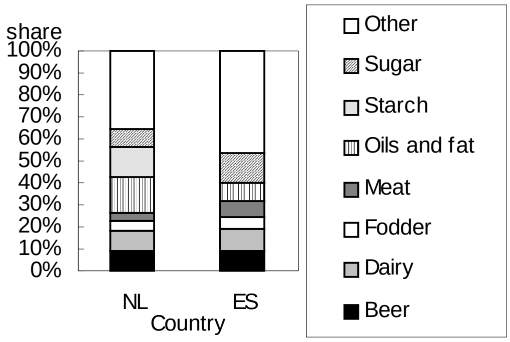

Exhibit 6.18 *Shares of subsectors in the energy consumption in the Food industry for Spain and the Netherlands*

Within the Spanish food industry, the following options are considered. Sugar industry (14% of sectoral energy consumption): replacement of traditional pulp dryers for new steam dryers with liquidised beds; substitution of the traditional evaporation cases for descending flow cases. For the canned vegetables industry: the introduction of regenerating sterilisers in concentric tubular interchanges, continual scalders with energy optimisation, and the substitution of vertical autoclaves for horizontal autoclaves. With regard to oil and fat manufacturing: installation of adapting and predictive control systems, and application of reversed osmosis. For cattle slaughtering and meat preservation: installation of heat recoverers, and thermal insulation measures. In starch and amylase manufacturing: heat recovery in evaporation installations. With regard to beer brewing: installation of a de-airing plant. In the Spanish food sector, no technological savings options have been considered for a group of subsectors which accounts for approximately 43% of 1994 energy consumption in the division. The most important ones not specified are dairy products, fodder, bread and bakery industry. This explains the relatively low saving potential of 10%.

In the Netherlands, technological saving options are specified for the most energy intensive processes, and general options for saving heat or electricity in all products and processes. In the dairy industry (17% of sectoral energy consumption), options are included for evaporation processes: multi-stage evaporation, vapour recompression, reversed osmosis, and for drying processes: frost drying, multi-stage drying, pinch optimisation, as well as options saving energy in cleaning, heat and electricity consumption. In meat preservation, general options are specified for saving heat and electricity. In the sugar industry, options such as heat recovery, multi-stage evaporation, vapour recompression, reversed osmosis are considered. Technologies for starch drying are for instance fluidised bed drying and improved pressing. With regard to oil and fat manufacturing, lower temperatures are used and new extraction techniques are introduced. Options in the fodder industry include process improvement, heatpumps, improvement of grinding techniques, and improved drying processes. Finally, in the production of beer, improvements can be found in heat recovery, using less steam and an efficient malting process. For the subsectors not explicitly mentioned, aggregate options for saving heat and electricity have been specified. Exhibit 6.17 shows that this extensive set of options results in a considerable saving potential of 30%, not all of which is utilised in the Reference case.

As mentioned before, Sweden has taken a different approach. Instead of explicitly distinguishing technologies in subsectors, the energy saving options for a number of energy services have been included for each division. It concerns the products and options presented in Exhibit 6.19. As a result of the Swedish debate regarding the phasing out of nuclear power plants, attention has only been paid to options that save electricity. All options except the last one are demand options.

Exhibit 6.19 *General structure of option specification in the Swedish case*

Product	Option
Lighting	High efficiency lighting
Pumps	Variable speed drives
Refrigeration	Miscellaneous
Compressors	Variable speed drives
Fans	Variable speed drives
Electrical heating in buildings	Fuel switch from electricity to oil

Most of these options also have been considered in some subsectors for the Netherlands and Spain, with the exception of saving energy on electrical space heating.

When looking at the saving potentials implemented in the baseyear, only the Netherlands and Spain have specified some options which already have a considerable market share. In Sweden all options in all divisions have a market share of 5% in the baseyear, due to lack of data. Obviously this will be an underestimate in some cases, and an overestimate in others. As the present market share is an important driving force behind market penetration of conservation options in REDUCE, this will considerably influence the saving potentials calculated for Sweden. The other main factor limiting the saving potential both in Sweden and in Spain is the incomplete specification of options, resulting in a substantial part of the energy consumption being unaffected by any option.

In Exhibit 6.20 the resulting energy demand in 2020 is presented as an index of 1994. In the Netherlands stabilisation of the consumption can be reached if the complete technical potential is implemented. In Spain, where the saving potential is underestimated due to the factors described above, the currently specified saving options can reduce the growth in consumption to 50% compared to 1994, instead of the projected 67%. The saving potential in Sweden is very small and underestimated as a result of the aggregated approach taken. The savings achieved are mainly due to efficiency improvements in cooling and to the introduction of variable speed drives in fans.

Paper and pulp industry
Spain and the Netherlands project a similar (physical) growth in the paper and pulp industry of approximately 70%. In these countries, this division consists for over 80% of paper producing industries, and contributes for 3-5% to the energy consumption of the manufacturing sector. Sweden, where this subsector is an important exporting branch contributing for 34% to the sectoral energy consumption, expects a more moderate growth of 30% due to an expectation of weak world market development.

In Spain, the following options are considered for the subsector ‘paper pulp, paper and cardboard’: transformation of lime furnaces from wet to dry processes; installation of high performance hoods; installation of discontinuous cooking processes using the ‘RDH system’; improvement of lime furnace efficiency through washing and drying lime sludge; heat recovery in fibre cellulose manufacture; installation of closed hoods in paper machines with an energy recovery circuit; and in coating machines heated with natural gas infrared lamps; heat recovery in wood cooking plants; heat recovery in paper machines. Finally, 6% of the divisional energy consumption is not affected by the options summarised above.

Within the Dutch paper and pulp industry, the following options are considered. Papermills: some innovative pressing and drying techniques such as extended nip press and impulse drying, and variable speed drives of pumps and fans to save electricity in stock preparation. In the paper converting industries, some thermal insulation options have been included for saving energy in space heating. For process heating, options such as good housekeeping and more efficient steam generation have been specified.

For Sweden the options in the pulp and paper industry are similar to the ones presented in Exhibit 6.19 for the food industry, except for refrigeration. One difference is for pumps, the option is an aggregate for exchanging overdimensioned pumps and motors, impeller trimming and installation of variable speed drives.

Both in the Netherlands and in Spain a small potential of 2% is already utilised in the baseyear. The total saving potential in Sweden is small, only 3%, and totally achieved in the Reference case. Since the paper and pulp sector is an important energy consuming industry in Sweden, this limited potential has a relatively large impact on the total saving potential in the Swedish manufacturing sector. In the Netherlands on the other hand, the saving potential is surprisingly large, with a technical maximum of 38%. This is largely due to impulse drying and the introduction of variable speed drives to save electricity in stock preparation. In Spain the saving potential is at most 13%. This potential could be slightly underestimated as a result of not specifying options for the graphical industry (7% of the sectoral energy consumption) and not including technologies that become available after 1998. As a result, illustrated in Exhibit 6.20, stabilisation of the energy consumption is almost within reach in the Netherlands, while in Spain also a considerable reduction of the 70% growth projection is possible. In Sweden obviously the lower growth is not counterbalanced by the potential savings.

Chemical industry
The chemical industry is an energy intensive sector in all considered countries. In the Netherlands it is a major energy consumer with a share of 62% in the industrial energy demand. The growth projections for this sector are quite different for the considered countries. Sweden expects export expansion and projects a growth of almost 150% in 2020. The growth in the Netherlands of 75% is based on the expectation that the Dutch industry succeeds in upgrading their products and strengthening their position in the international trade. The Spanish projection of 40% is most moderate.

In Spain, the following options are considered for the manufacturing of fertilisers: residual heat recovery from outgoing water in reactor sleeves; cooling of condensers through ammonium vaporisation; use of fumes from ammonium nitrate production. With regard to the manufacturing of plastics: incineration of residual currents of butadiene to replace fuel oil, and installation of steam accumulators. For rubber transformers, the only measure considered is the substitution of electrical heating of vulcanisation with thermal oil heating. For plastic transformation: installation of auxiliary tanks to save waiting time, and the installation of frequency changers in extrusion engines. For artificial and synthetic fibre manufacturing, the installation of recovery boilers for steam and hot water generation is considered. The following measures are considered for refineries (although this is not an end-use sector): multivariable dynamic control in crude units; multi-dilution in wax stripping units. Within the 'other industrial chemical products' sector, measures include: use of membrane electrolysis cells in chlorine plants; installation of press filters for drying the pulp in the manufacture of colours and pigments; use of single effect flash vapour evaporator in oil and fat processing for industrial uses; manufacturing of O_2 through N_2 absorption, the use of steam from heat exchangers.

Although an extensive set of options has thus been specified, still 78% of the energy consumption in the Spanish chemical industry is in other subsectors, mainly inorganic chemicals (11%) and petrochemical industry (60%) and therefore not affected by the measures considered. The graph on the right-hand side of Exhibit 6.17 shows that the energy saving potential in this sector is only 2%. Obviously one of the main reasons for this small potential is the fact that the options only affect 22% of the total energy consumption. Another factor is that a part of the energy consumption is non-energetic use of energy carriers.

Options in the Netherlands are specified for a number of subsectors in the chemical industry. For fertiliser production, options include adaptation of the primary reformer furnace, hydrogen recovery from the stack gases of ammonia production, integration of hot and cold streams, and the 'AMV process' for the production of ammonia. In the petrochemical industry, much attention has already been given to energy conservation. Still some overall measures, such as mechanical vapour recompression in distillation and condensing processes and improving process management in plants can make a contribution. In addition, approximately 20 options have been included for saving energy in specific processes in the production of olefines, benzene, methanol, isopropanol and styrene. For the inorganic chemical industry, options include replacement of the mercury process for chlorine production by the membrane process, as well as efficiency improvement within this process, and the introduction of a continuous process for the production of Siliconcarbide instead of a batch process. For the other chemical industries, options include insulation measures for space heating and recovery of process heat. For the production of salt and phosphor, options are still lacking in the model specification. In addition, most of these options only affect the energetic part of the energy demand in the chemical industry. Therefore, 43% of the energy consumption in 1994 is not affected by the technological saving options specified for the chemical industry.

This is one of the reasons for the limited saving potential of maximally 7% in the Dutch chemical industry. Another reason is the observation that many energy conservation measures have already been taken in the past.

For Sweden the options in the chemical industry are similar to the ones presented in Exhibit 6.19. However, 82% of the energy demand in the chemical industry is not affected by these options. Of the savings achieved, more than 80% is due to the introduction of variable speed drives in pumps and compressors. The overall savings reached amount 3% of the energy consumption in 2020.

Building materials industry
In Spain this sector is one of the major energy consumers and has a share of 21% in the total consumption of the manufacturing sector. Over 50% of the energy consumption is due to the cement, lime and gypsum industry. Both Spain and Sweden project a doubling of the energy demand in this sector. The Netherlands is more conservative and projects 34% physical growth. Here the glass industry is larger than in Spain (29% in the Netherlands vs. 12% in Spain), while the cement industry has a share of 22% in the sectoral energy consumption.

Spain has specified the following options in the glass industry: natural gas and oxygen combustion in fusion furnaces; substitution of feeding channels to allow manufacture of lighter packing; heat recovery in glass furnaces; introduction of AZS cruciform regeneration systems for the manufacture of hollow glass. Within ceramic products: dry clay processing, substitution of traditional kilns for tunnel kilns, heat recovery from kilns to dryers and in tunnel dryers, and finally, isostatic pressing in crockery manufacture, the installation of quick cooking kilns and steam boilers in dryers. Finally, in the cement, lime and gypsum subsector, which accounts for over 50% of the total energy consumption in the division, options include: combustion of industrial waste in clinker furnaces; installation of vertical mills for cement manufacture; installation of speed regulating choppers in gas output ventilators; use of limestone-bearing filler; installation of expert systems in furnace conduction; incorporation of variable speeds to fans; installation of double heating chamber reversible furnaces; heating in parallel current.

Considerable savings are possible in this sector, around 12% of the projected consumption in 2020. 63.5% of this (coal) saving is accounted for by industrial waste combustion in clinker furnaces in the cement subsector.

In the Dutch cement industry, options include pre-calcination in a fluidised bed reactor, reduction of heat losses by insulation, firing kilns using waste or biomass, and efficient grinding techniques. In the glass industry, electrical heating of the foreheath to the kiln and heat recovery (secondary regeneration) are considered. In the Reference case 7% saving is achieved, and an additional 3% is technically possible.

For Sweden the options in the building materials sector are similar to the ones presented in Exhibit 6.19. However, 90% of the energy demand in the building materials sector is not affected by these options. Consequently, the overall savings reached amount only 1% of the energy consumption in 2020. The savings achieved are mainly due to the introduction of variable speed drives in fans.

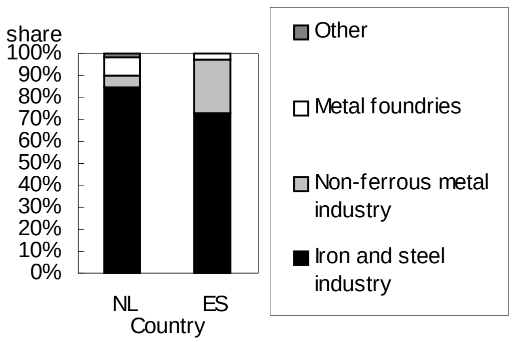

Exhibit 6.20 *Shares of subsectors in the energy consumption in the Basic metal industry for Spain and the Netherlands*

Basic metal

The basic metal industry is an energy intensive sector in all three countries, with a share in the industrial energy consumption of around 20%. The growth figures projected for the basic metal industry are different for the considered countries. Spain expects the industry to shrink with 3%. In the Netherlands the growth in all basic industries is expected to stay behind the growth in transforming industries. The reason is that the technological development leads to upgrading of final products, produced out of lesser amounts of basic materials (dematerialisation). Within the Dutch basic metal industry, the iron and steel industry is expected to grow moderately, foundries are expected to grow at a faster rate, whereas the non-ferrous industry is expected to shrink due to the closure of one or more aluminium plants after the year 2005. This leads to a weighted average of 18% growth for the basic metal sector. In Sweden on the other hand, the basic metal is expected to grow at a rate of 67%. Exhibit 6.20 gives the structure of the sub-sector as shares in the sectoral energy consumption for Spain and the Netherlands. For Sweden these figures have not been specified.

In the Spanish *basic metals sector*, the following options have been specified. With regard to iron and steel works, the measures considered are as follows: installation of oxy-gas burners in electric furnaces; installation of injection lance manipulators; coke recovery in the cupola; installation of half-frequency induction furnaces charged by automated vibratory feeders; preheating of combustion air in the thermal processing furnace; use of residual heat from forging in iron tube production. With regard to the production of non-ferrous metals (aluminium), measures considered refer to the installation of smelting furnaces with regenerative burners and the use of combustion gases in the annealing process. In the ‘metal foundries’, the following energy saving measures are considered: substitution of the conventional lamination process for lamination incorporated into the compact unit; installation of heat exchangers in exhaust fumes for high furnace stoves; installation of heat recovery boilers for combustion gases; energy recovery from expansion gases through installation of turbines; installation of submerged combustion equipment for bath heating; installation of radiant arches in furnaces. Still, 73% of the energy consumption in 1994 is in sectors for which no options have been specified. Therefore the saving achieved in the Reference case is only 7%.

In the Dutch iron and steel industry, options include: dry coke quenching, waste heat recovery in the coke production, direct injection of coal in blast furnaces, slag and waste heat recovery, and a new process called Converted Cyclone Furnace. In blast oxygen furnaces, gas recovery is distinguished, as well as the installation of an oxygen buffer and the input of extra scrap together with crude steel. In hot strip mills one of the options is improvement of recuperative burners at the slabbing furnaces. Other options affect the Electric Arc Furnace process and the cold rolling mill. In the non-ferrous industry, improved production processes for aluminium are considered (the Hall-Heroult process, and the AlCoA process). Other options are insulation of furnaces, better process control and regenerative burners. These options are also included for metal foundries. In the Netherlands 17% of the energy consumption is not affected by saving options specified in the model. This concerns the non-energetic use of coal, ores, oil products and the production of anodes, and does not imply that no additional saving is possible. The saving reached in the Reference case is 21% with an additional 1% technically feasible, and to a large extent due to the Converted Cyclone Furnace, gas recovery in blast oxygen furnaces, and ’hot connection’ - direct transportation of the cast metal at a high temperature to the hot strip mill.

For Sweden the options in the basic metal sector are similar to the ones presented in Exhibit 6.19. However, 95% of the energy demand in the basic metal sector is not affected by these options. Consequently, the overall savings reached amount only 1% of the energy consumption in 2020.

The impact of the options on the overall energy consumption in the basic metal industry is visible in Exhibit 6.21. It appears that despite the moderate growth in the Netherlands, a net reduction of the energy consumption below the level of 1994 is possible. In Spain this reduction is also visible, due to the projected shrinkage of the sector. The growth in Sweden in combination with only 1% saving means that the impact is limited in this country. However, this does not mean that there is no technical saving potential in Sweden, but that specific technologies for this sector have not been specified.

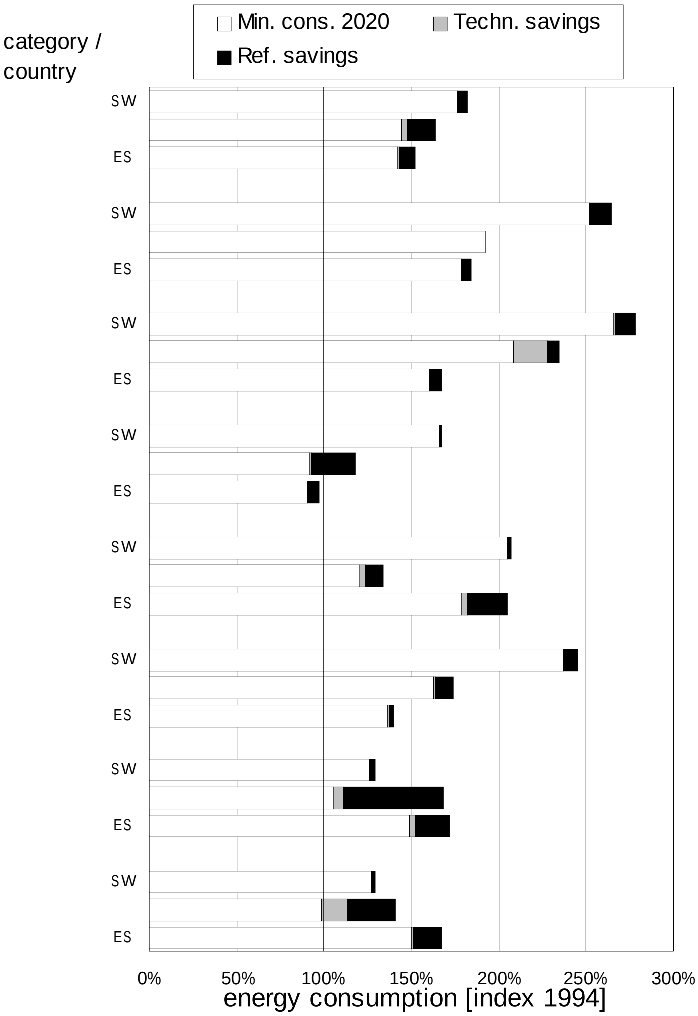

Exhibit 6.21 *For each division in the manufacturing sector for the year 2020, the projected growth of the energy demand baseline, energy savings in the Reference case and the Technical case, expressed as a percentage of the energy consumption of the baseyear 1994, all for relevant countries*

Metal products

As mentioned above, the growth in all basic industries in the Netherlands is expected to stay behind the growth in transforming industries, which will continue improving and upgrading their products. This technology development will allow for export expansion, and therefore a considerable growth of 135% is projected for the Dutch metal manufacturing industries. In Sweden the growth projection is even higher, 178%, for similar reasons. Spain is more moderate with a projection of 67% physical growth. In the Spanish *metal products* division, three subsectors are considered: ‘Forging and other metal treatments’, ‘Steelworks, structures and boiler forging’ and ‘metal articles’. In the first group, the following savings measures are considered: pirometric control, forging at half heat, and plunging. In the other two groups, only one technical measure is considered: in the case of steelworks, the installation of high speed burners and insulating ceramic fibre in furnaces for thermal processes, and for metal articles, the substitution of traditional heating furnaces with half-speed induction heating installations. 9% of the energy consumption is not within these subsectors. In the Reference case, the complete (specified) technical potential of 3% is utilised.

The Dutch metal manufacturing and engineering industries consists mainly of small companies, where the attention paid to energy conservation is low, because energy costs are only a small proportion of the production costs. Options therefore include insulation of furnaces, reducing leakages and recuperation of waste heat to save fuel for process heat, as well as insulation measures to save energy for space heating. In addition, some electricity saving options are specified: speed control systems on motors, more efficient compressors, lighting control equipment. The 3% savings achieved in the Reference case are mainly due to the options saving electricity. An additional 8% can be reached by (natural gas) savings on process heat and space heating.

For Sweden the options in the metal manufacturing sector are similar to the ones presented in Exhibit 6.19, except refrigeration. However, 70% of the energy demand in the metal products sector is not affected by these options. The overall savings amount 4% of the energy consumption in 2020. The savings achieved are mainly due to the introduction of variable speed drives in compressors and efficiency improvements in lighting. In addition, a shift from electricity to light fuel oil takes place for space heating, which means a small net increase in final consumption. The primary energy consumption is reduced however.

Other industry
The ‘other industry’ division summarises ‘Wooden products and furniture’, ‘Machinery and office equipment’, ‘Electrical machinery and appliances’, ‘Medical and optical instruments’, ‘Transport industry’, Textile, Clothes, ‘Leather and Leather products’. The aggregated growth projections for these subsectors range from 84% for Spain to 164% for Sweden.

Spain has specified options for four products: ‘Sawing of wood’, ‘wooden furniture’, ‘machinery and electrical materials’ and ‘motorcars, parts and accessories’. For sawing wood: installation of drying chambers with programmable robots and a closed air circuit for soft wood. This measure can also be applied for hard wood in the furniture industry. In the electrical materials industry, savings are proposed in the catalytic combustion of gases released. In the car industry, measures considered are: installation of equipment for induction heating; assembly of composite for welding vacuum furnaces; and improved incineration. 49% of the energy consumption in this sector is not affected by these options, leading to a saving potential of 3%.

In the Netherlands no options have been specified for these subsectors, and therefore no saving potential has been calculated.

For Sweden the options in the ‘other industry’ sector are similar to the ones presented in Exhibit 6.19, except refrigeration. However, 75% of the energy demand in the sector is not affected by these options. The overall savings achieved amount 4% of the energy consumption in 2020. The savings are mainly due to the introduction of variable speed drives in fans and efficiency improvements in lighting. In addition, a shift from electricity to light fuel oil takes place for space heating.

Summarising

Finally, the overall picture per country can be compared. It is clear that the average growth projections are not that far apart; 53% for Spain, 63% for the Netherlands and 82% for Sweden. The technological saving options as specified in the country models cause the following reduction in the 2020 energy consumption: in Spain the projected 53% growth can be reduced to 42%, in the Netherlands 63% growth can be reduced to 44%, and in Sweden the projected 82% can be reduced to 77%.

The absolute price level in the manufacturing sector is much lower than in households. This implies however, that this sector is more sensitive to increases in world market prices. In the Netherlands the price increases in the Reference case over the time horizon are twice as high as in the households. The price of natural gas increases with 72%, electricity with 17% and oil becomes 92% more expensive. The increases are comparable in the other countries. In principle this has a positive effect on the profitability of options, and thus on the saving potential in the Reference case, and in all other cases.

Country overview

For Spain and the Netherlands, it is interesting to compare the nature of the saving potentials from subsector to subsector. The largest potentials can be found in the food industry and in the paper and pulp industry, both in Spain and the Netherlands. The Building materials, Basic metals, and Metal products sectors are also worth investigating in more detail, and therefore the Reference cases will be compared. Sweden cannot be very well compared to the other two countries because, as mentioned before, only aggregate options have been specified, and branches have not been distinguished within the subsectors.

In the Dutch *Food industry*, the largest savings can be achieved in the cattle slaughtering and meat preservation industry (30% of baseline consumption in 2020). It concerns fuel saving measures such as heat recovery in meat production, good housekeeping in slaughterhouses, and electricity saving measures such as improvement of cooling installations and variable speed drives on pumps. Furthermore, the dairy and oils & fat industry can reach savings around 25% of the baseline consumption in 2020. In the dairy industry the evaporators and dryers are the largest energy consuming processes, and it is here that the largest savings can be gained, in particular by the six stage evaporator, drying by direct heating, and process heat integration (due to pinch optimisation). Pinch optimisation can also be effective in the oils and fat industry. In the sugar industry the technical potential is much larger than what is achieved in the Reference case, because technologies such as mechanical vapour recompression and reversed osmosis are still expensive and require some additional electricity. With regard to energy carriers, it appears that both electricity and natural gas or heat can be saved in comparable proportions.

In the Spanish food industry all options that were specified are saving fossil fuels. This suggests an additional potential for saving electricity. One of the largest energy consumers in the food industry is the sugar industry, where the saving potential is 40% of the baseline consumption in 2020. This is due to replacement of traditional pulp dryers with steam dryers with liquidised bed and substitution of the traditional evaporation cases for descending flow cases. In the oil and fat industry, installation of adapting and predictive control systems can cause a 15% saving. Heat recovery is effective in various sectors. These favourable saving potentials may be overestimated, because of the absence of competition between technologies in the model specification. On the other hand, the saving potential for the total food industry is probably underestimated, because no options have been included for the dairy, fodder, bread and bakery industries.

In the *Paper and pulp* industry, savings can mainly be achieved in the papermills in both countries. In the Netherlands saving is largely due to impulse drying, which saves natural gas and requires a small amount of additional electricity, and introduction of variable speed drives to save electricity in stock preparation. In Spain saving of fossil fuels is achieved by heat recovery in wood cooking plants, and installation of discontinuous cooking processes using the 'RDH system'. No options have been specified that save electricity, indicating an additional saving potential here.

In the *Building materials* sector, the technologies that can achieve savings are quite different in the two countries. In the Dutch cement industry, reduction of heat losses by insulation and firing kilns using waste or biomass achieve a saving of fossil fuels, while efficient grinding techniques save electricity. In the glass industry, heat recovery (secondary regeneration) is the most successful option. In the Spanish cement industry, 64% of the (coal) saving is accounted for by industrial waste combustion in clinker furnaces in the cement subsector. Some electricity is saved by the installation of vertical mills for cement manufacturing.

In the Netherlands the largest potential savings in the *Basic Metal* industry are in the iron and steel industry, and to a large extent due to the Cyclone Converted Furnace (saving coal and using a small amount of additional electricity), gas recovery in blast oxygen furnaces, and 'hot connection' - direct transportation of the cast metal at a high temperature to the hot strip mill. In the Spanish iron and steel industry, the most effective options are substitution of the conventional lamination process for lamination incorporated into the compact unit, the installation of heat exchangers in exhaust fumes of high furnace stoves, and energy recovery from expansion gases through installation of turbines. In the non-ferrous industry, the installation of smelting furnaces with regenerative burners can save natural gas.

In the Dutch *Metal Products* sector, the 3% savings achieved in the Reference case are mainly due to the options saving electricity (speed control systems on motors, more efficient compressors, lighting control equipment). An additional 8% can be reached by (natural gas) savings on process heat and space heating. In Spain natural gas can be saved by half-speed induction heating installations for the production of metal articles, and insulating ceramic fibre in furnaces for thermal processes.

The saving potentials in the *Chemical industry* are hard to compare, because Spain has concentrated the specification of options on the manufacturing of chemical products, whereas the Netherlands has mainly specified options for the basic organic and inorganic chemical industry. In addition it is not clear which proportion of the Spanish energy consumption is non-energetic.

From the comparison above, it becomes clear that conclusions regarding specific technologies in specific subsectors in the countries can hardly be drawn. For a more complete interpretation, more information would be required regarding the 'state of the art' of technology in the different countries. The most successful options within a subsector are often quite different in Spain and the Netherlands. Partly this will indicate 'gaps' in the option specification, but it may also reflect differences in technological development, or differences in costs for comparable technologies. Obviously, the comparability of results would be greatly improved by harmonisation of the databases of technological saving options in the countries involved.

With regard to the saving of specific energy carriers, the differences between the countries are significant, but consistent with the fuel mix in the different countries. In Sweden all options save electricity, as a result of the attention paid to the consequences of phasing out nuclear power in this country. In the Netherlands most options save natural gas, but a substantial saving of electricity is also achieved, because of the higher price. In Spain most attention is paid to options saving fossil fuels, in particular oil products, which are more expensive than natural gas. In all countries, fuel switch from electricity to a primary fuel takes place, for instance in space heating in Sweden (switch from electricity to light oil) and in the metal products industry in Spain (electricity to LPG). An important remark to be made here is that the savings thus achieved are underestimated, because the conversion losses in the generation of electricity are not taken into account.

Regarding the profitability of the options in the considered countries, it is interesting to compare the values of the Internal Rate of Return. Very profitable options (40% IRR) in the manufacturing sector need in REDUCE about 20 years to cover the full market, and that hardly profitable options (10% IRR) will need about 70 years. Looking at the options this way, we can distinguish three categories in the different countries. Spain has specified 102 options, of which 9 have an IRR smaller than 10% in the baseyear, and 43 have an IRR greater than 40%. This leaves 50 options in the range where policy measures have the most impact. The Netherlands has specified a total of 152 options, of which 56 options are in the unprofitable range with an IRR smaller than 10%, or even negative, and 48 options have an IRR greater than or equal to 40%. Therefore, in the Dutch model 48 options remain that are reasonably profitable. However, the large number of unprofitable options means that, in the model, financial policy measures can make a greater difference in overcoming the market barriers for these options. In Spain this possibility has been excluded beforehand by hardly specifying unprofitable options. In Sweden 36 options have been specified, of which 35 have an IRR greater than 40% (the remaining one has 35% IRR). This indicates either that Swedish investors are very insensitive to the profitability of energy saving measures, or that the costs of the options have been underestimated. Also, in general, the large number of profitable technologies suggests the existence of an ‘efficiency gap’ in industry. In other words, investors do not invariably implement whatever option is profitable. The replacement of installed equipment plays an important role here.

The actual energy consumption in 2020 depends both on the number of available and profitable options and on the projected growth in a division. In most divisions, the growth projections are large, and stabilisation of energy consumption (compared to the baseyear) seems out of reach. Exceptions are the food, paper and basic metal industries in the Netherlands, and the basic metal industry in Spain, where shrinkage is projected. Sweden is the only country that assumes a relatively high growth of energy intensive subsectors such as the basic metal and the chemical industry. The Metal products sector is expected to grow considerably in all three countries, as is the Other industry.

Technical potential

The saving potentials are different, not only in size but also in nature. The first observation is that modelling the manufacturing sector is probably more difficult than specifying the households sector. First, many industrial processes are very complicated, and most energy saving measures have an integrated effect on several parts of the process, for instance waste heat recovered in one process can be utilised in another process, which makes it harder to define the saving options in a correct way. Furthermore, the data requirements are large in the manufacturing sector, due to the number of subsectors and processes, whereas the availability of data is more limited. For instance, information available for the different saving measures often does not refer to saving percentages, but to amounts of energy saved in specific industrial installations as a result of changing equipment. Similarly, in certain industrial installations multiple saving options are introduced at the same time, making it difficult to decide the proportion of saving which corresponds to each measure. It is also difficult to determine the rate of penetration of such measures and their lifetime. For this reason, the results obtained from the REDUCE case studies should only be considered as a first analysis of the saving potentials in the different industrial subsectors.

The technical potential is smallest in Sweden, only 3%. The reasons have already been mentioned in the previous sections. The incomplete specification of options results in a considerable part of the energy consumption being unaffected by any option, and no innovative ‘future’ technologies are included. Exhibit 6.22 shows that in Sweden 84% of the total energy consumption in the manufacturing sector is not influenced by the measures specified. Since the continuing development of specific technologies for specific (sub)sectors has not been taken into account, the actual Swedish saving potential cannot be estimated from this study.

In Spain, a saving potential of 7% is achieved in the Reference case and an additional 1% is technically feasible. It is difficult to estimate how realistic this potential is, because all saving options have been specified without alternative technologies, so they conquer the market relatively easy in the absence of competition. Furthermore, the database of technical saving measures affects only 47% of the industrial energy demand. However, when the savings are related purely to the energy consumption in the sectors that have been modelled, then the saving potential amounts 15% of the total projected energy demand in the Reference case. Therefore a conservative estimate would be that a complete specification of the technical saving measures in all subsectors would lead to a potential over 10%.

Another factor limiting the Spanish saving potential is that the measures which may be introduced or developed in the period under study (up to the year 2020) have not been considered. 1998 is the latest year that has been considered for the introduction of an option in the market, and such options correspond to measures which are currently being studied by companies in the sector. Still another factor is that the Technical Case in the Spanish model may not reflect the complete technical potential. This case has been simulated by raising prices, which does not remove the barriers due to interaction of options and thus the complete technical potential has not been made visible.

In the Netherlands the saving potential is 9% in the Reference case, and an additional 2% is technically feasible. Part of the energy consumption specified in the baseyear is non-energetic use of energy carriers, and to a large extent not affected by the options specified. It concerns 33% of the industrial energy demand, see Exhibit 6.22. In addition, no options have been specified in the division ‘other industry’ which consumes 3% of the energy in the manufacturing sector. Excluding the unaffected energy consumption for non-energy use would result in 17% savings achievable in the Reference case.

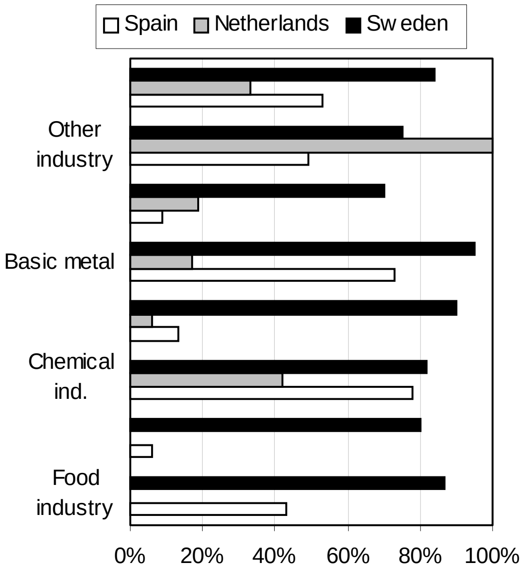

Exhibit 6.22 *Proportion of the energy consumption in 1994 that is unaffected by the options specified*

An important factor leading to underestimation of the saving potential, is the exclusion of CHP from the model specification, due to lack of time and data. In Spain there is considerable scope for saving energy by the combined generation of heat and power. In the Netherlands the main industry sectors for implementation of CHP are the food and paper industries, chemical industry and the basic metal industry.

Efficiency gap in industry

Although, as stated above, the technical potential is underestimated for various reasons, it remains striking that the savings achievable in the Reference case are not nearly as large in terms of energy consumption as in the households sectors in different countries. The higher energy price increases and the higher energy price sensitivity in industry result only in a large part of the technical saving potential being utilised in the Reference case. The investors in the industry have already made more rational decisions in the past, and therefore the energy efficiency level in the baseyear is already closer to what is technically feasible. In other words, the technical saving potential is smaller than in households.

Another result is that the 'efficiency gap' appears to be smaller in industry than in households. Actually, this efficiency gap will probably be larger than the difference between Reference and Technical case, because the Reference case does not present an autonomous development. In this respect, some results from Phase I of the project are relevant, regarding a survey conducted among industrial investors in the countries involved. It appears that the efficiency gap in industry is smallest in the Netherlands, that Spain comes second with a gap 1.5 times as large as in the Netherlands, and that this gap is relatively large in Sweden, almost twice the size of the Dutch efficiency gap. Unfortunately the case studies do not provide enough information to confirm these outcomes. In addition, the following barriers have been identified as being the most important obstacles preventing firms from implementing all profitable options:
- the guarantee of product quality,
- the environmental image,
- the current size of the energy bill,
- the degree of flexibility in the production process,
- the availability of own personnel.

With regard to policy instruments, a general conclusion from the survey is that the larger the efficiency gap, the more effective financial instruments will be. When the efficiency gap is smaller, information and knowledge proliferation tend to be more effective, for implementing more complex, less familiar technologies.

The underestimates of the technical potential summarised above also lead to an underestimate of the additional impact of conservation policy measures. These measures will be the subject of the next section.

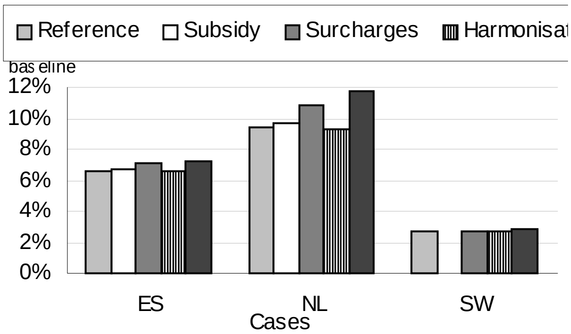

Exhibit 6.23 *Energy savings in manufacturing in different cases expressed as a percentage of Actual energy consumption in the year 2020 for relevant countries*

6.2.2 Policy cases

As explained before, the Reference case provides a 'what-if'-scenario approach that indicates which options achieve profitable energy savings, given the competition and interaction of options and the energy carrier price developments. Moreover, it shows the general barriers with respect to investment in energy conservation options as reflected by the market stages of technologies. The Reference case is not a 'doing nothing' case. Nevertheless, the Reference case can provide a basis for the investigation of additional policy measures, since the effect of certain types of measures can be calculated under the assumption that technology specific barriers or advantages are not affected by the policy measure to a different extent.

Exhibit 6.23 presents for all three countries the energy saving potentials for the Policy cases in combination with the Reference and Technical case in the manufacturing sector, expressed as a percentage of the Actual baseline energy consumption in the year 2020. Exhibit 6.24 shows the impact of the energy savings on the energy demand, which is expressed as an index of the baseyear energy consumption for the same cases and countries. The results in both exhibits will be discussed case by case in the next paragraphs.

Subsidy case

In this case, a grant or subsidy of 30% of the investment costs (additional to the Reference option) is given to a selection of five energy conservation technologies which are promising. In Section 3.4.1.2 is concluded that subsidies on energy conservation technology can be a good instrument for stimulating energy efficiency if:

- the option has net benefits without subsidy,
- the option has a low market share and needs to overcome the barriers of market introduction,
- the lifetime is not too short.

The last two conditions are necessary to reduce the share of free riders collecting the subsidy and to increase the market multiplier effect of the government subsidy. However, subsidy requires large government funds which indicate that this policy instrument will be applied scarcely for specific technologies only.

When comparing the Subsidy cases in the different countries it is clear that the overall impact on the saving potential, compared to the Reference case, is very small. The main reason for this is that those options that receive a subsidy only cover a small share of the total energy consumption in the manufacturing sector, and therefore only influence a minor part of the total energy saving potential.

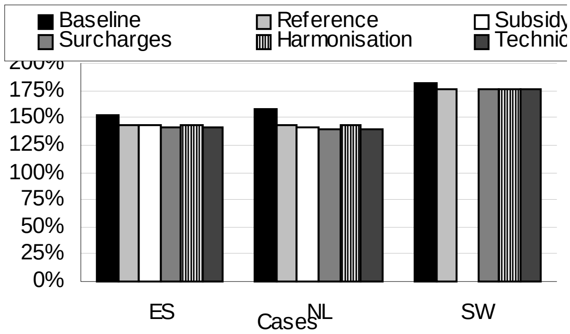

Exhibit 6.24 *Projected energy consumption in manufacturing in different cases expressed as index of the Actual energy consumption in the baseyear 1994 for relevant countries*

For Sweden no Subsidy case could be specified, because of the aggregated and generic character of the saving options.

In Spain, subsidies up to the year 2005 did not make a difference in the year 2020, because the selected options would have reached a market share of 100% anyway. Therefore an alternative case was specified, reflecting the current government subsidies up to the year 2020 for the same percentage of investment costs that the companies are presently receiving for these measures. It concerns over 60 options that receive subsidy percentages ranging from 4% to 40% of the investment costs, and 100% for one technology. In this case, savings increase around 0.1% in comparison with the Reference case, and are mainly achieved in the clothes and paper industries. In Spain an additional reason for this small impact is the absence of competing technologies, implying that in the Reference case already one of the barriers for market success has been removed.

In the Dutch case, the following options have received subsidies and are more or less effective in the long run. Process integration to design an optimum heat exchanger network in the plants producing olefines, the same option for sodium production, introduction of selective cracking in the production of olefines, enhanced gas recovery in the blast oxygen furnace, and extrusion processes in the fodder industry. An example of the impact of subsidies on the IRR and penetration is the introduction of selective cracking in the production of olefines: the IRR of this option becomes 18% in the year 2000, and the penetration in 2020 is 50% in the subsidy case, compared to 13% IRR and 30% penetration otherwise.

Surcharges case

Environmental surcharges have a considerable influence on the prices of fossil fuels in the manufacturing sector, see also Exhibit 5.9. Compared to the Reference case in 2020, prices are 60-120% higher for natural gas and up to 150% higher for oil products. Secondary energy carriers remain relatively unaffected by surcharges (increases of 4-18%).

The fuel mix used in the countries is important for understanding the effects of surcharges on the energy consumption (see Annex D). The relative price levels of different energy carriers have not changed much. In the manufacturing sector, the influence of a surcharge is much higher than in households, because the end-user prices are relatively lower. The relative price increases for fossil fuels are sometimes twice as large as in the households sector. Coal and heavy oil prices come to a similar high level, and natural gas becomes the most attractive energy carrier, next to heat. The weighted price increases illustrate the country differences in fuel mix. The highest average price increase of 94% is found in the Netherlands, due to the low share of electricity in the fuel mix. Spain follows with a 73% increase, and the price increase is much lower in Sweden, around 45%, as a result of the large share of electricity in the fuel mix (almost 50%), and the clean, in terms of air pollution, nuclear generation of electricity.

These price increases do result in additional energy savings, compared to the Reference case. Although the surcharges cause a large part of the technical potential to be utilised, the percentual increase is not that large: 0.6% for Spain, 1.6% for the Netherlands, and 0.1% for Sweden, expressed as a share of Reference energy consumption. Just as in the households cases, the order of countries is in line with the price increases by the surcharges in the countries.

In Spain, the Technical potential case has been simulated by a price increase only, not taking away other barriers to the implementation of energy conservation options. However, this means that the Surcharges case is very similar to the Technical potential case. Differences between the cases are caused by the relative price differences between energy carriers.

The following issues cause additional energy savings to be limited, compared to the high price increases as a result of surcharges:

- A large part of the technical potential is already utilised in the Reference case. Two main reasons for this are the higher sensitivity of investors in the manufacturing sector, and the fact that the price increase in the Reference case is already much higher than in households, because the end-user prices in the manufacturing sector are more sensitive for world market price rises. This leaves little room for improvement by imposing surcharges. For Sweden there is hardly a difference between the Reference and Technical potential case, because of the aggregated character of the saving options.
- Price increases as large as those imposed here would cause structural changes in the manufacturing sector, such as the replacement of complete processes, and shifts in the types of products manufactured. Although some of these changes may be anticipated and then included in REDUCE as special saving options, they are currently not included. Furthermore, innovative but expensive ‘future’ technologies have not been specified by Spain and Sweden. These technologies typically would become attractive as a result of rising prices.

Summarising, the technical potential itself is underestimated, and serves as an upper limit for the additional savings reachable by surcharges.

Harmonisation case

In the harmonisation case, the end-user prices are modified in such a way that all countries have a similar tax regime, to simulate a first step towards liberalisation of EU energy markets (see Annex B). In the manufacturing sector, only excise taxes are affected. Compared to the prices in the Reference case, the differences are not large. Sweden and the Netherlands, which already have relatively high taxes on energy, will even experience a 1% decrease of the weighted average prices. In Spain the average price level will rise 1.7%, again compared to the Reference case.

The only fuel becoming considerably cheaper is coal in Sweden, of which the price drops with over 50%. In Spain the tariffs for coal increase with 20%. Heavy oil becomes 3% cheaper in Spain and the Netherlands, and 10% more expensive in Sweden. Electricity becomes 3% more expensive in all three countries, while the growth of the natural gas prices is slightly lower than in the Reference case.

These end-user price rises or falls do cause some limited increases and decreases of the energy saving potentials compared to the Reference case, see Exhibit 6.23 and Exhibit 6.24. In the Netherlands the savings achieved in the Harmonisation case are even slightly less than in the Reference case, because options saving natural gas (which is the majority in the Netherlands) are less profitable. In Spain, additional energy savings would be achieved in the basic metal industry, but energy consumption would be higher than the Reference case in all other sectors. Still, the total saving potential becomes slightly larger than in the Reference case. In Sweden the effects of tax harmonisation are difficult to assess, due to the limited number of saving options.

Although it may seem that fiscal policies are not having much impact, there are other reasons explaining this apparently insensitive behaviour in the manufacturing sector. First, the price increase in the Reference case is already so large that additional effects of any financial policy are hard to distinguish. Furthermore, the inflexible specification of options is the main reason that only gradual differences are visible between the policy cases. For ‘structural’ differences to appear, it is necessary to have competition within market groups of options, and to specify innovative technologies that become available after the baseyear. Finally, it is concluded that investors in the manufacturing sector have already implemented a larger share of the technically feasible options in the baseyear.

7. CONCLUSIONS AND RECOMMENDATIONS

The most obvious finding from the work to date is that the information which is presently collected and reported is insufficient to guide policy transfer. Also, the study of policies, when carried out using varying baselines, assumptions and methodologies, does not assist the process. However, the range of promising policies identified by the work should provide scope for action in all Member States, allowing the particulars of national situations to be accounted for without the opportunity for improvement being lost, and therefore the issue deserves further study.

The comparative process would be improved by the application of common techniques and methodologies across all countries. In Phase II the use of a single energy conservation model REDUCE to assess policy options has been devoted to this issue. Future work is being considered, which would include a consideration of the policy assessment methodologies developed in individual countries, and the possibility of their application on a wider scale.

In addition to considering the standardisation of existing types of comparative data, alternative approaches could be developed. Reducing policies to short summaries may be necessary to facilitate the development of an overview. However, the most productive type of information to transfer between countries may be much more detailed and qualitative. For example, descriptions of the implementation of specific policies and programmes which have, in the opinion of their implementers, met their own set of objectives, may be of more use to the policy maker.

Phase I in the project, like much other recent work, has highlighted the lack of understanding which energy researchers and policy makers have about human behaviour. The modelling process referred to above will begin to integrate a closer consideration of the human aspects of energy conservation polices, based on the results of a survey of industrial energy users which was undertaken as part of the initial phase of the project. Whilst this will hopefully lead to some progress, much further work remains to be done, both to collect new information and to incorporate the knowledge and understanding already existing in disciplines, such as anthropology, which are less traditionally associated with the study of energy policy.

These developments, and others (such as geographical expansion of the present study or further investigation of the role energy policy studies can play in setting the context for international policy comparisons), will all benefit from continued research co-operation on a European level.

The seven national case studies have been conducted in Phase II with a new dynamic energy conservation model called REDUCE (Reduction of Energy Demand by Utilisation of Conservation of Energy). It provides a common ‘language’ and framework for transfer between countries of know-how of different aspects of energy conservation options and policy instruments based on comparable national case studies. This allows for assessing common aspects as well as understanding country-specific characteristics of energy conservation across the EU for improving the effectiveness of future policies.

The main objective of the present study is to provide input for strategies for energy conservation as a basis for the formulation and design of conservation policy programmes. The case studies assess which technologies can provide profitable energy savings given the competition and interaction of options and the energy carrier price projections. Moreover, the general barriers existing in the sectors with respect to investment in energy conservation as reflected by the technology market stage are taken into account. Two sectors have been specified in REDUCE, namely households for Denmark, Finland, the Netherlands, Switzerland and the United Kingdom and the manufacturing sector for the Netherlands, Spain and Sweden.

7.1 Households

7.1.1 General observations

The analysis of the results concerning scenario projections and energy savings up to the year 2020 for the different countries leads to the following general conclusions:

- Present and future volumes and energy intensities of energy services in households are in general strongly lifestyle related. Energy services with a share of at maximum 5% of the energy consumption can differ more than a factor two between countries due to lifestyle differences (including statistical errors). Demand for heating is also related to climate, type of building, fuel mix and related technologies and past conservation policies.
- Therefore, developments in volume and energy intensity of the energy services in households differ by energy service and country.
- Technical saving potentials for energy services in households are quite comparable between countries since most options are available on the EU market. Conservation options for heating are an exception to this due to the country specific character of heating and building types and the long lifetime of many technical measures in the building stock.
- The structure of energy services and the energy saving potentials for households are dominated by heating since heating covers a large share of 65% to 75% of the energy demand for households. Hot water covers 15% to 25% of the total energy demand.
- Country differences in energy pricing and energy intensities are not of large influence on the Reference energy savings. The profitability (IRR) of a large share of the saving technologies is already high at present prices. The market stage of conservation options is much more important, just as the replacement rate of existing devices.
- The comparability of the results for the different countries can be improved by further harmonisation of the scenario assumptions and conservation options in the database.

7.1.2 Country review

Total household energy consumption in the Reference case in the year 2020, relative to 1994 energy consumption, is expected to remain more or less constant for all countries except the Netherlands and Finland. Energy savings have a substantial contribution in the Reference case (which includes continuation of present conservation policies) for the year 2020 from 10% to 25% of the baseline consumption. The lower number is biased by energy savings which are included implicitly in the baseline development. Technical saving potentials are around 50% of the baseline energy demand in 2020.
The prospects for each energy service are as follows:

- An increase in electricity demand is expected for the energy services other appliances (10% to 40% for audio-video, hobby, personal care, sleeping etc.) and drying (up to 80%). Even the technically available saving potential can not counterbalance the growth in these demand categories.
- Despite growth of the energy service volumes, the energy demand is expected to decrease for washing (10% to 40%), cooling (10% to 45%) and cooking (5% to 35%). Application of the technical energy saving potential would lead to reductions of energy demand for washing down to 60%, for cooling down to 20% and cooking down to 40%.
- Energy demand for lighting is expected to grow with 30% in the Netherlands, to remain constant for Switzerland and Finland and strongly decrease in Denmark and United Kingdom. Implementation of the technical saving potential could lead to a further decrease of the energy consumption down to 60% of the 1994 energy consumption.
- Energy demand for hot water is foreseen to increase in the Netherlands (50%) and Finland (25%) and to decrease in the other countries (10% to 30%). It is not clear due to the

application of different definitions whether implementation of the technical saving potential could further decrease the energy consumption down to 50% of the 1994 energy consumption.
- Energy consumption for heating will, compared with the baseyear, increase with 10% in the Netherlands and 5% in Switzerland and decrease in the other countries: 1% in Finland, 7% in Denmark and 50% in the United Kingdom. The latter has only just started with cavity wall insulation, nevertheless it is an extreme result. Realisation of the technically feasible energy saving potential would lead to energy consumption of 40% to 50% of the baseyear energy consumption. The main part of the energy saving potential is found in existing houses.

7.2 Manufacturing

7.2.1 General observations

The results of the case studies for the manufacturing sector give rise to the following general conclusions:
- The savings achieved in the Reference case are, relative to the energy consumption, not nearly as large as in the households sectors in different countries. The higher energy price increases and the higher energy price sensitivity in industry result only in a large share of the technical saving potential being utilised in the Reference case. The investors in the industry have already made more rational decisions in the past, and therefore the energy efficiency level in the baseyear is already closer to what is technically feasible. In other words, the technical saving potential is smaller than in households.
- The actual energy consumption in 2020 depends both on the number of available and profitable options and on the projected (physical) growth in a division. In most subsectors, the projected growth is high and stabilisation of energy consumption (compared to the baseyear) seems unattainable.
- The assumed growth projections for the energy intensive subsectors and sometimes subsectors using energy carriers for non-energy purposes are highly important for the energy demand development of the manufacturing sector as a whole.
- Energy saving potentials are relatively large in terms of baseline consumption in the food and paper and pulp industry (up to 35%).
- In all three countries, at least 30% of the technologies has an IRR over 40% in the baseyear, which implies that they will need approximately 20 years to cover the full market in REDUCE. This large share of profitable technologies confirms the existence of an ‘efficiency gap’ in industry, although the gap is smaller than in households. In other words, investors do not invariably implement whatever option is profitable. The replacement rate of installed equipment plays an important role here.
- Country differences in fuel mix have a significant effect on the nature of the technologies used, mainly due to large price differences.
- In all countries, fuel switch from electricity to a primary fuel takes place. The savings thus achieved are underestimated, because the conversion losses in the generation of electricity are not taken into account.

Modelling the manufacturing sector requires more data for specifying the model adequately than for the households sector. First, many industrial processes are very complicated, and most energy saving measures have an integrated effect on several parts of the process. For instance waste heat recovered in one process can be utilised in another process, which makes it harder to define the saving options in a correct way. Furthermore, the number of subsectors and processes is large, whereas the availability of data is more limited.

7.2.2 Country review

The technological saving options as specified for the countries cause the following reduction in the 2020 energy consumption: in Spain the projected 53% growth can be reduced to 42%, in the Netherlands 63% growth can be reduced to 44%, and in Sweden the projected 82% can be reduced to 77%. The largest potentials can be found in the food industry and in the paper and pulp industry, both in Spain and the Netherlands. Sweden cannot be compared to the other two countries very well, because only general aggregate options have been specified, and branches have not been distinguished within the subsectors.

The technical potential is smallest in Sweden, only 3%. The actual Swedish saving potential cannot be estimated from this study. The options that have been specified are very general and only affect 16% of the industrial energy consumption, and the continuing development of specific technologies for specific (sub)sectors has not been taken into account,.

In Spain, a saving potential of 7% is achieved in the Reference case and an additional 1% is technically feasible. However, when the savings are related purely to the energy consumption in the sectors that have been modelled, the saving potential amounts to 15% of the total projected energy demand in the Reference case.

In the Netherlands the saving potential is 9% in the Reference case, and an additional 2% is technically feasible. Excluding the unaffected energy consumption for non-energy use, 17% savings can be reached in the Reference case.

The prospects per subsector can be summarised as follows:

- In the Food industry in Netherlands, stabilisation of the consumption can be reached if the complete technical potential is implemented. The largest savings can be achieved in the cattle slaughtering and meat preservation, dairy, and oil and fat industries. In Spain, the growth in consumption can be reduced with 17%, mainly achieved in the sugar and oil and fat industries. The saving potential in Sweden is very small and underestimated as a result of the aggregated approach taken.
- In the Paper and pulp industry, savings can mainly be achieved in the papermills. Stabilisation of the energy consumption is almost within reach in the Netherlands. This is largely due to impulse drying and the introduction of variable speed drives to save electricity in stock preparation. In Spain also a considerable reduction of the 70% growth projection is possible. In Sweden the lower growth is not counterbalanced by the potential savings.
- The chemical industry is an energy intensive sector and the growth projections for this sector are quite different, ranging from 150% in Sweden, 75% in the Netherlands and 40% in Spain. The savings achievable are limited compared to the size of the sector, due to the large share of non-energetic use of energy carriers, and the fact that many energy conservation measures have already been taken in the past.
- The Building materials sector is one of the major energy consumers in Spain, and both Spain and Sweden project a doubling of the energy demand in this sector. The Netherlands projects 34% physical growth. Considerable savings are possible in Spain, 12% of the projected consumption in 2020, while maximally 10% is feasible in the Netherlands. The saving potential in Sweden is underestimated.
- The growth figures projected for the basic metal industry are different for the considered countries. Spain expects the industry to shrink with 3%, the Netherlands project an average of 18% while in Sweden, the basic metal is expected to grow at a rate of 67%. It appears that despite the moderate growth in the Netherlands, a net reduction of the energy consumption below the level of 1994 is possible. In Spain this reduction is also visible, due to the projected shrinkage of the sector. In Sweden the high growth is not counterbalanced by the potential savings.

- A considerable growth of 135% is projected for the Dutch Metal manufacturing industries, in Sweden the growth projection is even higher, 178%. Spain is more moderate with a projection of 67% physical growth. In the Netherlands 3% savings are achieved in the Reference case, mainly due to the options saving electricity. An additional 8% can be reached by (natural gas) savings on process heat and space heating. In Spain a technical potential of 3% is identified.
- For the 'other industry' division, aggregated growth projections range from 84% for Spain to 164% for Sweden. Saving potentials are limited, due to an incomplete specification of options.

The comparability of results would be greatly improved by harmonisation of the databases of technological saving options in the countries involved. In this respect, a number of factors have been identified that cause the technical potential in the manufacturing sector to be underestimated:

- The exclusion of CHP from the model specification, due to lack of time and data. In the Netherlands and Spain there is considerable scope for saving energy by the combined generation of heat and power.
- For Sweden, and to some extent Spain and the Netherlands, an incomplete specification of options results in a considerable part of the energy consumption being unaffected by any option. The proportion of total energy consumption in the manufacturing sector not influenced by the measures specified ranges from 33% in the Netherlands, through 53% in Spain to 84% in Sweden. Partly it concerns non-energetic use of energy carriers.
- For Spain and Sweden no innovative 'future' technologies have been included, although those technologies will typically become more attractive at higher future energy prices.

7.3 Barriers and policy instruments

7.3.1 Barriers for conservation

The technical energy conservation potential is expected to be realised only partly due to a number of reasons. The following list summarises a number of important factors and gives between brackets how the specific issue is dealt with in REDUCE:

- The profitability of energy saving technologies is hampered by high investment costs of new advanced options, which are produced on a small scale (in REDUCE: the IRR).
- New entrants on the market have competitive disadvantages compared to well established technologies (S-curve).
- Successful technologies have difficulties to catch the last part of a saturated market (S-curve).
- Competition of technologies becomes in time more heavy since the reference is moving from standard to better, which hampers the relative profitability and success of the best technologies (competition in market groups).
- The long lifetime (over 30 years) of certain options such as wall insulation results in a very low replacement rate which results in bifurcation (permanent market penetration).
- Options of the supply and demand type interfere: they suppress each others effectiveness to some extent resulting in increasingly lower profitability and market success when the installed energy conservation increases (effectiveness).

Policy instruments address one or more of these barriers as will become clear in the next sections.

7.3.2 Subsidies

It is concluded that subsidies on energy conservation technology can be an effective instrument for stimulating energy efficiency if:

- the option has net benefits without subsidy,
- the option has a low market share and needs an incentive to overcome the barriers of market introduction,
- the lifetime is not too short (10 years or longer).

The last two conditions are necessary to reduce the share of free riders collecting the subsidy and to increase the market multiplier effect of the government subsidy. However, subsidy requires large government funds which indicate that this policy instrument is only feasible when applied scarcely for specific technologies only.

The saving results induced by subsidy in the model are probably too moderate since a decrease of the production costs of an advanced option due to an increasing market share, is not included in the model. Also the effect of a subsidy on investment behaviour is not taken into account (a subsidy programme has also effects in the area of information dissemination and image of the option).

7.3.3 Energy taxes

In the Surcharges case, the effects of environmental surcharges on energy prices have been investigated. In households, the order of the additional energy savings by country is completely in line with the price increases due to the surcharges in the countries. The highest energy savings additional to the Reference case are reached by the Netherlands and Switzerland (7% of the Reference energy consumption in response to an average price increase of about 45%). Only limited reductions of 2% to 3% of the Reference energy consumption are reached in Finland (2.8%), United Kingdom (2.2%) and Denmark (1.8%). The energy savings are relatively limited compared to the high price increases due to the surcharges. Apparently the price sensitivity is not very large in households or, in other words, the price elasticity is low, which is realistic. However, the elasticities of the energy demands in the different countries as viewed in response to the surcharges are in some of the models lower than expected due to inflexible specification of options.

In the manufacturing sector, the relative price increases for fossil fuels are sometimes twice as large as for households. The highest average price increase of 94% is found in the Netherlands, due to the low share of electricity in the fuel mix. Spain follows with a 73% increase, and the price increase is much lower in Sweden, around 45%. Although the surcharges cause a large part of the technical potential to be utilised, the percentual increase of savings is not that large: 1.6% for the Netherlands, 0.6% for Spain, and 0.1% for Sweden, expressed as a share of Reference energy consumption.

In the harmonisation case, the end-user prices are modified in such a way that all countries have a similar tax regime (VAT and excise tax). This represents a first step towards liberalised EU energy markets. Since the energy consumption in households is relatively insensitive for price changes, the effects of harmonised taxes in the EU in households is also limited. The energy consumption in Denmark, the Netherlands and Finland is a little higher than in the Reference case, the energy consumption in Switzerland and the United Kingdom is a little lower.

Tax harmonisation has less impact on the prices in the manufacturing sector, because it only affects excise taxes. In the Netherlands and Sweden the average price level even decreases with 1%, and it will only slightly rise in Spain, compared to the Reference case. In the Netherlands the savings thus achieved are a bit less than in the Reference case, while in Spain, some additional energy savings can be achieved in the basic metal industry. In Sweden the effects of tax harmonisation are difficult to assess, due to the limited number of saving options.

In case of a tax harmonisation it is fortunate that taxes have a limited impact on energy consumption. However, it is less fortunate that general energy price and tax policies, as an instrument for energy conservation policy, fail to address most of the barriers for market penetration of energy conservation options. Only the general profitability of all options increases as a result of a tax. Relative competitive advantages of new options, market barriers for new options, bifurcation of options and market saturation are not addressed by this instrument.

Of course, it must be added that changes in the demand for energy services in response to price changes are not taken into account in REDUCE. The demand is exogenous. In the manufacturing sector, even more important price responses as changes of the growth of sectors and products produced, are not included. Price increases as high as those imposed in the Surcharge case would cause structural changes in the manufacturing sector, such as the replacement of complete production processes, and shifts in the types of products manufactured. Although some of these changes may be anticipated and then included in REDUCE as special saving options, they are currently not included. Additional energy savings are also limited because a large part of the technical potential is already utilised in the Reference case. The additional technical potential is in some cases underestimated.

7.3.4 Investment behaviour

The sensitivity of options in REDUCE for policy measures influencing the investment behaviour through general measures, such as raising energy conservation awareness, has been tested for the household sector in the different countries. This was done by increases of the penetration speed factor at sector level. The results seem consistent for the countries but the energy savings additional to the Reference case are generally limited (up to 9% of the Reference energy consumption for the Dutch case). Again, the main reason is that a general increase of awareness of energy conservation fails to address the other barriers for market penetration of energy conservation options such as the profitability of options, relative competitive advantages of new options, market barriers for new options, bifurcation of options and market saturation. A technology specific policy (such as labelling) is much more effective, creating a competitive advantage for new technologies which in the long run have a larger energy saving impact. Moreover, an increasing market share of a new technology can result in decreasing production costs and thus higher profitability.

7.3.5 Combined policy instruments

A sensitivity analysis for the household sector to test the flexibility of the REDUCE model and to view the interaction of two policy instruments (surcharges and enhanced investment behaviour) resulted in 35% energy saving of the baseline. This is equal to 16% reduction of the Reference energy consumption, and is almost the sum of the additional energy savings in the separate cases with respect to the Reference case. It shows that the large Technical energy saving potential as it is known today can be expected to be implemented for a substantial part if a combination of types of stimulating policy instruments is used. Vice versa, the implementation of energy savings is limited when induced by only one type of instrument.

7.3.6 Regulation

Although the most frequently used policy instrument, regulation, was not studied explicitly, it is useful to elaborate on the results in the light of regulatory measures. Clearly regulatory measures are the most often used so far because it seems an effective, less complicated and more direct instrument than those discussed in the report. The present study confirms that it is very difficult to address exactly all the barriers for market penetration of specific energy conservation by financial and behavioural instruments only. Especially in households, where investors are very insensitive to stimuli to change their investment behaviour, regulation is often applied and very successful. In fact, present regulatory policies are implicitly included in the energy saving potential of the year 2020 of the Reference case. These energy savings are corrected for the energy conservation already achieved in the baseyear, but present regulation and other policies will continue to have impact on the implementation of future savings. The Reference energy saving potential in the year 2020 should be interpreted as the energy savings achieved by the present policies without changes.

However, regulatory measures can interfere strongly with existing interests and market competition. This means that the knowledge of the policy maker on the particular matter should be extensive. Furthermore, there is a tendency to develop less rigid regulatory measures which intervene into market behaviour as little as possible.

The use of a comprehensive limit on energy use in newly built dwellings, corrected for house size (the Netherlands Energy Performance Standard EPS) is an example of this trend. The EPS allows the market to decide for itself what the optimal set of options is for achieving this standard. It is important to make the targets for future years increasingly strict in order to keep the process of energy conservation going on in a sufficient pace. Furthermore, the market should be able to anticipate on targets a few years beforehand in order to adapt to them cost-effectively.

In the manufacturing sector, a similar ‘soft’ type of regulation is applied in the Netherlands, the Voluntary Agreements. These agreements are formed between the government and industrial branch organisation or other social groups and leave large degrees of freedom on how to achieve an agreed reduction of energy consumption. Since it is not entirely voluntary to meet certain targets but the result of negotiations, it is sometimes claimed that it is more correct to speak of Negotiated Agreements or Long Term Agreements. However, the effectiveness in the long run of these agreements is sometimes debated and needs further research.

REDUCE is very capable of investigating the cost-effective set of technologies for achieving certain efficiency or energy consumption targets and can support the policy maker with information on realistic target levels by sector and on required measures. The dynamic properties of the model make it very suitable for developing dynamic targets and selecting new technologies on their energy saving on the long term.

Clearly, the results of this study confirm that most energy conservation technologies are available at comparable conditions and investment costs in the different countries, which can be perceived as a favourable result of a more liberalised internal EU market. Nevertheless, one can therefore also see the possibilities of the application of EU standards for harvesting the technical energy conservation potential. Regulation is most effective and has the least side-effects when it is conducted at the highest (EU) level. Specific attention should be paid to institutional structures in the different countries because these structures are essential for the effectiveness of regulatory measures in the countries. Although different types of EU (environmental) standards are presently in place, not all of these affect efficiency and energy consumption.

7.4 Applied methodology

7.4.1 Description

The main objective of the REDUCE model is the evaluation of the effectiveness of economical, financial, institutional, and regulatory measures for improving the rational use of energy in end-use sectors. Not only the technical scope and ranking according to a range of criteria for investments in energy savings is assessed, but also the market dynamics of energy saving options are considered, on the short term (immediate policy actions and implementation) and longer term (strategic policy considerations).

The REDUCE model can be characterised as a bottom-up approach, taking into account all techno-economic aspects of energy conservation options. However, market barriers and consumer behaviour with respect to conservation options are taken into account without using demand- and price-elasticities. Therefore, impacts over time of policy instruments influencing market barriers, consumer behaviour and benefit-cost ratios can be assessed given certain technological and investment conditions and dynamic interactions of different saving technologies and policy instruments.

Obviously, the dynamics of market penetration of conservation options is influenced by a number of diverse, interacting and complex factors. These factors can be divided into three categories, such as properties of saving technologies, dynamic interaction between these technologies, and driving forces for penetration of technologies.

EU wide model application imposes additional requirements on the design of a model. The design has to strike a balance between country specific and more general aspects. Both types of aspects have been represented in REDUCE. In modelling terms: the balance between flexibility (of data requirements and structure) and structure (clear formats and consistent equations) has been taken into account. Furthermore, the current state of the art in software has been used to support the user in using and understanding the model.

7.4.2 Experiences

Based on the experiences in the case studies, the following remarks can be made:

- The energy saving potential as calculated by REDUCE is sensitive for explicit specification of energy saving options since the market share in the baseyear is an important factor for determining the market share in years after. Also, explicit specification of submarkets with different techno-economic characteristics (for instance operation hours) is necessary to obtain reliable results.
- The long term results are not heavily influenced by differences in the general value of the penetration speed factor α due to slow replacement (long lifetime) and heavy competition of technologies. Technology specific differences in α are important but data are hardly available.
- Production costs of new, advanced technologies should not be constant but allowed to decrease in time.
- Conservation options that concern fuel switch from electricity to a primary fuel are underestimated with respect to their saving potential since the conversion losses for electricity are not explicitly taken into account.

At the present stage of data specification, the Reference case does not reflect an autonomous development without present or additional policy measures, partly because present conservation policies are implicitly included in the model specification. More importantly, barriers for energy conservation options are specified for the sector as a whole, not taking into account technology specific barriers or competitive advantages other than the market stage and profitability.

To avoid misunderstanding, REDUCE does not reflect price responses in the form of changes in the demand for energy services and changes in the growth of sectors and the produced products. These are exogenous in the model.

7.4.3 Recommendations

The model results provide valuable information on the market penetration of energy saving technologies in sectors and countries. However, it is recommended to conduct a model validation by simulation on the basis of historical data in order to further assess the strengths and weaknesses of the approach.

The specification of options needs to be more extended for certain sectors and countries. The comparability of results can be improved by data harmonisation, but also by comparison with the international conservation database MURE. Also, the specification of baselines, and categorisation of products and options must be further harmonised. A next step would be a larger coverage of sectors and countries.

Inclusion and comparison of energy level and efficiency indicators for energy services would largely improve the transparency of the results. Investment costs of new, advanced technologies should be made variable in time in order to allow for improvement of the production costs, for instance through a ‘learning curve’ related to the market share of the particular option. Finally, a methodology to collect empirical data on competitive advantages of specific energy conservation technologies would improve the model results. An attempt during Phase I by a survey conducted in the manufacturing sector in the countries did not provide reliable information due to a low response.

More detailed recommendations for model improvement can be found in Annex F Peer review of the REDUCE model.

7.5 Policy recommendations

R&D policies

R&D policies should particularly pay attention to the energy services with a relatively small technical energy conservation potential available at the moment, in particular those for which the demand is projected to grow. It concerns energy services such as drying, other household appliances (audio-video, hobby, personal care, sleeping etc.) and washing, where the technical potential needs to be enlarged in order to reduce the level of energy consumption of households on the long term.

For the manufacturing sector, the subsectors Metal products and Building materials are the first ones to consider, because the current technical saving potential appears to be limited and energy demand in these sectors is expected to grow. The chemical industry is an example of an energy intensive subsector where the additional saving potential is limited, because many conservation measures have already been taken in the past. Although some of these saving measures do affect feedstocks, the fact that non-energetic use of energy carriers comprises a large share of the industrial energy consumption in some countries, requires more consideration in the future. Especially in this area, research on complex integrated process improvements, substitution of materials, the possibilities for recycling, utilisation of residuals, waste and biomass in industrial processes deserve further R&D attention.

Overcoming the present market barriers for introduction of new technologies are crucial for long term energy efficiency improvements. R&D policies should carefully check on existing market barriers related to the new technologies themselves to make them competitive with presently used technologies. Delay of market introduction of the Best Available Technologies (BAT) will give chances to moderately efficient technologies which will subsequently hamper the introduction of BAT by increasing the marginal costs of energy savings on the long term.

Energy conservation policies
Energy conservation policy should close the gap between realised energy savings and technically available potential, prioritising those energy services and manufacturing branches which require a large share of the energy consumption. In households, for hot water, cooking and cooling a large gap between technical potential and realisation is calculated. Furthermore, heating is important since it covers a large share. This ‘efficiency gap’ is smaller in the manufacturing sector where the investors are more rational. Therefore R&D policies are more important for this sector, to stimulate the development of new technologies that increase the technically feasible savings.

The case studies indicate that, in particular in households, the availability of profitable saving technologies is not directly a barrier for energy conservation. Competitive disadvantages of new entrants and bifurcation effects due to low replacement rates, strong competition and decreasing effectiveness of technologies after substantial savings are much more important. Therefore, the savings induced by general financial and behavioural instruments are limited because relative competitive advantages are not addressed. Hence, the most impact can be expected from:
- combinations of instruments addressing different barriers simultaneously,
- policies focusing on specific technologies,
- regulation because it overrules existing barriers.

The present study includes a case for households in the Netherlands which indicates that the application of a combination of surcharges and behavioural measures results in additional energy savings of almost 20%. This is almost the sum of the additional energy savings induced by the single application of these instruments. It confirms that different policy instruments, by addressing different barriers, utilise different ‘parts’ of the conservation potential and can be applied effectively at the same time.

A number of technology specific approaches exists to overcome barriers for market introduction. One example is technology procurement, programmes in which the government bring suppliers and customers together to improve the specific technology according to consumer requirements and, for instance guarantees a minimum demand to induce economies of scale. For instance in Sweden, procurement programmes have been successfully executed for different end-uses such as refrigeration, clothes washing, lighting and space heating. Another example, applied in the EU, is labelling of appliances, providing technology specific information to consumers. Subsidies of new advanced technologies to ease market introduction are effective in the long run, if applied at certain conditions.

Regulatory measures are often applied in the households sector, for example building codes. These are necessary to overcome the bifurcation related barriers, which are playing a large role in the building sector. However, the side-effect of forceful regulatory measures is that they can interfere with market competition. Especially in the manufacturing sector, regulatory measures (and taxes) are only used scarcely for reasons of international competitiveness. However, on EU level measures such as standards can be and are applied with a minimum of counterproductive side-effects. Another, softer and therefore less intervening form of regulation is Voluntary Agreements which leave large degrees of freedom for the branches or companies to decide how an agreed energy efficiency level can be achieved.

In all cases of regulation, a large expertise on energy saving technologies is required to design the standards or targets and periodic updates are necessary to keep the conservation process going.

National and EU conservation policy should complement each other because only a proper variety of energy conservation policy instruments can reach substantial reductions of energy consumption on the mid and long term.

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The following reports were also made in the framework of this project, and can be obtained from ECN or the authors.

ECN and ACE — *Present Situation: Review Of Energy Conservation Options, Studies And Instruments*
Ir. Martine Uyterlinde
Netherlands Energy Research Foundation ECN
ECN Policy Studies
P.O. Box 1
1755 ZG Petten
The Netherlands

Dr. Joanne Wade
Association for the Conservation of Energy ACE
Westgate House
Prebend Street
London N1 8PT
United Kingdom

VTT — *Evaluation Of The Role Of Liberalisation*
Prof. Seppo Kaerkkaeinen
VTT Energy
P.O. Box 1606
Tekniikantie 4 C
FIN-02044 Espoo
Finland

SEO — *Penetration Of Energy Conservation: A Survey In Six European Countries*
Prof. Jan Willem Velthuijsen
Foundation for Economic Research of the University of Amsterdam SEO
Roeterstr. 11
1018 WB Amsterdam
The Netherlands

Ecoplan — *Externalities And Surcharges*
Dr. Felix Walter
ECOPLAN
Monbijoustr. 26
CH-3011 Berne
Switzerland

LiU — *Peer Review Of The Reduce Model*
Dr. Mats Söderström
University of Linköping
Department of Mechanical Engineering
S-581 83 Linköping
Sweden