EUSUSTEL
European Sustainable Electricity

Comprehensive Analysis of Future European Demand
and Generation of European Electricity and its Security of Supply

WP-2: Anticipation of future energy demand
Final Report

Ugo Farinelli, Manuela Gusmerotti (AIEE, Roma)
Leander Cosijns, William D'haeseleer (KU Leuven)
Lazaros Exarchakos, Adam Hawkes, Matthew Leach (ICEPT, Imperial College, London)

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Introduction

1.1 Mandate of WP-2

The mandate of Work-package 2, “Anticipating future energy demand” is specified in the Work Programme as follows:

“This work-package deals with the demand side for electricity. The demand for electricity is, however, not a-priori easy to ‘predict’ independently. The demand of electricity depends on the demand for energy services, which in turn depends on the anticipated economic growth (and the structure of that economy). This WP is therefore subdivided into three sub-WPs:

“2.1 Economic evolution of the European Union (as part of world-wide economy), primary energy provision and ‘projected’ fuel prices;

2.2 Evolution of demand for energy services and the influence on electricity demand;

2.3 Rational use of electricity, energy efficiency of end-use technologies and demand side management.

“On the future demand for electricity*, a careful analysis is needed. Before considering the electricity supply side it is necessary to evaluate possible electricity consumption evolutions in the future. In fact, one can only guess the need for energy* services*. The required electricity demand follows from the things such as the efficiency and the cost of end-use technologies, exchange between energy carriers (depending on the price of electricity versus other energy carriers), etc. Based on a global comparison of the total cost of a saved kWh versus a supplied one (given that that can really be determined), it should be possible to appreciate whether electricity reductions should be exogenously encouraged or whether the market should be allowed to determine the growth of electricity demand. The issue is not trivial and is characterised by a fierce debate between the ‘conservationists’ (Lovins, Geller, et al) and the ‘classical economists’ (Joskow, Sutherland); furthermore, shifts between energy carriers may lead to less desirable effects, for environment, flexibility of use, etc.*

“Given that encouraging stimuli are desirable to reduce the demand for electricity, it is important to figure out precisely what is meant by the so-called energy-saving potentials. Top-down considerations will have to be confronted with bottom-up approaches (based on end-use technologies) to determine the technical, economic and market potentials. Furthermore, it is important to find out appropriate measures (that do not distort the markets and therefore do not lead to undesirable feedback effects) that should be used to manage a justified evolution of the electricity demand.”

A discussion among the involved partners and the coordinator of EUSUSTEL of the results expected from WP-2 brought to a slight re-formulation of the objectives of WP-2 as follows:

1. Supply input data on: demography; economic evolution (GDP); price of primary fuel; other indicators to the Work-package 5, “Most optimal solution for electricity provision” and in particular to the Subtask WP 5.3 “Performing and interpretation of four (contrasting) scenarios with one or two of the most appropriate models (with ‘improved’ input data)”
2. Evaluate trends of demand for energy services and electricity demand (mostly by a top-down, macroeconomic approach)
3. Evaluate the effects of energy efficiency policies and DSM measures (particularly by using bottom-up models)

In the course of this discussion, the role of top-down and bottom-up models was further clarified as will appear in Section 1.5.

In consideration of the time and resources available for this Work-package, it was decided that recourse should be made as much as possible to the results already available from other projects modelling the energy and electricity scenarios for the European Union, as will be better specified in Section 1.4.

1.2 Time horizons

The reference time horizon for this study is 2030; however, taking into account the long life-times of many of the interventions in the energy field (e.g. the evolution of the building stock) it seems useful to evaluate the evolution of some trends over a more extended period of time. For instance, many investments in the energy field done from now until 2030 will be operative for many years after that date, and their value in 2030 can be assessed only in the light of their role in subsequent years. For this reason, as well as for the possibility of assessing the perspective role of technologies that still require a long time for availability and maturation, such as nuclear fusion, some energy scenarios extend to even longer periods: such is the case for instance for the IIASA scenario to 2100, as well as the VLEEM (Very Long-Term Energy-Environment Model) based on the "back-casting" approach, also extending to 2100 **/VLEEM Consortium 2005/**.

Therefore, a consistent effort has been made to extend the input data at least until 2050. It will be kept in mind, however, that the period beyond 2030 is subject to much greater uncertainties than the period from now to 2030.

1.3 Space boundaries

The geographical reference is EU-25, i.e. the 25 Member countries of the European Union after the enlargement of 2004. Although two of the models the results of which will be used (PRIMES and WEO, see 1.4) refer to this same configuration, some efforts have been done in order to use results from other scenarios, in particular the US-DoE-EIA scenario, which has among its region Western Europe and Eastern Europe (both extending beyond the EU Member countries), and the White and Green calculations utilised in the last part of this work, which were relative to the former 15-country configuration of the EU plus a few "associated" countries, or EU-15+, as will be better specified in the following section.

1.4 Scenarios and sources

The main scenario studies the results of which have been used for the present analysis have been:

- EU-DG TREN European energy and transport trends to 2030 (PRIMES) **/Mantzos et al. 2003/**
- IEA World Energy Outlook 2004 (WEO) **/IEA 2004/**
- US-DoE/Energy Information Agency, International Energy Outlook (2004 and 2005) (DoE)
- EU-DG TREN White and Green Project results 2005

These scenarios have been used both as concerns the choice of the exogenous input data (see Section 1.5) and for the results of their modelling, particularly as concerns the anticipation of energy demand (see Sections 4 and 5).

Data and insights have also been derived from the following sources:

- EU- DG RES, WETO-2030 World Energy Technology Outlook to 2030; WETO 2050
- EUROSTAT
- UN-Habitat **/UN-HABITAT/**
- IIASA **/IIASA (2003-2004)/**
- World Energy Council (WEC)

We will now briefly review the four scenarios used.

The main features of these scenarios are summarized in Table 1.1.

Table 1.1 – Comparison of models

	EU-DG TREN European energy and transport trends to 2030 (PRIMES)	**IEA World Energy Outlook 2004 (WEO)**	**US-DoE/Energy Information Agency, International Energy Outlook 2005**	**EU-DG TREN White and Green Projects results 2005**
Geographical Coverage	EU-25	EU-25	EU-25	EU-15+
Objective	The scope is to explore possible energy and transport developments over the next three decades on the basis of an in depth modelling analysis of the European energy system and its driving forces. The study addresses in particular transport developments and their impact on energy demand.	The primary objective is to identify and quantify the key factors that are likely to affect energy supply and demand. The central projection provide a baseline vision of how energy markets might evolve if governments did nothing more or less than they have already committed themselves to do	The projections in *IEO2005* are not statements of what will happen, but what might happen given the specific assumptions and methodologies used. These projections provide an objective, policy-neutral reference case that can be used to analyze international energy markets.	The "White and Green" project aims at identifying the best characteristics of a market-based mechanism to increase the efficiency of final energy utilisation and analyse the effect of the various choices, using the experience obtained with instruments that are already implemented and assessment of innovative policies and measures, which have been proposed.
Utilized Models	The analysis was on the examination of world market trends and resulting international fuel price trajectories was performed using the POLES model, which is a global model for the world energy system. The results and conclusions of the projection of energy supply and demand in the European Union are presented here in the context of the "Long Range Energy Modelling" framework contract. They are based on quantitative analysis, with the use of the PRIMES and ACE mathematical models. The Baseline scenario of EU-15 was developed with the use of the PRIMES model, that is a partial equilibrium model for the European	The IEA's World Energy Model – a large-scale mathematical model that has been developed over several years – is the principal tool used to generate detailed sector-by-sector and region-by-region WEO projections. The World Energy Model (WEM) is a mathematical model made up of five main modules: *final energy demand; power generation; refinery and other transformation; fossil fuel supply and* CO_2 *emissions.*	The projections of world energy consumption appearing in this year's *International Energy Outlook* (*IEO*) are based on the Energy Information Administration's (EIA's) international energy modelling tool, System for the Analysis of Global Energy markets (SAGE). SAGE is an integrated set of regional models that provide a technology-rich basis for estimating regional energy consumption. Projections of world oil prices over the forecast horizon are provided to SAGE from EIA's International Energy Module, which is a sub module of the National Energy Modelling System (NEMS).	The chosen methodology was the usage of the WEU MARKAL model for analysing the response of this energy system to the following policy instruments: "White Certificates", "Green Certificates", and "Carbon Dioxide (CO2) emissions trading". MARKAL is a dynamic, multi-period, linear programming bottom-up model of a generalized energy system, in which both the energy supply and demand side are depicted, including energy sources, conversion technologies, energy carriers and demand technologies and sectors. MARKAL computes a partial equilibrium for energy markets. Partial because MARKAL deals with one part of the economy: the energy sector.

	Union energy system The acceding countries have been modelled with the ACE model that is less sophisticated than PRIMES.			

1.4.1 EU-DG TREN European energy and transport trends to 2030 (PRIMES)

This report **/Mantzos et al. 2003/** reviews the key issues arising from an assessment of likely economic, energy, transport and CO_2 emission trends over the period to 2030 for current EU Member States, and EU candidate and neighbouring countries.

Countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, The Netherlands, Portugal, Spain, Sweden, United Kingdom, Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia (the last ten countries are called for brevity reasons Acceding Countries-ACC).

Main Assumptions*:*

World energy prices

In the first version of this scenario (2003), assuming the continuation of current world energy market structure and taking a conventional view on fossil fuel reserves, world energy prices develop moderately as no supply constraint are likely to be experienced over the next 30 years under Baseline conditions:

- Oil prices decline from their high 2000 levels over the next few years, but they then gradually increase to reach a level in 2030 no higher than that in 2000 (and 1990). The long-term increase in oil prices results from the increased dependence upon Gulf region output and the higher production costs for unconventional oil supplies.
- Gas prices broadly follow oil prices as these fuels compete for many end uses. Gas prices are influenced by two contrasting trends: the cleanliness and high use efficiency cause gas prices to rise faster than for oil; but factors such as more intensive gas-to-gas competition and greater integration of regional gas markets (with more LNG) exert downward pressure on gas prices. Gas import prices in Europe stay well below the oil prices.
- Coal prices remain flat and well below those of oil and gas especially in the long run.

Table 1.2
Energy prices in PRIMES

Average border prices in the EU							***Annual Change***				
	Unit:	**1990**	**2000**	**2010**	**2020**	**2030**	***'90-'00***	***'00-'10***	***'10-'20***	***'20-'30***	***Source:***
Crude oil	***$00/b***	**27.9**	**28.0**	**20.1**	**23.8**	**27.9**	***0.0%***	***-3.3%***	***1.7%***	***1.6%***	***POLES model***
	$00/GJ	4.9	5.0	3.6	4.2	4.9					
Natural gas	*$00/b*	15.6	15.5	16.8	20.6	23.3	*-0.1%*	*0.8%*	*2.1%*	*1.2%*	*POLES model*
	$00/GJ	2.8	2.7	3.0	3.6	4.1					
Hard coal	*$00/b*	13.1	7.4	7.2	7.0	7.0	*-5.6%*	*-0.3%*	*-0.3%*	*0.0%*	*POLES model*
	$00/GJ	2.3	1.3	1.3	1.2	1.2					

Subsequent evaluation of the recent price trends have brought to reconsidering these values in terms of much higher energy prices that have been introduced in the most recent scenarios run with the PRIMES model [1]. These values will be presented in Section 2.4.

[1] P. Capros, private communication, October 2005

Baseline Scenario:

The Baseline scenario is a projection of energy supply and demand in the European Union for the short, medium and long term (up to 2030). It was developed with the use of the PRIMES model.

The definition of the Baseline scenario is important because it constitutes the basis for further policy analysis in addition to its function as a projection on the basis of current trends and policies. The Baseline scenario includes existing trends and effects of policies in place and of those in the process of being implemented by the end of 2001, whereas tax rates reflect the situation of July 2002 in the EU Member States. For analytical reasons the Baseline scenario excludes all additional policies and measures that aim at further reduction of CO_2 emissions to comply with the Kyoto emission commitments.

Population: EU-25 population is projected to remain rather stable, peaking in 2020 at some 462 million but declining thereafter to reach 458 million by 2030. EU-15 population is assumed to rise modestly between 2000 and 2010, by some 9 million people (at a growth rate of 0.24% pa). The divergence in population growth rates among individual Member States varies from +0.03% pa for Italy to +0.98% pa for Ireland. A further increase of the EU population by some 2.62 million people is projected between 2010 and 2020 (0.07%). Only Ireland, Luxembourg and The Netherlands show growth rates of more than 0.3% pa in the period while Germany, Italy and Spain experience small declines in population over this period. Beyond 2020 the EU population is assumed to decline slightly (-0.04% pa) to reach 389 million in 2030. However, the population in Belgium, France, Ireland, Luxembourg, The Netherlands, Portugal, Sweden and the United Kingdom is projected to experience a slight increase. The population in ACC is projected by 2030 to decline by some 5.6 million people or 7.5% of the population in 2000. Population in ACC accounts by 2030 for 15% of EU-25 population compared to 16.5% in 2000.

Household size: rising life expectancy, combined with declining birth rates and changes in societal and economic conditions, are the main drivers for a significant decline in average household size (i.e. number of inhabitants per household). Following UN projections **/UN-HABITAT/**, household size in the EU-15 is assumed to decrease further to reach 2.23 persons per household in 2010 (ranging between 2.84 for Ireland and 1.99 for Sweden) and 1.97 persons per household in 2030 (with Austria, Belgium, Greece, Ireland, Luxembourg, Portugal and Spain still having more than 2 persons per household in that year). The corresponding decline in ACC is less pronounced than in the EU-15 (-0.52% pa, from 2.66 persons per household in 2000 to 2.27 persons in 2030). Average household size in EU-25 amounts to 2.0 persons per household in 2030 compared to 2.44 in 2000, with the projected decline giving rise to significant growth in the number of households (+0.7% pa in 2000-2030) despite the rather stable evolution of population.

Number of households: despite the lack of population increase in the period to 2030, the declining size of the average EU household will lead to a significant increase in the number of households. Thus, between 2000 and 2030, the number of households is projected to increase by nearly 41.8 million, whereas the population increases by just 5.3 million. This trend, together with rising household incomes, is likely to prove the major factor behind a significant increase in the number of appliances and in the total floor area that will have to be heated and cooled.

Gross Domestic Product: the economic outlook of EU-25 is dominated by the evolution of the current EU economy. This is because the contribution of acceding countries, despite their much faster growth over the projection period (+3.5% pa in 2000-2030 compared to +2.3% pa in EU-15), remains rather limited in terms of overall EU-25 GDP. The GDP projections for EU-25 Member States are based on macroeconomic forecasts from WEFA (now DRI-WEFA), adjusted to reflect recent developments, for the horizon to 2030. It is derived from exogenous assumptions about the evolution of technological progress associated with production factors, changes in the global economic and environment context, and the continuation of the current pattern of public finance policy. Economic growth is not uniformly distributed across countries, but the convergence of Member States' economies (including ACC) is assumed to continue over the projection period.

Furthermore, the integration of ACC into the European Union is assumed to generate accelerated growth for their economies. However, the convergence of ACC economies towards EU-15 levels remains far from complete even by 2030.

Gross Value Added: the Baseline assumption for economic growth of EU-15 Member States and acceding countries also reflect the long established trend of structural changes in developed economies, away from primary and secondary sectors and towards services. Services value added increases over the projection period at rates above average, implying a continuous increase of its share in total economic activity (71.1% in 2030 compared to 68.3% in 2000). This increase in market share of services occurs in correspondence to the decrease of the shares of all other sectors of the economy. The market share of industrial activity, which grows at rates slightly below average, declines by 1.7% points over the projection period. The lowest economic growth is projected for agriculture (+1.0% pa in 2000-2030), while the energy branch and construction sectors are also projected to exhibit a significant decline in terms of market shares, growing by 1.5% pa and 1.9% pa, respectively, to 2030. Despite the significantly faster growth of services, the ACC's economies are projected to remain more reliant on industry and agriculture than the EU-15 to 2030. This clearly reflects the existing structural differences of their economies in 2000, differences that are not projected to be fully eliminated by 2030.

Table 1.3
EU-25 demographic and economic parameters according to PRIMES

Geographic Area:	***EU-25***						***Annual Change***			
	Unit:	**1990**	**2000**	**2010**	**2020**	**2030**	***'90-'00***	***'00-'10***	***'10-'20***	***'20-'30***
Population	***million***	**441.1**	**453.4**	**461.2**	**462.1**	**458.2**	***0.3%***	***0.2%***	***0.0%***	***-0.1%***
Average households size	*persons*	2.6	2.4	2.3	2.1	2,0	*-0.8%*	*-0.4%*	*-0.9%*	*-0.5%*
Number of households	*million*	167	185.8	204.2	217.9	227.6	*1.1%*	*0.9%*	*0.7%*	*0.4%*
GDP	***G€'00***	**7315**	**8939**	**11433**	**14462**	**18020**	***2.0%***	***2.5%***	***2.4%***	***2.2%***
Households expenditure	*G€'00*	4256	5161	6580	8278	10196	*1.9%*	*2.5%*	*2.3%*	*2.1%*
Gross Value Added	*G€'00*	6833	8351	10793	13730	17165	*2.0%*	*2.6%*	*2.4%*	*2.3%*

1.4.2 IEA World Energy Outlook 2004 (WEO)

This report **/IEA 2004/** has adopted a scenario approach to analyse the possible evolution of energy markets to 2030. The primary objective is to identify and quantify the key factors that are likely to affect energy supply and demand. The central projections are derived from a Reference Scenario. The IEA's Worlds Energy Model – a large scale mathematical model that has been developed over several years – is the principle tool used to generate detailed sector–by–sector and region-by-region projection for the scenario.

Countries: the European Union: Austria, Belgium, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, the Slovak republic, Slovenia, Spain, Sweden and the United Kingdom.

World energy prices

Average end-user prices for oil, gas and coal are derived from assumed price trends on wholesale or bulk markets. Tax rates are assumed to remain unchanged over the projection period. Final electricity prices are based on marginal power-generation costs. The assumed price paths should not be interpreted as forecasts. Rather, they reflect IEA's judgement of the prices that will be needed to encourage sufficient investment in supply to meet projected demand over the *Outlook* period. Although the price paths follow smooth trends, this should not be taken as a prediction of stable energy markets. In fact, we are likely to see even more volatile prices in the future. However, IEA does not expect large divergences from the assumed price paths, such as the recent surge in oil prices, to be sustained for long periods in the Reference Scenario.

The average IEA crude oil price, a proxy for international prices, is assumed in the Reference Scenario to fall back from current highs to $22 (in real year-2000 dollars) in 2006. It is assumed to remain flat until 2010,and then to begin to climb in a more-or-less linear way to $29 in 2030.

The uncertainty surrounding the near-term outlook for oil prices is unusually pronounced at present, complicating the analysis of overall energy-market trends. The Reference Scenario assumes that the prices reached in mid-2004 are unsustainable and the market fundamentals will drive them down in the next two years. In June and September 2004, OPEC agreed to increase its production, move which should have bolstered supply and replenish stocks, driving prices lower. But a continuing surge in demand and under-investment in production capacity, combined with a large and sustained supply disruption still resulted in a new price hike.

The assumed rising trend in real prices after 2010 reflects an expected increase in marginal production costs outside OPEC (where marginal cost of production in mature basins is rising) and an increase in market share of a small number of producers with higher unit costs). The increasing dependence of oil-importing regions on a small number of OPEC producers and Russia will increase those countries' market dominance and their ability to impose higher prices(according to higher public spending on welfare programmes and infrastructure). Yet it is in their interest to avoid prices rising so much that they depress global demand and encourage production of higher-cost oil in other countries. On balance, the Reference Scenario remains of the view that the combination of these factors points to a moderate increase in prices in the longer term.

Unlike for oil, natural gas markets are highly regionalized , because it is expensive to transport gas over long distances. Prices often diverge substantially across and within regions. Nevertheless, regional prices usually move broadly in parallel with each other because of their link to the international prices of oil, which reflects the keen competition between gas and oil products. Rising supply costs also contribute to higher prices from the end of the current decade in North America and Europe. Increased short-term trading in liquefied natural gas (LNG), which permits arbitrage among regional markets, will cause regional prices to converge to some degree over the projection period. In the Reference Scenario, gas prices are assumed to fall back in all regions in 2006, and then to rise steadily from 2010 in line with oil prices.

International steam coal prices have risen steadily in recent years, from $33.5 per tonne in 2000 to $38.5 in 2003 (in year-2000 dollars). Higher gas prices have encouraged some power stations and industrial end users to switch to coal; however, recently, serious production problems in several countries have added to the upward pressure on coal prices. By mid-2004, spot steam-coal prices in nominal terms have surged to over $70 per tonne and coking coal to over $100. Market fundamentals are expected to drive coal prices back down by 2006; OECD steam coal import prices are assumed to average $40 per tonne until 2010. Thereafter, prices are assumed to increase slowly and in a linear fashion, reaching $44/tonne in 2030.

Table 1.4
Energy prices in WEO

Fossil-Fuel Price Assumption *(year-2000 dollars)*	***2003*****	***2010***	***2020***	***2030***
IEA crude oil imports ($/barrell)	27	22	26	29
Natural gas ($/Mbtu):				
US imports	5.3	3.8	4.2	4.7
European imports	3.4	3.3	3.8	4.3
Japan LNG imports	4.6	3.9	4.4	4.8
OECD steam coal imports ($/tonne)	38	40	42	44

*** Historical data*

Population: population growth-rate assumptions are drawn from the most recent United Nations population projections contained in *World Population Prospects: the 2002 Revision* **/UN-HABITAT/**. European population is assumed to remain broadly unchanged over the projection period, rising very gradually through to the mid-2010s and falling back very slowly thereafter

Gross Domestic Product: economic growth in the European Union remains sluggish in major countries, though the pace of recovery has picked up in some countries, notably Spain and the United Kingdom. Overall, EU's GDP grew by only 1.1% in 2003. The economies of the main euro-zone countries – France, Germany and Italy – continue to lag. Growth is expected to average over 2% in 2004 and above 2.6% in 2005. Over the period 2002-2010, growth is assumed to average 2.3%. It then slows to 2.1% from 2010 to 2020 and to 1.7% from 2020 to 2030. The differences in growth rates among countries are expected to shrink with the macroeconomic convergence that should result from economic and monetary integration.

Other assumptions*:* unemployment remains stubbornly high, averaging nearly 9% across the region in August 2004, and consumer demand is weak. A sharp appreciation in the euro against most leading currencies has depressed exports and undermined industrial production but it has also shielded European consumers from some of the pain of high dollar-denominated oil prices.

Table 1.5
EU-25 Demographic and Economic Parameters according to WEO

Geographic Area	*EU-25*								*Annual Change*			
	Unit	***2000***	***2002***	***2010***	***2015***	***2020***	***2025***	***2030***	***00-'02***	***02-'10***	***10-'20***	***20-'30***
Population	***Million***	453	456	460	460	460	457	455	*0.3%*	*0.1%*	*0.0%*	*-0.1%*
GDP	***Geuro '00***	8939	9373	11243	12474	13840	15356	17038	*2.4%*	*2.3%*	*2.1%*	*1.7%*

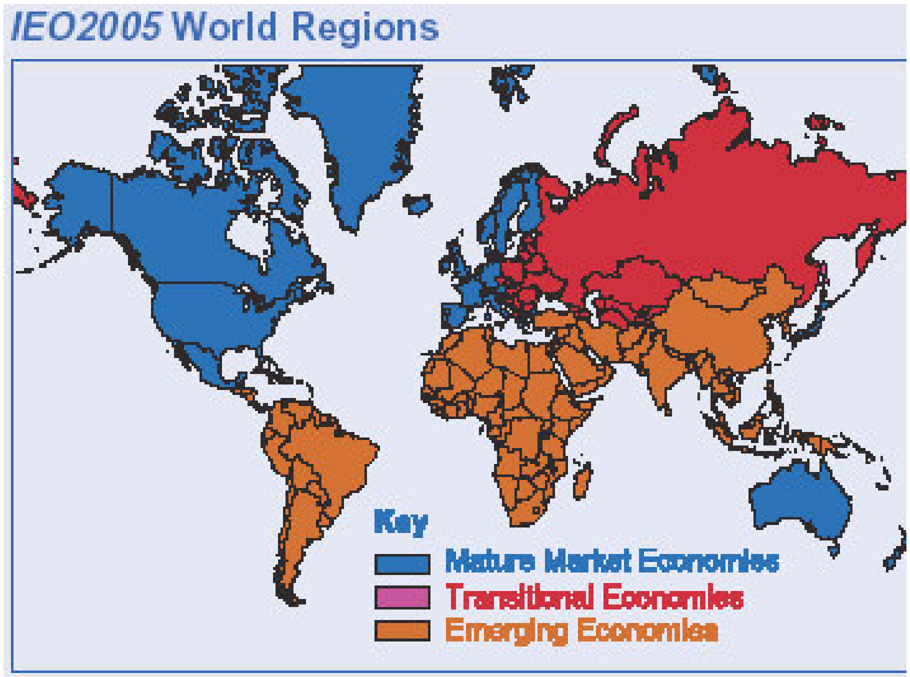
1.4.3 US-DoE/Energy Information Agency, International Energy Outlook (2004 and 2005) (DoE)

The projections in **/EIA 2005/** are not statements of what will happen, but what might happen given the specific assumptions and methodologies used. These projections provide an objective, policy-neutral reference case that can be used to analyse international energy markets. As a policy-neutral data and analysis organization, EIA does not propose, advocate, or speculate on future legislative and regulatory changes. The projections are based on U.S. and foreign government laws effective as of March 1, 2005. Assuming fixed laws, even knowing that changes will occur, will naturally result in projections that differ from the final data.

Models are abstractions of energy production and consumption activities, regulatory activities, and producer and consumer behaviour. The forecasts are highly dependent on the data, analytical methodologies, model structures, and specific assumptions used in their development. Trends depicted in the analysis are indicative of tendencies in the real world rather than representations of specific real-world outcomes. Even where trends are stable and well understood, the projections are subject to uncertainty. Many events that shape energy markets are random and cannot be anticipated, and assumptions concerning future technology characteristics, demographics, and resource availability cannot be known with certainty.

Countries: IEO 2005 uses country grouping designation based on relative levels of economic development: The three major grouping (or "regions") used in this report are the mature market economies, transitional economies and emerging economies. The market mature economies include nations whose energy markets are generally well-established, and whose industrial sectors have trended away from more energy -intensive manufacturing industries toward less energy-intensive services industries. As shown in the map below , the mature market economies include the countries of North America (the United States, Canada, and Mexico), Western Europe, and "mature Market" Asia (Japan, Australia, and New Zealand). Western Europe includes Austria, Belgium, Denmark, Finland, France, Germany Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom. Eastern Europe is part of the transition economies, and includes Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Serbia and Montenegro, Slovakia and Slovenia.

Figure 1.1
Area subdivision in DoE model



Main Assumptions:
World energy prices Three distinct world oil price scenarios are represented in *IEO2005*, reaching \$21, \$35, and \$48 per barrel in 2025, respectively, in the low world oil price, reference, and high world oil price cases in 2003 dollars. Although the *IEO* typically uses the same reference case as the *Annual Energy Outlook*, *IEO2005* has adopted the October futures case from the *Annual Energy Outlook 2005* (*AEO2005*) as its reference case for the United States. The October futures case, which has an assumption of higher world oil prices than in the *AEO2005* reference case, now appears to be a more likely projection. The low world oil price case reflects a future market where oil production becomes more competitive and plentiful. The high price case, in contrast, assumes that world oil prices will remain close to current levels for the foreseeable future.

Table 1.6
Energy prices in DoE

World Oil Price Projections						***Annual Change***	
	Unit:	**2010**	**2015**	**2020**	**2025**	***'10-'20***	***'20-'25***
Crude Oil_Reference Case	***$ 2003/b***	**31.00**	**32.26**	**33.57**	**35.00**	*0.8%*	*0.8%*
Crude Oil_Low Price Case	*$ 2003/b*	21.00	21.00	21.00	21.00	*0.0%*	*0.0%*
Crude Oil_High Price Case	*$ 2003/b*	36.50	40.00	45.00	48.00	*2.1%*	*2.4%*

Baseline Scenario:

In the International Energy Outlook 2005 reference case, world marketed energy consumption is projected to increase on average by 2.0% per year over the 23-year forecast horizon from 2002 to 2025 – slightly lower than the 2.2% average annual growth rate from 1970 to 2002.

Worldwide, total energy use is projected to grow from 10,382 Mtoe in 2002 to 13,936 Mtoe in 2015 and .16,254 Mtoe.in 2025.

Population: In the mature market economies and in the EE transitional economies, population growth generally is slow or negative over the forecast.

Gross Domestic Product: Economic growth is among the most important factors to be considered in projecting changes in the world's future energy consumption. In the *IEO2005* forecast, assumptions about regional economic growth—measured in terms of gross domestic product (GDP), in real 2000 U.S. dollars at purchasing power parity rates— underlie the projections of regional energy demand. Over the 2002 to 2025 period, Western Europe's GDP is projected to grow by 2.0 percent per year in the reference case. Over the medium to long term there are structural impediments to economic growth in many Western European countries, related to the region's labour markets, product markets, and costly social welfare systems. Reforms to improve the competitiveness of European labour and product markets could yield significant dividends in terms of increases in regional output. An average annual expansion of 4.1 percent per year is projected for Eastern Europe's GDP over the 2002 to 2025 period. The accession of 10 Eastern European (EE) countries to membership in the European Union in May 2004 (Poland, Czech Republic, Slovakia, Hungary, Estonia, Latvia, Lithuania, Slovenia, Malta, and Cyprus) is expected to boost consumer confidence and economic activity in the medium to long term. Membership in the European Union is expected to result in more foreign direct investment, bolstering domestic investment and growth.

Table 1.7
Western and Eastern Europe: Demographic and Economic Parameters according to DoE

Geographic Area	***Western Europe***								***Annual Change***			
	Unit:	**1990**	**2001**	**2002**	**2010**	**2015**	**2020**	**2025**	***'90-'01***	***02-'10***	***'10-'20***	***'20-'25***
Population	***million***	376	391	392	396	397	397	397	*0.4%*	*0.1%*	*0.0%*	*0.0%*
GDP_Reference	***G$'00***	7246	9314	9416	11044	12255	13563	14958	*2.3%*	*2.0%*	*2.1%*	*2.0%*
Geographic Area	***Eastern Europe***											
Population	***million***	122	121	121	119	118	117	115	*-0.1%*	*-0.2%*	*-0.2%*	*-0.3%*
GDP_Reference	***G$'00***	914	1040	1068	1527	1863	2253	2702	*1.2%*	*4.6%*	*4.0%*	*3.7%*

Energy intensity: Another major source of uncertainty surrounding long-term forecasts is the relationship of energy use to GDP—or energy intensity—over time. Economic growth and energy demand are linked, but the strength of that link varies among regions over time. In the mature market economies, history shows the link to be a relatively weak one, with energy demand lagging behind economic growth. The historical behaviour of energy intensity in the EE is problematic. Since World War II, the EE economies have had higher levels of energy intensity than either the mature market or emerging economies. Over the forecast horizon, energy intensity in the EE region is expected to continue to decline but still remain higher than in any other region of the world.

Alternative growth rate: to account for the uncertainties associated with economic growth trends, *IEO2005* includes a high economic growth case and a low economic growth case in addition to the reference case. The reference case projections are based on a set of regional assumptions about economic growth paths—measured by GDP—and energy elasticity (the relationship between changes in energy consumption and changes in GDP). The two alternative growth cases are based on alternative assumptions about possible economic growth paths; assumptions about the elasticity of energy demand are held constant, at reference case values. For the high and low economic growth cases, different assumptions are made about the range of possible economic growth rates among the industrial (Western Europe) and transitional Eastern Europe. For the mature market economies, 0.5 percentage point is added to the reference case GDP growth rates for the high economic growth case and 0.5 percentage point is subtracted from the reference case GDP growth rates for the low economic growth case. Outside the industrialized world (excluding the FSU), reference case GDP growth rates are increased and decreased by 1.0 percentage point to provide the high and low economic growth case estimates.

Table 1.8
Western and Eastern Europe: alternative growth-rates

Geographic Area	***Western Europe***								Annual Change			
	Unit:	**1990**	**2001**	**2002**	**2010**	**2015**	**2020**	**2025**	***'90-'01***	***02-'10***	***'10-'20***	***'20-'25***
Population	***million***	376	391	392	396	397	397	397	*0.4%*	*0.1%*	*0.0%*	*0.0%*
GDP_Reference	***G$'00***	7246	9314	9416	11044	12255	13563	14958	*2.3%*	*2.0%*	*2.1%*	*2.0%*
GDP_High Growth	***G$'00***	7246	9314	9416	13001	13001	14717	16602	*2.3%*	*4.1%*	*1.2%*	*2.4%*
GDP_Low Growth	***G$'00***	7246	9314	9416	10639	11537	12478	13446	*2.3%*	*1.5%*	*1.6%*	*1.5%*
Geographic Area	*Eastern Europe*											
Population	***million***	122	121	121	119	118	117	115	*-0.1%*	*-0.2%*	*-0.2%*	*-0.3%*
GDP_Reference	***G$'00***	914	1040	1068	1527	1863	2253	2702	*1.2%*	*4.6%*	*4.0%*	*3.7%*
GDP_High Growth	***G$'00***	914	1040	1068	1632	2074	2613	3268	*1.2%*	*5.4%*	*4.8%*	*4.6%*
GDP_Low Growth	***G$'00***	914	1040	1068	1426	1667	1930	2217	*1.2%*	*3.7%*	*3.1%*	*2.8%*

1.4.4 The White and Green Project scenarios

The Western European (WEU) MARKAL model used in this modelling exercise **/Farinelli et al. 2005/** builds on the work carried out by the Energy Information Administration of the US Department of Energy (EIA-DOE) for the production of the International Energy Outlook, starting in 2003. This organization has developed the System for Analysis of Global Energy markets (also called SAGE) in order to examine a wide range of global energy issues, integrating a set of regional models.

Countries: The energy system in Western Europe is treated as a single geographic region rather than distinct countries. The WEU MARKAL model, developed for SAGE, includes the following countries: Austria, Belgium, Denmark, Finland, France (including Monaco), Germany, Gibraltar, Greece, Greenland, Iceland, Ireland, Italy (including San Marino and Vatican City), Luxemburg, Malta, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland (including Liechtenstein), United Kingdom. This group of countries is larger than the original EU-15 (by the countries underlined in the former list), but includes only one of the new access countries, namely Malta; it is therefore indicated as "EU-15+".

Main Assumptions :

The Reference Energy System for the WEU MARKAL model contains input data from 2000 up to a maximum time horizon of 2050 (using 5-years as time step).

Population and GDP projections are based on official data from UN **/UN HABITAT/** and EIA **/EIA 2005/**. In the WEU MARKAL, energy service demands of the base case are exogenous variables (user-defined).

The developers of the WEU MARKAL model forecast future energy service demands by using estimates of demand drivers (as presented in Table 1.9) such as population, GDP and housing stocks. Further figures were estimated based on IEA documents.

Table 1.9
Demand drivers for the WEU BASE Case scenario

Driver	No	2000	2005	2010	2015	2020	2025
GDP (1997 Billions US$)	1	9312	10378	11694	13125	14724	16395
Population (Millions)	2	389	391	391	389	387	385
GDP/ Population	3	24	27	30	34	38	43
Housing Stock Total (Millions)	4	148	152	155	158	161	164

Source: Energy Information Administration - US Department of Energy. (2003b) *Model Documentation Report: System for the Analysis of Global Energy Markets (SAGE).* Volume 2. Washington: EIA-DOE.

End-use sectors and structure of the model

With regard to the structure and terminology of the model, the demands for energy services are grouped in five energy consumption or end-use sectors: residential (RES), commercial (COM), agriculture (AGR), industrial (IND) and transportation (TRA). The energy system that supplies the 5 end-use sectors is split in electricity production (ELC) and upstream/downstream (UPS) producing primary and secondary energy carriers other than electricity.

The WEU energy system entails the energy commodities that are extracted or imported, processed by technologies, and ultimately consumed by end-use technologies to satisfy a set of demands for energy services. When it comes to the electricity sector, this entails electricity production, co-generation and heat production. Attention should be given to the fact that self-production of electricity in the industrial sector and heat by power plants or by co-generation is excluded from the electricity sector and is included in the specific sectors. The different resources used by the electricity sector are aggregated into different categories, including fossil fuels, biomass fuels, and non-fossil fuels (hydro, nuclear, non-conventional renewables). The EIA-DOE estimates the ratios based on data provided by the International Energy Agency (IEA).

1.5 The role of top-down (macroeconomic) and bottom-up (microeconomic) models

In order to anticipate future energy demand, three main approaches are in principle possible:

1. Straightforward extrapolation from present trends
2. Top-down (macroeconomic) models
3. Bottom-up (microeconomic) models.

Extrapolation methods are the most commonly used, but only for short-term prediction, especially if linear extrapolation is used. If a longer time horizon is considered, non linear behaviour, as well as changes in boundary conditions, are likely to become important. Therefore, simple extrapolation of the energy demand for a period longer than, say, five years is considered to be unsuitable. We will therefore not base our considerations on this kind of approach.

Macroeconomic models, unless they are conceived as global models concerning the world economy, have to make a number of assumptions and consider a set of data as exogenous inputs: in our case, in particular, the economic growth for the country or group of countries considered is given as an input for the period of time under consideration; international prices of energy commodities are also considered as exogenous to the model. The development of the economy and the energy prices may be derived from global economy models, or they may derive from other considerations.

The energy demand is evaluated in this kind of models with different methods, but generally in a rather aggregated form. The simplest method is to correlate energy demand with GDP (Gross Domestic Product) through the consideration of energy intensity (energy demand per unit of GDP) taking into consideration that this intensity (in industrialised countries) is generally decreasing with time, both as a consequence of shifts in the composition of GDP towards less energy-intensive goods and services, and as a result of the introduction of progressively more efficient technology that allow to obtain the same (or equivalent) service or products with less energy. The energy demand may be subdivided in sectors (such as industry, transportation, residential and commercial) but the demand is generally not examined in detail.

Microeconomic models (or bottom-up scenarios) start from a much more detailed analysis of the energy demand. Their starting point is not the demand for energy, but rather the demand for energy services, i.e. those services and products which are requested by the final users and which need energy to be delivered. The demand for energy services is linked to a certain number of indicators: typically the population, the GDP per capita, the number of households etc. The energy demand corresponding to these energy services will depend on the technology used: the more efficient the technology, the less energy will be required for the same service or product.

The most complete models contain a detailed representation of the different technologies that are already available or that are supposed will be available in the future to supply the energy services. The description of each technology includes its efficiency and cost. The models (such as MARKAL-TIMES or PRIMES) then calculate an economic optimisation, i.e. they simulate the behaviour of the final energy user which corresponds to its maximum convenience for satisfying its demand for energy services. The models start from a "partial equilibrium" situation, i.e. they have to account for the actual situation as resulting from an optimal economic choice. These models assume a perfectly functioning market, which is not the case in reality: lack of sufficient information, difficulty of access to the financial market, personal choices which escape the model, account for a consumers' behaviour that would be judged in the logic of the model as not completely rational. In order to account for the situation as it is observed, some further details or some changes in the parameters is used by the model; one of the most commonly used is the introduction of an "effective" discount rate for the families, higher than the social discount rate.

The models used can also simulate the effects of legislation introduced to promote energy efficiency and/or reduce GHG emissions, such as tradable emission permits, white certificates, energy or CO_2 taxation, incentives etc.

In the present analysis, information about the scenarios for EU-25 is used first of all to discuss the input data for the modelling work to be done within the EUSUSTEL project in WP-5, to ensure their consistency and to suggest possible variations; in particular, the application of the set of input data as employed for the more recent scenarios studied with the PRIMES model is assessed. These data include the indicators that are required to predict the demand for energy services, as specified above. Secondly, the evolution of energy demand is evaluated by means of macroscopic evaluations, using the results of the different models. Finally, the last part of this Chapter deals with the effects that can be expected from energy efficiency policies. This section is based on the results of bottom-up calculations, essentially on the MARKAL-TIMES modelling in the White and Green project **/iiiee 2005/**, as well as on considerations deriving from other sources.

2 Basic input data for the models

2.1 Demography

All models predict a substantially stable population in EU-25 until 2030.

These predictions can be considered very reliable over this period (since the age distribution of population is predictable) at least for the internal evolution; contributions from immigration could be much more significant should policies or external conditions vary.

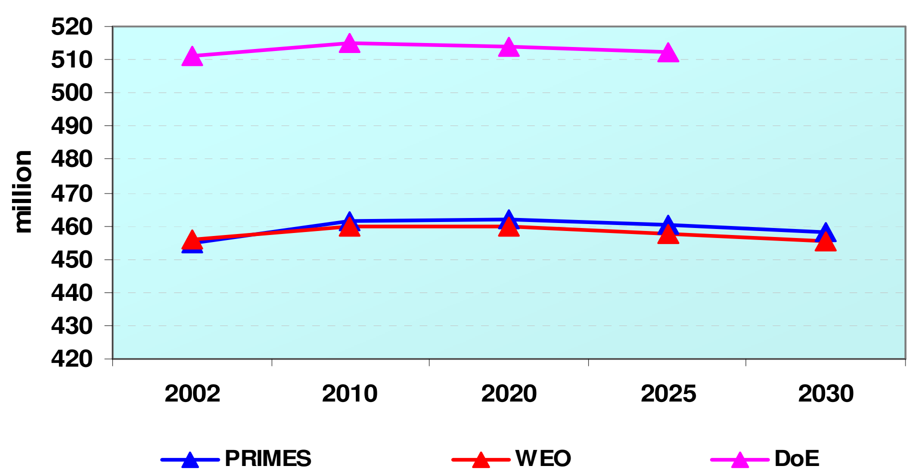
An extrapolation of constant population from 2030 to 2050 is reasonable but subject to increasing uncertainties. The prediction of total population for the European Union in its present configuration is given in Table 2.1 as assumed in the PRIMES model calculations until 2030, and kept constant thereafter.

Table 2.1
EU-25 population (million) 2000-2050
(from PRIMES until 2030)

Year	**2000**		**2010**		**2020**		**2030**		**2040**		**2050**
Population	**453.4**		**461.2**		**462.1**		**458.2**		**458.2**		**458.2**
Growth rate (% per year)		**+0.2**		**0.0**		**-0.1**		**0.0**		**0.0**	

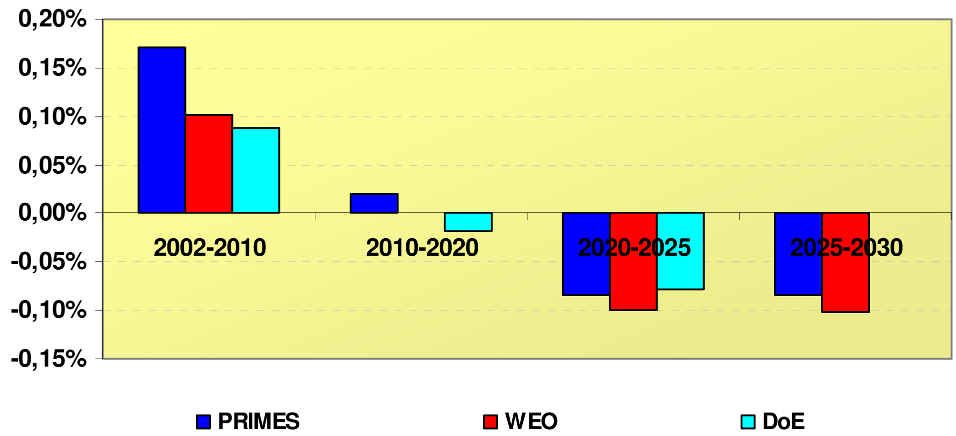
The predictions in the various models considered are compared in Fig. 2.1. The DoE figures are much higher simply because the reference geographical configuration is different (see 1.4).

Fig. 2.1 **Population to 2030 according to various models**



The growth rates assumed in the various models are indicated in Fig. 2.2.

Fig. 2.2 **Population growth rate to 2030**



As concerns longer-term evolution of the population, IIASA **/IIASA (2003-2004)/**has a projection of world population from 2000 to 2100, divided by groups of countries and by age group. The European region (one of 13) includes Western Europe, Eastern Europe and former Soviet Union. With some effort and a number of assumptions it would be possible to elaborate these data in a format compatible with ours (EU-25)

However, it is doubtful that this analysis would actually improve the credibility of our scenarios.

2.2 Gross Domestic Product

This is a much more difficult and sensitive prediction.

All scenarios assume a positive, but limited, growth of the economy in the European Union. This is clearly one of the major objectives of economic policies and it is to be expected that, especially on the longer term, appropriate instruments and interventions will be put in place in order to ensure at least such a minimum growth rate.

In most models, the growth rate decreases in the period from 2015 to 2025.

The Eastern European component of EU-25 grows more than the West European countries (at least to recover a part of the large set-back of the last 15 years), but the Western EU countries, however, have a predominant weight.

Since the population is substantially stable, it is not important to distinguish between the growth rate of total GDP and of GDP per capita.

Table 2.2 shows the assumptions of the various models considered as concerns GDP until 2030. In the case of PRIMES, the absolute values are given as well as the growth rates; for the other models, only growth rates are indicated.

Table 2.2
GDP and GDP growth rate in EU-25

Year	2000		2010		2020		2030
PRIMES: GDP (G€)	8393		11433		14462		18020
% p.a.		2.5		2.4		2.2	
WEO		2.3		2.1		1.7	
DoE ref.		2.2		2.3		2.2	
DoE high		2.6		2.9		2.8	
DoE low		1.7		1.8		1.7	
	DoE data are calculated as averages of Western and Eastern Europe, weighted over GDP The DoE time horizon is 2025, not 2030						

The same values are shown in Fig. 2.3 as concerns the absolute values of GDP and in Fig. 2.4 as for the growth rates. As before, the higher absolute values of DoE in 2.3 are due to the different geographic composition.

Fig. 2.3

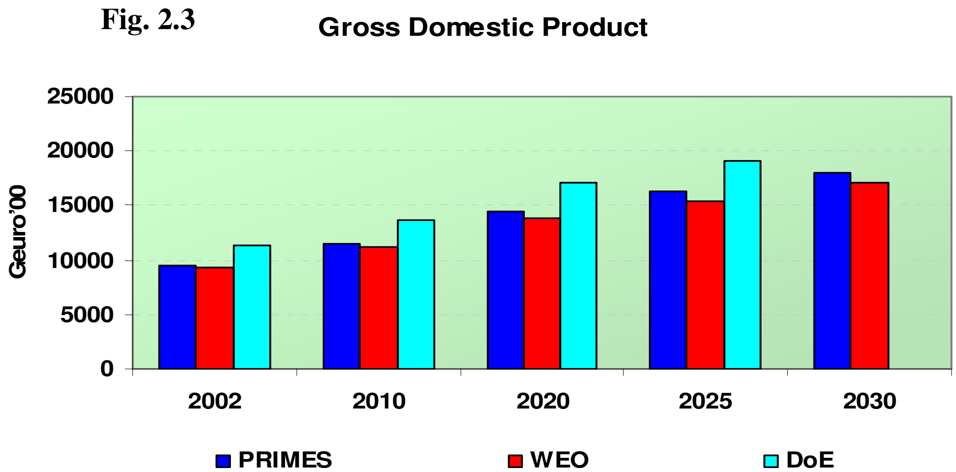
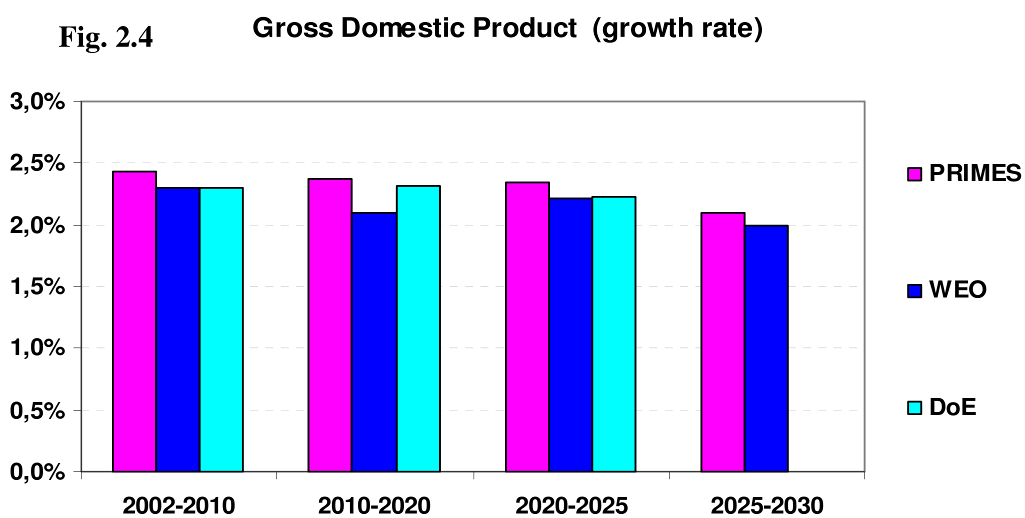


Fig. 2.4



The simplest way to extrapolate the evolution of GDP to 2050, starting from the PRIMES values, is to assume that the growth rate will continue to decrease slowly.

We suggest to assume a GDP growth rate of 1.9% p.a. in the period 2030-2040, and of 1.7% p.a. in the period 2040-2050.

With these assumptions, the GDP would be as shown in Table 2.3.

Table 2.3
GDP and GDP growth rate 2030-2050

Year	2030	2035	2040	2045	2050
GDP (G€)	18,020	19,798	21,751	23,664	25,746
Growth rate (% p.a.)		1.9		1.7	

2.3 Energy prices: the low-price scenarios

Future energy prices are the most difficult, critical and controversial prediction; for instance in 2005 oil prices have grown well beyond any forecast made one year before; some sources have already reevaluated predictions for 2010.

The price predictions of the scenarios referred to previously (PRIMES, WEO and DoE) were all made before the oil shock of 2004-2005; we shall therefore call them "low price scenarios". Of course, it is still conceivable that these predictions may be correct, if one assumes that the present price crisis is due to temporary effects and has no structural justification; in this case, the price trends will go back to the long-term trends predicted before.

The data of the three reference scenarios are given in the following figures, where a high-price scenario is also included (see next section).

Fig. 2.5 Oil Price Scenarios

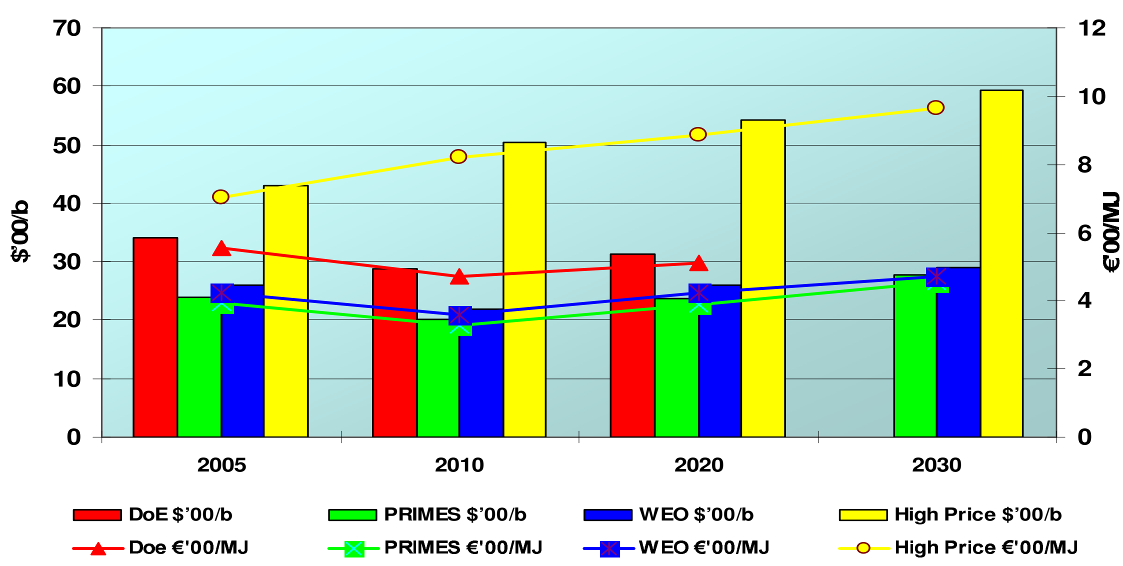
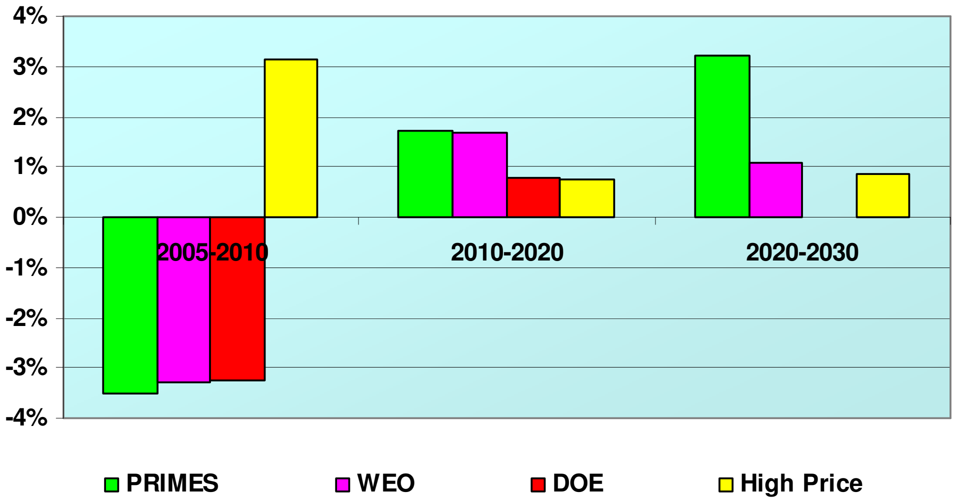


Fig. 2.6 **Oil Price Scenarios (growth rate)**



2.4 Energy prices: the high-price scenario

In 2004 the world oil demand increased by 2.7 Mbbl/day (more than in 2000-2003); the OECD demand increased by 0.6 but its production decreased by 0.4 Mbbl/d with an increase of import of 1 Mbbl/d.

In the same year the demand from emerging countries increased by 2.1 Mbbl/d, 0.9 of which from China alone.

The demand of oil products has further shifted towards lighter products (gasoline and diesel), putting more pressures on refineries, which had been optimized for a different basket and are late in adjusting.

The main problem is that there is no agreement on the relative weights of the possible reasons for the increase of oil prices: lack or delay of investments, expectation of dwindling resources, huge increase of the demand from rapidly developing countries, worries on geopolitical situations, etc.

Another controversial question: is there a stop-value for the price due to: non-OPEC supply; non-conventional oil; other energy sources?

Finally, the results may be sensitive to the projected exchange rate $ / €.

For all these reasons, it seems necessary to consider – in addition to the prevalent forecasts of a limited increase of oil prices starting from values much lower than the present (seen as a fluctuation) – a high price scenario, accounting for a continuation of geopolitical problems, a delay in investments due to the uncertain environment, a further rapid growth of demand from developing countries.

Such a high growth (but by no means extreme) scenario would see the price of (Brent) oil (expressed in constant 2002 $ values) soar from 45.2 $/bbl in 2005 to 57 in 2020 to 62 in 2030.

2.5 The price of other fuels

As a matter of fact, the international price of oil is not the only input as far as (international) energy prices are concerned. Europe depends for a majority of its needs from imports also in the case of gas and of coal, so that reasonable assumptions are required also for these fuels.

The price of gas is presently linked to the price of oil in supply contracts.

A trend towards a greater independence of the gas market from the oil market has been envisaged and some signs have shown in this direction. The direct competition for power production between oil on one side, and natural gas and coal on the other, is disappearing as oil is everywhere being phased out of the thermo-electric sector. This tends to lead to a decoupling between the oil and the gas market. As oil prices increase, however, there is more interest in transforming gas as well as coal into liquid products that could replace oil derivatives, and this tends to create a new coupling in the markets for the various fossil fuels.

Such increased possibilities of substituting one fuel for another involve large investments and require long lead times

Of course, in the same way in which fuel substitution will put pressure on the coal and gas market as oil becomes more expensive and thus increase their prices, it will also, on the long term, put a cap on oil prices, especially in view of the utilisation of the large resources of coal.

On this basis, a high energy price scenario has been imagined, involving also gas and coal.

Table 2.4
The high-price scenario to 2030

Year	2005	2010	2020	2030
Oil (Brent)	**39.32**	**45.05**	**56.51**	**71.74**
Gas	**22.07**	**25.19**	**30.41**	**40.66**
Coal	**9.69**	**9.92**	**11.86**	**14.38**
Prices in €2000/bbl; Source: PRIMES. 2005				

Extrapolation beyond 2030 becomes very uncertain

2.6 Energy prices and GDP

In principle, the choice of an energy price scenario and a GDP scenario should go together in order to ensure consistency, in the sense that the cost of energy will influence the global economy, hence the creation of GDP.

However, although it is undoubted that the price of energy may have a strong influence on the evolution of GDP, quantitative relationships are questionable and past experience is not easy to interpret. Recent events have shown the world economy more resilient to energy prices than in the past. The reaction of the macroeconomy to changes in international energy (or more specifically petroleum) prices depends on a number of factors which change with time. In 1974 and even more in 1980 the sudden rise in petroleum prices induced a generalised recession of the economy in the whole world, while this did not happen in 2004-2005. The possibility of substituting one fuel for another is one of the important factors. One can identify short-term, medium-term and long-term effects of changes in energy prices. The effects are generally non-linear and non-reversible (a decrease of price does not have the same effect with reversed sign as a price increase. We are not saying that it is not possible to predict the effects of energy prices on the economy, it has been done and it is being done, only it is not simple and the answers do not always prove correct.

In general, it makes more sense to couple high-growth GDP scenarios with low energy price assumptions and vice versa.

3 Other possible inputs

3.1 Age distribution

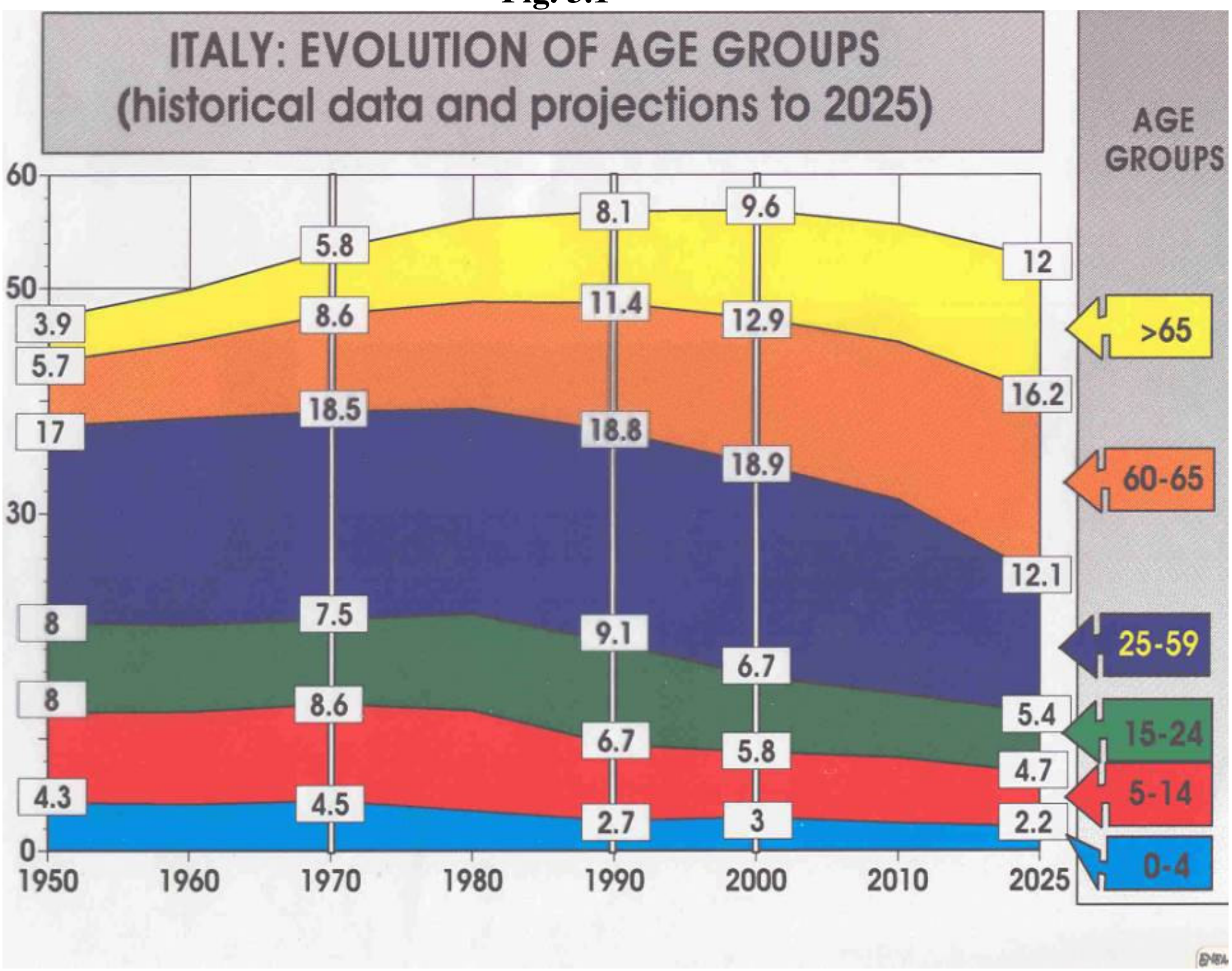
More important than the change in size of the population is the change in age distribution.

The trend toward stable or (slowly) decreasing population in Europe involves a progressively older population (see example for Italy in the following figure 3.1).

This fact is relevant at least in two respects: it changes the distribution of the demand of energy services; it influences (negatively) the generation of GDP as it reduces the working proportion of the population.

No convincing analysis of the change in demand of energy services with age profile is known to us.

Fig. 3.1



3.2 Number of households

The demand of some of the energy services, especially in the domestic sector, depend more on the number of households than on population or GDP. This is for instance the case for home refrigerators and freezers, where there is a practical saturation in the sense that nearly all households have one, and, apart from the replacement of old appliances, an expansion of the market can be expected only as a consequence of an expansion in the number of households. Since the total population in EU-25 is expected to be stable, such an expansion can be expected only as a consequence of a reduction of the average number of people per household. Such a reduction is actually being observed and the trend is expected to continue in the future.

As we mentioned in Section 1.4, following UN projections **/UN-HABITAT/**, household size in the EU-15 is assumed to decrease further to reach 2.23 persons per household in 2010 (ranging between 2.84 for Ireland and 1.99 for Sweden) and 1.97 persons per household in 2030. The average size will slightly increase passing from EU-15 to EU-25, but it will remain just above 2 person per household in 2030.

4. Top-down prediction of energy demand

4.1 Energy intensity of GDP

Although the energy demand can be expected to decrease for increasing energy prices, the elasticity of demand to (international) energy prices is lower than one could expect for two reasons:

1. Only a part of the changes in international prices for energy reach the final consumer, since a relevant fraction is damped by the fiscal charges
2. The demand for many energy services is rigid as the user considers them essential

Therefore the main link between energy prices and demand is through the GDP:

higher prices ⇒ lower GDP ⇒ lower demand.

The main assumptions (common to all models) are as follows:

- The demand for energy services will grow at a rate somewhat slower than GDP (for instance because of saturation)
- A further reduction of growth rate in energy will be brought about by efficiency improvements
- The two phenomena will compound in a progressive decrease of the energy intensity of GDP
- The same will happen for electricity demand, but the electricity intensity will decrease less than the energy intensity because electricity penetration is expected to increase.

All macroeconomic models assume that energy intensity (expressed as the ratio of energy demand to GDP, in Mtoe/G€) will continue to decrease with time, as a consequence of more efficient technology, miniaturisation, shifts in consumer's demand and behaviour, and economic pressure.

Primary energy intensity is thus assumed to decrease at a rate between 1 and 2 % per year: this rate is different in the various models, and may vary with time.

The assumption that this rate of decrease is of 1.5 % per year will be roughly in line with the models we have considered.

Fig. 4.1 Primary Energy Intensity (growth rate)

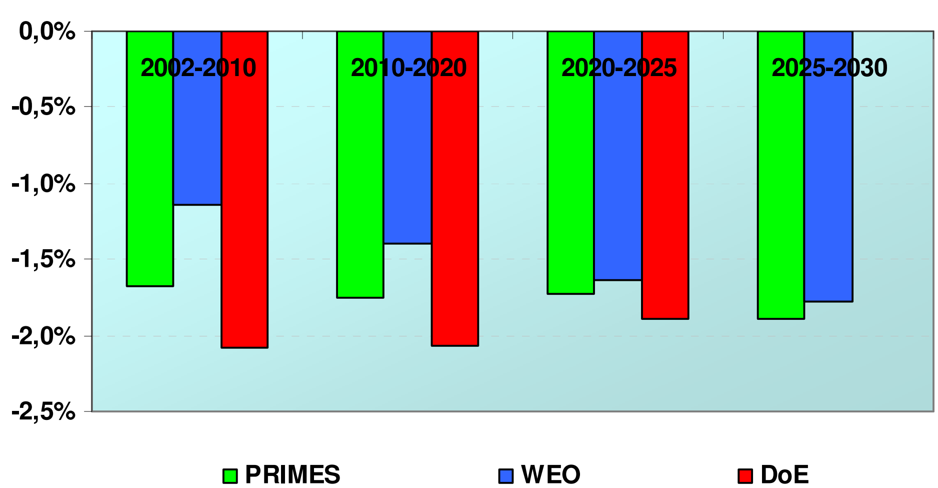
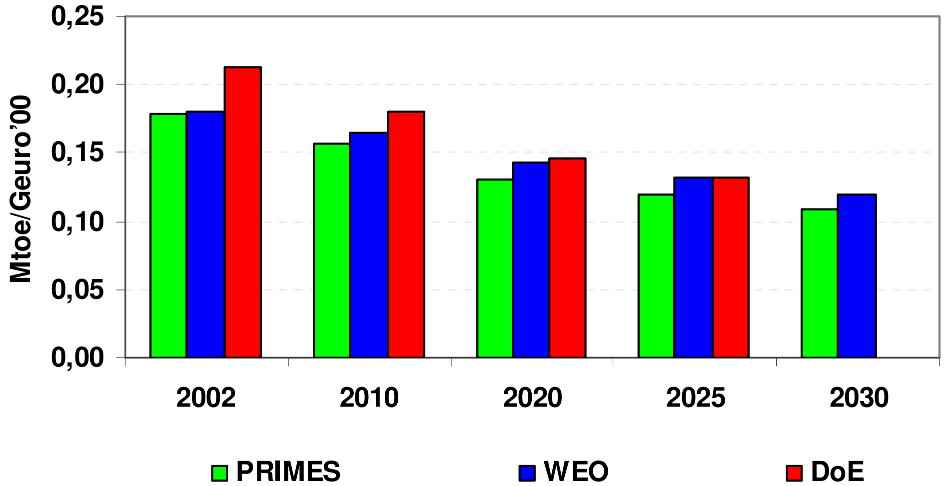


Fig. 4.2 **Primary Energy Intensity**



4.2 Total final energy demand

Although the energy intensity is expected to decrease with time, its rate of decrease will not compensate for the increase of GDP, so that in the reference scenarios (i.e. in the absence of new, stringent initiatives in favour of energy efficiency) the absolute value of energy demand will continue to grow, although more slowly than the economy as a whole.

Fig. 4.3 **Final Energy Demand**

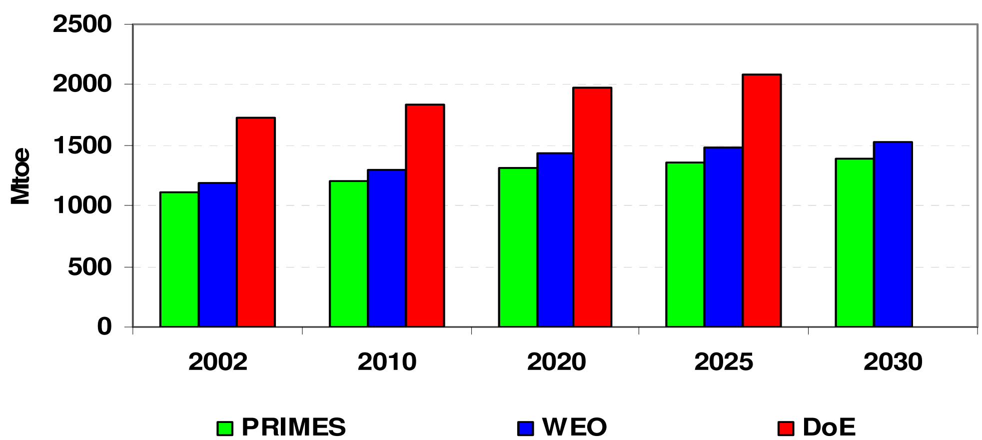
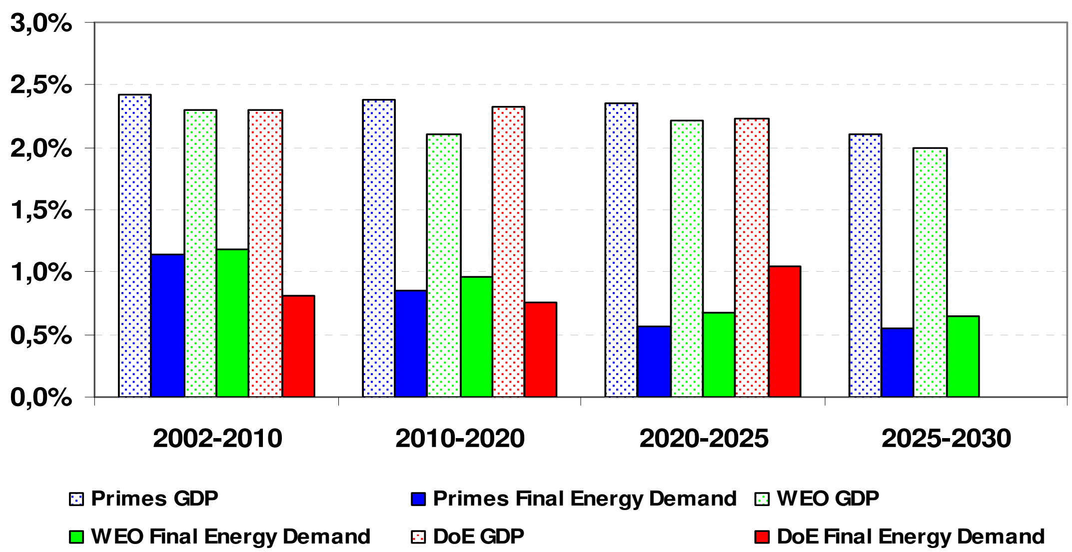


Fig. 4.4 **GDP and Final Energy Demand (growth rate)**



5 Top-down prediction of electricity demand

5.1 Electric penetration

The share of the final demand that is covered by electricity (i.e. the "electricity penetration") grows with time, both because the demand shifts towards more sophisticated energy services that are more likely to involve electricity than fuel (such as informatics and telecommunication) and because higher efficiency and increased automation can be obtained through electricity-based processes.

This trend is expected to continue in the future, and the EU is likely to reach values of electricity share closer to countries like US and Canada, which are at least 2 to 4 % higher than the average for the EU.

Fig. 5.1 Electric Penetration (growth rate)

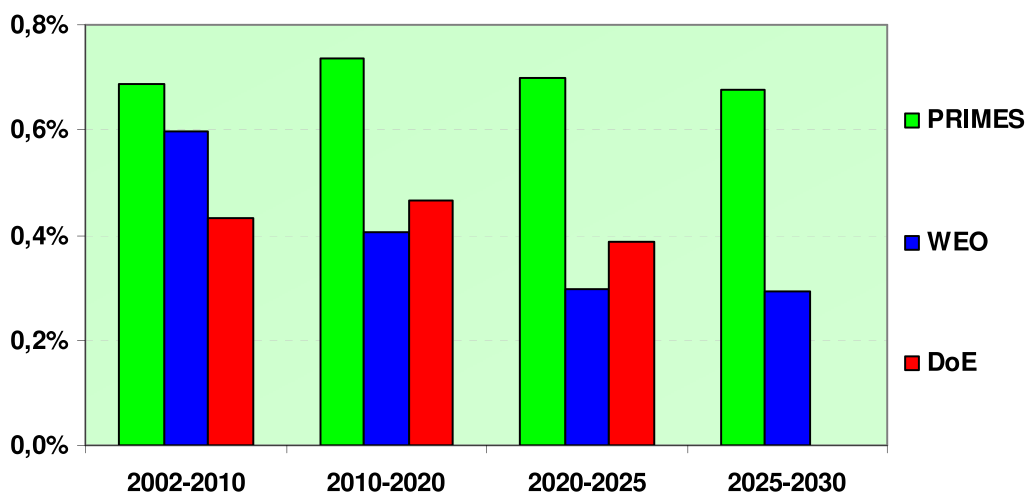
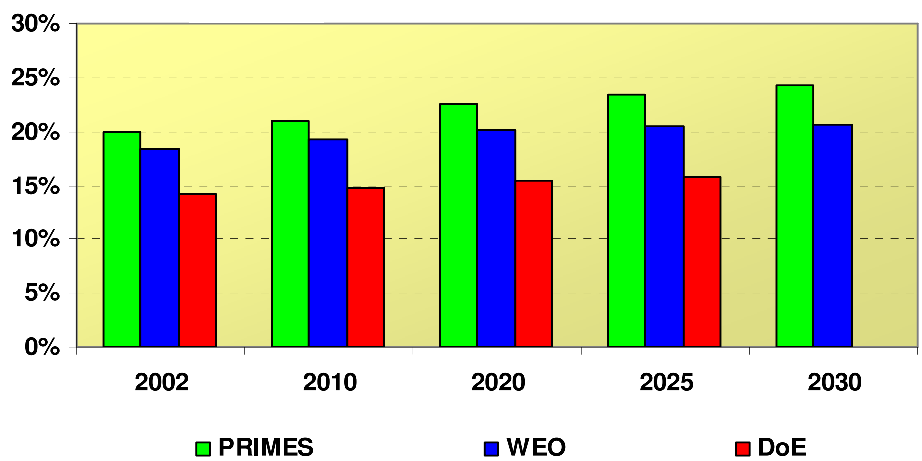


Fig. 5.2 Electric Penetration



There are substantial differences between the growth rates predicted by PRIMES and by WEO. For the reasons mentioned at the beginning of this section, we are inclined to rely more on the higher values of PRIMES than to the others.

5.2 Electricity demand

As a consequence of the increasing electricity penetration, the electricity intensity of GDP will decrease less steeply than the energy intensity of GDP.

Once assumptions are made on the trends in electric penetration, it is easy to express the variations in electricity demand and its absolute values over time.

The discrepancies between models on the values of penetration between 2010 and 2030, however, are partly compensated by the variations (in the opposite sense) of total energy intensity, so that there is a certain convergence in the prediction of electricity intensity, at least between PRIMES and WEO, which may make an extrapolation to 2050 possible.

Fig. 5.3

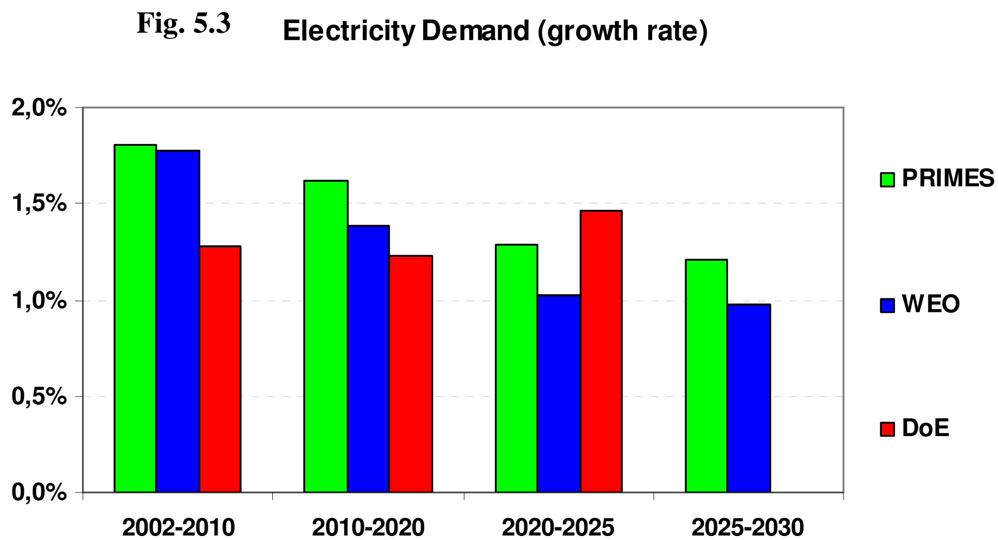
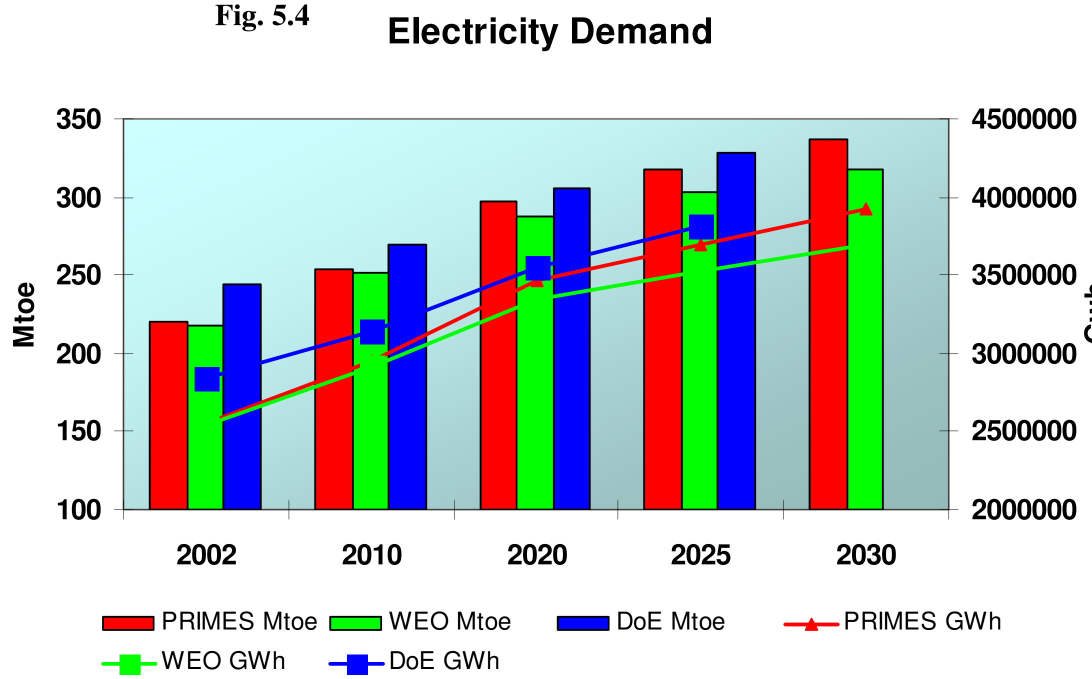


Fig. 5.4



5.3 Electricity intensity of GDP

Straightforward division of electricity demand by the predicted values of GDP allows to calculate the electricity intensity of GDP (Fig. 5.5), and its (negative) growth rate, as given in Fig. 5.6. The slower growth of electricity penetration assumed by DoE accounts for its steeper decrease with respect to the other models.

Fig. 5.5

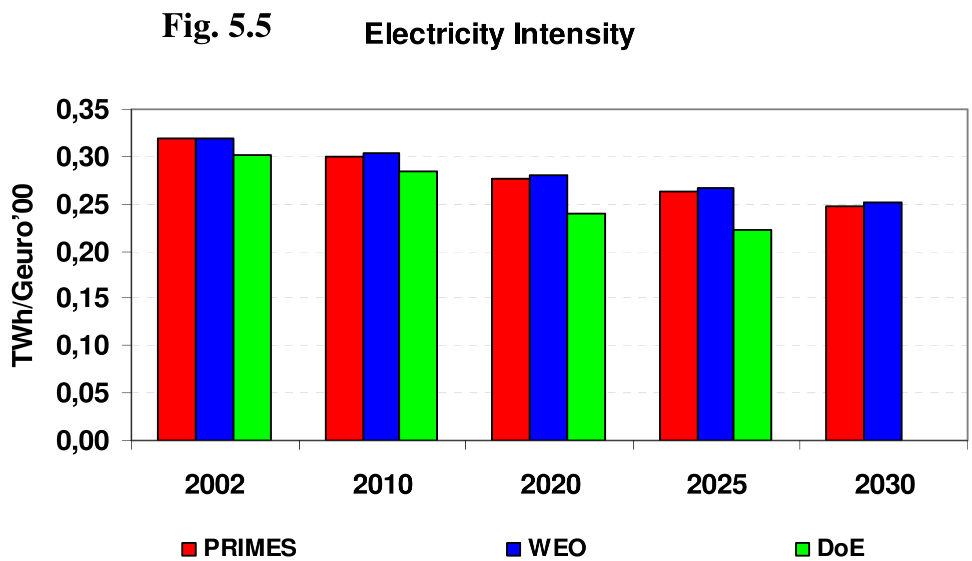
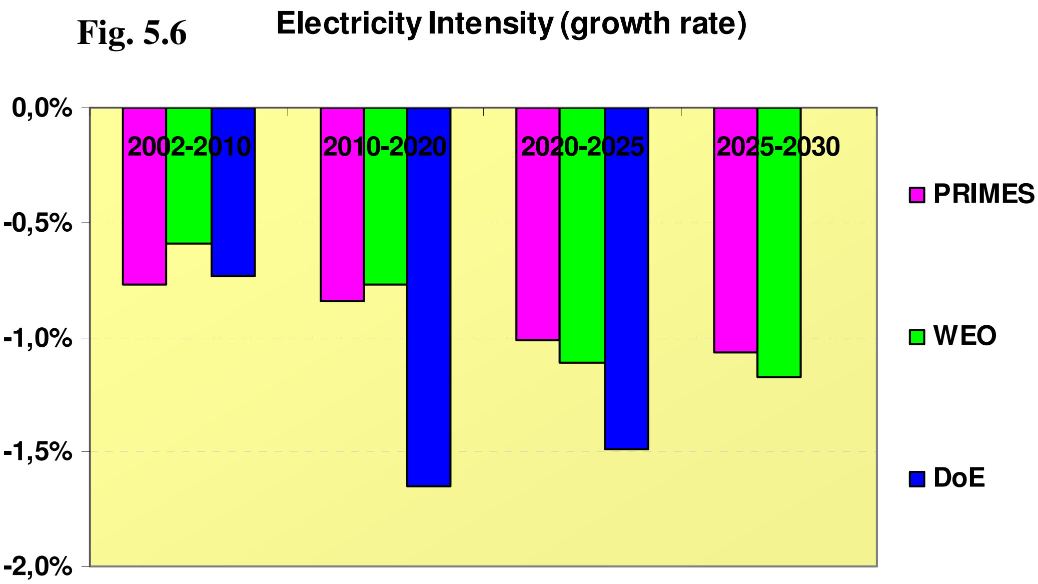


Fig. 5.6



5.4 Power requirements

In addition to the forecast of energy demand, it is important to have ideas on the peak power demand, which, together with the reserve margin, actually determines the requirement of installed power.

This could best be done by knowing (or predicting) the load distribution by hours, day of the week, and month of the year; however, if we consider an electrical system (for instance, the Italian or the Belgian electricity grid), we measure the power peak (maximum power in GW supplied to the grid during a certain year) and the total energy in GWh supplied to the grid during that year. The ratio of the total energy to the peak power (expressed in hours) is the time for which the system would have worked at peak power to supply the total energy. The ratio of the number of hours during a year (8766 hours) to this number of equivalent hours is the peak ratio. Reducing this ratio means having more spare capacity (or power margin) or needing less installed power, or more generally using the electric system more effectively hence at lower costs. DSM interventions that even if they do not reduce the electricity demand tend to distribute it more evenly over time are therefore useful.

This ratio today is of the order of 1.65, and could be reduced by DSM interventions.

6 The demand for energy services

In this chapter, we shall look with some more detail at the demand for energy (and for electricity) in Europe, starting first from the concept of “energy services” which is the basis of this demand (Section 6.1). Using indicators (such as population, GDP and number of households) as the starting point (Section 6.2) the evaluation of the demand for energy services in the EU until 2025, calculated for each service by means of the WEU MARKAL model is presented in Section 6.3. These demand values, coupled with a detailed data base on end use technologies, can be used for a bottom-up prediction of the energy demand, as mentioned in Section 6.4. Section 6.5 goes back to a more macroscopic examination of the trends of energy consumption in the EU, but divided by sectors, based on the ODYSSEE study.

6.1 Energy versus energy services

The analysis carried out so far, based on “top-down” considerations, aimed at predicting the demand for energy and electricity directly from macro-economic arguments. If one wants a more detailed analysis based on a “bottom-up” approach, one should start from the definition of the demand for “energy services”. The final energy user is not interested in energy in itself, but in the services that energy can provide: the production of material goods, immaterial goods and services; heating, cooling and ventilation so as to maintain conditions of comfort inside buildings; cooking, refrigerating foods; pumping water for irrigation and heating it for household usage; provide the desired amount of lighting inside and outside buildings, washing dishes and laundry, operating computers and telecommunication equipments; transporting people and goods from one place to another; and so on and so forth. All these services can be obtained spending more or less energy, according to the energy efficiency of the technology which is employed.

More precisely, the total demand for energy or for electricity can be represented by the following function:

$$\mathbf{D = \Sigma\, d_{serv} * f_{behav} * \eta_{ave.stock}}$$

where the sum is extended over all energy services, $\mathbf{d_{serv}}$ is the demand for the final service required (eg m^3 of space to be heated, kg of cloths to wash etc.); $\mathbf{f_{behav}}$ is a factor representing the behaviour of the final user, which can be more or less waste-oriented (lights on when no one is present, overheating of buildings corrected by opening windows, etc.); $\mathbf{\eta_{ave.stock}}$ represents the average efficiency of the stock of plants or appliances supplying each service (how many kWh needed on average for washing 1 kg of laundry etc.)

Energy demand should thus not be taken as an exogenous variable: energy policies can act on the demand for energy even without reducing the demand for energy services by:

1. Reducing the behavioural coefficient (i. e. reducing wastes) by means of information campaigns, diffusion of automatic controls like thermostats or time switches etc.
2. Increasing the average efficiency of supplying each energy service, by encouraging the diffusion of more efficient equipment and technology, by developing and bringing more rapidly to the market new efficient technology, by encouraging the replacement of obsolete, energy-wasting appliances etc.

6.2 Indicators relevant for the prediction of energy service demand

The “genuine energy services” desired by the end-user are not simply heat, cooling or lighting, but the amenities of modern life such as the comfort of a heated house, adequate lighting in the house, and many others. Provided adequate measures (such as information campaigns and immediate access to energy costs involved) are taken to reduce wastes (i.e. to bring $\mathbf{f_{behav}}$ as much as possible towards one), reducing the demand for energy services would imply a reduction in the well-being of citizens, which one would like to avoid.

Therefore, it is reasonable to assume the demand for energy services as exogenous variables, which however are not rigid, in the sense that they are (in greater or smaller measure) influenced by the costs of obtaining these services: therefore -as will be specified further on – the demand for each energy service is accompanied by a coefficient of elasticity to prices.

In the MARKAL modelling exercises, such as those carried out within the White and Green project, the demand for energy services is evaluated according to the indicators presented in Table 1.9, that we repeat here as Table 6.1.

Table 6.1

Demand drivers for EU-15+

Driver	No	2000	2005	2010	2015	2020	2025
GDP (1997 Billions US$)	1	9312	10378	11694	13125	14724	16395
Population (Millions)	2	389	391	391	389	387	385
GDP/ Population	3	24	27	30	34	38	43
Housing Stock Total (Millions)	4	148	152	155	158	161	164

The dependence on drivers 1, 2 and 4 can be assumed as direct proportionality. The dependence on driver 3 (in practice, per capita income)[2] means that the coefficient of proportionality (to one of the other 3 indicators) will depend on the level of income, i.e. will be non-linear. In our further calculations, we shall ignore this factor and use one of the other drivers.

Proportionality to GDP means essentially that the demand for the corresponding energy service will not be saturated: if one earns more, he is likely to use more air travel, or to buy more paper. Other demands are practically saturated: in the EU, virtually every household today has a refrigerator, so that the demand for food refrigeration will be proportional to the number of households rather than to GDP. The demand of travelling by bus or by train, vice versa, can be assumed to be independent of GDP and proportional to population.

Of course, the attribution to one or another indicator may have a degree of uncertainty, other indicators could be taken into account, or a combination of indicators (for instance for services the demand of which is moving towards saturation), but and the lack of detailed knowledge on the service-drivers relationships does not justify the additional complication.

6.3 Evaluation of the demand for energy services

In the WEU MARKAL, energy service demands of the base case are exogenous variables (user-defined). The developers of the WEU MARKAL model forecast future energy service demands by using estimates of the demand drivers presented in Table 6.1, as explained in the previous section. Further figures were estimated based on IEA documents. Table 6.2 shows all

[2] We want to simplify the analysis by making the demand for each energy service dependent on only one driver, or, to say better, proportional to one driver and not dependent on the others – in some cases it will be population, in other cases GDP or number of lodgings. It cannot be dependent on GDP/capita alone, because GDP/cap is an "intensive" indicator, while the total demand will depend (even if not exclusively) on an "estensive" operator such as population, and Luxemburg would use more energy than Germany... The more complete treatment of the demand for energy services would include more parameters (for instance, it may be found that the demand for air travel interests only people with income above a certain level). The choice here was to divide energy services between those the demand for which is practically saturated (elasticity near zero, total demand proportional to population or to the number of households) and those for which the demand will depend on the income (elasticity different from zero, total demand proportional to GDP). It is certainly not the most precise model, but in practice it seems to be adequate when considering aggregate demand for different energy services.

energy service demands for each sector. With the exception of the agricultural sector, the rest contains different segments for specific energy demands. One column indicates the driver used to project each energy service demand. The actual demands for energy services in each scenario are different: each exogenous demand in each time period fluctuates around the base case value, because it depends on own prices with elasticities specified in the last column of Table 6.2.

It will be noted that the demand for energy services is often not expressed in energy units, but rather in units describing directly the service required: how many tonnes of steel to be produced, or how many kilometres to travel. When this is not practical, the service demand is expressed in energy units assuming that the efficiency corresponds to the average efficiency of today. Energy is thus used only as a proxy of the actual measure of the demand.

Table 6.2: Energy service demands in the WEU MARKAL Model (PJ if not indicated) EU-15+

Sector/ Segments	2000	2005	2010	2015	2020	2025	Driver	Price elasticity
Agriculture	1048	1072	1100	1127	1154	1180	1	0 ~ 0.1
Commercial								
Cooling	1217	1287	1368	1452	1540	1628	1	-0.15 ~ -0.05
Cooking	124	128	133	137	141	143	3	-0.05 ~ 0
Space heat	1380	1427	1478	1523	1560	1586	1	-0.1 ~ 0
Hot water	573	593	614	632	648	659	1	-0.1 ~ 0
Lighting	4078	4311	4585	4865	5162	5454	1	-0.15 ~ 0
Office equipment	398	489	613	763	949	1154	1	-0.05 ~ 0
Other	131	132	134	136	137	139	1	-0.15
Refrigeration	187	194	200	207	212	216	3	0
Industrial								
Chemical	5707	6282	6919	7569	8282	9015	1	No data available
Iron & Steel (Mt)	123	127	131	135	139	143	1	
Pulp & Paper (Mt)	81	92	105	117	130	143	1	
Non-ferrous metal (Mt)	5	5	6	7	8	9	1	
Non-metals (Mt)	112	126	144	160	176	190	1	
Other industry	5320	5929	6680	7497	8411	9365	1	
Residential								
Cooling	40	41	42	43	43	44	4	-0.15 ~ -0.05
Clothes drying	12	12	13	13	13	13	4	-0.05 ~ 0
Clothes washing	2	2	2	2	2	2	4	-0.05 ~ 0
Dishwashing	2	2	2	2	2	2	4	-0.05 ~ -0.03
Other electronics	65	79	97	114	133	152	3	-0.20 ~ -0.05
Space heat	5032	5152	5271	5366	5462	5559	4	-0.05 ~ 0
Hot water	704	720	737	750	764	777	4	-0.05 ~ 0
Cooking	266	272	278	283	288	293	4	0
Lighting	25	25	26	27	27	28	4	-0.1 ~ 0
Others	0	0	0	0	0	0	4	-0.1
Refrigeration	28	29	29	30	30	30	4	-0.05 ~ -0.03
Transportation								
Domestic aviation	434	471	513	554	595	632	1	-0.20
Intern'l aviation	1589	1753	1953	2168	2379	2568	1	-0.30 ~ -0.20
Bus (10^9Vkm)	24	24	24	24	24	24	2	-0.15 ~ -0.05
Comm Trucks (10^9Vkm)	112	120	129	138	149	159	1	-0.15 ~ -0.05
3 wheels (10^9Vkm)	9	9	9	9	9	9	2	
Heavy trucks (10^9Vkm)	153	164	176	189	203	217	1	-0.15 ~ -0.05

Light vehicles (10^9Vkm)	442	452	463	475	486	497	3	-0.15 ~ -0.05
Medium trucks (10^9Vkm)	97	104	112	120	129	137	1	-0.15 ~ -0.05
Automobiles (10^9Vkm)	1086	1110	1138	1166	1194	1220	3	-0.15 ~ -0.05
2 wheels (10^9Vkm)	17	17	17	17	17	17	2	-0.05
Rail-freight	100	105	110	115	121	126	1	-0.15 ~ -0.05
Rail-passengers	233	234	234	233	232	231	2	-0.15 ~ -0.1
Domestic navigation	284	294	305	316	328	339	1	-0.20 ~ -0.15
Intern'l navigation	1337	1383	1435	1488	1542	1595	1	-0.20 ~ -0.15

Source: Energy Information Administration - US Department of Energy. (2003b) *Model Documentation Report: System for the Analysis of Global Energy Markets (SAGE)*. Volume 2. Washington: EIA-DOE. Note: Elasticities are those used in the WEU MARKAL standard input.

By assuming proportionality to the driver in the last-but-one column (where driver n. 3 appears it has been replaced by driver n. 1) a new Table (Table 6.3) has been generated for EU-25 instead of EU-15+. For instance, for a line where driver 2 appears (population), all numbers are multiplied by the ratio between the predicted population of EU-25 in that year (as from Table 2.1) and the values appearing in Table 6.1 (with simple extrapolation to 2030). In the case of driver 1 (GDP), in order to have consistency, the values of Table 6.1 have been transformed from US $ 1997 into euro-2000. For driver n. 4, the number of households in EU-25 has been taken from Table 3.1. Elasticities have not been re-evaluated, and it can be assumed that they remain the same as in Table 6.2.

Table 6.3: Evaluation of energy service demand for EU-25

Sector/ Segments	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**Driver**
Agriculture	867	900	927	951	977	1001	1030	1
Commercial								
Cooling	1007	1080	1152	1226	1303	1381	1468	1
Cooking	103	107	112	116	119	121	124	1
Space heat	1141	1198	1245	1286	1320	1345	1376	1
Hot water	474	498	517	534	548	559	572	1
Lightning	3373	3618	3862	4107	4368	4626	4909	1
Office equipment	329	410	516	644	803	979	1193	1
Other	108	111	113	115	116	118	120	1
Refrigeration	155	163	168	175	179	183	188	1
Industrial								
Chemical	4720	5272	5828	6390	7009	7646	8379	1
Iron&Steel (Mt)	102	107	110	114	118	121	125	1
Pulp&Paper (Mt)	67	77	88	99	110	121	134	1
Non-ferrous metal (Mt)	4	4	5	6	7	8	9	1
Non-metals (Mt)	93	106	121	135	149	161	175	1
Other industry	4400	4976	5627	6329	7118	7943	8899	1
Residential								
Cooling	50	53	55	57	58	60	61	4
Clothes drying	15	15	17	17	18	18	18	4
Clothes washing	3	3	3	3	3	3	3	4
Dishwashing	3	3	3	3	3	3	3	4
Other electronics	54	66	82	96	113	129	148	1
Space heat	6317	6603	6944	7163	7392	7550	7694	4
Hot water	884	923	971	1001	1034	1055	1075	4
Cooking	334	349	366	378	390	398	405	4
Lightning	31	32	34	36	37	38	39	4
Others	0	0	0	0	0	0	0	4

Refrigeration	35	37	38	40	41	41	41	4
Transportation								
Domestic aviation	359	395	432	468	504	536	575	1
Internal aviation	1314	1471	1645	1830	2013	2178	2362	1
Bus (10_9 Vkm)	28	28	28	28	29	29	29	2
Comm Trucks (10^9 Vkm)	93	101	109	116	126	135	145	1
3 wheels (10^9 Vkm)	10	11	11	11	11	11	11	2
Heavy Trucks (10^9 Vkm)	127	138	148	160	172	184	198	1
Light Vehicle (10^9 Vkm)	366	379	390	401	411	422	434	1
Medium trucks (10^9 Vkm)	80	87	94	101	109	116	124	1
Automobiles (10^9 Vkm)	898	932	959	984	1010	1035	1065	1
2 wheels (10^9 Vkm)	20	20	20	20	20	20	20	2
Rail-freight	83	88	93	97	102	107	112	1
Rail-passengers	272	274	276	277	277	276	273	2
Domestic navigation	235	247	257	267	278	288	299	1
Internal navigation	1106	1161	1209	1256	1305	1353	1404	1

The growth rates of the demand for each energy service has been calculated for both EU-15+ (Table 6.2) and for EU-25 (Table 6.3). The results are compared in Table 6.4.

Fig. 6.4 Annual Growth Rates

	EU-15+						**EU-25**					
Sector/Segments	***00-’05***	***05/’10***	***10-’15***	***15-’20***	***20-’25***	***25-’30***	***00-’05***	***05/’10***	***10-’15***	***15-’20***	***20-’25***	***25-’30***
Agriculture	*0.45*	*0.52*	*0.49*	*0.47*	*0.45*	*0.45*	*0.75*	*0.59*	*0.53*	*0.52*	*0.49*	*0.58*
Commercial												
Cooling	*1.12*	*1.23*	*1.20*	*1.18*	*1.12*	*1.10*	*1.42*	*1.30*	*1.24*	*1.23*	*1.16*	*1.23*
Cooking	*0.64*	*0.77*	*0.59*	*0.58*	*0.28*	*0.28*	*0.93*	*0.84*	*0.64*	*0.63*	*0.33*	*0.41*
Space heat	*0.67*	*0.70*	*0.60*	*0.48*	*0.33*	*0.33*	*0.97*	*0.78*	*0.65*	*0.53*	*0.38*	*0.46*
Hot water	*0.69*	*0.70*	*0.58*	*0.50*	*0.34*	*0.34*	*0.98*	*0.77*	*0.62*	*0.55*	*0.38*	*0.47*
Lighting	*1.12*	*1.24*	*1.19*	*1.19*	*1.11*	*1.07*	*1.41*	*1.32*	*1.24*	*1.24*	*1.15*	*1.20*
Office equipment	*4.20*	*4.62*	*4.48*	*4.46*	*3.99*	*3.90*	*4.51*	*4.70*	*4.52*	*4.51*	*4.04*	*4.03*
Other	*0.15*	*0.30*	*0.30*	*0.15*	*0.29*	*0.22*	*0.44*	*0.38*	*0.34*	*0.20*	*0.34*	*0.35*
Refrigeration	*0.74*	*0.61*	*0.69*	*0.48*	*0.37*	*0.35*	*1.03*	*0.69*	*0.73*	*0.53*	*0.42*	*0.48*
Industrial												
Chemical	*1.94*	*1.95*	*1.81*	*1.82*	*1.71*	*1.72*	*2.24*	*2.03*	*1.86*	*1.87*	*1.76*	*1.85*
Iron&Steel t	*0.64*	*0.62*	*0.60*	*0.59*	*0.57*	*0.55*	*0.94*	*0.70*	*0.65*	*0.64*	*0.62*	*0.68*
Pulp&Paper	*2.58*	*2.68*	*2.19*	*2.13*	*1.92*	*1.90*	*2.88*	*2.76*	*2.23*	*2.18*	*1.97*	*2.03*
Non-ferrous metal	*0.00*	*3.71*	*3.13*	*2.71*	*2.38*	*2.35*	*0.29*	*3.79*	*3.18*	*2.76*	*2.43*	*2.48*
Non-metals	*2.38*	*2.71*	*2.13*	*1.92*	*1.54*	*1.51*	*2.68*	*2.78*	*2.17*	*1.97*	*1.59*	*1.64*
Other industry	*2.19*	*2.41*	*2.33*	*2.33*	*2.17*	*2.17*	*2.49*	*2.49*	*2.38*	*2.38*	*2.22*	*2.30*
Residential												
Cooling	*0.50*	*0.48*	*0.47*	*0.00*	*0.46*	*0.45*	*0.91*	*1.04*	*0.74*	*0.28*	*0.53*	*0.48*
Clothes drying	*0.00*	*1.61*	*0.00*	*0.00*	*0.00*	*0.71*	*0.41*	*2.18*	*0.26*	*0.28*	*0.07*	*0.74*
Clothes washing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.41*	*0.55*	*0.26*	*0.28*	*0.07*	*0.03*
Dishwashing	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.41*	*0.55*	*0.26*	*0.28*	*0.07*	*0.03*
Other electronics	*3.98*	*4.19*	*3.28*	*3.13*	*2.71*	*2.71*	*4.28*	*4.27*	*3.33*	*3.18*	*2.75*	*2.84*
Space heat	*0.47*	*0.46*	*0.36*	*0.36*	*0.35*	*0.35*	*0.89*	*1.01*	*0.62*	*0.63*	*0.42*	*0.38*
Hot water	*0.45*	*0.47*	*0.35*	*0.37*	*0.34*	*0.34*	*0.87*	*1.02*	*0.62*	*0.65*	*0.41*	*0.37*
Cooking	*0.45*	*0.44*	*0.36*	*0.35*	*0.34*	*0.34*	*0.86*	*0.99*	*0.62*	*0.63*	*0.41*	*037*
Lighting	*0.00*	*0.79*	*0.76*	*0.00*	*0.73*	*0.38*	*0.41*	*1.35*	*1.02*	*0.28*	*0.80*	*0.41*
Others	–	–	–	–	–	–	–	–	–	–	–	–
Refrigeration	*0.70*	*0.00*	*0.68*	*0.00*	*0.00*	*0.00*	*1.12*	*0.55*	*0.95*	*0.28*	*0.07*	*0.03*
Transportation												
Domestic aviation	*1.65*	*1.72*	*1.55*	*1.44*	*1.21*	*1.28*	*1.95*	*1.80*	*1.59*	*1.49*	*1.26*	*1.41*
Internal aviation	*1.98*	*2.18*	*2.11*	*1.87*	*1.54*	*1.50*	*2.28*	*2.26*	*2.15*	*1.92*	*1.59*	*1.63*
Bus	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.07*	*0.17*	*0.12*	*0.12*	*0.02*	*-0.10*
Comm Trucks	*1.39*	*1.46*	*1.36*	*1.55*	*1.31*	*1.33*	*1.69*	*1.53*	*1.40*	*1.60*	*1.35*	*1.46*
3 wheels	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.07*	*0.17*	*0.12*	*0.12*	*0.02*	*-0.10*
Heavy Trucks	*1.40*	*1.42*	*1.44*	*1.44*	*1.34*	*1.34*	*1.69*	*1.50*	*1.48*	*1.49*	*1.39*	*1.47*
Light Vehicles	*0.45*	*0.48*	*0.51*	*0.46*	*0.45*	*0.44*	*0.74*	*0.56*	*0.56*	*0.51*	*0.49*	*0.57*
Medium trucks	*1.40*	*1.49*	*1.39*	*1.46*	*1.21*	*1.21*	*1.70*	*1.57*	*1.43*	*1.51*	*1.26*	*1.34*
Automobiles	*0.44*	*0.50*	*0.49*	*0.48*	*0.43*	*0.44*	*0.73*	*0.57*	*0.53*	*0.53*	*0.48*	*0.57*
2 wheels	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.07*	*0.17*	*0.12*	*0.12*	*0.02*	*-0.10*
Rail-freight	*0.98*	*0.93*	*0.89*	*1.02*	*0.81*	*0.80*	*1.28*	*1.01*	*0.94*	*1.07*	*0.86*	*0.93*
Rail-passengers	*0.09*	*0.00*	*-0.09*	*-0.09*	*-0.09*	*-0.09*	*0.15*	*0.17*	*0.04*	*0.04*	*-0.07*	*-0.19*
Domestic navigation	*0.69*	*0.74*	*0.71*	*0.75*	*0.66*	*0.63*	*0.99*	*0.81*	*0.75*	*0.80*	*0.71*	*0.76*
Internal navigation	*0.68*	*0.74*	*0.73*	*0.72*	*0.68*	*0.62*	*0.97*	*0.82*	*0.77*	*0.76*	*0.72*	*0.75*

6.4 Energy-efficient technologies

The increase of energy efficiency implies the availability of technologies that are able to perform the same energy service while consuming less energy. The bottom-up analysis of energy demand thus requires an in-depth analysis of energy technologies, and in particular of end-use technologies. If we look at the short- to medium-term future, we can limit ourselves to the consideration of technologies that are already on the market, or close enough to the market to be able to make reliable assumptions on their capability of entering the market in the future. If we consider a longer time horizon (e.g. more than 10 years) we should also consider that new technologies are going to be developed and will eventually be available. Such a prediction is of course difficult to make, but one can make "educated guesses" that a new unspecified technology delivering a given energy service at a certain level of efficiency will be available on the market in a certain time frame and at a certain price; although each guess may well be wrong, on the average overestimates should roughly compensate underestimates.

In any case, as we shall see, a consistent increase in energy efficiency could be obtained (at a cost) by employing technologies which are already on the market. In the following, an examination of EU trends in energy efficiency will be presented, at an intermediate level between the aggregated economy and the single technologies, i.e. classified by end-use sector. This will give some indications on the possibilities of extrapolation by sector and on the technological evolution of end-use technologies by energy service.

6.5 EU Trends in Energy Demand and Energy Efficiency

IEA [OECD/IEA, 2004] has studied the overall trends in IEA-11 over the period 1973-1998. From 1973 to 1990 average saving by efficiency gain and structural changes were in the order of 2%/year, but during the subsequent period 1990-1998 they collapsed to 0,9%/year because of economic slump down. The following section considers only the last period for each sector of the economy (households, services, industry and transport), and efficiency indicators and consumption trends are reported on.

Table 6.5 - Overall EU Trends

Statistic	Time Period	Change
Energy Consumption Trend	1990-2003	18% increase
Electricity Consumption Trend	1990-2002	24% increase[3]
Energy Efficiency (ODEX)	1990-2002	9.6% improvement

Final consumption of energy in the EU-15 has increased between 1990 and 2003. Electricity consumption shows the most consistent increase with an average growth rate of 2% per year over the period Table 6.5). However, energy efficiency has improved by approximately 7% in the EU-15.

Structural change accounts for some of the energy efficiency improvement in individual Member States and for the whole EU-15. Structural change is particularly important in manufacturing industry where it represents 1/3rd of the avoided energy demand, converting to less energy intensive products (like electronics) Most significant trends in each sector's share of final energy consumption are a decrease share for industry (-3%), and an increase in share for transport (+3%). Fuel switching can also influence energy efficiency, and a trend towards increasing share for electricity and gas is evident in the EU-15, as is a move away from solid fuels. Overall energy efficiency (ODEX indicators) shows consistent improvement in every sector for the EU as a whole. More detailed analysis of trends appears below.

Finally, a measure of the potential for further demand reduction (or energy efficiency) has been investigated in the ODYSSEE project **/ODYSSEE 2004/**[4]. Results are debateable because the adjusted indicators may suggest a potential that is difficult to achieve in practice where each economy is defined by its incumbent structure. However, the countries are ordered according to their perceived potential for improvement (descending order). The reported order is Luxemburg, Norway, Belgium, Finland, Greece, Portugal, Ireland, Netherlands, Sweden, UK, Spain, Germany, Denmark, France, Austria, and Italy. All countries "above" Germany are below the EU average adjusted energy efficiency.

[3] Electricity consumption trends are reported from **/IEA 2004b/**
[4] A brief description of indicators developed in the ODYSSEE project is given in Appendix A.

6.5.1 –The Households Sector

Table 6.6 – Households Sector

Statistic	Time Period	Change
Energy Consumption Trend	1990-2003	7% increase
Electricity Consumption Trend	1990-2002	23% increase
Energy Efficiency (ODEX)	1990-2002	9.6% improvement

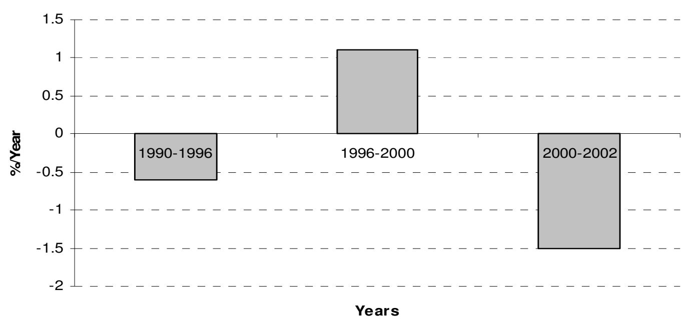
Energy services at the residential sector can be distinguished into heating (space and water heating), electrical appliances and lighting.

Overall Trends for Households

The average consumption per dwelling has shown a slight decrease between 1990 and 2002 **/ODYSSEE 2004a/**. The trends between1990 and 2002 are not clear, as evidenced in Fig. 6.1, probably because of a compound of climate fluctuations and changes in consumers' behaviour.

Figure 6.1

% Change in average consumption per dwelling in the EU-15[9]



The trends of consumption in the residential sector are different across the EU-15 countries and Norway for the period 1990-2002. Decreasing consumption is apparent in the Netherlands, Denmark, Norway, Sweden, France, and Ireland. All other EU-15 countries have experienced increasing consumption over the period.

Between 1973 and 1998, the share of appliances' energy consumption in EU Member States households' sector grew from 5% to between 10 and 15%. Space heating share reduced from 67% to 55% in IEA-11 countries over this period and it appears a similar downward trend was evident in Europe. Shares of other uses remained reasonably stable with the exception of a small increase for water heating **/IEA 2004/**.

The factors that affected consumption trends were shown to be income, energy price and the effectiveness of building codes and standards. EU-15 households' energy consumption showed a slight decrease (around 0.18% annually) even though income progressed by almost 1% per year and the energy prices decreased by approximately 0.75% per year. It appears that introduction of new and stricter standards and codes for building of new dwellings in the EU-15 have had direct impact on their consumption. However, the simultaneous enlargement of dwellings' surface offset half of the gains in terms of consumption per m^2 for the period 1985-2001.

Efficiency of the residential sector exhibited a rapid improvement through the period 1990-1996 of almost 10%, but from then until 2002 it remained essentially stable (total 8% over that period). Almost the same pattern has been followed by the heating efficiency of dwellings, whilst the efficiency of large appliances constantly improved (by 20%) between 1990 and 2002.

Regarding CO_2 emissions, more efficient use of energy and fuel switching combined to result in a faster decrease in emissions per dwelling compared to decrease in consumption per dwelling.

Heating (Space and Water Heating)

Space heating is the dominant consumer of energy in the households' sector. The energy consumed for space heating between 1990 and 2002 has increased by almost 9%, while its share in an average household's energy consumption decreased from 70.8% to 68.8%. The efficiency of heating showed a 10% improvement for the time period between 1990 and 1996, but between 1996 and 2002 remained effectively constant.

Consumption related to domestic hot water has also increased overall, and its share in consumption of and average household has increased slightly (from 13.3% in 1990 to 13.8% in 2002).

Cooking, Electrical Appliances and Lighting

Total energy consumption of appliances and lighting has increased in the EU-15 between 1990 and 2002. The largest increase is apparent for small electrical appliances (ODYSSEE divides electrical appliances into large and small categories. The large category includes refrigerators, freezers, washing machines, dish washers, televisions and dryers). The percentage share of energy consumption in an average household has been falling constantly between 1985 and 2001 for large appliances and lighting (whilst overall energy consumption increased, as noted above). Conversely, the share for small electrical appliances is rising rapidly and could soon surpass large appliances.

6.5.2 The Services Sector

Table 6.7 -Services sector

Statistic	Time Period	Change
Energy Consumption Trend	1990-2003	20.8% increase
Electricity Consumption Trend	1990-2002	45.9% increase
Energy Efficiency (ODEX)	1990-2002	15.6% improvement

The Services sector has undergone significant growth over the period analysed by ODYSSEE **/ODYSSEE 2004c/**

Productivity, value added and space used have all increased. Fuel switching has been a strong driver of efficiency in the sector, and solid fuels were virtually non-existent in the mix by 2002.

The energy consumed per employee has slightly fallen, whereas the consumption per m^2 and the total energy intensity have shown substantial decrease in the period 1990-2002. There has been a decoupling of energy consumed from the value added for the EU-15 as a whole, but this trend is not evident at the same magnitude for every EU-15 country. Greece, Ireland, Italy, Portugal, and Spain exhibit increasing electricity intensity (kWh/Euro), whilst the other EU-15 countries (and Norway) show either saturating or decreasing intensity.

Other observations from this sector include the diversity of consumption profiles across different parts of the sector, and the importance of building standards. When the services sector is segregated into its constituent parts, wide variation is apparent between EU Member States. The role of the building codes, particularly aspects concerning thermal efficiency, has been a significant efficiency-related factor, as the annual reduction of consumption per meter square varies from less than 1% in the UK (1995-2000) and roughly 1% in France (1990-2002) to almost 5.5% in Germany (1996-2002).

The emissions abatement during the period 1990-2002 has been dominated (60% of the reduction achieved in the sector) by the fuel switching in the services sector. There appears to be further potential for emissions reduction in this sector.

6.5.3 The Industrial Sector

Table 6.8 Industrial Sector

Statistic	Time Period	Change
Energy Consumption Trend	1990-2003	1.5% increase
Electricity Consumption Trend	1990-2002	18.9% increase
Energy Efficiency Trend	1990-2002	13.2% improvement

The EU Industrial sector has shown superior performance in energy intensity reduction between 1990 and 2002, mainly driven by energy efficiency improvements, fuel switching, and structural changes **/ODYSSEE 2004d/**. All of the EU-15 countries, apart from Portugal and Spain, display this trend. However, total energy consumption in the sector remained virtually stable over the period.

Paper and Pulp, Chemicals, Non-metallic minerals, and Metals accounts for a very large share of the sector's energy consumption, but are only responsible for a small share of the value added in the sector. "Other Manufacturing" contributes roughly 70% of value added, but for example, displays an energy intensity 1/10th that of Metals production **/IEA 2004a/**.

Another important issue is the trend in energy intensity of different types of manufacturing in the EU-15 for the time period from 1990 to 2002. The manufacturing as a whole accomplished a net decrease in intensity, mainly due to improvements by the chemicals, metals and non-metallic minerals production, and partially from the equipment industry. However, the trends for the first two industries show a deceleration of improvement after 2000, whilst equipment manufacturing has significantly deteriorated between 2000 and 2002, with energy intensity increasing by around 1.7% annually.

Interestingly, the majority of the EU-15 countries have managed to retain a pace of energy intensity reduction within a range of 1-1.5% per year, with Finland and Germany achieving over 2% per year. An outlier is Ireland, which achieved an annual reduction of almost 7% per year. However, wide variation in structure (and thus energy intensity) of industry in Member States makes comparison difficult. As for the savings in CO_2 emissions, 75% out of savings came from energy efficiency progress and the rest from fuel switching from coal and oil to gas.

6.4 The Transport Sector

Table 6.9 Transport Sector

Statistic	Time Period	% Change
Energy Consumption Trend	1990-2003	22.7% increase
Electricity Consumption Trend	1990-2002	30.6% increase
Energy Efficiency Trend	1990-2002	7.2% improvement

Transport in the EU-15 Member States is consuming more energy every year; from 9% per year increase for the light vehicles to less than 0.9% per year for rail **/ODYSSEE 2004e/**. Air transport is also an important energy consumer with an annual growth rate of approximately 4%. This is despite an EU-wide energy efficiency improvement, measured via an ODEX indicator, of approximately 6% over the period.

The trends of energy consumption show a decline of road transport's share in total transport's consumption falling to 80% in 2001 from 84% in 1990, but a substantial growth in air transport, from 10% to 14%, in the same time period. About half of the transport energy consumption is caused by cars, although there has been a small decline in its share from 53% in 1990 to 48% in 2001.

The increased share of goods transport (from 25% to 30%) has affected the total energy efficiency of the sector, which underwent a relative stabilisation since 1999, after consistent improvement before this time.

The emissions of CO_2 caused by all types of transport have been constantly rising since 1990. In fact, transport is the only sector whose emissions still grow by more than 1.5% per year. This figure should be considered alongside the fact that the global warming impact of emissions from aviation, a rapidly growing transport mode, is still relatively poorly understood.

7 Policy instruments to increase energy efficiency

7.1 From energy services to energy: energy efficiency and consumers' behaviour

A complex array of factors influence the evolution of demand for genuine energy services. Final energy demand is further influenced by the efficiency of device providing the service. The tension between increased demand for energy services (resulting in increased aggregate consumption) and improving energy efficiency is important. As we have seen in section 6.1, this can be done both by promoting a more "rational" behaviour by the consumer (in particular by discouraging waste) and by promoting the adoption of more energy-efficient solutions.

The fact that externalities[5] are not included (or at least not fully included) in the price paid for energy, makes it unlikely that the market, left to itself, will take these externalities into account. For this reason, most people (even if not all, as we shall see) consider it appropriate that governments regulate the energy market and introduce price signals that take into account the societal aspects of the energy cycle, such as the protection of the environment, the stability of global climate etc.

As we shall see further on, many types of energy policy instruments to improve energy efficiency are available and have been used in different contexts. On overview of the variety of such instruments and some attempts to classify them are presented in Section 7.2. A brief history of the recent efforts in directing legislation towards the promotion of energy efficiency at the level of the European Union is given in Section 7.3, and an overview of the status of legislation in the Member countries in Section 7.4, based on the results of the ODYSSEE study. Section 7.5 looks at the situation from a somewhat more general viewpoint, and discusses the theoretical approaches to Demand Side Management and Integrated Resource Planning: a view that may help in planning future moves towards converging instruments in the EU for the future.

7.2 Variety and classification of policy instruments

Measures to promote energy efficiency are a cornerstone of most energy policies in the European Union, where studies have shown that energy consumption could be decreased by 20%, making a significant contribution to achieving a low carbon future **/European Commission 2005/**. These measures are perceived to create a mutually beneficial situation where reduced energy use and subsequent greenhouse gas emissions reduction complements economic benefits and improved security of supply, implying a "no regrets" potential to meet a number of general policy aims. In addition to no regrets potential, there appears to be substantial additional benefit to be obtained, in terms of reduced greenhouse gas emissions, at very low cost. However, although improving energy efficiency is a trend evident across European Member States, it appears that in general the full potential is rarely realised, and total energy demand consistently increases.

An arsenal of policy instruments influence improvement in energy efficiency in Europe. These range from efficiency targets where non-compliance is heavily penalised, to purely market based measures. Measures can target supply and/or demand side, based on incentives for retailers, distributors, generators, or consumers, and can be focused on greenhouse gas abatement or directly on energy use. They can be voluntary or obligatory. The precise impact of the measures is difficult to interpret given the number and complexity of factors influencing uptake of energy efficiency technology, fuel switching, structural change in economies, and behavioural change.

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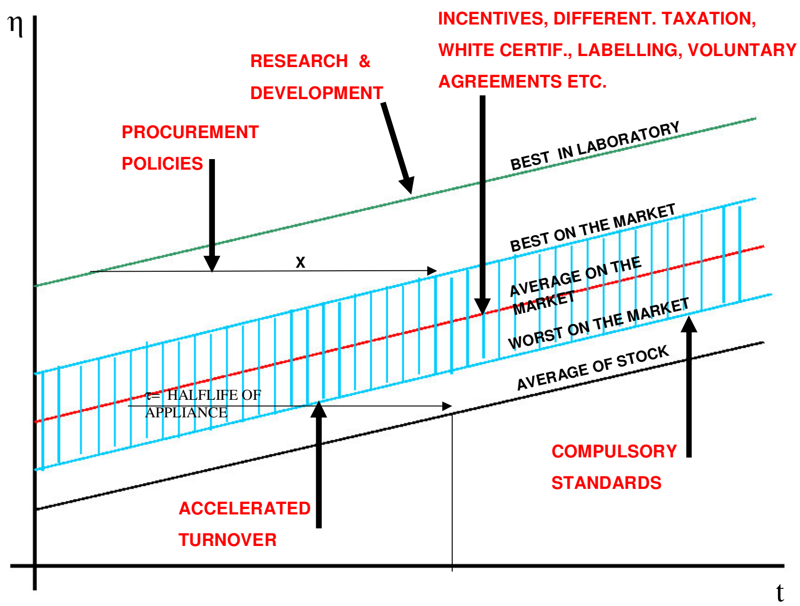
[5] Externalities are indirect costs of the energy system which are not paid by the final user of energy, or not fully or proportionally to the quantity of energy used, but by other groups of citizens and, often, by society as a whole. Examples are damages to the environment or to health. In some cases externalities can also be positive (e.g. job creation); in this case, they are considered externalities if the advantages do not concern the client who pays for the energy.

Many possible classifications of energy policy measures have been proposed and applied; we shall shortly mention three of them.

The first scheme is indicated in Fig. 7.1, and it refers to the possible measure to improve the average energy efficiency of the stock of a certain appliance (e.g. a refrigerator), but could be extended with small changes to virtually all other types of energy services.

Fig. 7.1 Schematic representation of measures to improve the efficiency of appliances



The average efficiency (quantity of service delivered per unit of energy consumed, η) increases spontaneously with time as a consequence of the natural improvement of technologies. Assuming all processes to be linear, if the half-life of the appliance considered is τ years (i.e. half of the stock of this appliance is renewed every τ years), then the average efficiency of the stock existing today is equal to the average efficiency of the appliances sold on the market τ years ago. The market will offer (at various prices) appliances with efficiencies falling in a certain range, from a minimum ("worst on the market") to a maximum ("best on the market"). The client will make his choice according to price, performance, energy consumption and other criteria.

The "best on the market" will in term derive from the efforts of R&D (curve "best in laboratory") which will be brought to the market with a certain delay, assumed to be x years.

Policies and measures to improve energy efficiency can address all of these steps by increasing the slope of the curves, lifting them, or bringing them closer to each other. In particular:

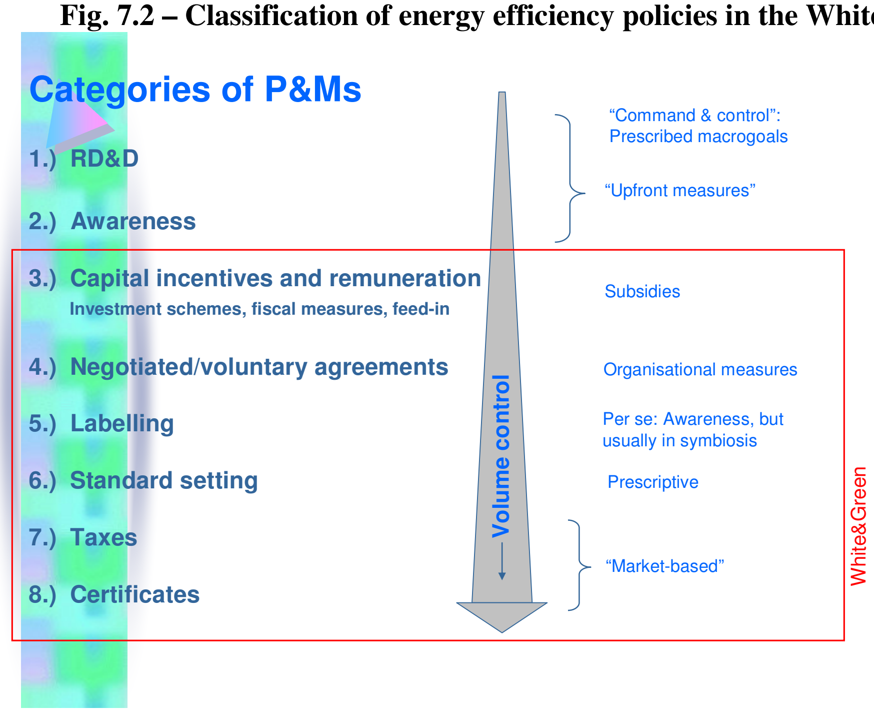
- The stock average can be brought closer to the market average by decreasing τ through the promotion of an accelerated turn-over (incentives to replace a low-efficiency appliance with a new one)
- The curve of the "worst on the market" can be brought upwards by introducing minimum efficiency compulsory standards
- The clients' choices in the market (hence the "average on the market" curve) can be influenced in the direction of higher efficiency models by a number of different instruments, including: labelling (which makes the buyer conscious of the energy consumption of the appliance); incentives for the more efficient models; differential taxation (e.g. a higher VAT for inefficient than for efficient models); voluntary

agreements between producers and government; and the system of "white certificates" requiring a compulsory improvement of energy efficiency

- The "best on the market" curve can be improved by speeding up the transfer from the laboratory to the market, which has been done in some cases by appropriate public procurement policies demanding efficiencies above those present in the market
- Finally, the "best in the laboratory" curve can be increased by greater investments in R&D.

The second classification of energy efficiency policies is the one adopted in the first phase of the White and Green Project /Oikonomou 2003/ (see Fig. 7.2). The organizing principle of this scheme is the ability **of the Policies and Measures (P&M) to directly steer the absolute level of energy use and emissions**: While, for example, **RD&D** (Research, Development and Demonstration) is undoubtedly crucial for improving energy efficiency the concrete outcome in absolute terms is usually hard to foresee since a substantial share of all RD&D efforts does not result in a commercial product or service. **Labelling** operates via awareness and relies on the judgement of the well-informed buyer who has, however, the freedom of choice. Freedom of choice is no more present in the case of **standards** which have a "prescriptive", i.e. mandatory, character and may hence allow to reduce energy use more directly. Systems of **certificates or emission permits** may directly prescribe a level of emissions, or a specified reduction in energy consumption, and result therefore in a direct modulation of the absolute level of energy use.

Fig. 7.2 – Classification of energy efficiency policies in the White and Green project



The White and Green paper also considers that according to economic theory, policy measures can be divided into **four main categories** depending on their market approach and the participant's actions required.

The **first category** is widely known as **financial measures;** they include subsidies, grants and taxes. The government can change the cost of the use of energy through taxation and subsidy policies. Subsidies include grants and low-interest loans while taxation policies could include energy use or pollution taxes. The following types of taxation can be distinguished:

- Emission charges/taxes: Emission charges/taxes stand for direct payments based on measurements or estimates of the quantity and quality of pollutant discharged.
- User charges: User charges are payments for the cost of collective services, and are primarily used as a financing device by local authorities e.g. for the collection and/or treatment of solid waste or sewage water.
- Product charges/taxes: Product charges/taxes are applied to products that create pollution either when they are manufactured, consumed or disposed of. Product charges/taxes are intended to modify the relative prices of the products and/or to finance collection and treatment systems. One form which product charges/taxes may take in practice, is that of tax differentiation leading to more favourable prices for "environmentally friendly" products and vice versa (e.g. car sales differentials as on fuel efficiency, existence of catalytic converter, compliance with emission standards etc.); and tax differentiation between leaded and unleaded fuel) **/OECD 1999/**.

The **second category** of instruments is the **legal or regulatory instruments**. In this case, governments can set legal requirements on power companies, industry and households with financial penalties for non-compliance. They have been considered as a traditional main pillar of environmental policy (command-and-control). Examples include appliance, vehicle and building standards (on energy use or emissions), land and other resource management codes and standards for technology (e.g., a renewable portfolio standard in electricity requires that a minimum percentage of electricity is produced by renewable technologies).

The **third category** of measures is the **organizational measures** that mainly include the negotiated and voluntary agreements. These agreements are commitments undertaken by power producers or industries in consultation or negotiation with a public authority, and usually recognized by that agency; they are expected to have a high degree of effectiveness if they are combined with other P&M's **/Carter 2001/**. These agreements can take many forms concerning the degree of bindingness (e.g. legally non-binding press statements to legally binding covenants) and the way in which they have been arrived at. They may include a wide range of issues, such as a decrease in energy consumption or the phasing in of low sulphur petrol **/Jordan et al, 2003/**.

The **last category** is the **Certificates or the marketable (tradable) permits/quotas**. Under this market based mechanism fall the Emissions Trading scheme, the White and the Green Certificates. For the emissions trading scheme the basic principle is that any increase in emission from a given source must be offset by a decrease in emissions of an equivalent quantity. For example, when a statutory ceiling on pollution levels is fixed for a given area, a polluting firm can set up a new facility or expand its activities only if it does not increase the total pollution load. The firm must therefore buy "rights" or allowances to pollute from other firms located in the same control area, which are then required to abate their emissions by an amount equal to the additional pollution emitted by the new activity (OECD, 1999).

A variant of the classification of measures based on their directness proposed by ICEPT considers that measures addressing the demand side energy efficiency of various genuine energy services are implemented through a variety of direct and indirect means:

- Direct
  - Measures to encourage or oblige energy retailers or electricity distributors to reduce consumption of their customers,

    - agreements between (government or government funded) agencies and industry,
    - labelling, accreditation and auditing schemes (e.g. for appliances or buildings).
- Indirect
    - Energy and/or emissions taxation (e.g. the UK climate change levy),
    - market liberalisation with a responsive demand side,
    - emissions trading.

These measures can be further classified into voluntary and compulsory schemes, and it is common that a country is subject to a combination of measures

A common criticism of measures applied is lack of economic efficiency, where it is perceived that the market is not given the choice of where it is cheapest to improve energy efficiency. Whilst any approach, market-based or not, can be tailored in an attempt to encourage improvements where it costs least, these attempts can often be viewed as inappropriately artificial. Therefore, there are proponents of purely market based systems, where in theory energy efficiency improvements will occur where it is cost effective. However, this will only occur in a perfect market, where all participants have equal access to information, are equally exposed to market movement, and are equally motivated to take part. Experience shows that market liberalisation alone, whilst arguably effective in improving supply side efficiency, appears unlikely to achieve significant improvement of demand side efficiency under current market structures. This is because although market opening creates competition between retailers to attract customers, and the customers themselves are directly exposed to at least one benefit of energy efficiency (reduced energy bills), liberalisation itself usually creates few *new* incentives for demand side efficiency over previous energy market systems. Newer measures such as emissions trading may be a more effective tool to improve demand side efficiency, where national allocation plans directly involve consumers in several sectors, but may suffer from the same issues as the liberalised market where important sectors (i.e. residential) are exposed indirectly. Experience has shown that significant benefit can be obtained from more direct non market-based intervention, such as target-based regulation, but whether or not this action can be economically efficient remains a point of contention.

7.3 Recent history of energy efficiency policies in the EU

This sub-section and the following one review European energy efficiency related policy and recent developments, including consideration of major actions by each of the EU-15 Member States. Trends revealed from the ODYSSEE indicators projects **/ODYSSEE 2004b/**are reviewed, and energy efficiency potential of accession states considered.

The current state of EU energy efficiency policy is primarily related to the consultation underway in relation to the Green Paper on Energy Efficiency **/European Commission 2005/**, the proposal for a Directive on Energy End-Use Efficiency and Energy Services **/European Commission 2003/**, and the recent Directive on the Energy performance of Buildings **/European Parliament and Council 2002/**. The Green Paper identifies options for achieving energy efficiency aims and seeks opinions regarding the suitability and cost effectiveness of these options in order to form the EU's energy efficiency (and possibly new directives) from 2006 onwards.

The proposal for a directive on energy end-use efficiency and energy services began in 2003, and has been revised on many occasions. Whilst the primary aim of the proposed directive is to increase energy end-use efficiency, an important part of this is the suggestion that binding demand reduction targets should be set for each member state. A number of other operational measures were suggested to achieve energy end-use efficiency, including opening the market for energy services, and obligation on Member States to ensure some distributors and retailers offer energy efficiency services. The current status of this proposal for a directive is that Member States have reached a common position where binding targets would not be enforced, and would be replaced with indicative targets. Debate continues regarding the proposal.

The Union is eager to reduce energy demands in buildings, as its recent Directive[6] 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings shows (**/EU 2002/**). The overall objective of the Directive on the energy performance of buildings is to promote the improvement of energy performance of buildings within the Community taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness. It will greatly affect awareness of energy use in buildings, and is intended to lead to substantial increases in investments in energy efficiency measures within these buildings. Legislation must be in place by 4 January 2006, and will affect all buildings, both domestic and non-domestic. The major responsibility for practical measures to meet the requirements will fall on building services engineers. It facilitates requirements to measure energy use in buildings by: introducing agreed measurements of relative energy performance, regular inspections and re-evaluations; requiring higher standards for upgrading larger buildings; improving standards for new buildings.

Regardless of the overall direction of the EU, each member state has moved to some form of energy saving policy. These have achieved different outcomes, often due to differing primary aims of the various policies. Overall EU energy efficiency has gained 7% between 1990 and 2000, but only 3% between 1993 and 2000. The remaining cost-effective potential for demand reduction was estimated at 1900TWh, which is divided into approximately 17% of consumption in the industrial sector, 14% in transport, and 22% in household and service sectors **/European Commission 2000/**. Trends in demand for energy services and energy efficiency are discussed in detail below.

In the liberalised energy markets of most EU Member States the energy companies have rarely entered the market of value added services, preferring to concentrate on the existing unit-based service provided. Competition has been focused on unit prices, largely ignoring the demand side. However, some small steps have been achieved concerning new products or value added to existing ones (not necessarily energy efficiency improvements) for some groups of customers **/Thomas et al. 2002/**. The large customers have obtained the clearest benefit from these energy efficiency services. In these cases appropriate policy framework should accelerate this process. In Member States where policy does not support such action by energy retail companies, only a few companies that wish to be identified as innovators or environmentalists in the market have entered the energy efficiency services market **/Thomas et al. 2002/**.

7.4 Recent history of energy efficiency policies in the Member states

Policies and trends revealed in this section are based on EUSUSTEL individual country reports and the ODYSSEE indicators project **/Odyssee 2004/**. Similarly to above, the consumption trend and efficiency progress of each country are noted.

7.4.1 Austria

Climate Action Plan and *Eco Electricity Act 2002* have been launched to support the ongoing changes in the energy consuming sectors. In industry, energy efficiency programmes and the allocation of the greenhouse gas emissions for the EU emissions trading scheme (EU-ETS) dominate the policy instruments. The *klima:activ* action programme commenced in 2003 and incorporates many programs for climate protection related to improvements in energy efficiency in the residential sector (households and services). Other measures include building regulations, and subsidies for suitable energy efficiency measures.

[6] In order to meet the agreed Kyoto targets, the European Union must implement reductions of 330 million tonnes between 1990 and 2010 and the Directive, according to the European climate change programme, is intended to contribute to achieving the commitment to reducing emissions. According to the European energy commissioner, a cost-effective savings potential of around 22% of present consumption in buildings can be realised by 2010 and the directive could deliver up to 45 million tonnes of carbon dioxide reduction by 2010.

The development of a sustainable transport system, fuel and vehicle taxation system, adoption of the European standards for emissions as well as the information of customers regarding the efficiency of vehicles are the most important measures to promote energy efficiency in transportation.

The country's overall energy efficiency has been improved by 16% between 1990 and 2002, with savings spread approximately equally across all sectors of the economy. Effective measures in industry, especially the allocation of emissions for the EU-ETS, are aiming to further ameliorate the sector's energy efficiency. Households and buildings benefit from regulations and subsidies for efficiency measures such as renovations and renewals of the heating systems.

7.4.2 Belgium

In Belgium, several measures have been adopted for energy efficiency improvement in all sectors of the economy. The *Federal Plan for Sustainable Development 2000-2004* set target of 7.5% reduction in energy consumption between 1990 and 2010, linked with incentives for the development of cleaner technologies. Industry, Households and Services, and Transport have all been subject to planned energy consumption reductions and efficiency measures. More specifically, in industry, energy efficiency is based on voluntary agreements between the sector's firms and the regional governments.

For the residential sector the implementation of the European Directive 2002/91 into legislation has been undertaken by the Flemish Government while for the other two regional governments it is under preparation. Public transport promotion and support, including free use, are included in the efforts for efficiency improvement.

The overall energy consumption has decreased by almost 8%. This figure is largely due to the efficiency improvement in the industrial sector of 15% compared to the 1990 levels. On the other hand, the households and transport sectors' experienced less substantial efficiency performance, with improvement of roughly 5% between 1990 and 2002.

7.4.3 Denmark

To achieve reduction of end-user energy demand, Denmark has applied green taxes, primarily targeting space heating. Subsidies exist for efficiency measures in households, and some DSM measures have been implemented by electricity retail companies. Programmes for raising public awareness on efficiency of electrical appliances are in effect. In industry green taxes and voluntary agreements enhance energy savings. Further, the taxation system that has been applied for energy use has been quite successful in promoting energy savings.

All sectors of the economy in Denmark have experienced efficiency improvement – industry 13.3%, households and services 9.3% and transport 14.6%. Total efficiency improvement was 12.9% between 1990 and 2002. The only part of industry that has not progressed at all is the steel industry, remaining at the same levels as in 1990. The energy efficiency improvement of the large electrical appliances has been influential to the stabilisation of the electricity consumption in the country.

7.4.4 Finland

The *Energy Efficiency Action Plan* and the *Action Plan for Renewable Energy Sources* combined aim to achieve half of the emissions reduction target, along with emissions control in the electricity generation for the other half. In industry, measures include voluntary agreements and energy audits. In households and services, the 2003 Act on repair and energy aid for houses targets a 25-30% reduction in energy consumption of new buildings, while in the services sector, agreements for energy conservation currently involve almost 80% of the existing building stock. The voluntary energy conservation agreement for trucks and transport completes the measures in the economy's sectors for energy efficiency.

From 1990 to 2002 the total energy efficiency improvement of the country was 14%. The most important improvements have been recorded in the industrial sector, while in residential and transport the figures are 4% and 6% respectively. Energy efficiency in households is closely associated to the heating demands.

7.4.5 France

The National Programme against Climate Changes (PNLCC) and the National Programme on Energy Efficiency Enhancement both began in 2000, and were supported by the new Climate Plan of 2004. For future trends, it is planned to reduce the country's dependency on oil, to cut the GHG emissions to one forth and to guarantee competitive prices of energy. These targets are incorporated into the *Project of Energy Orientation Law*, which foresees support to nuclear energy, improvements in energy intensity by 2.5% before 2030, energy efficiency progress, as well as support for renewables and biofuels.

In the industrial sector, funding for energy efficiency investments, called FOGIME, is available for energy companies. Under this program, loans from the financial sector to the companies making investment are guaranteed by ADEME.

The new building insulation standards set in 2001 were aiming for energy savings of 15% for households and 40% for the services sector. Subsidies are provided for building improvements, while the spread of knowledge is conducted by the local information centres.

Between 1990 and 2002 the energy efficiency of final consumers has been improved by 11%. All sectors have shown progress with industry accounting for 16% compared to the 1990 levels while households and transport both achieved 9%. More specifically, the 'leaders' of the industry in efficiency improvement are the steel and chemical producers. In the residential sector, the space heating requirements have decreased due to the larger number of the new dwellings in the total stock, which substantially affects the total energy demand of this sector.

7.4.6 Germany

From mid 1990's energy efficiency in industry was based primarily on voluntary agreements. However, from 2004 the *National Allocation Plan* (linked with the EU-ETS) allocated emissions rights to each plant for the trading period 2005-2007. Also in 2004, the implementation of the EU Directive *Law on greenhouse emissions trading* supported the emissions trading system.

For the residential sector the *Energy Conservation Ordinance* for reducing buildings' energy use by 25-30%, the *Housing Modernisation Programme* to improve buildings energy efficiency, and an *information campaign on efficient electricity* all became active from 2002. Furthermore, taxation reforms under the *Ecological Tax Reform* have been introduced in stages from 1999 to 2003 and include tax reductions mainly for manufacturing and agricultural sectors (initially 20% of the normal rate, 60% after 2003) and 50% reduction on electricity tax for the railways.

In Germany, total energy efficiency improved by 10.2% in the period 1991-2002. This general result was consistent across all sectors apart from the residential one where a slight deterioration of 1.5% is indicated. The German industry shows a better efficiency improvement compared to the average member state in terms of energy used for a unit of product (22.1% for Germany compared with almost 10% for the EU-15). The minor degradation of the residential sector is potentially due to the extreme weather conditions in winters. Nevertheless, this has been ameliorated by significant improvement of efficiency for large electrical appliances'.

7.4.7 Greece

The most important instrument for the industry is the *Operational Programme for Competitiveness 2000-2006* which targets the support on energy efficiency and rational use of energy in general, along with the promotion of renewables. Several laws have been in force to provide financial support for energy efficiency and renewables investments in industry. For households and transport sectors there is only a decision to reduce the energy consumption and new energy and CO_2 labelling respectively. From early 2002 the *Joint Ministerial Decision 90364* incorporates the EU Directive in the Greek legislation concerning the fuel consumption and CO_2 emissions labelling of vehicles.

In Greece the total energy efficiency for the period 1990-2002 was improved by 7.1%. All sectors have affected this development, apart from the residential one, which became more energy intensive by 16.8% due to energy inefficiency for space heating and cooling. The industrial sector has shown energy efficiency improvement by 15.6% in 2002 compared to the 1990 levels, which is dominated by the important improvements in the steel and chemical industry (53.3% and 54.7% respectively). Transport achieved almost equivalent progress as the industrial sector (15.2% in 2002 over the 1990 levels).

7.4.8 Ireland

The progress of Ireland in meeting its energy demand in an eco-friendly way is mainly presented in the Green Paper on Sustainable Energy and the National Climate Change Strategy. The latter outlines strategies for meeting the Kyoto agreements. Further, in 2004 the idea of a carbon tax was abandoned as it was considered to be too great an economic burden, especially for the residential sector. The *Large Industry Energy Network* for the industry, the *House of Tomorrow,* the *Low Income Housing Programme* and the *Proposed Energy Conservation Standards for New Dwellings 2002* for the households and services and the *Car Labelling* for the transport are the government measures to promote more efficient use of energy on the demand side.

The Irish state is experienced in DSM programmes for energy efficiency, and has successfully applied measures between 1976 and 1993, saving 7% of the final energy consumption. For the period 1990-2002 the total energy efficiency has been improved by 20%, much more than the EU-15 average (9.5%). The only sector that showed a worsening of energy efficiency was transport, by 17%, while the other two, industrial and residential, both have been improved by 57% and 18% respectively. Specifically, the *Proposed Energy Conservation Standards for New Dwellings 2002* came into force in 2003 and is planning to have reduced the energy consumption by 23-33% depending on the type of dwelling by 2012.

7.4.9 Italy

Energy efficiency on the demand side is promoted by the creation of a market of certificates *(White Certificates)* starting in 2005, and granted to distributors of electricity and gas for installing efficient technologies to the end-users. This action incorporates all sectors, i.e. industrial, residential and transport. An estimate of primary energy saved by this measure is 2.9 Mtoe in the next five years.

Energy efficiency in the country has improved by only 1.1% between 1990 and 2002, and during almost all of that period the efficiency remained worse than 1990 levels. This trend is evident in all sectors. In industry there has been an almost constant efficiency of 3% above 1990 levels, followed by a return to 1990 levels in 2002. The residential sector shows a fluctuating pattern which resulted in 1% of improved efficiency in 2002. It is hoped the White Certificates program will kick-start Italy's energy efficiency market.

7.4.10 Luxemburg

The *National Plan for Sustainable Development* aims to both reduction of energy consumption and more efficient electricity production. High efficiency technologies in electricity generation, in domestic appliances and in building insulation are some of the measures generated by laws and regulations for reducing energy intensity by 20% by 2010 compared to 1990 levels. These measures also intend to achieve 28% greenhouse gas emissions reduction between 2008 and 2012.

Consequently, energy efficiency between 1990 and 2002 has been improved by 23% on the demand side, much more than the EU average. Especially at the industrial sector a voluntary agreement for improving efficiency was effective. The residential sector achieved 8% efficiency improvement.

7.4.11 Portugal

From 2001 the *Energy Efficiency and Endogenous Energies* programme began. This is a government effort to support energy efficiency and balanced matching of supply and demand. In late 2003 the *Programme of Incentives to the Modernisation of the Economy* was launched and amongst other objectives, recognised the importance of increasing the efficiency of energy products and services. For industry and transport, the mandatory *Regulation for Energy Management* sets targets for improving energy intensity. The households and services sector has been regulated from the *Characteristics of Thermal Performance of Buildings* and the *Regulation for Energetic Systems in Buildings.*

The country's energy efficiency at the customer side has been improved more than the European average; 12.5% in 2002 over the 1990 levels. Households and transport have been moderate in efficiency enhancement (9.5% and 11.5% respectively) while industry presented a better performance of 13.4%.

7.4.12 Spain

The *Spanish Strategy for Energy Efficiency (E4)* up to 2012 predicts lower annual final energy consumption due to higher energy efficiency. It aims to achieve 1% annual reduction of energy intensity. The industrial sector has received public aid for improving its energy efficiency, while for the households and services the regulatory framework concerns the labelling of electrical appliances, new technology for lighting and solar thermal installations. As for the transport sector, car labelling is the only measure.

The country's energy efficiency indicators for the period 1990-2001 have remained relatively stable; 1.3% improvement for Spain compared with 9% for the EU. In 2001, industry was 4% more efficient than 1990 levels, transport 1.6% more efficient, whereas households had become less efficient; their energy efficiency worsened by 4.6% for the period. The outcome in the households sector has been influenced by both technical energy efficiency degradation and changes in the peoples' lifestyle.

7.4.13 Sweden

Apart from several measures designed to improve the generation side efficiency, there are also several demand side measures, such as the *"ByggaBo dialouge"*, a voluntary agreement between the building industry and the government for efficient use of energy. In 2004, a new energy tax on electricity was introduced in the sectors of industry, agriculture and forestry. As an alternative to this new tax, these energy intensive activities could participate on a voluntary basis in energy efficiency programs. Further, financial support is also available for various kinds of improvements in buildings related to efficiency. Fuel taxes on households have increased by almost 50% since 2001.

In Sweden, the energy consumption has increased by a rate of 0.6% annually from 1990 to 2002. However, the energy efficiency of the economy as a whole has improved for the same time period (7.5% improvement). To a varying extent, all sectors have shown an improvement of energy efficiency in the period. For example, industry's efficiency fluctuated, having a period of decline between 1990 and 1993 and recovery after that until 2002. Households indicate a minor decrease in consumption by 1%, while the transportation's energy consumption has fluctuated due to effects from taxation and changes in the country's economy.

7.4.14 The Netherlands

Policy instruments include the Energy Performance Standard (EPN) for the domestic and services sectors which regulates the energy performance of buildings and *Long-Term Agreements* (LTAs) for industry where energy efficiency investment with payback of less than five years is compulsory, and energy management systems must be implemented. Additionally, there are various taxation incentives such as accelerated depreciation in investment supported the LTAs.

During the decade of 1990 to 2000 the energy efficiency of the final customers has increased by 7%, while in several sectors, the figures are higher. For the period 1990-2000 industry improved energy efficiency by 11%, and households by 13%. However, the transport sector fell by 4%, primarily due to changes in haulage energy efficiency

7.4.15 United Kingdom

The reduction of emissions has been the 'backbone' of environmental and energy policy in the UK, for which energy efficiency is intended to play a major role. The primary direct measure is the *Energy Efficiency Commitments* (EEC) which requires Suppliers of electricity and gas to deliver energy savings through supplying energy efficiency measures to the end-users. The savings target was more than doubled for the second commitment period to 130TWh (2005-2008). Further targets are expected for the 2008-2011 period. There are severe non-compliance penalties if Suppliers fail to meet their targets. In addition to the EEC, the Carbon Trust, which is a company financially supported by the Government, is helping businesses and the public sector reduce their energy consumption and energy intensity by information programs, investment consulting and research support over new 'carbon-free' technologies.

7.4.16 New EU Members from Central Europe and the Baltic

New EU members and accession states are perceived to have significant potential for improved energy efficiency. However, a substantial portion of this perceived potential may be due to structural and economic features of each state.

Lapillone and Bosseboeuf **/Lapillonne et al. 2005/** reported adjusted primary energy intensity indicators for some new EU members (plus Bulgaria and Romania) relative to EU-15. The indicators were adjusted for comparable GDP (purchasing power parity) and to match EU-15 structure, climate and primary fuel mix. Resulting primary energy intensity, from an economic viewpoint, range from just above that of EU-15 (Lithuania), to more than 50% higher intensity (Bulgaria, Romania, and Slovakia). The other countries reviewed (Czech Republic, Estonia, Hungary, Poland, and Slovenia) display adjusted primary energy intensity just below 50% higher than the EU-15 average.

Of more relevance to the potential for energy efficiency in a specific country is the theoretical intensity under their actual economic structure with the energy efficiency performance of the EU-15 **/IEA 2003/**. This provides policy makers with insight into potential without significant change in their economy (although some would argue that structural change is likely in these countries).

In addition to the economic energy efficiency indicators discussed above, physical indicators of energy efficiency are also important. They measure the energy consumption of a sub-sector (or activity) relative to the number of physical units produced in that sector. Where a sector produces a homogeneous product, such as cement, physical indicators are straight-forward. Sectors such as "Households" are more ambiguous, but can be compared when differences in diffusion of central heating, equipment ownership, fuel mix, and levels of personal comfort are **accounted** for. When physical indicators are compared, particularly in industry, the disparity between EU-15 and reviewed countries are less pronounced **/Lapillonne et al. 2005/**

7.5 Demand-side management: who should be responsible?

Energy efficiency can be considered from a number of often conflicting viewpoints. For example, end users that consume energy and pay energy bills have different perspectives and motivation to energy retailers that are obliged to maximise profit for their shareholders. Regulation often serves to create artificial motivations that may not always be complementary to energy efficiency, and market based solutions are frequently ineffective or unable to introduce fully open competition (particularly in electricity distribution). Further to this, and adding extra complexity to analysis, measures relating to energy efficiency are devolved from any one centralised administration centre to various government departments/divisions and funded bodies. This is a natural result of the fact that many stakeholders have an interest in energy efficiency.

The International Energy Agency (IEA) notes that *demand side management* (DSM) is a broad expression that encompasses any method to manage energy demand including load reduction and load shifting**/IEA 2003/.** Load reduction is an energy related measure concerned with efficiency of end use technologies, energy conservation, rebound effects, fuel switching, etc. Load shifting is a power related measure concerned with moving load away from time of system peak demand, thereby reducing system investment costs and possibly improving environmental outcomes. Load shifting does not necessarily imply reduced energy consumption, and in some cases may even increase overall consumption.

Demand response is a more specific term than *demand side management*. It refers to the use of market-based measures (i.e. pricing) to influence timing and scale of electricity demand. A demand response programme could be considered an element of demand side management. In a perfectly structured market (e.g. reflecting all externalities, investment costs, perfect access, etc), demand response can be achieved by simply exposing the demand side to market prices. Demand response is designed to encourage two-sided market behaviour, where demand is more actively traded in the market alongside supply. The purpose of demand response it to reduce the need for investment in power plants that only operate at peak times, or to enhance the security of electricity supply in systems where generation is scarce or transmission is constrained. Demand response may also provide environmental benefits because it is usually associated with reduction in energy consumption, and shifting of load away from peak times usually results in a higher proportion of demand being met by cleaner base-load plant.

For larger customers, demand response is largely accomplished through pricing structures that reflect market prices, where a time-of-use tariff is applied to encourage the consumer to reduce demand at peak times. Smaller customers often do not receive these pricing signals, but only receive an (arguably small) incentive to reduce demand through reduced energy bills. Therefore, the majority of research effort is focused on the smaller customers, investigating ways to persuade them to shift load away from peak times, and to reduce overall demand. The IEA's DSM group **/IEA 2003/** is currently assessing appropriate methods to motivate small customers to accept time-of-use tariffs or enter load control agreements.

The EFFLOCOM project (part of EU/SAVE) searched for solutions to remove barriers to energy efficiency through research on customer response to different market based customer services in deregulated markets. This project undertook load profiling, investigated demand response enabling technology such as advanced metering, load control, and innovative communication mechanisms, and considered suitable incentives to encourage demand response **/EFFLOCOM 2004/.**

The following considerations are based on an article by Didden and D'haeseleer, published in Energy Policy **/Didden et al. 2003/**

The installation of energy efficient equipment is far below the level which would be economically justified. It is even claimed, that overall savings of 15-20% in electricity consumption could be accomplished in Europe if all energy saving measures[7] with a payback time of less than 3 years would be carried out **/European Commission, 1998/**.

However, the existence of so-called market-barriers (which will not be discussed here, but see e.g. **/Hirst et al. 1990/**) prevents the implementation of energy efficient measures, even though they are economically attractive. Throughout the years, many initiatives have been implemented to change consumers' behavior towards a more efficient one. These initiatives are referred to as Demand Side Management (DSM). It is obvious that a DSM initiative will only be successful if both the actors who have to implement the initiative and the actors who can choose to participate in it will benefit from doing so. Since governments strive to maximize the welfare of their inhabitants,

[7] For practical reasons, the term 'energy saving measure' or just 'measure' will be used instead of 'implementation of an energy saving retrofit or installation of energy efficiency equipment'.

it is their responsibility to create a suitable DSM-framework in order to fill in the potential for Rationale Use of Energy. It should be noted that a correct welfare maximization process has to include external costs such as environmental costs due to the emission of gases such as NO_x and SO_x, and, to the extent that it is possibòle to evaluate, CO_2 and other greemhouse gases.

It has been argued in **/Didden et al. 2003/** that a large fraction of this potential could be accomplished if governments gave the responsibility for implementing energy efficient measures to a proper actor. A proper actor is an actor who does not suffer a financial loss due to the implementation of the framework, which is illustrated by the following qualitative example. This example analyzes the financial impact on all actors being affected by an energy efficiency measure. Table 7. subdivides all these affected actors into winners and losers, where a winner is defined as an actor who will financially benefit from the measure. Only the usual case in the US and Europe, in which the utilities'[8] supply cost is lower than the kWh price charged to the customer, will be considered, implying that the utility will appear on the loser's side. The consumer will appear on the winner's side, due to the fact that the energy savings will pay back the initial investment. Other winners are the manufacturers of efficient equipment. On the losers-side, one notices the manufacturers of conventional equipment and the suppliers of primary energy.

Table 7.1 Balance, showing the actors whose prosperity will increase (winners) or decrease (losers) by an energy efficiency retrofit

+	-
Winners	Losers
Consumers Manufacturers efficient equipment	Manufacturers conventional equipment Primary energy suppliers Utilities

If governments consider setting up a, or altering the, DSM framework in their country, they should answer the question to which organization they should give the responsibility for its implementation.

Two categories of frameworks can be distinguished:

1. Create an artificial DSM framework

A first type of DSM framework, that we shall refer to as an artificial framework, is obtained if an actor who does not have a primary incentive in saving energy, and is therefore in the 'loser'-column of Table 7.1, gets the responsibility for implementing DSM. In order to retain a successful DSM-framework, this actor must be incentivized by financial compensation, which means that he would 'artificially' be transferred from being a 'loser' to a 'winner'. Alternatives to financial compensation are mandated governmental rules or market forces to retain customers. The best-known example for such an artificial situation is Integrated Resource Planning.

2. Create a natural DSM framework

This situation will be obtained, if an actor who is not in the 'loser' column of Table 7.1 gets the responsibility for Energy Efficiency. A well-known example of such a natural framework is the non-profit institution Energy Savings Trust (EST) in the United Kingdom. Among other initiatives, the EST is responsible for the implementation of the franchise of 1.2 pound per consumer per year that will be spent on energy efficiency in order to meet some pre-defined goals.

[8] The term 'utility' is used as a collective noun, which encompasses generation, transmission, distribution and retail. In this paper, this term will be used for the supply-side companies in both a regulated and a liberalized context; a single (usually vertically integrated) company in a regulated environment and more than one company in a deregulated environment.

The next three sub-sections will discuss both possibilities thoroughly. Subsection 7.5.1 discusses the best-known artificial DSM framework, namely Integrated Resource Planning. Subsection 7.5.2 deals with other artificial DSM frameworks. In Subsection 7.5.3, the natural DSM frameworks are discussed.

7.5.1 Artificial DSM frameworks; Integrated Resource Planning (IRP)

Before discussing the benefits and disadvantages of IRP we first want to clearly define what we mean by IRP and give a brief historical overview. We feel that this is needed because many people consider IRP only as a planning process that includes a vaguely defined amount of demand side options into the traditional planning process of the utility. The next section stresses that IRP explicitly defines the amount of demand side options into the planning process. Based on the height of the electricity tariffs, which appear as a free 'adjustable' parameter, different variants of IRP can be distinguished.

A clear definition of IRP

Integrated Resource Planning is an artificial DSM framework that has been introduced in the US in the early eighties. Before its introduction, utilities in the US planned according to the Traditional Electricity expansion Planning (TEP) models. The primary objective in these models was to meet the projected demand for electricity at the lowest cost. Demand side options were not included in this planning process.

Triggered by increasing electricity consumption after the energy crises of the seventies, governments introduced and imposed the IRP planning process. IRP is based on the idea that utilities must provide energy services (such as lighting) at minimal societal costs to the customer. Therefore, utilities should consider both supply and demand side options and sometimes also take into account environmental costs. Minimal societal costs are defined as the minimum of the joint expenses of utility and customers, which can be measured with the Total Resource Cost test or the Societal test if environmental externalities are taken into account **/EPRI, 1991/**. Figure 1 shows the concrete application of IRP. The societal costs are subdivided into primary sources, generating capacity, externalities, etc. on the supply side, and information, cost for audits, etc. on the demand side (Figure 7.3).

The payment of the electricity bill by the consumers to the utility is seen as an internal money transfer within the IRP process, which means that the price per kWh does not affect the optimization of the IRP process (e.g. **/Rentz et al. 1997/.** The often-used Rate Impact Measurement test (which measures how the electricity rates are affected by DSM), however, will assure that the rates do not rise excessively.

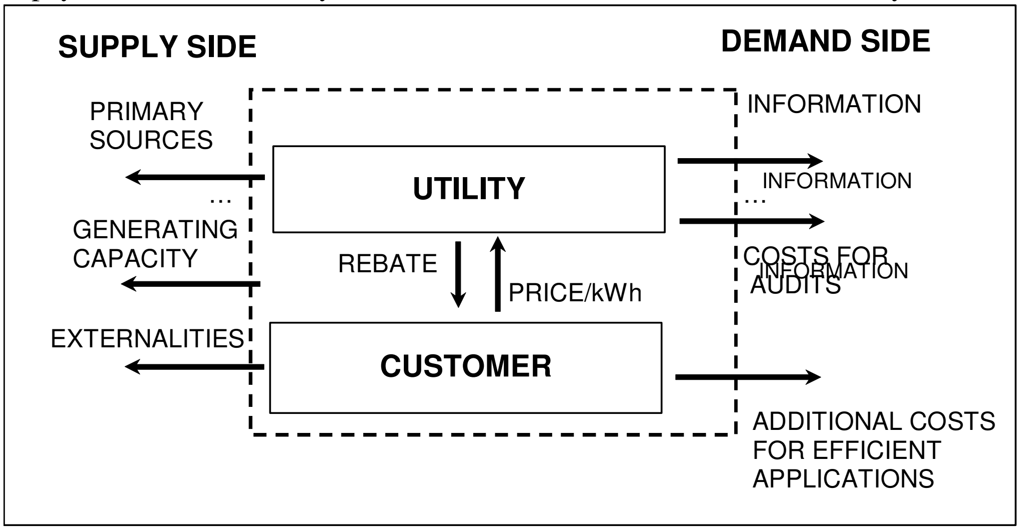
By varying the price per kWh we obtain the four general IRP-variants, which have been applied throughout the years:

- The customers pay the same price per kWh as they did before the introduction of the IRP-process. This implies that the utility will pay all the costs on the demand side, as well as the lost profits due to the decrease in sales of kWh's. This form of IRP will hereafter be addressed as 'naked IRP',
- The utility raises the tariffs to pay for the DSM-initiatives. The regulator has to approve the increase in tariff. The raise of the electricity tariff in order to pay for DSM initiatives is called a 'public benefit charge', 'wires charge' or 'system benefit charge' **/Hirst et al. 1996/**). It should be mentioned that a wires charge is only part of an IRP-process if the amount of the charge is set according to an IRP planning process and if the money is spent by the utility accordingly. Using the wires charge outside the IRP-process will be discussed in Subsection 7.5.3.
- The utility does not only raise the tariffs to pay for the DSM-initiatives, but also to recover the lost profits due to the energy savings caused by the DSM-initiatives. Because this variant

was mandated by the Energy Policy Act in the US in 1992 it will be referred to as 'Regulatory mandated DSM',

- In the last variant, the utilities not only can recover programme costs and lost profits, but they are also allowed to make a profit on their spent DSM-money. This will be addressed as 'Incentivized DSM'

Figure 7.3 Overview of the costs affecting the optimization of the IRP-process
(payments between utility and customer are considered as internal money transfers)



IRP in the regulated environment

In this subsection, we discuss the implementation of the four above-distinguished IRP variants as they have been applied in Europe and in the US.

In Europe, most IRP-processes have started in the late eighties or the early nineties and have been of the 'naked IRP' or a 'wires charge' type. The common characteristic of these variants is the absence of an incentive for the utility to plan according to these IRP variants. Without financial incentive, utilities will only plan according to the IRP process because of governmental obligation, to prevent governmental obligation or just for image building. Either way, history has shown that these variants of IRP will only have limited success (e.g., in the Netherlands, where the electricity distribution companies implement a public benefit charge, there are serious discussions about the spending of the raised tariff **/Slingerland 1997/**. Some distribution companies have been accused for spending the money merely for their own commercial activities.)

To prevent the above-mentioned problem, the regulators in the US have given the utilities a financial incentive to properly invest in DSM. This was decided in the 'Demand-side Profitability' standard, which required utilities to treat investments in energy efficiency and demand-side management on an equal footing as supply-side investments. This resolution which was adopted by NARUC in 1989 **/NARUC, 1989/** stated that utilities could plan according to the variants 'regulatory mandated DSM' and 'incentivized DSM'. In both variants, the utility cannot only recover the costs made for the DSM incentives, but also the lost profits as a consequence of successful DSM programs by raising the tariffs. Even though a close monitoring and evaluation was required, the amount of the tariff-raise for recovering these lost profits has led to much arguing. Many utilities have claimed debatable 'lost profits'. Indeed, it is not straightforward to account for some side effects of DSM. A typical side effect is due to the so-called 'free riders'. These are customers who would have implemented the energy efficient measure anyway without DSM program. A second side effect is the 'rebound effect', in which the customer will use efficient equipment more because it costs less **/Joskow et al. 1992/.** If these side effects are not properly taken into account, the utility may claim too many lost profits. Many US utilities seem to have done just that. These items have caused a bad name for DSM and IRP. The driving force for those types of IRP processes had moved from minimal societal costs to maximum utility profits. Even without the liberalization of the market, this framework was already severely criticized **/Sioshansi, 1996/**.

The general qualitative conclusion that can be drawn from the historical application of the IRP-philosophy is, that although IRP is the best theoretical framework looking from the societal perspective and although it has admittedly achieved considerable load reduction, its practical application has some severe problems. Whether it is justified to promote IRP further depends on how IRP can be upheld in a competitive environment and whether there are better alternatives.

IRP in a competitive environment

In order to investigate the possible role of IRP in a competitive environment, we first take a look at the market structure that is likely to occur with the introduction of competition. We will limit the discussion to the most common structure used nowadays in Europe, namely a complete unbundling, implying unbundling of Generation, Transmission, Distribution and Retail.

We will successively discuss the applicability of IRP for each of the different entities: generation, transmission, distribution and retail. It should not be forgotten that a general disadvantage of imposing the IRP process upon one of these entities would always remain: due to the fact that the revenue of these entities will rise with higher electricity consumption, they will have no natural incentive to reduce electricity consumption. Therefore, they will appear in the 'loser'-column of Table 7.1.

Generation

Requiring an IRP-strategy from the generators is not feasible in an open market. Especially in a power pool, it is not known which generator is covering which part of the load-flow. Apart from this practical problem, the European directive for liberalization **/EU 1996/** implies that the IRP-strategy cannot be forced upon the generators. Within this directive, every country can choose between an authorization and a tendering procedure for granting permission to build new plants. But in both the authorization and the tendering procedure the directive states that Independent Power Producers (or IPP's) must be able to obtain a license according to some criteria for granting authorization. The directive explicitly states in its explanatory memorandum that 'the need for new capacity is not among the criteria for granting authorization'.

Transmission or distribution

Due to the fact that the transmission and distribution networks will remain a monopoly in every country, there are opportunities for an obliged IRP-process. Theoretically, it is possible to require the network owner and/or operator to compare demand side options and supply side ones on an equal basis.

However, there are some practical difficulties:

The first difficulty is where the grid owner and/or operator should obtain demand side information? In many countries, only the retailers and the generators know this information. The Commission of the European Union, which is trying very hard to have the transmission network separated from generation and retail, will not allow them to cooperate. Founding an independent organization, which gathers the information on the supply- and demand side, could however solve this. An additional, more technical, problem is the fact that in many cases it is not clear which customer is responsible for which part of the load-flow. In Europe, this problem exists, because a network operator of one country does not know where loads and generators are situated in other countries. Therefore, it is not clear to whom the DSM-actions should be addressed. A final problem is responsibility. The transmission owner and/or operator will have to compensate consumers if the DSM actions did not result in the projected load reduction and if the network constraints have consequently not been resolved.

Separate Retail

If the electricity market would be fully unbundled it is for many reasons very unlikely that the retailers would be submitted to governmental restrictions such as IRP. One important reason lies in the fact that IRP requires a long-term planning vision, which is very hard if customers can switch any time. Upholding IRP would also require a considerable amount of measurement and evaluation costs.

7.5.2 Artificial DSM frameworks, other than IRP

Energy Services

It is often assumed that providing energy services (e.g. heat) by generators or retailers rather than only selling kWh, would be the proper framework to achieve maximum energy efficiency in the open market. In the framework of energy services, the utility makes an inventory of the demand of energy services such as lighting, cooling and heat in a building. The consumer pays a fixed price for the energy services per year. In this framework, the utilities' profit will depend on the costs they make. The utility will therefore install the most efficient equipment in order to maximize its profit. In Sweden, however, there has been some unfavorable experience with this framework. It has been concluded that providing energy services, as it had been applied there, was just a smoke screen by the utility to retain its clients. The clients could not compare different prices between utilities and therefore calculate the real savings **/Olerup 1998/**. An additional disadvantage with this framework lies in the fact that it can only be used with a few applications such as lighting and heating. Finally, we argue that if a customer pays a fixed price for his lighting, he does not have an incentive for energy efficient behavior.

Mandated energy efficiency goals

Although a government cannot force an IRP process upon a retailer, it has other instruments to make him promote energy efficiency. One example that is standing in the spotlight is 'mandated sourcing of sustainable energy'. Regulators can require retailers to achieve energy-efficiency goals (e.g., a minimum amount of Compact Fluorescent Lights, or CFL's, per household) after a certain period of time. It is the retailers' responsibility which DSM programs he will implement to achieve these standards. If they do not achieve the standards the retailers could be financially penalized, or even worse, their supply license could be withdrawn. The main disadvantage of this system is the high monitor and evaluation cost. An obligation on suppliers to operate energy efficiency programs for their customers would also constitute a barrier to market entry **/Eyre, 1998/**.

7.5.3 Natural DSM frameworks

The main idea of a natural DSM framework is to give the responsibility for energy efficiency to an entity that will have no financial losses if electricity consumption is reduced. (
tThe entities that will have financial losses are listed in the 'loser'-column of Table 7.: manufacturers conventional equipment, primary energy suppliers and utilities).

In the following, we will discuss two different natural DSM-frameworks: Energy Performance Contracting (EPC), and a wires' charge outside the IRP process.

Energy Performance Contracting (EPC)

Few people will dispute that Energy Performance Contracting (mostly carried out by Energy Service Companies or ESCO's) is an effective means to create a natural DSM framework. The ESCO installs an energy efficient measure and takes full responsibility for its proper functioning. The ESCO is only paid for by the savings, the details of which are stipulated in a performance contract (for detailed information see e.g. **/Lefevre 1997/**).

In states where IRP has been abolished (e.g. California, New York, New Jersey and Texas) it appears that Performance Contracting can survive on its own **/NAESCO 2001/**. It is even interesting to notice that the restructuring of the electricity markets can produce interesting opportunities for Performance Contracts. It is expected that some utilities will cooperate with

ESCO's to provide energy-efficiency services, such as performance contracting, to distinct themselves from other utilities **/Vine 1999/**.

It should be noted that Energy Performance Contracting is different from Outsourcing. With EPC, the ESCO is paid for by the savings due to the installed equipment. With outsourcing, on the other hand, the ESCO will be paid for supplying energy services, such as light, for a fixed price. The incentive for installing the most efficient equipment with outsourcing will be less than in the Performance Contracting case, which is illustrated by the fact that often there is no retrofit with outsourcing **/Moor et al. 1998/**. With outsourcing, the ESCO will only be paid for taking the responsibility for maintenance, interruptions etc. In the automobile industry, it has been proven that consumers want to outsource some energy services, even if the costs will be higher than the average costs before the outsourcing.

With EPC, the financial benefit for the customers is divided between the ESCO and the consumer, as being showed in Table 7.2. There is no governmental obligation needed for achieving energy efficiency; energy efficiency in this philosophy is a market product of its own.

However, there are some issues that should be discussed:

- ESCO-Revenue: An ESCO must at least recover the costs of its audit, which may not be the case with small customers.
- Installed equipment: A second disadvantage with EPC is that ESCO's may not always install the newest and mostly most efficient equipment. Indeed, because the ESCO's are responsible for the maintenance and proper operation of the installed equipment they may only install equipment that has reached a certain technological maturity and which they are familiar with **/Moor et al. 1998/**.
- A third issue that has to be addressed is ESCO penetration. Because the ESCO industry is very young (especially in Europe), governments have to play an active role to stimulate their activities. In the United States, there have been successful examples: an ESCO accreditation scheme to promote their credibility **/NAESCO 1997/** or temporary taxes on the transmission network in order to subsidize ESCO's **/Nadel, 1998/**.
- Finally, when promoting performance contracts by ESCO's, governments should investigate whether the cost effective level for DSM from the users' perspective is equal to the socially efficient level of DSM. If this is not the case, for example because external costs are not incorporated in electricity tariffs (e.g. **/Hirst et al. 1996/**), an electricity tax can be a solution.

Table 7.2 Balance in which an ESCO installs efficient equipment

+	-
Winners	*Losers*
Consumers *ESCO* *Manufacturers efficient equipment*	*Manufacturers conventional equipment* *Primary energy suppliers* *Utilities*

A public benefit charge, outside the IRP process

As mentioned previously, a public benefit charge is a levy on the kWh-tariff that will be spent for Demand Side Management activities. In contrast to having this money spent by utilities within the IRP process, which has been discussed in subsection7.5.1, this money should be spent by a different organization. Two different types of organizations can be considered: a governmental

organization or an independent organization. Both options will fit in the philosophy of a 'natural' DSM framework, since the 'losers' in Table 7.1 will have no responsibility for the DSM framework.
The main difference between this public benefit charge and the one in the IRP concept is the amount of the tariff raise. The tariff raise in the latter case is fixed as a result of a deliberate planning towards minimal societal costs. In case of a public benefit charge outside the IRP process, the tariff raise has to be set in a different way. In the UK, there is a tariff raise of 1.2 pound per household per year. The actor that spends the public benefit charge, the EST, has calculated that the reduction in the consumer's electricity bill will grossly outweigh this 1.2 pound. Also in Belgium, there is a levy per kWh, which is spent on DSM programs that result in a high net profit for the customers. Neither in Belgium nor in the UK, the current level of the tariff raise is a result of a cost-benefit analysis of the funded DSM-measures nor is it set by a utility. This implies, that it cannot be considered as IRP.

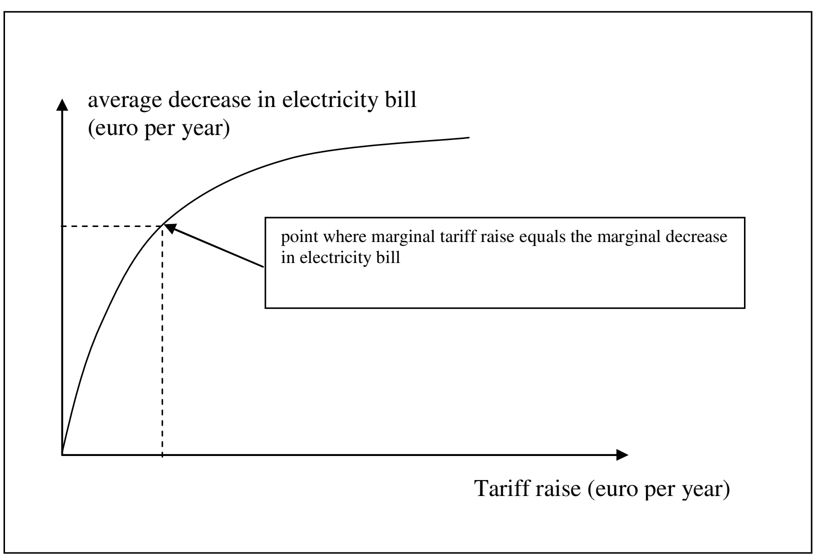
If this external actor, responsible for the charging and spending of the PBC has detailed information on the cost for delivering a kWh, he could use this information together with demand side information (which he obtains for example through enquiries) to set the tariff raise. If he would set the tariff raise (for simplicity expressed as an amount per customer per year like in the UK) in such a way that the marginal tariff raise would be equal to the marginal decrease of the delivering cost (see Figure7.4), energy services would be supplied at minimal societal costs.

In a liberalized market it can be argued that the consumers' electricity price (raised by a certain percentage to incorporate externalities) reflects the price for supplying energy to the end-customer.

Two cases have to be discussed to check whether this assumption is justified:

- If we assume that electricity suppliers are allowed to set their tariffs according to the rules of the open markets, the electricity prices (comprising generation, transmission, distribution and retail costs) will be equal to the marginal supply costs. By setting the appropriate tariff raise, as mentioned before, the planning towards minimal societal costs would be achieved without the usual conflict of interest in which an actor who has a benefit in selling more kWh spends the DSM-budget.

Figure7.4 Diagram indicating the decrease in electricity bill as a function of the amount of the wires charge



- Opponents of this framework will argue that it is not likely that suppliers are allowed to set there tariffs according to the rules of the open markets because some governments will still demand equal prices in the entire country, especially for residential customers. However, this demand for equal prices for some consumer groups will create a distorted situation in which setting a DSM-framework to achieve minimal societal costs is not appropriate. People who live in French rural areas for example, have paid the same tariffs as people in Paris, but the electricity supplier has made more DSM-efforts in the rural areas because its avoided costs were higher than in Paris (e.g. **/Cauret 1997/**). Consequently, the rural-area people were able to benefit more from DSM actions such as rebates, whereas they paid the same for their electricity as in Paris.

•

Table7. 3 Options for a 'public benefit charge' and their disadvantages /Nadel 1998/

Formula	*Disadvantage*
Proportional to the kWh sold	*No load-management*
Proportional to the entire bill	*Customers in a cheap area pay less for DSM programmes*
Constant	*Smaller customers are being disadvantaged*

Although the concept explained at the beginning of this Section is addressing minimal societal costs while not causing any conflict of interest, some other disadvantages of IRP will remain. If this money is used for some sort of DSM, especially for rebates, free loans etc., this appears only to be a second best solution, because customers who had already purchased the equipment before the program and customers who do not participate will not benefit. Especially some categories of the non-participants should be taken care of because it has been shown that they tend to be the low-income families **/Sioshansi 1996/**. In order to prevent this so-called 'reversed Robin Hood phenomenon' governments should take additional measures for them.

A point that should be addressed is the form of the charge **/Nadel 1998/**. According to Nadel, every form has disadvantages, as shown in Table7. .

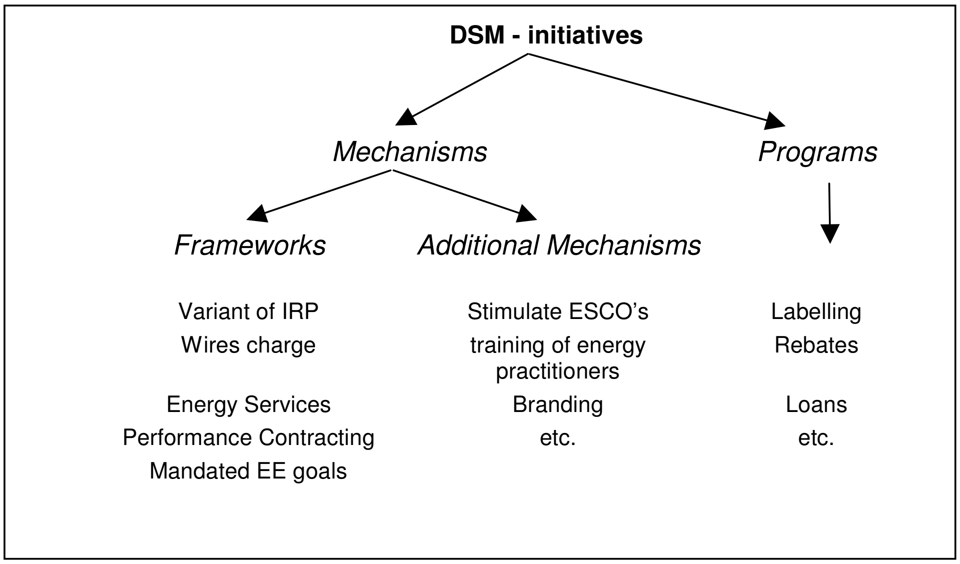
In addition, it should be considered carefully who should be responsible for implementing this framework. An independent organization with experts will have the disadvantage of being more costly; a governmental agency has the disadvantage of being less flexible.

7.5.4 Compatibility

This subsection puts the considerations of the previous sections in a broader perspective, in which all DSM-activities are comprehensively gathered. In order to do so, a subdivision of DSM-activities that has been made in a working group of the DSM Implementing Agreement within the International Energy Agency is used. In this working group, called Task VI, 14 countries studied 'Mechanisms for Promoting DSM and Energy Efficiency in Changing Electricity Businesses' **/IEA 1999/**.

In the IEA subdivision, all DSM-initiatives are divided into two groups. The first group, called the programmes, consists of those initiatives trying to change the consumers' electricity consumption directly. The second group, called mechanisms, stimulates the implementation of the programmes. A mechanism would be: raising a fund through a public benefit charge; whereas a programme would be: giving rebates with this charge. Although there are some DSM-initiatives that cannot be classified unambiguously, it is a clarifying classification. By integrating the statements of this paper into the above categories, a more differentiated classification is obtained (Figure 7.5).

Figure 7.5 Classification of all DSM-initiatives into three categories: frameworks, mechanisms and programmes.



The mechanisms have been further subdivided into two sub-categories: frameworks and additional mechanisms. Frameworks are mechanisms that determine how DSM-programs will be paid for by a certain consumer group (e.g. residential consumers).

Using more than one framework for a certain consumer group simultaneously will give the responsibility for DSM to more than one actor, which will lead to counter-productivity. General arguments to back up this statement are:

- Confusion: If the responsibility for DSM for a certain customer group lies with more than one actor, customers can get confused because both actors are offering DSM programs. The costs for DSM will also be higher than necessary.
- Bureaucracy: If two actors have responsibility for DSM it could lead to bureaucracy and therefore inefficiency.
- Legislation: Governments require some actors (especially the grid owners and/or operators) not to cooperate with players in the free market.

Furthermore, every combination will have its own disadvantages. We will mention one combination that is carried out in the US and that is promoted in several papers (e.g. EU, 1998) namely the mixture of Performance Contracting by ESCO's and one of the variants of Integrated Resource Planning. This mixture will cause Market distortion. In the IRP-process in the US, ESCO's have operated under the flag of 'utility demand side management (DSM) programs'. In that mode of operation, the utilities bought the saved kWh from the ESCO's, to be able to forego investments in supply-side options in certain regions. ESCO-contracts within the IRP structure, however, will distort the full market-oriented ESCO-industry. It is very arbitrary that the utility can choose which customers can benefit from a utility-sponsored ESCO.

7.5.5 Conclusions on DSM frameworks

It would seem, in agreement with various sources (e.g. **/Thomas 1996/; /EU 1997/**), that theoretically speaking the IRP philosophy is the most appropriate DSM framework viewed from a societal perspective. But looking at the European directive for the opening of the electricity markets and looking at some practical disadvantages, it can also be argued that it is very hard to uphold the IRP-process in Europe.

The governments' fear for departing from the current IRP-process is partly due to the bias, that without IRP there will be no more DSM as we have seen with the TEP-models in the eighties. Many people in Europe also fear a similar dramatic decrease in DSM-spending as in the US due to the liberalization. However, as shown before, the IRP process in the US was different from the one in Europe.

Nevertheless, alternatives resulting in a delivery of energy services at minimal societal costs do exist. These alternatives do not give the responsibility for energy efficiency to actors who do not have a primary incentive to reduce electricity consumption. Therefore, one should consider departing from the current IRP implementation and promote performance contracting for the big customers and levy a wires charge spent by an independent organization for consumer groups who are unattractive for performance contracts. The latter will even result in an 'implicit form of IRP', if electricity prices reflect marginal costs.

8. Bottom-up prediction of the effects of efficiency policies

The bottom-up approach starts with the break-down of the energy demand into sectors, and for each sector into specific energy services (e.g. for the domestic sector the energy services required will include space heating and cooling, lighting, cooking, food refrigeration and freezing, dish and laundry washing, entertainment etc.)

The demand for each service can be linked to an exogenous driver: population; GDP per capita; age distribution; family size etc.

The first step is therefore the identification of these drivers, their links with demand for specific energy services, their evolution with time (Section 8.1). Once one has the projection of the demand for energy services, one can look into the best way (from the point of view of the market) to satisfy this demand: by which energy carrier and by which end-use technology (either already on the market or supposed to come to the market as time goes by). The so-called "Negawatt debate" has shown that one can get at very different conclusions according to the assumptions made; some clarification of these bases are attempted. The representation of the policy instruments in the MARKAL models is discussed in Section 8.2. Some results from the MARKAL EU simulation model obtained in the course of the White and Green Project are reported in Section 8.3, and some limits of the model are discussed in Section 8.4. The main recommendations issuing from this project are presented in Section 8.5.

8.1 Identification of the technical and economic potentials; the Negawatt debate

In order to understand effective energy efficiency policy measures, it is important to first understand the barriers to energy efficiency. The most important barriers for the deployment of efficiency measures could be summarised as follows:

- Unit-based sales models of most energy retail companies, where there is little incentive to reduce the number of units sold. Additionally, in the residential sector, the common "tiered" pricing structure where larger consumption is rewarded with lower prices.
- Lack of information on the costs and technical characteristics of available efficient end-user technologies and on savings achievable with improved efficiency of consumption. Lack of consistent standards in labelling the energy efficient products hinders the adoption of such services **/European Commission 2005/**.
- Energy prices are an important driver of consumption, but do not adequately reflect externalities **/European Commission 2005/**. It has been estimated that lower electricity prices could result in consumption increase by 20% **/Thomas et al 2000/**.

Split-incentives discourage energy efficiency investment because of the incompatibility of different parties' interests. The most common example of this is the reluctance of a landlord to install energy efficiency measures for a tenant because the landlord does not receive the financial benefit of the measure **/European Commission 2005/**].

Inefficiently designed policies, which affected, affect and will affect investment decisions on energy efficiency for some years to come make the need to reform the regulatory framework and support mechanisms more important **/European Commission 2005/**

Designing ways to encourage people to change the way they use their electrical appliances is rather complicated. According to Van Raaij and Verhallen **/Van Raaij et al. 1983/** energy use behaviour is influenced by energy attitudes of people such as price concern, environmental concern, energy concern, health concern, and attitudes to personal comfort. They suggest that in order to increase participation in DSM programs the advantages of such measures need to be clearly communicated, the right incentives given to boost change in behaviour, and methods of altering demand behaviour made obvious through education campaigns and accessible technology.

In order to convince network operators, network owners and retailers to pursue demand response options it is useful to evaluate the potential load reduction. A recent study designed to evaluate the potential of participation of residential customers in demand response programs in the UK [33] used statistical data on personal time use to build up aggregate demand profiles that can be segregated into activity or usage types (such as clothes washing, drying, dishwasher, lighting, etc).

This modelling work was applied to determine the peak load reduction that could be achieved through load control of various appliance types, or introduction of various efficiency measures. For example, if demand from the residential sector accounts for approximately 45% of system peak demand **/EFFLOCOM 2004/**, it is possible to further break this down into cooking (~17% of system peak), electric water heating (~7%), lighting (~7%), cold appliances (~4%), wet appliances (~3%), etc. Therefore the peak load shifting potential in this sector is limited to very small values (essentially cold and wet appliances only). Direct load control potential, however, is substantially larger because appliances such as water heaters, cooking hobs and air conditioners can be briefly controlled without significantly influencing the energy service being provided.

Similar results have been demonstrated by a partner in the Efflocom Project that explored savings potential of direct load control on residential electric heating in Denmark. Results of this study suggest households can save approximately 120 Euros per year. Installation costs were estimated at 31 Euros per kW_e load reduction, which is an improvement on estimated CCGT investment costs **/EFFLOCOM 2004a/**, making this type of load control an attractive investment that is effective in creating responsive demand. The Efflocom project also piloted demand side management measures relating to access to energy consumption information, time-of-use pricing, and other energy efficiency related actions. Although the technology applied was partly unreliable, it was shown that customers are usually responsive to time-of-use pricing, are amenable to direct load control that does not cause noteworthy discomfort, and can generally save money from many DSM measures.

As energy consumption is a product of energy intensity and a demand for energy services, savings can be enacted through both factors.

A reduction of “energy services” amounts to a reduction of comfort, increasing discipline, etc. Examples of this category are a lower temperature of the thermostat, a reduction of the number of driven kilometres by car, a lower light intensity, etc. As this is a “loss of comfort” at the level of the end-user, there is an effective cost related to it. The user will accept that loss of comfort and implement the reduction of energy service if the “benefit” (from saving kWh’s) is larger than the value attached to by the “sacrifice” of comfort. This can be used to determine the effective cost of a saved kWh. One could argue that this is not an unambiguous cost as it is related to the perception of loss of comfort. In fact, however, it is nothing less than the willingness to loss of comfort to save costs, this is fundamentally the same as a common economic demand curve, which is a translation of the marginal willingness to pay and which determines the selling price by taking the intersection with the supply curve, representing the marginal costs.

A second kind of energy savings is related to “energy intensity”. The aim in this case is to reduce the energy input by the use of efficient energy technologies, but by keeping the level of comfort constant. Here, one focuses on the efficiency of the energy conversion technology. By the use of particularly efficient appliances or facilities, less energy can be used, so consumer costs can be reduced. However, usually those efficient appliances have a higher investment cost. The gross cost of a saved kWh can be determined by the division of the higher investment cost by the number of saved kWh’s seen over the lifetime or depreciation period of the investment. This is a simplified (see further) gross cost; the net cost follows from subtraction of the avoided purchasing price of the saved kWh’s. It is this kind of cost (related to efficient technologies), which people mostly have in mind when talking about the cost of a saved kWh.

Imagine the purchase of a new, energy efficient apparatus which results in an energy saving of ΔE_i in the year ‘i’ compared to a “common” apparatus. At an electricity price or tariff ‘t_i’ (expressed in €/kWh), this results in a saving of expenditure of ($t_i \Delta E_i$) € in year ‘i’. On the other hand, the purchase of this high performance apparatus means a higher investment cost of ΔI . If we suppose a (higher) residual value ΔR (than a common apparatus) at the end of its lifetime N (year), the net cost per saved kWh can be calculated according to the following common used expressions:

$$\Delta F = \Delta I - \frac{\Delta R}{\left(1+\frac{r}{100}\right)^N} - \sum_{i=I}^{N} \frac{t_i \, \Delta E_i}{\left(1+\frac{r}{100}\right)^i}$$

and

$$\text{K (€/kWh)} = \frac{\Delta F}{\sum_{i=I}^{N} \Delta E_i}$$

with ‘r’ the discount rate (expressed in %) on an annual base. ΔF is the global financial difference due to the new investment and K is the net cost per saved kWh. The presented calculation brings all future resources back to their present values. As a consequence, the cost per saved kWh is an average value over its lifetime, but expressed in today’s currency.

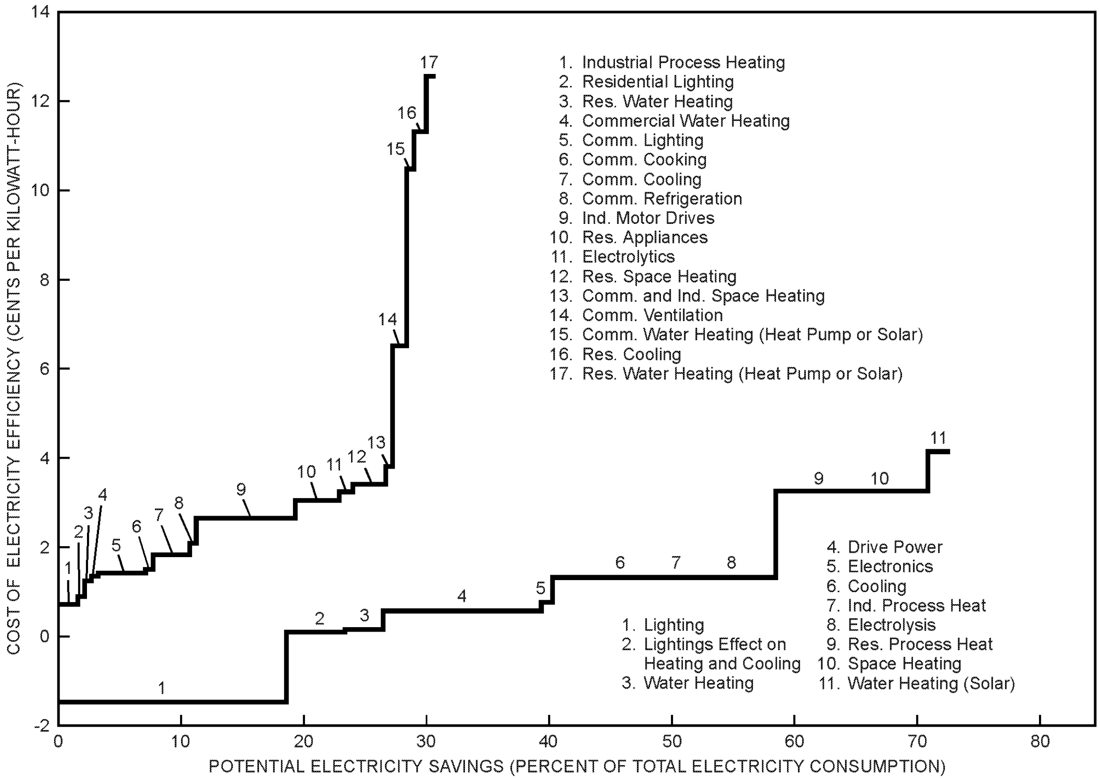
Further on, it will be clear that this is a simplified expression and that more terms should be taken into account. Even more, apparently simple parameters like the discount rate r and the lifetime N, can lead to different interpretations, depending on the point of view (engineering-economy versus market economy).

In a joint article in Scientific American **/Ficket et al. 1990/**, which makes a case for electric energy savings for a healthy energy supply policy, EPRI[9] and RMI[10] give their vision on the possibilities to savings and their related costs. As can be seen in Figure 8.1, they “agreed to disagree” in the same article. The lower curve is the one of RMI, the upper one that of EPRI. They represent the potential electricity savings (expressed in % of consumption in the US in 1990) versus the gross cost of a saved kWh. So the cost saving of a saved kWh is not yet subtracted.

[9] EPRI = the Electric Power Research Institute; this organisation manages the research programmes of the American utilities.

[10] RMI = Rocky Mountain Institute; the institute of Amory Lovins, which strongly emphasises on energy savings, as a means to “sustainable” electricity provision.

Figure 8.1 Comparison of the electric energy saving cost curves according to EPRI (upper) and RMI (lower)



At first glance, the two estimates differ considerably. The RMI-curve is rather "optimistic" in projecting large cumulated savings: more than 70% of the electricity usage could be saved against only a very small cost. Some measures even result in a negative (gross) cost! In contrast, the potential versus cost curve of EPRI, limits the saving potential to approximately 30%, because costs rise very quickly if further savings are envisaged.

According to the RMI, lighting, drive power and cooling (in order of highest potential and lowest cost) are the three main measures. Or as mentioned in **/Ficket et al. 1990/**: "The biggest savings in electricity can be attained in a few areas: lights, motor systems and the refrigeration of food and rooms" (p. 30). EPRI also stresses the same three measures, but in another sequence: drive power, lighting and cooling respectively.

When assuming that the computations have been performed correctly, it must be the case that both curves rely on different assumptions, definitions, etc. But as the Scientific American-article does not provide any detailed information and the full EPRI and RMI-reports are only available for members or for rather high prices, this can not be investigated in detail. Below, only some general comments, as mentioned in **/Ficket et al. 1990/**, concerning the discrepancy between the two curves will be made. In the next paragraphs, the discussion, as held in the literature, will be dealt with.

According to **/Ficket et al. 1990/**, the curve of EPRI deals with a 10-year scope. **/ Ficket et al. 1990/** mentions on p. 30: "According to a 1990 report by EPRI, it is technically feasible to save from 24 to 44 percent of U.S. electricity by 2000 – some of it rather expensively – in addition to the 9 percent already included in utility forecasts". On the contrary, the RMI-curve is valid for an unlimited horizon, but based on today available technologies: this is the "ultimately" reachable technical potential. According **/Ficket et al. 1990/**:"Rocky Mountain Institute estimates a long-term potential to save about 75% of electricity at an average cost of 0.6 cent per kilowatt-hour…" The Scientific American-article remarks that expected savings and costs are comparable in the Western

European countries and in Japan: on the one hand it says that both Europe and Japan have already done a big effort and that further savings will be less and more expensive, but on the other hand it states that “the differences are probably not substantial”.

The negative (gross) cost for lighting (Nr. 1) is the most remarkable fact of the RMI-curve. The reason for this negative cost is that the RMI not only brings into account the installation cost (which is according to **/Ficket et al. 1990/** approximately 1 ct/kWh), but the so-called maintenance costs as well (by which is meant the fact that compact fluorescent light bulbs need to be changed less often than incandescent light bulbs), which represents a negative cost of 2.4 ct/kWh. The sum of both results in a negative cost of 1.4 ct/kWh. According to Lovins of the RMI it is not “a free lunch; it is a lunch you are paid to eat”, (**/Ficket et al. 1990/**, p. 31). Note that this negative cost is still a gross cost which does not yet bring into account the saved costs due to a reduced use of electricity.

It seems appropriate to comment on this. According to p. 30 of **/Ficket et al. 1990/**, the electricity consumption for lighting amounts to approximately 20% of the total electricity consumption. If one saves 18% on that consumption, as stated by the RMI, this corresponds to a saving of 90% on lighting, which seems rather unrealistic (even more if one knows that already a lot of fluorescent light bulbs are in use, even in the 1990s). Despite the authors’ feeling of “exaggerating”, reference **/Ficket et al. 1990/** states at p. 30: “Converting today’s best hardware could save some 80 to 90% of the electricity used for lighting, according to the Lawrence Berkeley Laboratory”. For Belgium, a study by the University of Louvain (UCL) and the engineering/study company Laborelec **/Collard et al. 1998/** estimated the potential savings in the Belgian tertiary sector at approximately 50%. In the residential sector, one estimates less potential savings, as the importance of lighting for creating a cosy atmosphere is more important.

Concerning the cost of a saved kWh thanks to lighting, a negative cost seems reasonable when incandescent lights are replaced by compact fluorescent lights and bringing into account the longer lifetime of the latter. But a negative cost seems less plausible if lighting armatures need to be replaced, which is the case in the service and commercial sector.

There is a difference of a factor of 5 between the average costs of saved kWh as calculated by EPRI versus RMI. According to the EPRI-curve, the weighted average cost of a saved kWh adds up to 2.6 ct/kWh, whereas it amounts 0.6 ct/kWh in the RMI calculations.

After the presentation of the cost curves, the Scientific American **/Ficket et al. 1990/** argues in favour having the utilities involved to promote energy savings to the consumers: “ they have technical skill, permanence, credibility, close ties to customers, a relatively low cost of capital and a fairly steady cash flow”. The story continues with the argument that utilities have to be compensated for this loss of income according to the “regulatory mandated DSM” and “Integrated Resource Planning” philosophy.

This article started a wave of criticism and a lively debate. In a rather noteworthy analysis of the cost of a saved kWh **/Joskow et al. 1992/** Joskow & Marron (of the Departement of Economics of the MIT, USA) argue that the cost curves as presented by both RMI and EPRI **/Ficket et al. 1990/**, are a strong underestimation of the real costs.

Joskow & Marron (JM) claim to have examined some DSM-programmes of 10 American utilities and they conclude that not only the real cost of a “negawatt” (by which a negawatt-hour or a saved kWh is meant) is a lot higher than what EPRI and RMI are claiming, but even more, that a lot of cost are not brought into account. These forgotten costs are all direct and indirect costs which are at the expense of both the utility and the consumer. Among this are the additional investment cost and the “administrative” cost at the expense of the utility and the “transaction cost” at the expense of the consumers. Promotion and advertisement and the ‘monitoring’ and evaluation of the saving measures are part of the administrative costs.

JM stress the fact that both the EPRI- and RMI-curves give a technical saving potential, in which a total substitution (or upgrading) of all apparatus by the best available technology is assumed. Hence, JM state that the curves are upper limits of what is achievable by realistic means. .

In a certain way, EPRI does bring into account those costs, but according to JM in a rather arbitrary way. On the other hand, RMI considers the savings due to operation and maintenance (these are the so-called O&M-costs); EPRI ignores this aspect. Finally, JM state that neither EPRI nor RMI consider the "free-riders". These are consumers which would have installed the new appliances anyway, but do make use of e.g. the rebates of the utilities. This is another reason for an increased cost of a saved kWh of the examined DSM-programmes.

Moreover, according to JM, the cost curves of EPRI and RMI do not take into account the "opportunity cost" which is related to the taking out of service of good working devices: there is an effective cost related to the fact that existing devices could possibly still be good working and that this is prevented by the installation of an "enforced" device. Even more, JM notice that the curves represent a long-term equilibrium because the time dynamism of the penetration of new appliances is not considered.

In addition, JM have a problem with what they call the "engineering estimation" of the lifetime of the devices and the appliances. (The lifetime N is important for accountant measures when discounting future energy savings.) New installed capacity does not necessarily remains operational during those N years; sometimes – and the more when market dynamism grows – the economic lifetime is shorter than the engineering one. This results in a higher cost per saved kWh for that specific device.

JM try to explain further the discrepancy between the two cost-potential curves (a factor 5 for the cost and a factor 2 for the potential) by highlighting a number of differences in the general assumptions and concerning several specific technologies.

Based on what they call "field data" (FD) of the DSM-programmes of utilities, JM find average weighted prices of saved kWh's seen over all sectors of 1.9 to 6.9 ct (eurocent). (For the residential sector, averages vary from 3.5 ct to 12.4 ct – when ignoring an outlier of 22.1 ct – while the variation in the commercial and industrial sector varies between 1.5 ct and 6.7 ct.) On the one hand, these numbers have to be compared with the average cost of RMI of 0.6 ct and the one of EPRI of 2.5 ct, and on the other hand with the average electricity tariff of 6.9 ct /kWh (in fact, 8.1 ct for households and 5.1 ct for the commercial and industrial sector). If those numbers are correct, it stipulates that DSM-programmes are more cost effective in the commercial and industrial sector than in the residential one.

This brings JM to the conclusion that the abovementioned results "are likely, on average, to be significant underestimates of the true societal costs of utility-sponsored conservation programs" and that the mentioned costs, as given by the utilities, "… are, on average, too low by a factor of at least two."

This "Negawatt debate" continued among the originators (see **/Lovins 1994/** and **/Joskow 1994/**) and involved other authors (see **/Hirst et al. 1996/**). A further contribution came from the "classical" economic point of view of R.J. Sutherland (**/Sutherland 1996/** and **/Sutherland 2000/).** Sutherland contrasted the "engineering cost analysis" and confronted the "energy saving paradigm", based on "engineering economics", with the "economic paradigm" in which costs and estimates are based on market data and deduced from how market players estimate the value of costs and benefits. Sutherland stated that market barriers are an artificial concept: they actually represent cost reflections of market adaptations. These costs account for the gradual diffusion, rather than fast penetration, of the new technologies. In contrast, he states that *market failures* are the real sources of economic inefficiency, but they are rather rare and do not result in a permanent tendency to use too much energy. One consequence (which we shall meet again shortly) is that the discount rate applied to energy saving investments cannot be the typical market interest level, but it must be much higher to account for future uncertainty factors.

The debate sometimes assumed rather heated tones on both sides. However, it had the merit of clarifying most of the reasons of difference among the contenders, and to show that both points of view were useful: one to establish an upper limit to the achievements of DSM that resulted so high and attractive as to stimulate more ambitious goals for energy conservation policies; the other to stress the practical difficulties, obstacles and hidden costs to keep in mind when designing such policies.

A schematic comparison of the two points of view, as perceived by Sutherland, is given in Table 8.1

Table 8.1 – Differences between the "energy saving" and the "classical economic" paradigms

Energy saving paradigm	***Classical economic paradigm***
The energy gap is the difference between the present (or projected) energy costs and the energy costs which are a result of investing in cost effective energy efficient equipment. This is a very large gap.	*There is no large energy gap. There exist investment opportunities to reduce the costs of work, capital and energy. The market fills in those opportunities, in an efficient way and with reasonably efficient proportion.*
Market barriers which discourage investments in energy efficient measures are the cause of that energy gap.	*Market failures are the real causes of economic inefficiencies and they form only a small share of the so-called market barriers.*
The saved energy cost is the criterion to evaluate the benefits of energy saving programmes. The benefit is estimated as the present value of future reductions in energy costs.	*The willingness to pay for an ameliorated market result, like an enhanced environmental quality, is the standard economic way to measure benefits.*
The discount rates, as used by households and companies for energy saving investments, are much higher than the financial interest rates. The benefits of saving investments have to be discounted at lower discount rates.	*The market discount rates for risky investments with large sunk costs are higher than those of less risky financial investments. These discount rates illustrate the market efficiency.*

A further contribution to the cause of the conservationists was the book "Factor Four" **/von Weizsäcker et al. 1997/** , co-authored by Amory Lovins, in which 50 "case studies" are discussed, in which it one has succeeded to save large quantities of energy and raw materials. The title of the book seems to imply that it would be possible in general to reduce the energy intensity (and the CO_2 emission intensity) of GDP by a factor 4. However, the 50 case studies are not representative of the average situation, and it is not made clear how much the results are applicable on a much larger scale. Several other criticisms have been addressed to this book. Savings are calculated but not measured. Only cases leading to a factor four saving are mentioned and not less favourable ones; the choice of a factor four is in itself quite arbitrary (even if in line with the reduction in energy intensity in industrialised countries that would be needed to stabilize CO_2 concentrations in the atmosphere at 450 ppm). The examples given often start from rather old and inefficient equipment, and do not take into account the natural trend to improvement when the equipment is changed at the end of its lifetime.

Whatever its shortcomings and distortions, the book is a laudable effort to motivate a larger public for a higher energy efficiency. It should not conceal the fact that there many obstacles on the way and that an effort is required of the end-user.

Together with "Factor Four" the book "Das Einsparkraftwerk" (full title: "Das Einsparkraftwerk – eingesparte Energie neu nutzen") **/Hennicke et al. 1996/** is key literature when dealing with energy saving policy. The authors, Peter Hennicke and Dieter Siegfried, are collaborators of the Wuppertal Institut and the Öko-Institut respectively. Both institutes work already for a long time together with the Stadtwerke Hannover. This book is the result of that cooperation.

"Das Einsparkraftwerk" is not a scientific study, but a collection of results and analysis. It is more documented and especially, it is more nuanced than "Factor Four" **/von Weizsäcker et al. 1997/**, the book it is often compared with. There are no 'miracle solutions' presented and the authors realise that the implementation of a RUE-policy[11] is likely to meet many practical and institutional difficulties.

As discussed in many other RUE-books, like "Factor Four" **/von Weizsäcker et al. 1997/**, the link has been made to nuclear phase-out, and introducing an ideological bias rather than concentrating on the economic and environmental benefits of energy saving..

This book takes Least Cost Planning (LCP) as a basis. In LCP, electricity producers are asked to postpone the extension of the generation capacity until all possible energy savings are realised, of which the cost per saved kWh is lower than the cost of a newly produced kWh. This book has been written when LCP was not yet thought to be in contradiction with the governmental energy policy. The European guideline for the liberalisation of the electricity market **/EU 1996/** however does not allow a country to require that an electricity producer has to implement energy savings before it is allowed to supply energy. More details on that subject can be found in "Explanatory Memorandum to the 'Internal market for Electricity Directive' " **/EU 1997a/**[12]. As a consequence, in the current institutional framework, the results and analyses presented in this book have only a limited use.

As many other books, "Das Einsparkraftwerk" **/Hennicke et al. 1996/** focuses on *electricity* savings instead of on more general *energy* savings. Probably, the reason is that the electricity sector mainly consists of large (monopolistic) companies, while the authors of "Das Einsparkraftwerk" sympathise with smaller (public) companies and with decentralised production. Moreover, the electricity sector is the only sector which makes use of nuclear energy at a relatively large scale (and this only by the large electricity companies) and the authors of "Das Einsparkraftwerk" are set against nuclear energy. In their view, energy savings are mostly urgent in the electricity sector, because by this the authors can hit two "opponents": large energy companies and nuclear energy.

Finally, one should mention that much of this energy saving debate has taken place in the United States, and many of its conclusions may not be simply applicable to European countries. The energy intensity of GDP is much lower in Europe, and the average efficiency of equipments, appliances, motorcars and industrial processes has been for a long time much higher than in the USA and energy prices have been higher (even if now the gap is reducing). There are other important differences: in the USA, the demand for energy services is consistently considered as saturated, i.e. if the efficiency increases, proportionally less energy will be used. This is often not the case for Europe, where a decrease in the price paid for an energy service as a consequence of improved efficiency will in many case involve a rise in the demand for that service (e.g. the lighting in a house is not as much as it would be desired, i.e. the level one would have if the service were free): This brings to a "rebound effect" which in the USA is generally assumed to be negligible. Another difference is that the turn-over of buildings is much slower in Europe than in the USA, and therefore the relative importance of new buildings (where it is relatively easier to introduce energy-saving features) is less in Europe than in USA, while retrofits are more important. This should caution against simple application or extrapolation of energy saving conclusions from one region to the other.

8.2 Representation of energy efficiency policies in Markal: the "White and Green" project

The "White and Green" Project completed under the EU SAVE Programme **/Farinelli et al. 2005/**, **/iiiee 2005/** reviewed policies and measures to promote energy efficiency, which involved analysing the experience with instruments that are already implemented, and assessing innovative

[11] RUE = Rational Use of Energy

[12] Both documents **/EU 1996/** and **/EU 1997a/** have been repealed by a Directive in 2003, **/EU 2003/**. This last document is not in contradiction with the subject discussed in this paragraph, based on the original Directive and Explanatory Memorandum, although the 2003 Directive is less explicit.

instruments that are proposed. In particular, the practicability of using “White Certificates” (Energy Efficiency) along the same lines as “Green Certificates” (Renewable Energy) was explored.

The study consisted in collecting and reviewing the policy instruments aimed at increasing energy efficiency, with emphasis on market-based mechanisms; in choosing three representative policy instruments for further analysis, and collecting information and results of their actual implementation; in simulating the effects of each instrument and of some combinations thereof by means of technical-economic computer models (of the “MARKAL” type for the European Union (EU-15) and for three EU countries: Italy, Germany and Estonia; in drawing some conclusions and recommendations from the results of the three previous phases, and discussing them among stakeholders in order to identify the most significant results, which can be used as a help in shaping future energy efficiency policies; and finally in diffusing the results as widely as possible.

The definition of the base case for WC (no new energy-saving policy being introduced, continuation of the present trends) proved in itself to be at the same time difficult and enlightening **/Mundaca et al. 2004/**. The MARKAL approach is an equilibrium approach seeking an economic optimisation, and assuming that market forces will automatically bring the system to this (dynamic) equilibrium. The actual situation is different, and does not always correspond to an optimal solution, insofar as economically (and financially) convenient technological solutions do not diffuse as much as the optimisation would predict. This points to the fact that there are imperfections in the market, especially when one considers the level of single households. This brought to an approach that takes into account the market imperfections and financial aspects (difficulties of access to credit and information, scarcity of capital available for investments etc.) not through constraint equations, but by introducing an apparent discount rate applied to the investments in new energy technologies in the residential and service sectors.

By comparing the results of the simulation with reality, it was found that a discount rate of about 30% per year has to be assumed in order to explain the limited diffusion of “convenient” energy saving technologies. Such apparent discount rate (much higher than the system's "social" discount rate), has proved to simulate well the displacement of the system from the economic optimum in the business-as-usual scenarios. Such an apparent discount rate, much higher than the social discount rate, attempts to simulate the displacement of the system from the economic optimum from the BASE case scenario, as we have mentioned in Section.8.1 and suggested by Sutherland **/Sutherland 2000/.** Indeed, Ruderman et al. (**/Ruderman et al. 1987/**)) point out that an “implicit real discount rate” used in investment decisions in the residential-household sector goes from 35% to 70%. In our case, we select an apparent discount rate of about 30%; which approaches the bottom level given by **/Ruderman et al. 1987/**.

The application of the White Certificate system, coupled to well-targeted and diffused information campaigns, and to simplified and publicly guaranteed access to credit, should cause the apparent discount rate to decrease, tending to the value of the social discount rate. This approach can be considered as one of the relevant conclusions of the project.

8.3 Results of MARKAL modelling simulations

In the following, some of the results of the MARKAL simulation work for EU-15+ are reported from **/Farinelli et al. 2005/**.

As concerns the application of “White Certificate” schemes, for the EU-15+ market there is a financial potential of increasing energy efficiency by 15% until 2020 ("zero-cost target"); in other words, the average unit cost of the energy system, following the application of a WhC system for a reduction of 15% (-3 EJ) of the overall energy consumption of residential and service sectors with respect to the Business-As-Usual (BAU) scenario, is equal to the average unit cost of the energy system in the BAU case; in other words, the increase of the energy efficiency is free of cost to society.

For less ambitious targets, and in particular for the 1% per annum for 6 years target defined by the EU directive proposal, the cost of the energy savings is negative and, by freeing resources, it involves a positive impact on GDP growth. If the target of energy saving in the residential and service sectors is greater than 1% per annum (cumulative) until 2020, the cost of the energy savings may become positive; for instance, a target of 1% until 2010, then of 2% from 2010 to 2020 ("medium target") implies for the year 2020 a reduction of consumption by 5 EJ (-27% of BAU) and an increase of the average unit cost of the energy system of 1 €/GJ (+13%).

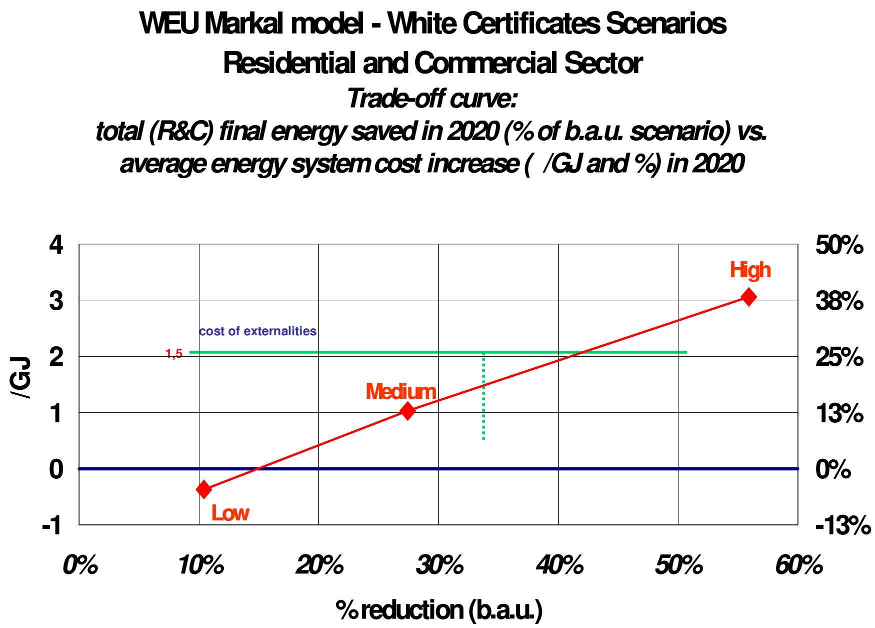
More ambitious targets have relatively high costs, but are technically possible; for instance, a target of 2% per annum until 2010 and of 4% per annum between 2010 and 2020 ("high target") brings to more than halving the energy consumption of the residential and service sectors with respect to BAU (-56%), with an increase of the average system unit cost of 38% (or 3 €/GJ).

However, these evaluations do not include externalities. If the environmental and other externalities were taken into account, one would evaluate an economic potential of energy saving much higher than the 15% indicated above, which is "zero cost" only in strictly financial terms.

With reference to the trade-off curve shown in Fig. 8.2, if instead of the conventional zero-cost axis one introduces an external cost of energy of about 1.5 €/GJ (a reasonable assumption according to several studies on externalities[13]) the trade-off value rises to a value of about 35%.

The model also allows predicting where and how these energy savings would be obtained. For instance, if the cap in consumption is posed on the sum of gas plus electricity and not on each of them separately, the market (choosing by economic optimisation) will lead to a nearly fifty-fifty share of gas and electricity in terms of primary energy, while the reduction will be stronger for gas than electricity if expressed in terms of final energy. As concerns the subdivision by sector, the reduction is stronger in the service sector until 2010, while the residential sector takes a slight prevalence in the following decade. The estimated market price of White Certificates (based on marginal cost of energy savings) should grow from about 5 €/GJ/y in 2005 to a little more than 25 €/GJ/y in 2020. The reduction of CO_2 emissions resulting from the application of the White Certificate system is of 1.5% in 2020 ("low target") vs. the base case.

Fig. 8.2



[13] See "ExternE - Externalities of Energy", a series of volumes issued by the European Commission, Brussels - Luxembourg starting from 1996

The application of the mechanism of WC involves in any case an increase of the investments in new technologies for energy utilization. The low target scenario implies for the year 2020 an increase of 7% in investments in energy demand technologies for the residential and service sectors relative to BAU, while the average unit cost of the energy system is decreased (more technology, less fuel!). For the more ambitious medium and high scenarios, investments in technology grow much more: for the year 2020 by 30% and 80% respectively. Therefore, even when there is a trade-off between cost of saving and value of the energy saved, there will be a displacement from expenditure for fuels to investment in new technology, which in itself is likely to have a positive effect on the economy as a whole.

The reduction of CO_2 emissions associated to the "zero-cost" scenario identified above is of the order of 5% with respect to BAU, or about 190 Mt CO_2.

As concerns the technologies involved by the WCS, for natural gas the largest improvements of energy efficiency are in the segment of space heating, while for electricity the major opportunities are in the field of lighting. The White Certificate system promotes more energy-efficient technologies, which have been considered in some detail: examples are hot water production by heat pumps, conditioners based on centrifugal chillers, natural gas heat pumps, solar water heaters etc.

As for tradable emission rights, when simulating this instrument, the model results in a containment of emissions obtained mostly on the supply side, i.e. in the energy sector and in the generation of energy (electricity, heat or CHP) in the 8 high energy-intensive industrial activities considered by the EU directive. The reason for this is that the energy consumption in the energy-intensive activities considered is rather rigid, having gone through a long process of optimization, unless radical changes of process are introduced: this is likely to happen only when entirely new plants are built, which seldom occurs today in Europe for the energy-intensive sectors. The substantial reductions of CO_2 emissions that are required have the effect of radically changing the structure of the energy production park. For the lower-ambition target, there is a strong increase of the natural gas combined cycle plants, which is sufficient to comply with the emission cap. In the other two cases, there is also a strong increase of RES plants, especially wind and biomass..

The average overall cost of the reduction of CO_2 emissions, calculated as the ratio of the increase of the total thirty-year overall cost of the energy system with respect to the base case to the total reduction obtained for the emissions is about 30 €/tonne of CO_2 for the slower scenario, about 35 €/tonne of CO_2 for the intermediate and over 50 €/tonne of CO_2 for the more demanding one. The CO_2 emission cap is realistically simulated with a system of allocation and trading of emission permits. The price of the "black certificates" is calculated by the model and is roughly in line with the cost of emission reduction: about 30 €/tonne of CO_2 for the first scenario, 40 €/tonne of CO_2 for the second and, for the most demanding scenario, decreasing from 90 €/tonne of CO_2 in 2005 to 50 €/tonne of CO_2 in 2030, in relation with the dynamics applied to the emission cap. The resulting electricity price increases 30% in the first scenario, a little more in the second and about 60% in the third. These relatively high price increases are partly due to the fact that, as we mentioned, all the reduction in CO_2 emissions is obtained on the supply side; also, on the 2030 horizon the technology of CO_2 sequestration may well have evolved to present smaller costs than those picked up by the model. It should also be considered that these costs implicitly include the costs of the incentives for the installation of RES plants, not considered elsewhere in the ETS scenarios.

8.4 Limits: transaction and administrative costs; rebound effects; free riders

The result of an energy efficiency policy may be lower than expected because of the "rebound effect": more energy efficiency brings to less cost for the energy service, leading to more demand for services and thus less energy saved.

Actually, the rebound effect may come from 2 sources:

1 Direct: since the cost for a given service is lower, the demand for that service will increase (elasticity)
2 Indirect: the lower cost frees up some money which is spent for something else, which will have some energy demand implication.

The direct effect may reduce the expected savings by a maximum of 40%, but many services are rather inelastic (e.g. “white goods”, or home appliances). 20% seems a reasonable assumption on the average. The indirect effect is more difficult to evaluate, but it is unlikely to be higher than 10%

A MARKAL-MACRO calculation for Italy has shown a 27% total rebound effect for a specific case.

Moreover, one should take into account the transaction and administrative costs and the problem of free riders, as mentioned in Section 8.1, which tend to decrease further the effect of market policies for energy efficiency.

8.5 Some recommendations from the White and Green study

The White and Green Project resulted in a set of recommendations for energy-saving policies that we report in the following, as they appear to be relevant in the present context and in great part coincide with conclusions we have already reached.

1. There is ample space for increasing energy efficiency in all sectors of final energy utilisation as well as in energy production and transformation, so as to contribute to all energy and environmental goals while promoting rather than hindering economic development. This space should be used!
2. Environmental, climate and energy policy should be more strictly co-ordinated than in the past; all impacts of an energy-related policy on climate, economy, environment, health, security of supply, competitiveness, employment etc. should be considered at the same time with appropriate weights, which are the result of general political decisions.
3. In particular, action in the domain of energy should be carried out jointly by Ministries responsible for Energy and those responsible for Environment at all levels (Member states, Commission, Regional and local governments).
4. Guidelines on the design and implementation of energy efficiency measures, and in particular of the White Certificate systems, should be issued at the EU level, and the performance of the different systems at country and regional level monitored and benchmarked, so as to help in their further development and diffusion. If this system is going to diffuse in the EU Member states, it would be important to ensure that they develop in a compatible manner, allowing for a EU market, and avoiding the difficulties inherent in the GC situations where many non-compatible schemes have been adopted.
5. The quantification of energy-saving objectives should be quite more ambitious than has been the case so far both at the EU and at the Member-state levels and related to the overriding objectives of energy security, health and environment, and climate change mitigation.
6. An energy efficiency policy (and more generally a sustainable energy policy) requires a number of different policy instruments and not just one. Norms, regulations and incentives are necessary and have their role; however, market-based instruments, properly designed and implemented, should be used as widely as possible.
7. Specific instruments should be employed for heat and power generation (in particular district heating), for biofuels and for energy valorisation of wastes
8. While the ET system appears adequate to cover the energy-intensive industrial sectors, the White Certificate system now considered for the residential and commercial buildings seems more adequate for reaching new sectors, in particular the industrial sectors with medium and low energy intensity; it is suggested that this system should progressively be extended from the domestic and the service sectors to industry

9. The transport sector is still waiting for market-oriented mechanisms to improve energy efficiency; although great progress has been obtained in terms of the energy efficiency of single vehicles, this has been more than compensated by the increase in the demand for private transport, larger average size of cars and in many cases worse traffic congestions, and little or nothing has been achieved in terms of transport systems and modal shifts. Inventive thought is required in this direction; new ideas and experimentation should be encouraged; an eventual extension of a WC-like system to transport should be evaluated.

10. The evaluation of projects should be standardised as much as possible and be based on simple and agreed criteria to calculate the base-line, as done in the UK and proposed for most technologies in Italy so as to simplify procedures and reduce transaction costs. Due to the importance of transaction costs for the success of WC schemes, R&D in this direction is recommended. Progressive implementation of the WC scheme, gradually introducing new technologies and new sectors, may be considered.

11. In order to have an effective implementation of a White Certificate system, a parallel or preliminary action is needed to eliminate or at least reduce market imperfections: this is a task for national and regional governments. The first step should be through effective and objective information campaigns, starting from the residential sector, where the largest potentialities are present.

12. There is generally a lack of effective and objective structures to carry out the field work required for demand side management. Such Energy Service Companies (or ESCO) should be the backbone of a WC system, which creates a market for their services. However, this market has been slow in stimulating the birth of such companies, or the expansion of those which are already present. Public support in the start-up and in the first phases of ESCOs is recommended, as is a system of qualification of ESCOs that can guarantee the client of their competence and ability to deliver. Investing in ESCOs also brings benefits in terms of job creation.

13. Financial barriers have been recognised as one of the main obstacles to the introduction of energy saving measures, even when they are cost-effective. Provisions to facilitate financing of such measures by bundling similar projects, or by guarantees through a rotating fund should be introduced by the banking system with public back-up

14. Legislative and normative constraints slowing down the penetration of effective energy-saving measures should be identified and removed whenever possible; such barriers may be present for instance in (outdated) building codes, in unnecessary safety regulations or in competition-protecting rules.

15. Energy efficiency can not only be the right solution for the long-term energy system (e.g. by reducing import dependence and hence increasing security of supply) but also provide the quickest and most effective response to unbalance between energy supply and demand (e. g. in order to avoid blackouts). Schemes to remunerate energy efficiency as a “power credit” should be explored.

16. Technological development is a pre-condition for a sustained improvement in the efficiency of energy use. Long-term energy scenarios as those considered in the present work show that the gradual improvement of the technologies available or being studied today will not be sufficient to feed the efficiency improvements needed beyond 2015 or 2020. Fundamental research on many aspects of energy utilisation and innovative approaches are needed and should be supported.

9 EU-25 vs. member country data; extension of the EU

9.1 Comparison of aggregated and disaggregated modelling

Among the disadvantages of using a non-disaggregate model is that locally energy-related opportunities cannot be identified (Zongxin et al., 2001). However, its main advantage is that the complexity of the model is reduced as well as the required input data.

9.2 **Effect of future extension of the EU**

The PRIMES report also deals the wider group of countries that applied for membership and received the status of candidate countries, including Bulgaria, Romania and Turkey in addition to the acceding ones. This part also includes Norway and Switzerland, which being direct neighbours, have close economic relations with the EU and are also relevant for future EU energy developments. This group of 15 countries, which for purpose of brevity will be called Candidate Countries/ Neighbours are called by the acronym CCN, is clearly quite diverse. It includes some of the most developed countries in the world, like Switzerland and Norway; some middle income market economies, as well as many countries that had centrally planned economies and started transition to market economies around 1990.

In PRIMES , the population of CCN grows by close to 14 million people between 2000 and 2030, to reach 200 million people by 2030. There are important differences among individual countries. Thus, whereas Turkey's population rises by around 23.5 million people, most candidate countries see considerable reductions in population. Only Cyprus and Malta are projected to experience some population growth to 2030. The population in Norway and Switzerland grows very modestly to 2030.

According to the UN-HABITAT projections adopted in the PRIMES model, the trends in the last decade in CCN countries (reduction of household size from 3.33 persons in 1990 to 3.09 in 2000) are expected to continue. By 2030 the average household size in CCN countries reaches 2.61 persons.

Appendix A: Odyssee Indicators

Energy efficiency performance and its trends for the future are monitored using indicators associated with each sector of the economy, for each type of end use, or for each country/region. Six different indicators have been developed by the EU-SAVE (ODYSSEE project) for this purpose:

Energy intensity

Energy intensity (in tonnes oil equivalent (toe) or MWh per monetary unit) is related to the measurement of the energy consumption of a sector of the economy or of a type of end use, for a specific indicator of activity in monetary units. For example, what is the energy consumption of an activity for a unit of value added to the economy? It is appropriate for assessing the energy efficiency at an aggregated level.

Unit consumption

Unlike energy intensity, unit consumption is more suitable for disaggregated comparison. It associates energy consumption with indicators of physical activity such as per tonne of product or per vehicle manufactured.

Diffusion indicators

These indicators measure the penetration of a particular technology or practice in a sector, sub-sector, or for a specific activity or application.

Adjusted indicators

For more accurate and objective comparisons of indicators between countries, differences in climate, economic structure, fuel mix, and purchasing power can be accounted for. Different adjustments are relevant depending on the type of analysis required, and baseline for comparison.

Target indicators

These indicators are used to reveal the energy efficiency target in two different ways; one technical and one non-technical. The technical targets refer to the potential a country has for efficiency, when compared with the average of the three best countries. On the other hand, the non-technical target indicators are related to the potential (compared with the average of the three best countries) for diffusion and acceptance of the 'efficient practices'.

CO_2 indicators

CO_2 indicators are defined as the CO_2 emissions per unit of monetary output across the entire range of scales from a single unit up to the whole economy. They are distinguished into direct and the total inidcators. The former are related to the emissions from fossil fuels burnt per sector, and the latter also includes emissions derived from the electricity production and heating requirements.

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