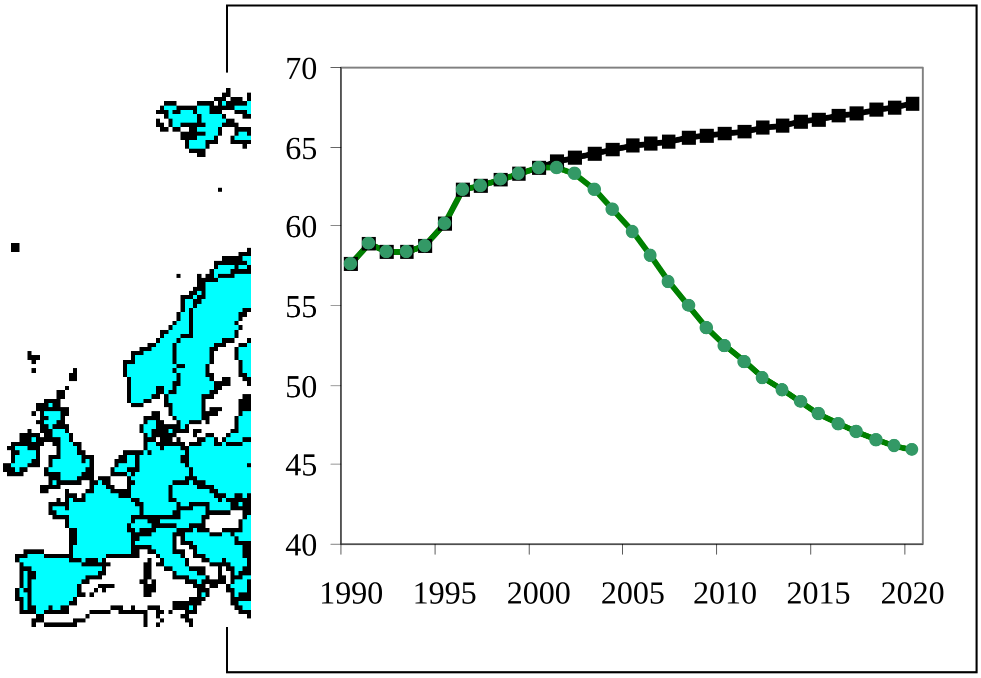
AIR POLLUTION AND CLIMATE SERIES NO. 14

An Alternative Energy Scenario for the European Union



for

The European Federation for Transport & Environment

The Swedish NGO Secretariat on Acid Rain

The European Environmental Bureau

SENCO Sustainable Environment Consultants Ltd

AIR POLLUTION AND CLIMATE SERIES NO. 14

An Alternative Energy Scenario for the European Union

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Any errors remain the responsibility of the author.

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EXECUTIVE SUMMARY

Energy scenarios are key inputs to the projection of pollution emission, and the formulation of strategies to reduce pollution and achieve environmental objectives. Energy use determine carbon dioxide emission, and also largely determine the uncontrolled emissions of many other pollutants.

Alternative energy strategies including demand management, energy efficiency, and low carbon fuels are explored in this report. In addition to abating greenhouse gas emissions, these strategies can facilitate cheaper and greater abatement of other atmospheric pollutants as compared to 'official' scenarios. This work is aimed at starting an exploration of the interaction between strategies to limit global warming, and strategies for reaching other environmental objectives such as reduced acidification and improved air quality.

The given objective was to produce scenarios in which the total emission of carbon dioxide from the fifteen countries of the European Union is reduced by fifteen percent over the period 1990 to 2010. To this end scenarios, called **Carbon15**, have been produced for each of the fifteen EU countries taking into account recent historical data and assumed economic and population growths. The fifteen percent objective, and the energy scenarios developed here, do not necessarily represent the views and favoured options of the study's clients.

For most countries the scenarios do not require the most extreme application of the carbon dioxide reduction measures, although there are exceptions. In this study the exploration of policy options has not been exhaustive and the assumption has been made that historical economic growth patterns continue. Other options and changed economic growth could make it easier to meet needed reductions in carbon dioxide emissions.

In general it can be concluded that the Carbon15 scenarios are technically feasible. In particular the level of demand management is such that, even though natural gas increases its market share, the total European Union consumption of natural gas does not increase very much. It is argued that the Carbon15 scenarios are economically feasible in that the end use measures are cost effective as against conventional energy supply, and there is no requirement for a large expansion of the supply of any conventional primary fuel. However further work would be required to thoroughly assess both technical and economic feasibility.

The policies required to implement the technical changes to energy systems assumed have not been explored here: these might include regulatory and fiscal measures.

1 INTRODUCTION

1.1 Background

Energy scenarios are key inputs to the projection of pollution emission, and the formulation of strategies to reduce pollution and achieve environmental objectives. In particular, work on the development of strategies in the European Union for the control of carbon dioxide, acidification and ground-level ozone uses energy scenarios extensively[1]. When using computer modelling for the purpose of developing emission abatement strategies, the energy scenarios used determine carbon dioxide emissions, and also largely determine the uncontrolled emissions of many pollutants prior to the application of abatement technology such as flue gas desulphurisation and catalytic converters.

According to the energy scenarios used by the Commission when developing the acidification and ozone strategies, and which also are the basis for the recently proposed directive on National Emission Ceilings (NECs), total EU emissions of carbon dioxide will rise by about 9 per cent. This is contradictory to the commitments of the EU and its member countries under the Kyoto protocol, which requires them to reduce emissions by 8 per cent. If the total energy used – and especially the part generated from fossil fuels – is overestimated, the estimated cost of reducing emissions to a certain level will also be exaggerated. Moreover, the possibilities of reduction will be underestimated, thus weakening the setting of interim environmental quality targets.

As compared to 'official' scenarios, energy strategies can include more demand management, energy efficiency, and low impact fuels. In addition to abating greenhouse gas emissions, these scenarios can facilitate cheaper and/or greater emission abatement as compared to the 'official' scenarios.

The emissions of atmospheric pollutants causing air quality degradation and acidification are determined by processes occurring throughout the whole chain of energy supply and demand. Therefore strategies aimed at reducing the emissions of these pollutants should assess the potential abatement brought about by changes to any link in this chain. An overview of this chain, with examples of mitigating measures is given in Figure 1. The measures can be usefully split into two categories: preventative and curative. Preventative measures, which may be applied to end-use sectors, generally reduce any types of environmental impact engendered upstream in the energy system. For example: low energy electric appliances reduce electricity demand and thereby reduce the environmental impact of electricity supply whether it relates to sulphur dioxide, nitrogen oxides, carbon dioxide, nuclear waste or the various impacts of hydroelectric generation. Curative measures on the other hand, often substitute one form of environmental impact

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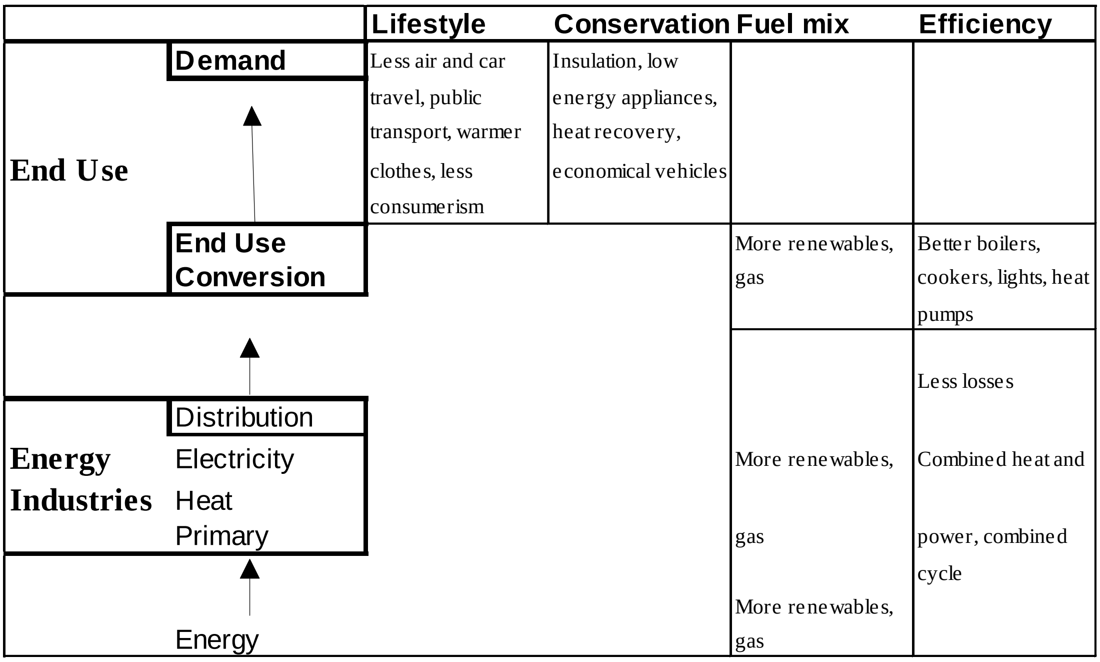
[1] See *Seventh Interim Report: Cost-effective Control of Acidification and Ground-level Ozone* by IIASA (January 1999) for an important recent example of this.

for another - albeit a more benign one. For example: flue gas desulphurisation (FGD) systems reduce gaseous acidfying emissions, but increase other impacts including carbon dioxide emission and solid waste output; switching to gas from oil reduces carbon dioxide and sulphur dioxide emission, but may increase the emission of methane, a greenhouse gas.

Figure 1 : Abatement Measures



		Lifestyle	Conservation	Fuel mix	Efficiency
End Use	**Demand**	Less air and car travel, public transport, warmer clothes, less consumerism	Insulation, low energy appliances, heat recovery, economical vehicles		
	End Use Conversion			More renewables, gas	Better boilers, cookers, lights, heat pumps
Energy Industries	Distribution				Less losses
	Electricity Heat Primary			More renewables, gas	Combined heat and power, combined cycle
	Energy			More renewables, gas	

The basic demand for energy services is determined by factors including wealth, population and lifestyle.

An array of technologies at the point of service determine how much delivered fuel is required, and what the emission of pollutants will be at the end use stage. Emission can be reduced here by demand management and by increased efficiency of conversion. These measures are important since they reduce energy flows upstream in the supply system and thereby also diminish pollution engendered upstream. Demand management measures such as insulation and efficient appliances could reduce emissions engendered by domestic energy services by something of the order of 20% to 80% in most industrialised countries. Fuel switching can reduce emissions at the end-use stage. Switching to gas or renewables reduces most atmospheric pollutants. Switching to electricity reduces emissions at end use, but will generally increase the environmental impact of electricity supply which in most industrialised countries includes the emission of sulphur and nitrogen oxides and carbon dioxide. 'End-of-pipe' abatement technologies at the point of end use reduce emissions of sulphur and nitrogen oxides but in some cases decrease energy efficiency and produce wastes. Decreasing energy efficiency generally increases carbon dioxide emissions.

A range of efficiency and fuel switching abatement measures similar to those applicable to end use sectors can be applied at the point of energy supply - but lifestyle change and demand management can not act directly here. Additional means of sulphur and nitrogen oxides abatement can include some renewables (especially those producing electricity), nuclear power, and the lowering of sulphur levels in coal and oil. Combined Heat and Power (CHP) and District Heating (DH) can also be further applied at the energy supply level.

1.2 This study

This study aims to develop energy scenarios with low carbon dioxide emission. This is done in order to explore the possible effect of such scenarios on the costs of meeting environmental objectives other than reduced global warming – most notably those relating to the problems of acidification and ozone pollution. The energy scenarios developed are for this exploration and are not to be regarded as being official NGO scenarios.

The remit of this study is to produce energy scenarios for the fifteen European Union countries such that the total carbon dioxide emissions from are reduced by 15% by 2010 as compared to 1990. This scenario is labelled Carbon15.

These scenarios assume extra CO_2 abatement measures being introduced in 2000, and would therefore have ten years at most to take effect to achieve a reduction in 2010. Judgements as to which measures to introduce have been based on technical feasibility, cost effectiveness and speed of introduction.

For example, key measures include:

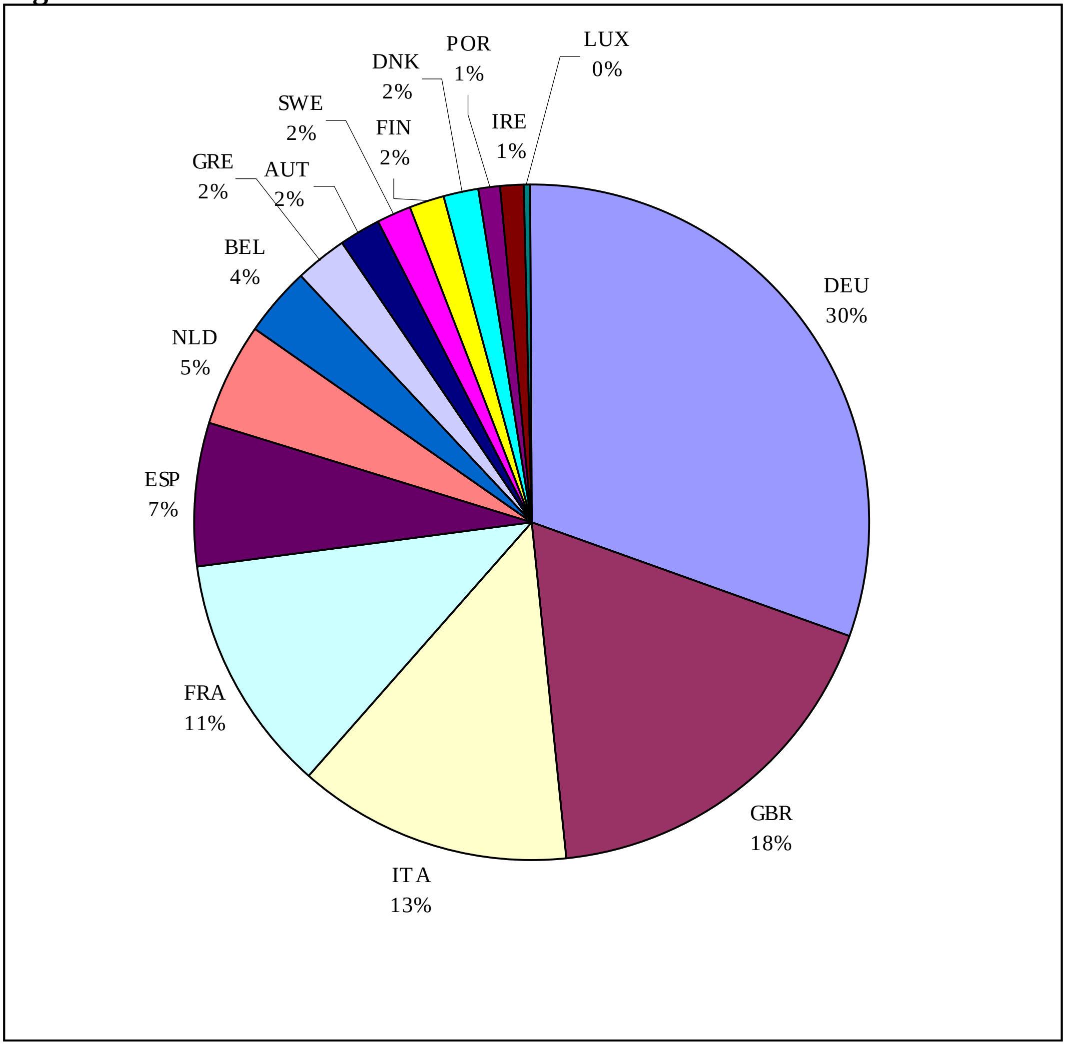
- Increased efficiency of electricity use (stock turnover rate about 10 years).
- More energy efficient cars (stock turnover rate about 10 years).
- Energy conservation in buildings.

The energy flows in these scenarios are put into the same categories as in IIASA’s RAINS model. These flows may be used to generate cost curves which may then be input to the RAINS model. The RAINS model may then be used to find optimal allocation of measures to achieve given reduced levels of acid deposition and ground-level ozone.

1.3 EU carbon dioxide emission

The Figure below shows the distribution of CO_2 emissions in 1990 across the EU15. It is apparent that, from the EU15 perspective, that the 'Big Five' (Germany, UK, Italy, France and Spain) are most important. Germany and the UK account for nearly 50% of emissions, and the five together nearly 80%.

Figure 2 : EU15 carbon dioxide emission: 1990



Source: Submissions to Kyoto

1.3.1 Targets

The individual countries of the European Union, and the EU as a whole, have committed to reductions in the emissions of a basket of greenhouse gases in the Kyoto protocol. The commitments are to changes in emission from 1990 to be achieved by 2008-2012. In the following it is assumed that the emissions of carbon dioxide, a principal greenhouse gas, would follow the changes in emission for the basket of gases. Table 1 summarises the commitments. Overall the sum of the individual Kyoto commitments would result in an EU reduction of about 8.6% over the period 1990 to 2010. The Carbon15 scenario requires a reduction in the total of nearly double this.

Table 1. EU greenhouse gas emission burden sharing

Member states	**Commitments in accordance with Article 4 of the Kyoto protocol**
Belgium	- 7.5%
Denmark	-21%
Germany	-21%
Greece	+25%
Spain	+15%
France	0%
Ireland	+13%
Italy	- 6.5%
Luxembourg	-28%
Netherlands	- 6%
Austria	-13%
Portugal	+27%
Finland	0%
Sweden	+ 4%
United kingdom	-12.5%
EU15	**-8.6%**

This burden sharing is an outcome of negotiations taking into account factors such as:

- **The relative wealth and economic growth prospects for each country.** The less wealthy countries allow for greater economic growth and its concomitant energy consumption and carbon emission - most of the countries in the table above with positive changes in CO_2 may be so characterised. However, in such countries the potential for introducing energy efficiency in new stocks may be quite high.

- **The potential for switching to low carbon fuels.** Some countries have a large and readily realised potential for reducing the average carbon content of their primary energy from 1990 (e.g. the large switch from coal to gas for electricity generation in the UK): others do not because the further availability of low carbon fuels is small (e.g. in France because electricity generation has been predominantly nuclear and hydro for a long time).

2 DEVELOPING THE SCENARIOS

2.1 Process

The process for the development of the scenarios is as follows:

i. Extract International Energy Agency (IEA) data for the period 1990 to 1996. Build energy flows and carbon emissions.

ii. Project for the period 1997 to 1999 with no change in measures.

iii. Project energy flows and carbon emission for the period 2000 to 2020 with assumed programmes of measures.

iv. Put energy flows for the year 2010 into RAINS format, calculate cost curves.

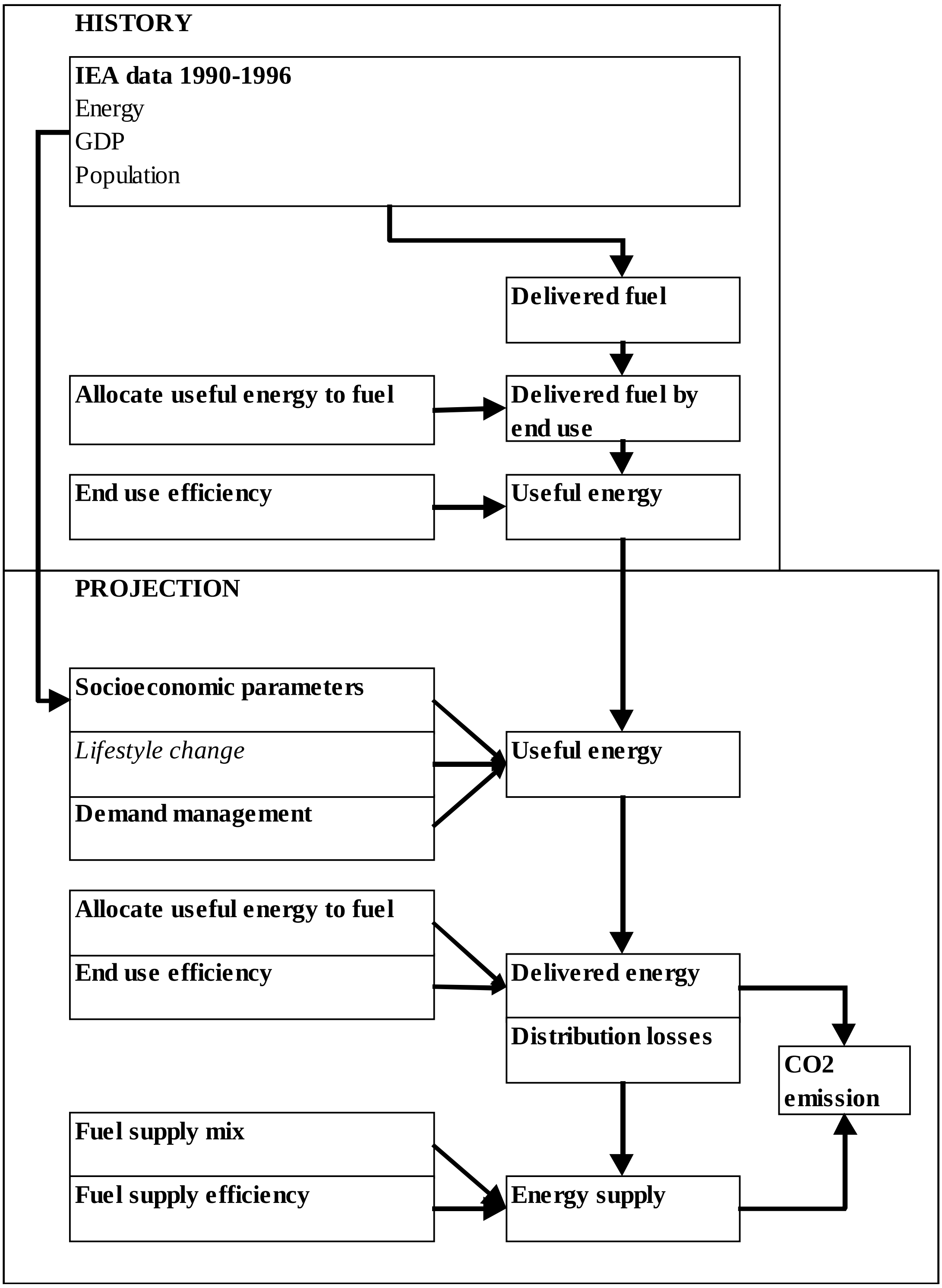
2.2 ScenaGen Model

SENCO has developed an energy model called ***ScenaGen*** (Scenario Generator). It is designed to rapidly produce energy scenario which may be used in the analysis of environmental impacts. The model is characterised as follows:

- It uses historical energy, economic and population statistics from the IEA.
- It projects useful energy consumption with functions based on GDP and population.
- It uses exogenous assumptions for measures which change energy flows: these are lifestyle (not considered in this report), demand management, energy conversion efficiency, and fuel supply mix.
- Costs and prices, and their effects through elasticities etc., are not currently included in this model.

The structure of the model is shown schematically in Figure 3.

Figure 3 : Model Overview



The IEA has assembled a database of the energy statistics for most countries of the world (IEA, 1996), the most recent data year being 1996. These data have been compiled into country energy balances. These balances include sectoral data for the consumption and production of fossil fuels, hydro, nuclear, geothermal and other renewables, electricity and heat. This database also includes GDP and population.

The consumptions of delivered fuel in 1996 are allocated to eleven end uses as shown in Table 2 – the are ordered by temperature. Some of these end uses are generally regarded as electricity specific; others can utilise heat from cogeneration or other sources (as opposed to fossil fuels or electricity). These features are also shown in the Table.

Table 2 : End uses

	Electricity specific	**Heat substitution**
Motive power	e	
Electrical equipment	e	
Process work		
Lighting	e	
Process heat (>120C)		h
Process heat (<120 C)		h
Cooking		
Water heating		h
Space heating		h
Space cooling	e	
Refrigeration	e	

Delivered fuels by end use are multiplied by a set of efficiencies to produce useful energy consumed for the eleven end uses. This establishes useful energy consumption for the last year for which there are IEA data (1996).

These useful energy data are then projected into the future using ‘energy activity functions’ based on GDP, population of people and households. GDP and population change rates are taken as the average of historic data for 1990 to 1996. Every scenario for a particular country assumes the same demographic and economic changes - i.e. these are invariant.

This basic projection of useful energy is then modified according to control measures (changes in lifestyle (Li), demand management (DM), energy conversion efficiency for end use and supply (EE and FE); and fuel switch for end use and supply (ES and FS). These programmes are assumed to start in the earliest possible year, 2000.

Dividing the modified useful energy by the appropriate projected efficiencies results in the projected figures for delivered energy for the various sectors of final consumption.

After adding on distribution losses, and allowing for imports and exports the requirements for domestic inland energy supply may be found. Supply side efficiency improvements and fuel switching are then applied so that the fuel used in energy industries may be calculated.

Carbon dioxide emissions arising from the combustion of fuels by energy consumers and suppliers are calculated. Emissions from the non energy use of fossil fuels is included – they are assumed to remain constant at the 1996 level. Emissions from international transport are not included as they currently lie outside national emission commitments.

2.3 General information sources

Information on the technical scope and economic potential of the measures explored in the scenarios is drawn from a large number of sources. Some of these are set out in Chapter 5 and the references.

A similar exercise to the present one was carried out for the Stockholm Environment Institute in 1994. Information collated for this was also used. In addition information from more recent work has been used. This includes EU studies of electricity use efficiency, and the Auto Oil programme.

To comprehensively update the information on the measures for each of the EU15 countries is a worthwhile endeavour, but it is beyond the scope of this exercise. Therefore the assumptions about the measures are taken as typical for the EU. From the perspective of EU15 carbon emission, it is important these values are reasonable for the ‘Big Five’ countries as they so dominate total emission.

In any case, it should be recognised that the cost effective scope of the measures, and the rate at which they might be introduced are not fixed values – they can vary widely according to the context of the scenarios. For example:

- The scope for gas substitution in one country will depend on the overall balance of supply and demand in the EU (and indeed elsewhere in Europe and Asia).

- The lifetime of a coal power station will depend, inter alia, on any targets for atmospheric emissions – with tight SO_2, NOx and CO_2 emission limits the life might be 25 rather than 40 years since earlier replacement with gas (for example) becomes more cost effective.

- The cost effectiveness of end use efficiency depends on the costs of supply, which are scenario dependent. The higher cost the cost of energy supply, then the greater increase in end use efficiency is economically justifiable.

- Further improvements in technologies may be expected, the speed and extent of which will depend on factors including policy context. For example the expansion and development of renewable electricity sources in the UK has been accelerated by the requirement that a certain fraction of electricity should be derived from non fossil fuel sources.

These comments should be borne in mind when considering the assumptions input to the scenarios concerning cost effective potential for energy efficiency and fuel switching, and the rates of turnover and change assumed for the technologies.

2.4 Rate of change

A key issue in this exercise is the rate at which the carbon reduction measures can be introduced, there is only ten years from the earliest possible introduction of extra measures (2000) and the target year (2010).

Table 3 summarises the average ‘natural’ technology lifetimes assumed. These points should be noted:

- In some cases the measure lifetimes are less than the lifetime of the pertinent technology. For example; a lifetime of 25 years is assumed for residential space heating. This may be appropriate for space heating systems and the rate of introduction of insulation, but houses typically have much longer lifetimes, e.g. about 100 years in the UK.

- It is generally possible to increase the rate of introduction of a measure if required, but usually only at an extra cost. For example, the average life of a car might be 10 years, but this might be reduced with a scrappage subsidy so as to accelerate the introduction of ‘cleaner’ cars.

- Many technologies are made of components with different lives. For example, a power station’s boilers might be changed after 10 years so as to use a different fuel or increase efficiency, but other original components (turbogenerator etc.) be retained.

Table 3 : End use technology lifetimes Fel! Bokmärket är inte definierat.

	Motive power	Electrical equipment	Process work	Lighting	Process heat (>120C)	Process heat (<120 C)	Cooking	Water heating	Space heating	Space cooling	Refrigeration
Iron and steel	15	12	25	15	20	20	15	15	30	25	10
Chemical and petrochemical	15	12	25	15	20	20	15	15	30	25	10
Heavy industry	15	12	25	15	20	20	15	15	30	25	10
Light industry	15	12	25	15	20	20	15	15	30	25	10
Services		12		15		25	15	15	25	25	10
Residential		12		15			15	25	25	25	10
Other demand	15	12	25	15	25	25	15	25	25	25	10
Agriculture	12	12		15	25	25	15	25	25	25	10
Air: Int	20										
Air: Dom	25										
Road: Pass	10										
Road: Freight	10										
Rail	25										
Sea:Int	25										
Other	25										

The lifetime of energy supply technologies, most notably fossil fuelled power stations, is assumed to be 30 years.

2.4.1 Lifestyle

In the scenarios discussed in this document no lifestyle changes are assumed.

2.4.2 Demand management

Demand management is defined as energy savings achieved through measures such as insulation, ventilation control, heat recovery, improved controls, low mass vehicles, and showers. Demand management can only be applied in the sectors of end use or final consumption.

Table 4 shows the maximum savings and time scales assumed for demand management for an average west European country.

Table 4 : Overview of demand management potential

	Motive power	Electrical equipment	Process work	Lighting	Process heat (>120C)	Process heat (<120 C)	Cooking	Water heating	Space heating	Space cooling	Refrigeration
Iron and steel	30%	50%	20%	30%	20%	20%	40%	5%	50%	30%	50%
Chemical and petrochemical	30%	50%	20%	30%	20%	20%	40%	5%	50%	30%	50%
Heavy industry	30%	50%	20%	30%	20%	20%	40%	5%	50%	30%	50%
Light industry	30%	50%	20%	30%	20%	20%	40%	5%	50%	30%	50%
Services		50%		30%		20%	40%	5%	50%	30%	50%
Residential		50%		30%			40%	5%	50%	30%	50%
Other demand	30%	50%	20%	30%	20%	20%	40%	5%	50%	30%	50%
Agriculture	30%	50%	20%	30%		20%	40%	5%	50%	30%	50%
Air: Int	30%										
Air: Dom	30%										
Road: Pass	50%										
Road: Freight	20%										
Rail	30%										
Sea:Int	10%										
Other	10%										

2.4.3 Efficiency of energy conversion

Efficiency is defined as the ratio of useful energy output from a technology to the fuel energy input - it thus refers mainly to energy conversion. Efficiencies can be improved in end use sectors (boilers, lights etc.) and in energy supply (power stations, refineries etc.).

Table 5 summarises the assumptions for maximum efficiency improvements. The efficiency gains are in general less according to the fuel used. For example, the potential improvement in efficiency for electric water heating is assumed to be 15%, less than the 30% which might be expected for water heating with oil.

Table 5 : Typical maximum end use efficiency improvements

Motive power	20%
Electrical equipment	20%
Process work	20%
Lighting	30%
Process heat (>120C)	30%
Process heat (<120 C)	30%
Cooking	30%
Water heating	30%
Space heating	30%
Space cooling	30%
Refrigeration	30%

For energy supply the following is assumed:

- a 27% increase in average electrical generation efficiency over 30 years
- no change in the efficiency of heat plant.

2.4.4 Fuel switching

Changing the mix of fuels supplied directly to consumers and to the producers of secondary fuels such as electricity and heat can reduce carbon emissions. This may be done in two ways:

i. Switching to inherently lower carbon fuels: the order of carbon emission per energy content is renewable and nuclear (zero), and then fossil natural gas, petroleum and coal.

ii. Switching to delivered fuels which reduce emissions from the energy system as a whole. This includes switching from electricity to gas where marginal electricity supply is from fossil fuelled electricity only (i.e. non cogeneration) stations; switching to heat where heat is supplied by cogeneration or efficient heat only plant.

The amount of switching possible is limited by the technical and economic potential for different energy forms in different countries, and the rate at which energy mixes may be changed. Judgements about these are based on the existing situation and the reference materials.

For electricity generation, the merit order is cogeneration (or Combined Heat and Power), hydro, other renewables, nuclear, and fossil sources. Cogeneration produces electricity in a given ratio to the heat load.

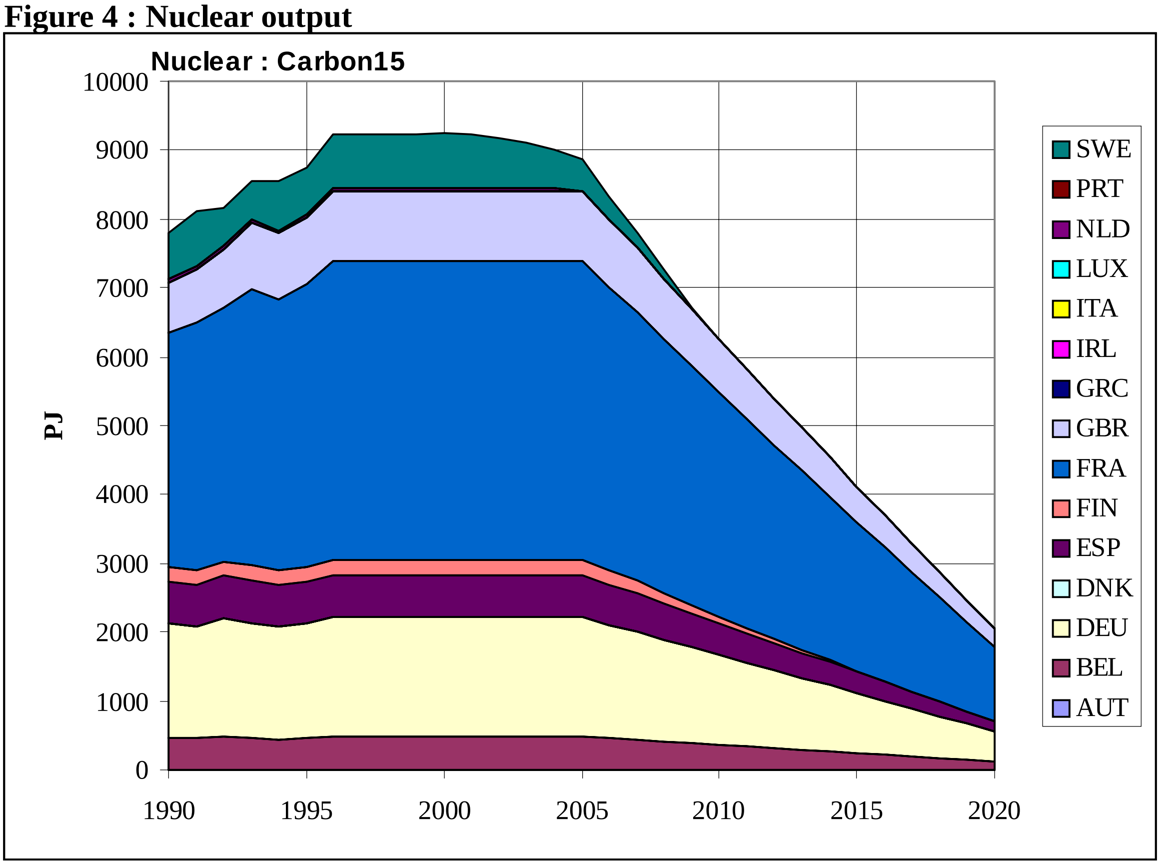
If the potential electricity production from cogeneration and non fossil sources is greater than demand, the surplus would in reality be exported. This electricity could be used to replace carbon based generation in another country. ***ScenaGen*** does not account for any export.

Nuclear power

One important assumption concerning carbon dioxide emission is the future output from nuclear power stations. Recent ‘official’ views project nuclear output to remain near current levels up to 2010. In this study a more cautious assumption is made. In all country and scenario it is assumed that the total output from nuclear stations declines at 5% per annum from 2005. If electricity demand can be met by renewables and cogeneration, then nuclear output may fall faster. Nuclear output is shown in Figure 4.

Obviously the less zero carbon nuclear output, the more difficult it is to meet CO_2 targets. Therefore, if nuclear output is as ‘officially’ forecast, the measures assumed in the Carbon15 scenarios would not be required to be implemented to the same degree.

Figure 4 : Nuclear output



2.5 Scenario assumptions

The policy measures of demand management (DM), end use efficiency (EE), end use fuels switch (ES), fuel supply efficiency (FE) and fuel supply fuel switch (FS) are implemented to different degrees in the each countries. Judgements about these were made according to:

i. What is required in order for each country to meet its Kyoto commitment. This is the most important consideration.

ii. The degree to which the measures have already been applied

iii. The potential for further application especially of heat and renewable energy supply.

Table 6 summarises the assumptions. As an example, the measures for Austria are:

DM(90) EE(90) ES(0) FE(90) FS(30)

This means demand management (DM) is applied to 90% of maximum, end use efficiency (EE) to 90%, end use fuels switch (ES) to 0% - and so on. The rate of introduction of these measures depends on the relevant lifetimes for the end use and technology. The measures reach full implementation to the given level between the shortest lifetime (10 years) and the longest lifetime (30 years) – in general the programmes do not have their full effect until 2030.

Table 6 : Carbon15 scenario measure implementation (%)

	Demand management	End use efficiency	End use fuels switch	Supply efficiency	Supply fuel switch
	DM	EE	ES	FE	FS
Austria	90	90	0	90	30
Belgium	70	80	30	80	30
Germany	60	60	20	60	20
Denmark	95	90	80	90	85
Spain	30	50	2	40	15
Finland	65	65	0	60	5
France	65	60	25	75	20
United Kingdom	60	65	15	60	10
Greece	70	70	20	80	10
Ireland	95	95	95	95	30
Italy	40	35	1	35	1
Luxembourg	95	95	95	95	80
Netherlands	95	95	95	95	70
Portugal	25	50	0	50	5
Sweden	100	100	100	100	100

It is to be noted that the measures are most strongly applied in those countries where high levels of nuclear, renewables and gas are already in place and therefore the potential for proportionally increasing the use of these is less than for other countries. The situation is particular difficult for countries with a large nuclear component given the assumed phase out of this component.

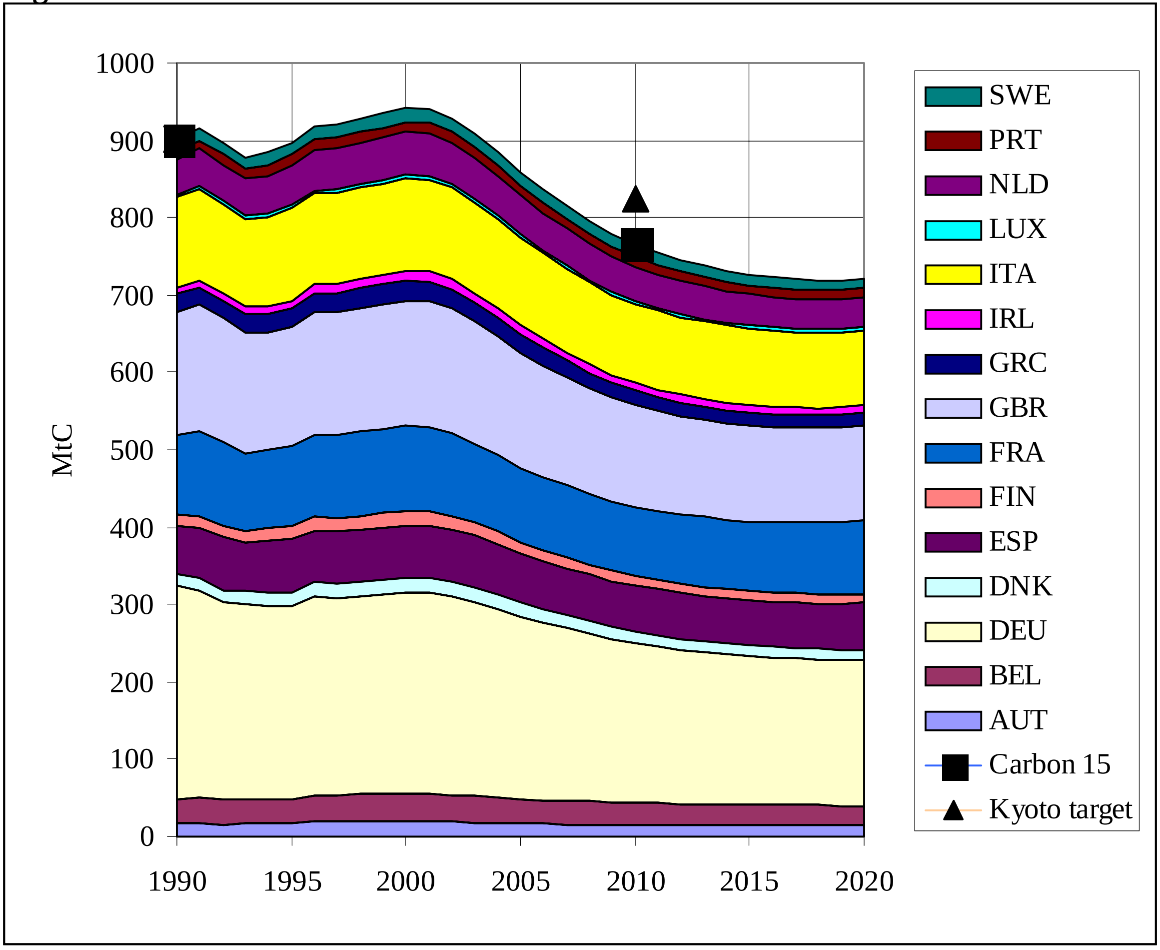
3 RESULTS

The *SENCO* ***ScenaGen*** model was run for all 15 EU countries, and for five scenarios for comparison: No Measures, Business-as-Usual, Kyoto, Carbon15, and Maximum Reduction.

3.1 European Union results

Figure 5 shows the carbon emission for the EU15 countries in the Carbon15 scenarios. One notable feature is that EU15 carbon emission are still falling quite steeply after 2010, this is because of the measures take time to fully affect the stock of technologies. This means that the scenarios are quite robust in that the 15% reduction target is met up to 2020.

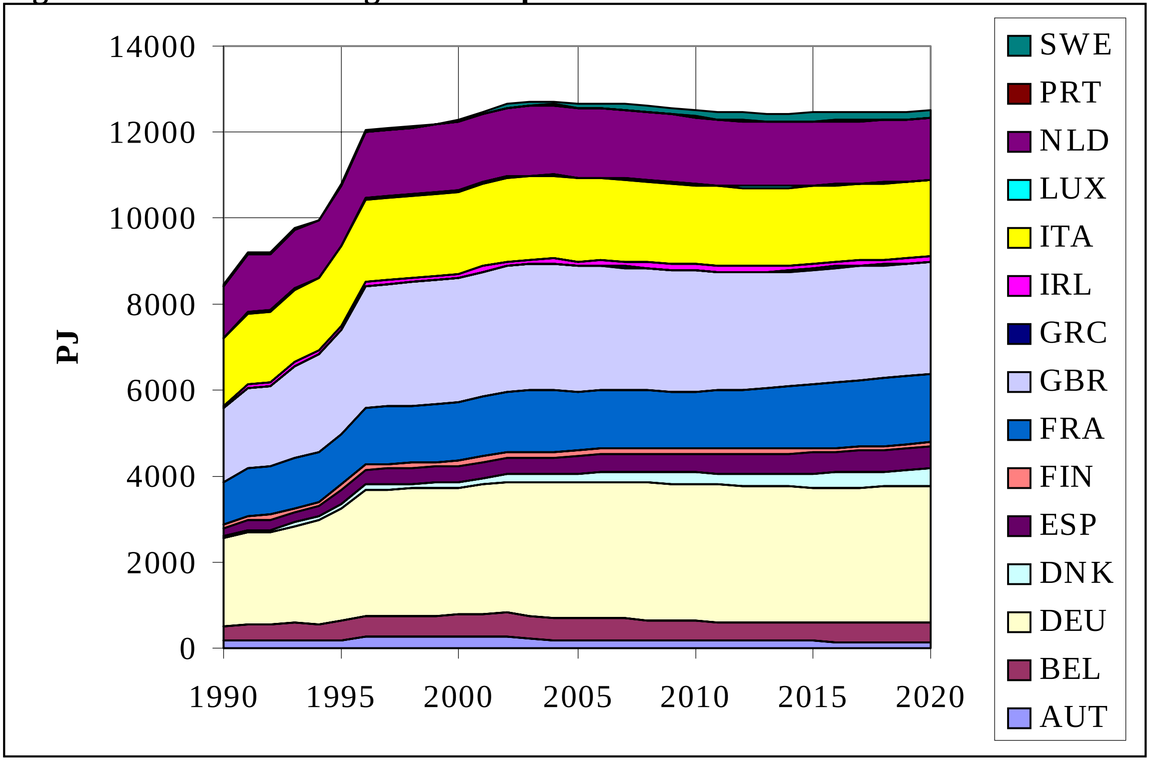
Figure 5 : EU15 countries carbon emission: Carbon15 scenario



3.1.1 Gas supply

One concern in low carbon scenarios is the consumption of gas given a switch to this fuel away from higher carbon coal and oil. Figure 6 shows total gas consumption in the Carbon15 scenario: it shows consumption growing marginally to 2003, and thereafter remaining almost constant over the scenario period. This scenario should not impose to great a need on gas supply from EU and extra-territorial sources. This underlines the importance of minimising delivered fuel requirements through demand management and energy efficiency at the same time as switching to low carbon fuels.

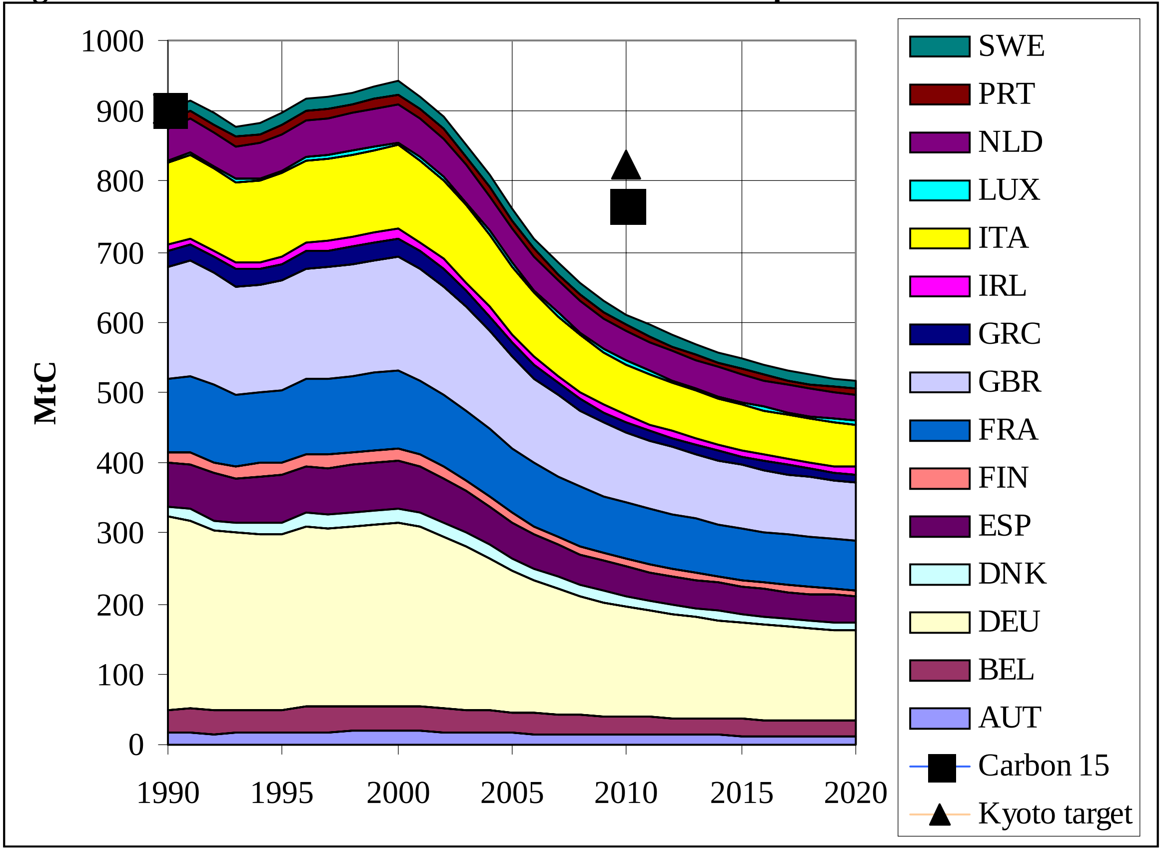
Figure 6 : EU15 countries gas consumption: Carbon15



3.1.2 Maximum reduction

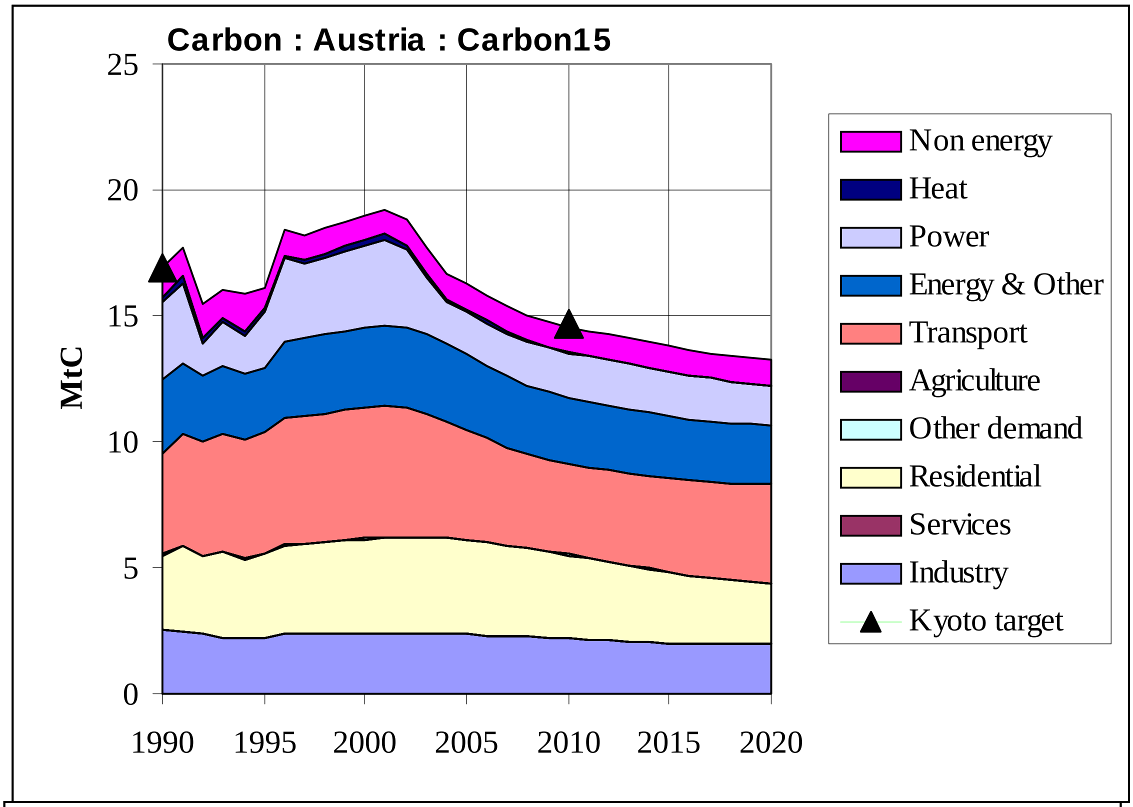
Figure 7 shows EU15 carbon emission if the measures are implemented to the maximum degree. Given the assumed potential of the measures, carbon emissions are reduced by over 30% by 2010 as compared to 1990 – i.e. twice the reduction of the Carbon15 scenario. Although it is not argued that the maximum scenario is necessarily desirable or practicable in policy terms, it does give some indication of the robustness of the Carbon15 scenario in that the potential of the measures would have to be greatly overestimated for the Carbon15 scenario to be infeasible.

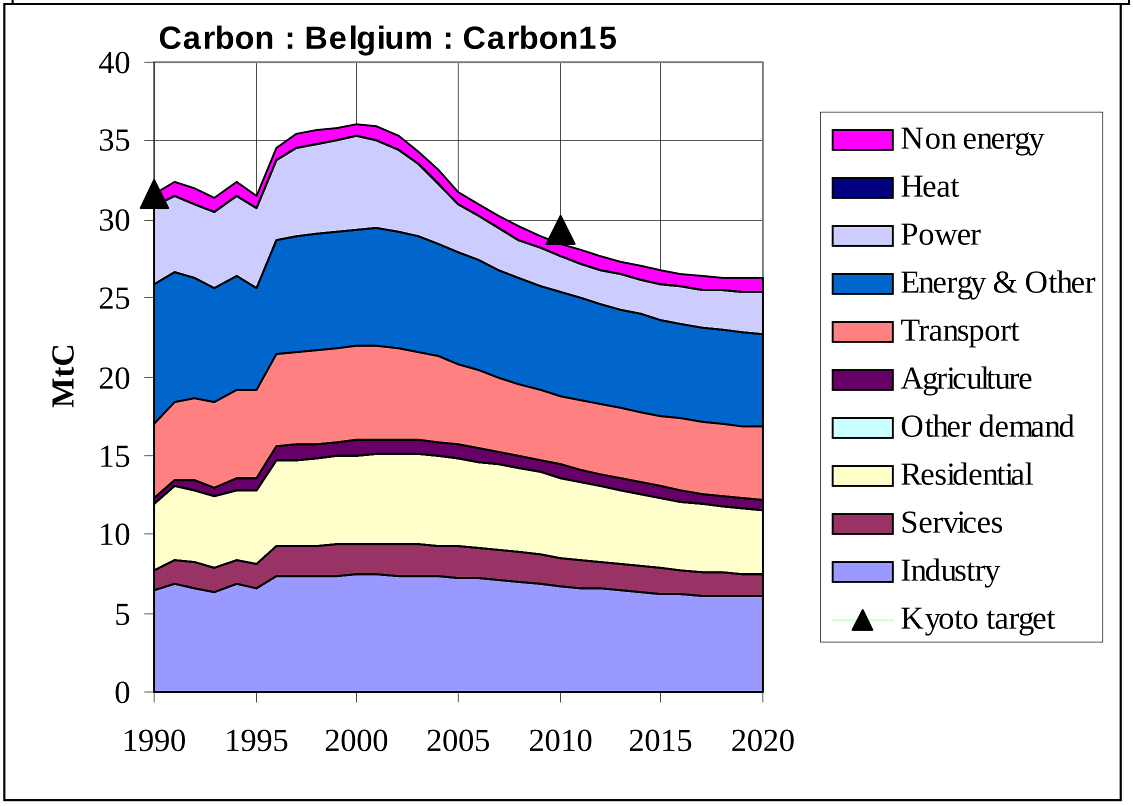
Figure 7 : EU15 countries carbon emission: measures implemented to maximum

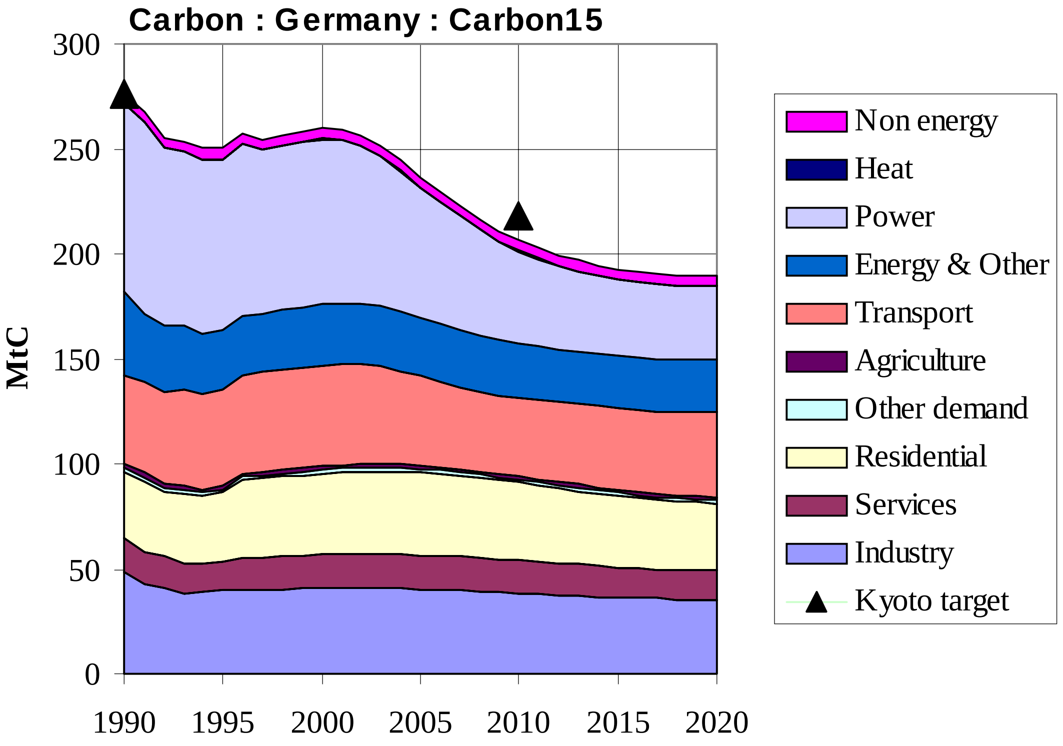


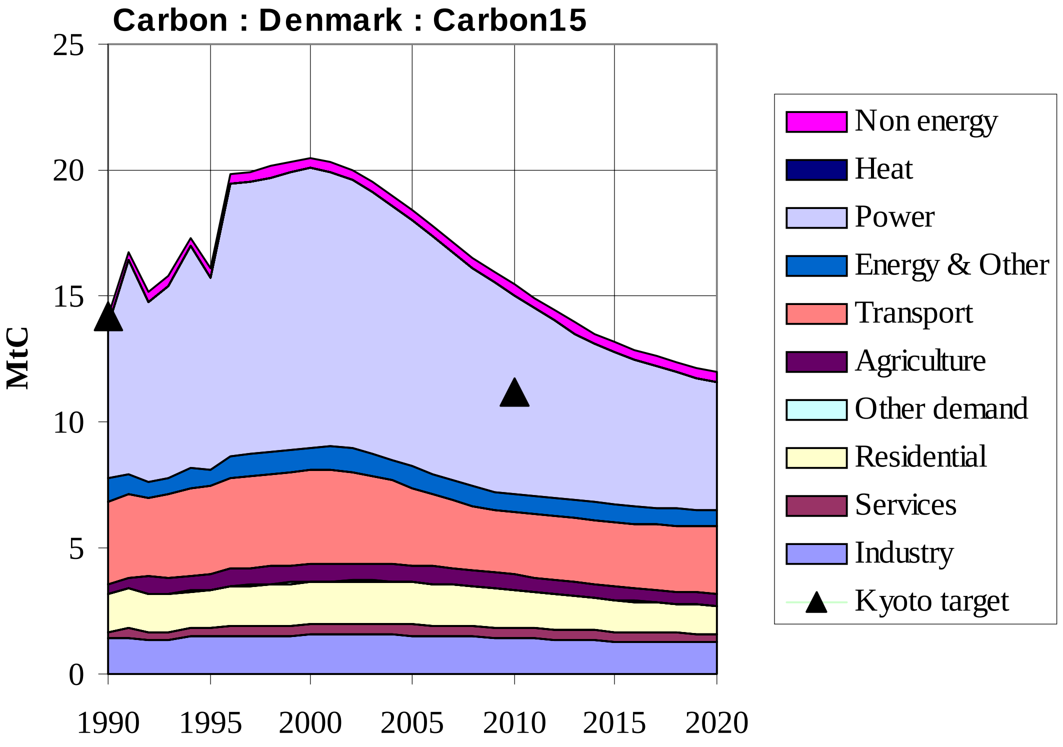
3.2 Country results

The following sequence of Figures gives the sectoral carbon emission for each of the EU15 countries for the Carbon15 scenario.


Carbon : Austria : Carbon15
MtC
25
20
15
10
5
0
1990
1995
2000
2005
2010
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target


Carbon : Belgium : Carbon15
MtC
40
35
30
25
20
15
10
5
0
1990
1995
2000
2005
2010
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target


Carbon : Germany : Carbon15
300
250
200
150
100
50
0
MtC
1990
1995
2000
2005
2010
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target


Carbon : Denmark : Carbon15
25
20
15
10
5
0
MtC
1990
1995
2000
2005
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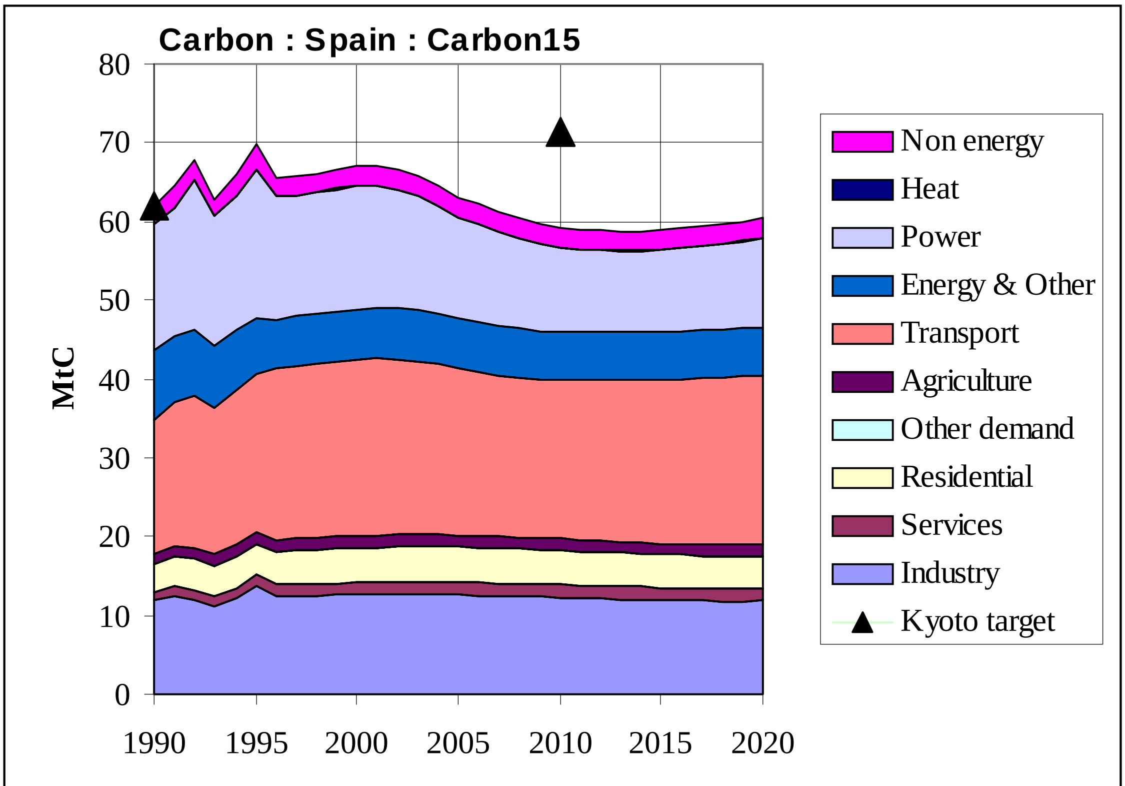
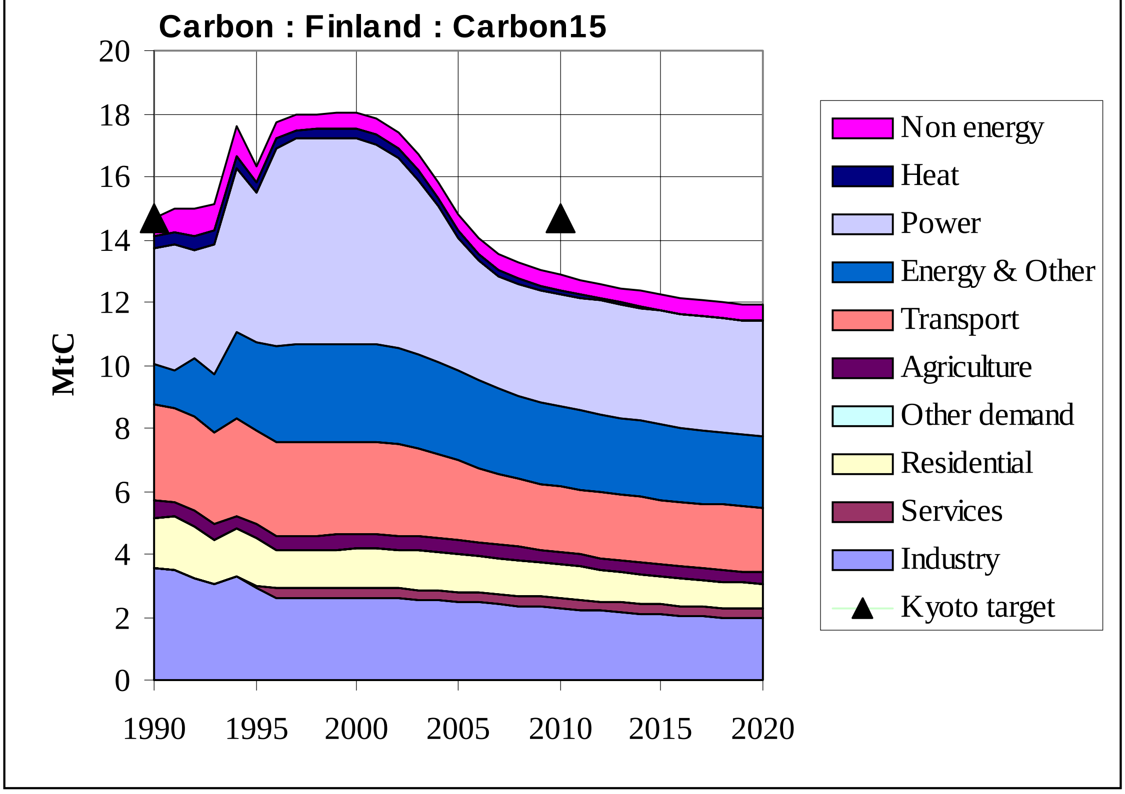
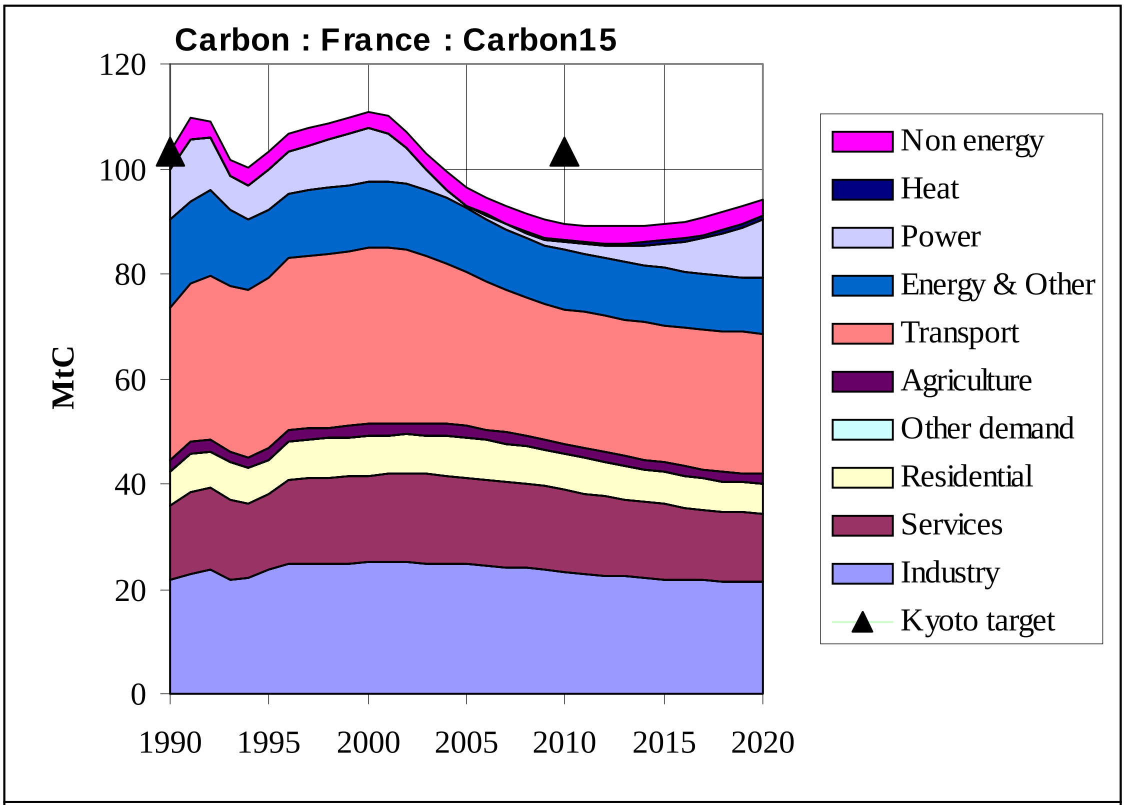
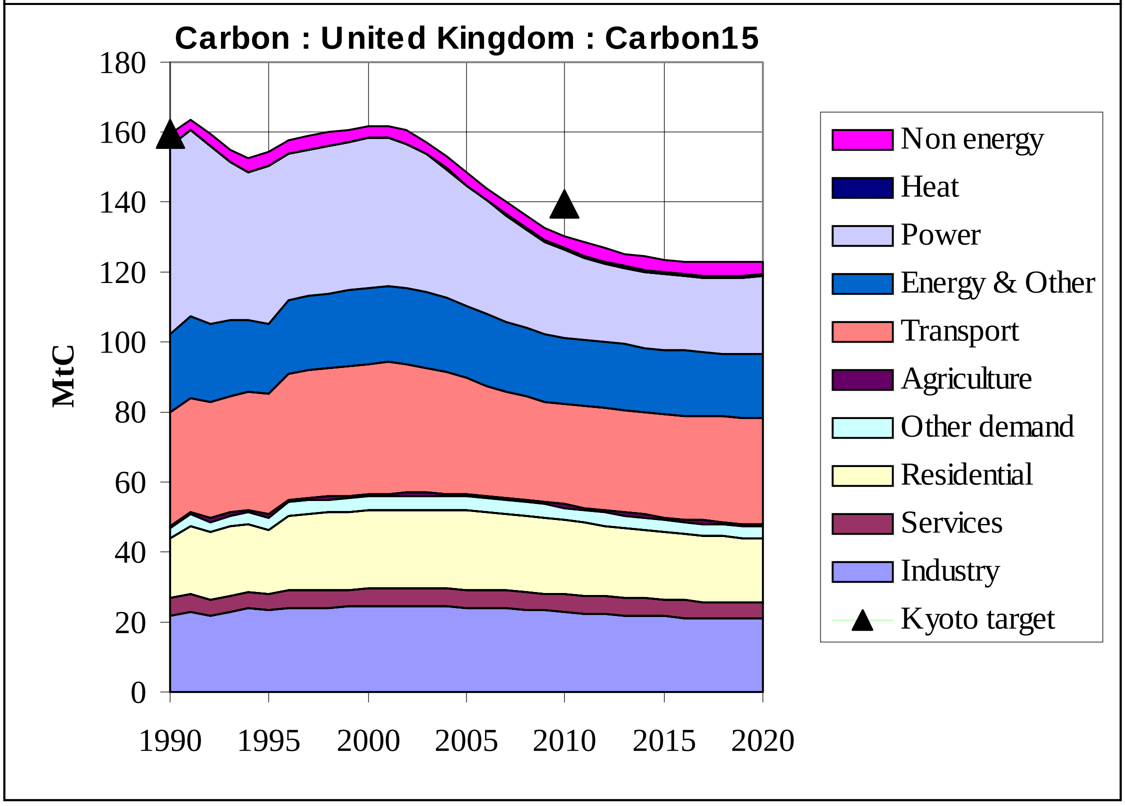
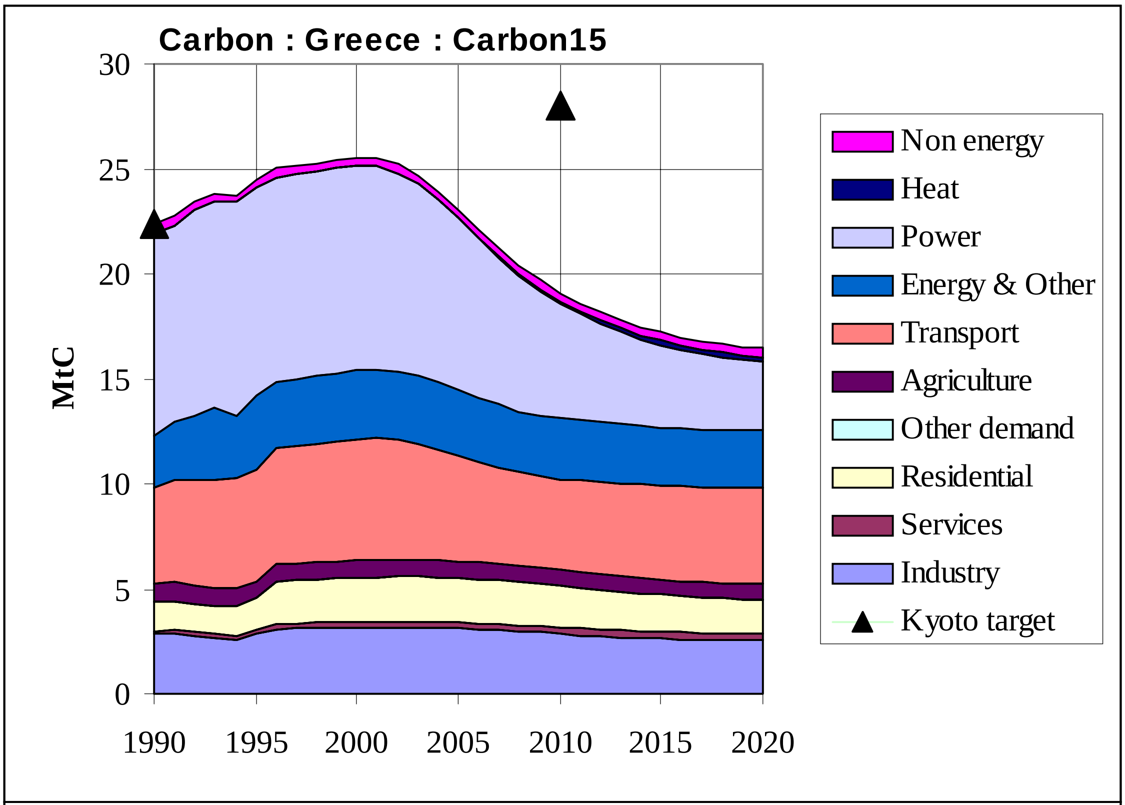
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target

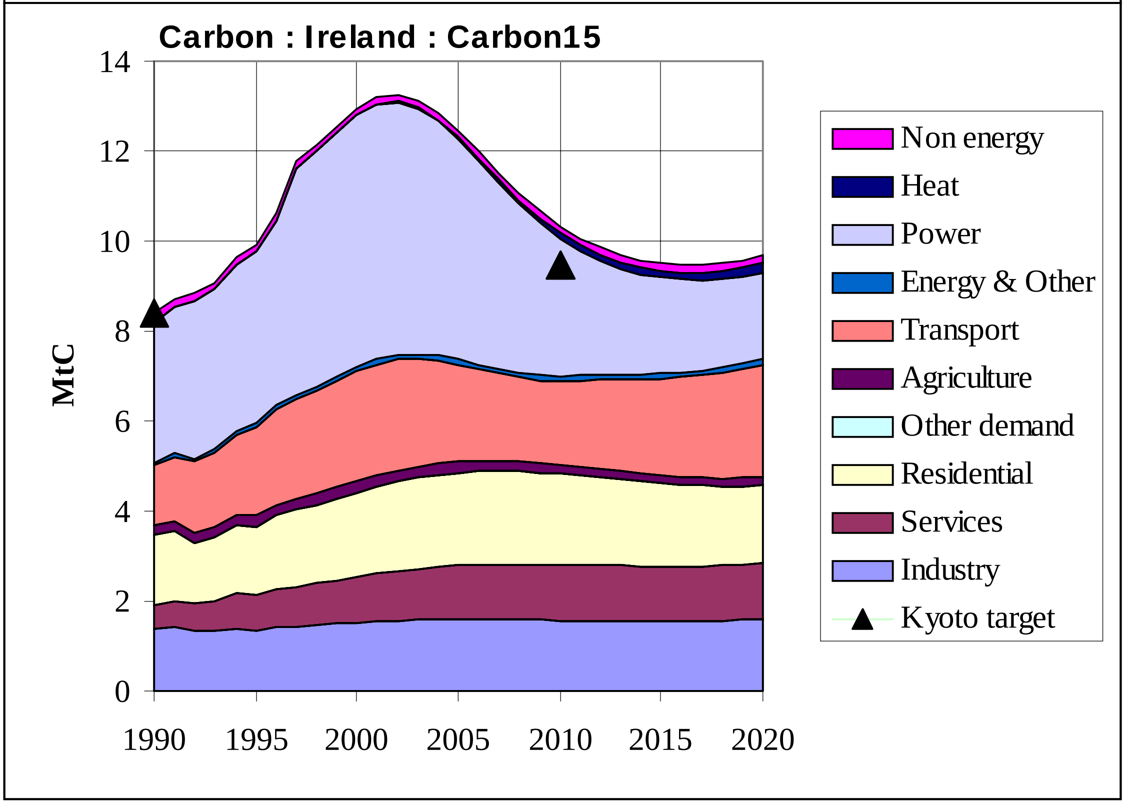

Carbon : Spain : Carbon15
MtC
0
10
20
30
40
50
60
70
80
1990
1995
2000
2005
2010
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target

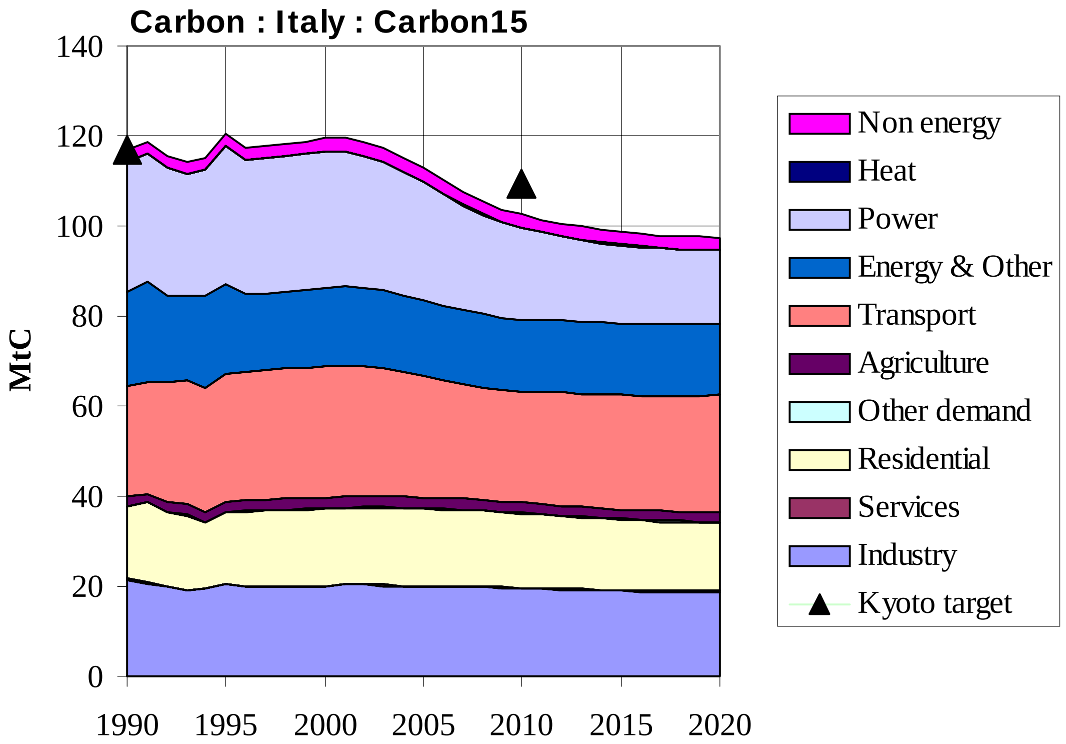

Carbon : Finland : Carbon15
MtC
0
2
4
6
8
10
12
14
16
18
20
1990
1995
2000
2005
2010
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target


Carbon : France : Carbon15
MtC
120
100
80
60
40
20
0
1990
1995
2000
2005
2010
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target


Carbon : United Kingdom : Carbon15
MtC
180
160
140
120
100
80
60
40
20
0
1990
1995
2000
2005
2010
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target


Carbon : Greece : Carbon15
MtC
0
5
10
15
20
25
30
1990
1995
2000
2005
2010
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target


Carbon : Ireland : Carbon15
MtC
0
2
4
6
8
10
12
14
1990
1995
2000
2005
2010
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target


Carbon : Italy : Carbon15
MtC
140
120
100
80
60
40
20
0
1990
1995
2000
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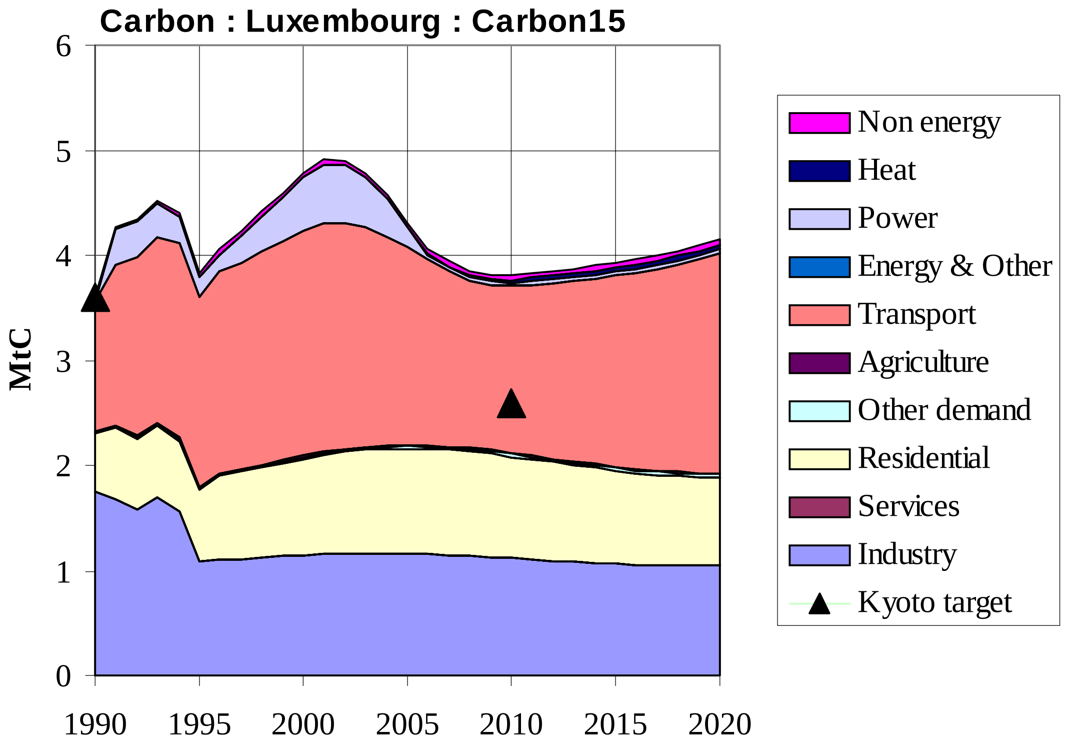
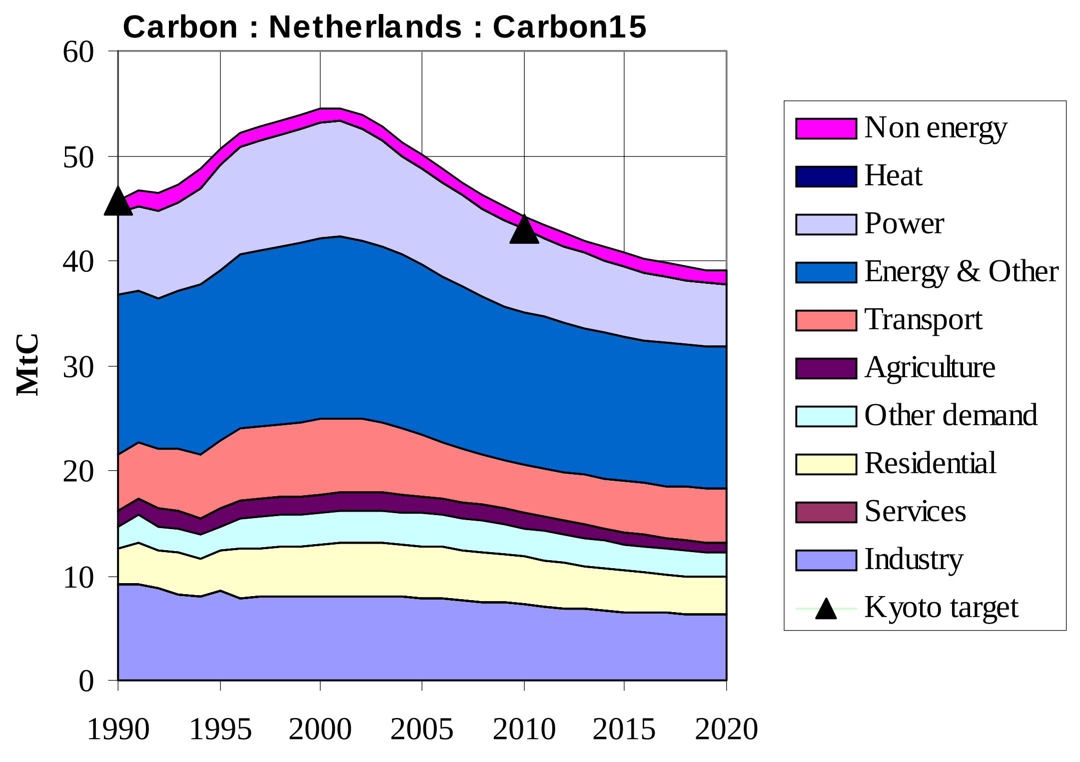
2010
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target


Carbon : Luxembourg : Carbon15
MtC
6
5
4
3
2
1
0
1990
1995
2000
2005
2010
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target


Carbon : Netherlands : Carbon15
MtC
60
50
40
30
20
10
0
1990
1995
2000
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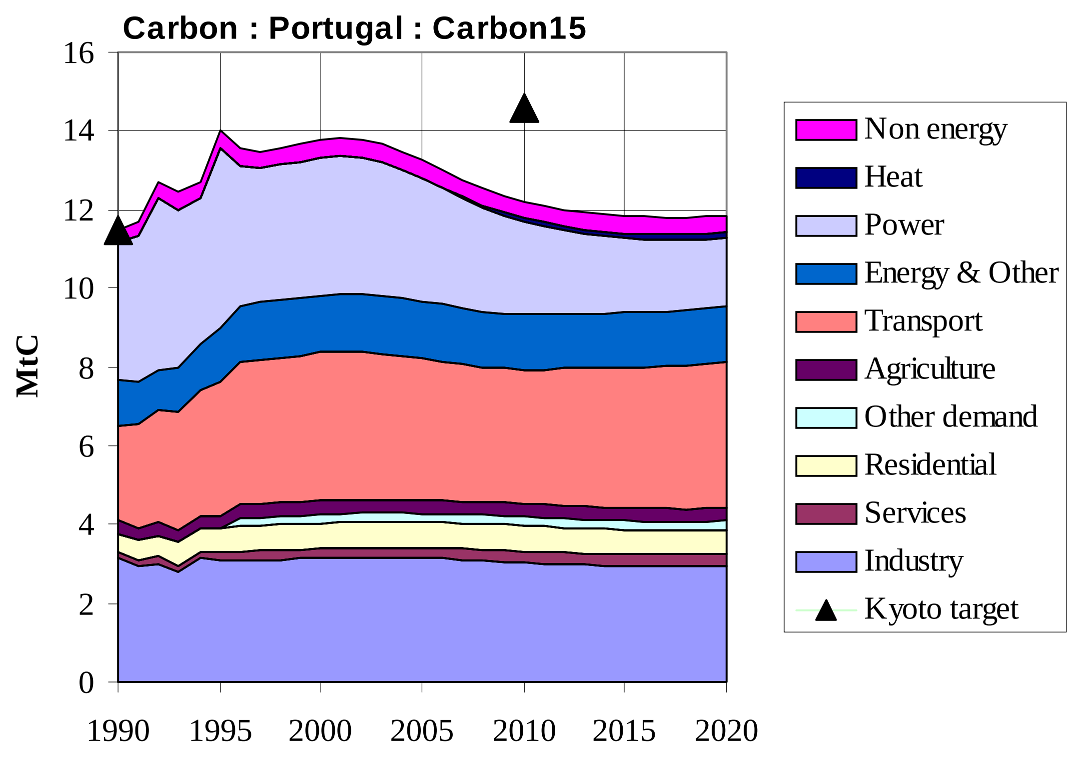
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target


Carbon : Portugal : Carbon15
MtC
16
14
12
10
8
6
4
2
0
1990
1995
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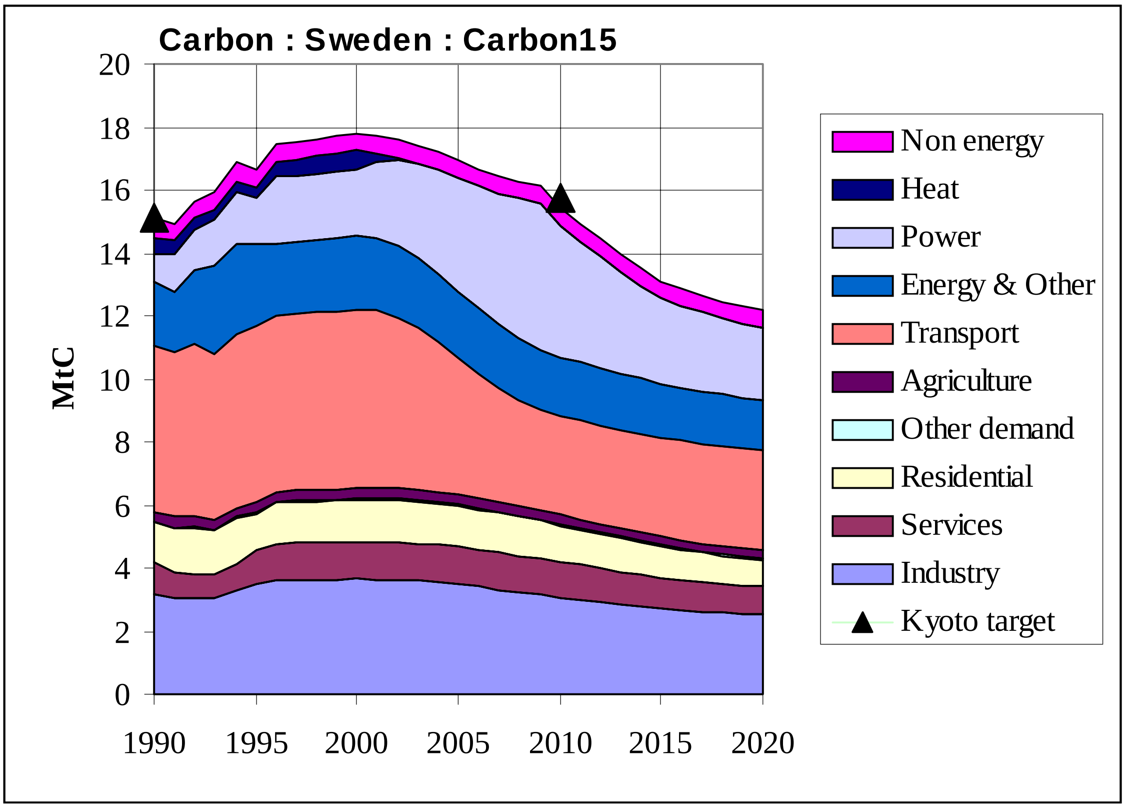
2015
2020
Non energy
Heat
Power
Energy & Other
Transport
Agriculture
Other demand
Residential
Services
Industry
Kyoto target

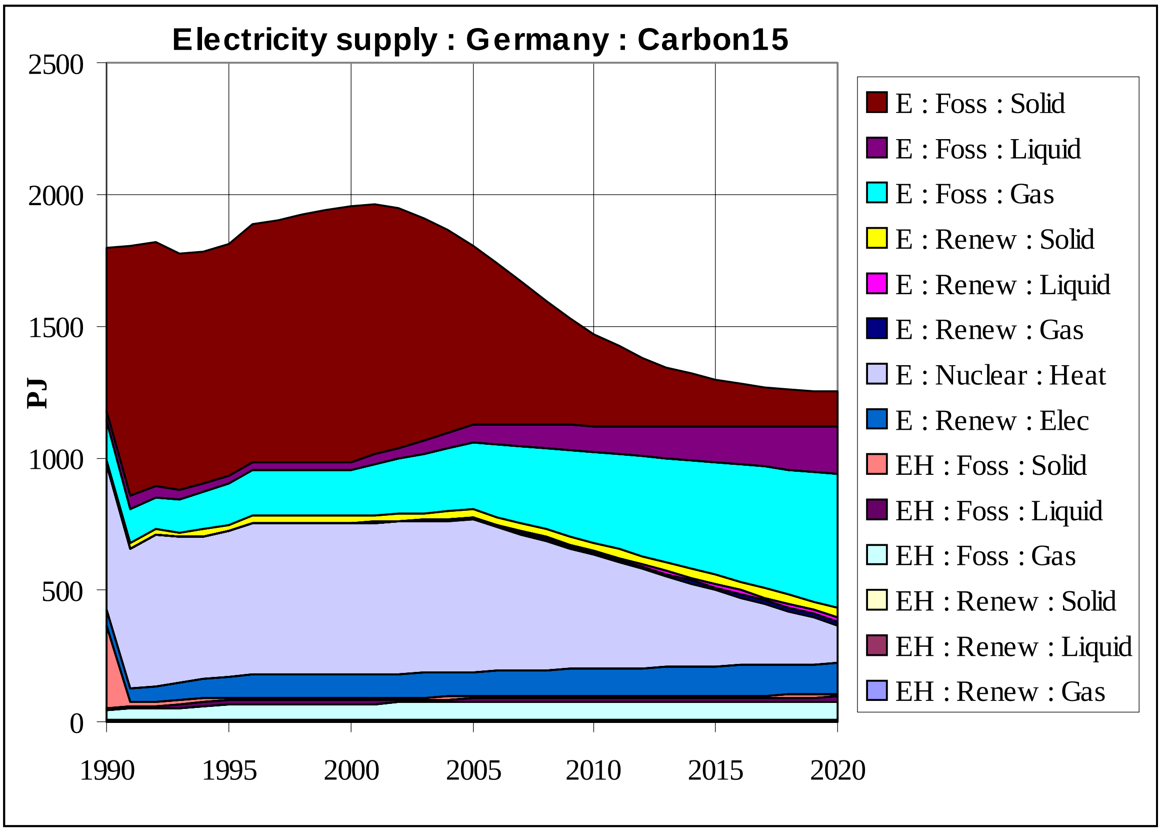


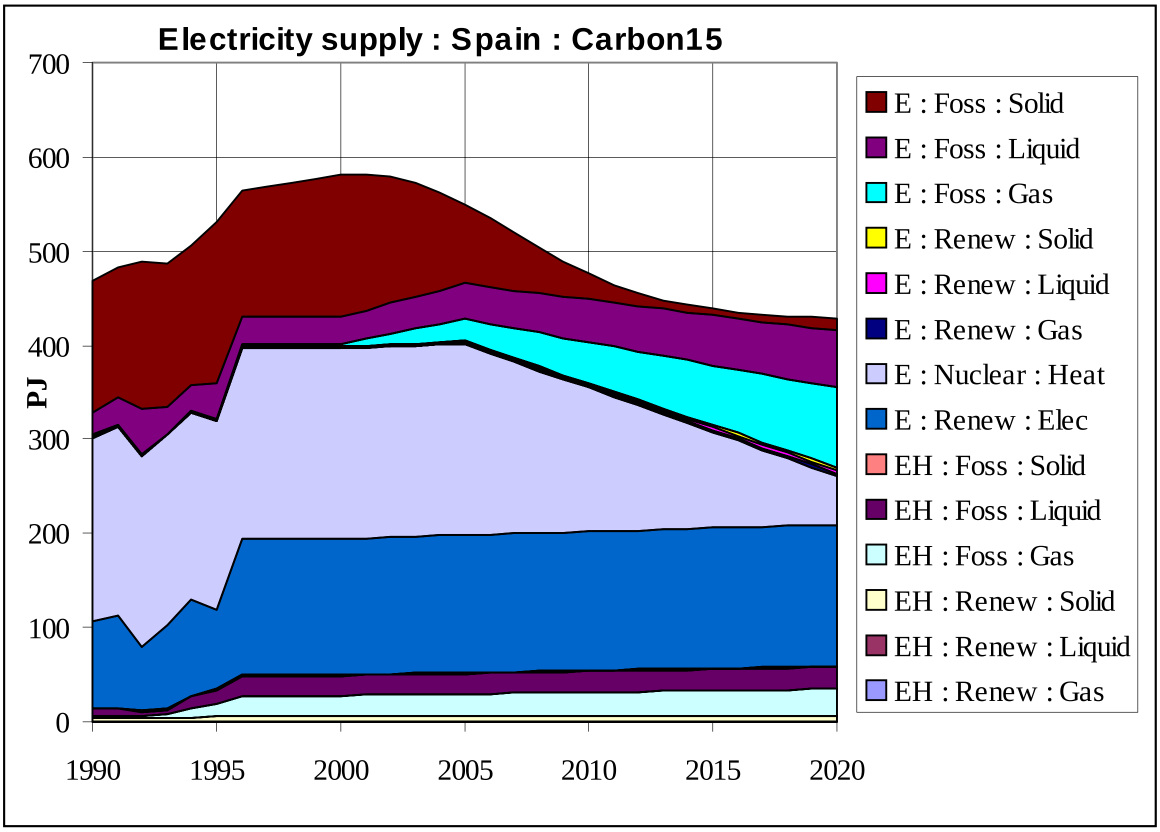
3.3 Electricity supply

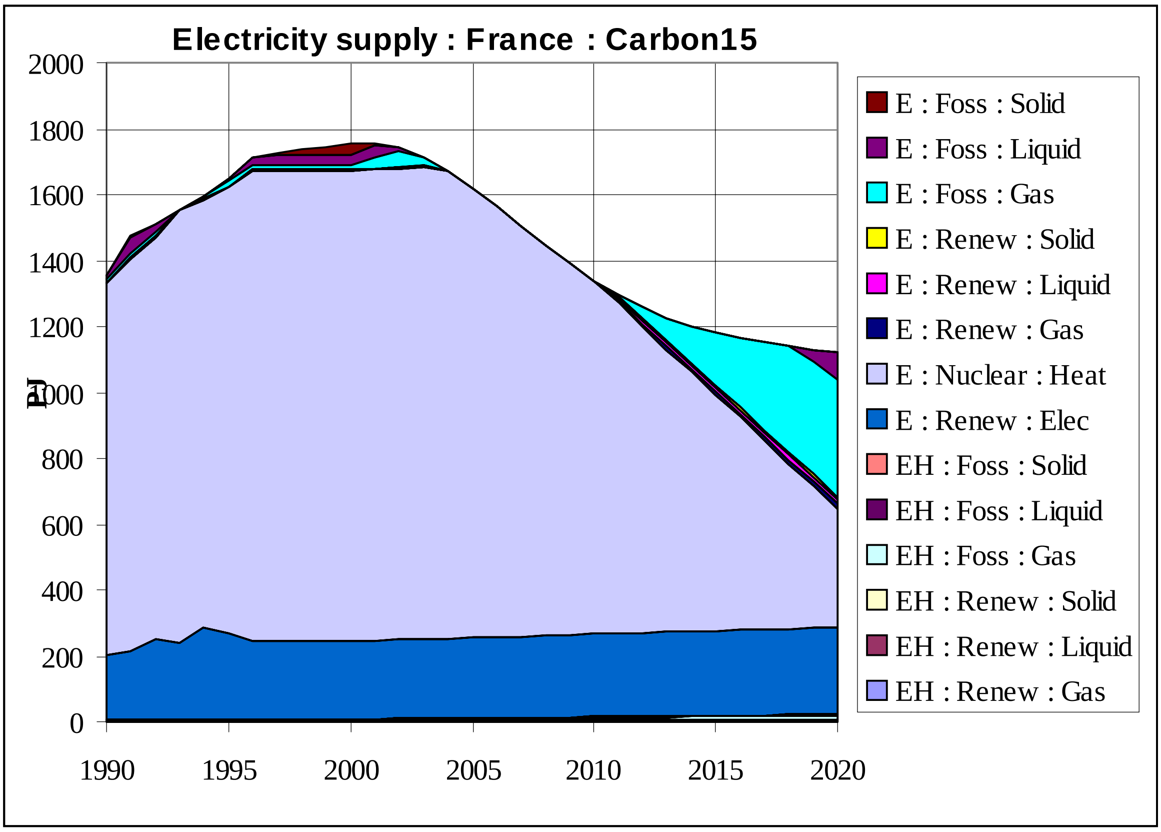
A key and complex sector is electricity supply. The following Figures show the mix of electricity supply in the Carbon15 scenario for the five countries emitting the most carbon dioxide. They illustrate:

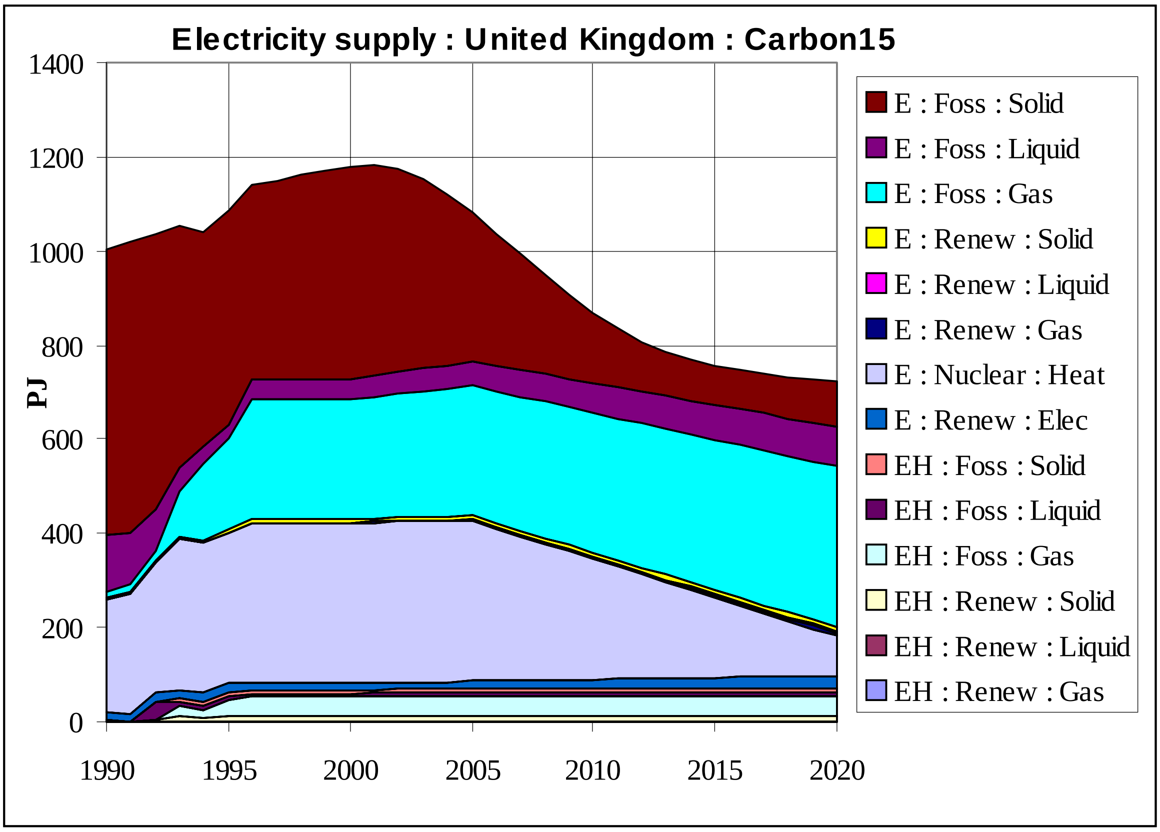
- The importance of demand management and fuel switching in reducing electricity consumption.
- The decrease in nuclear generation.
- The reduction in the use of coal as a generating fuel, and the maintenance or increase in renewables and gas.

In the Figure legend: E denotes plant producing only electricity; EH denotes plant producing electricity and heat – cogeneration or combined heat and power plant.


Electricity supply : Germany : Carbon15
2500
2000
1500
1000
500
0
PJ
1990
1995
2000
2005
2010
2015
2020
E : Foss : Solid
E : Foss : Liquid
E : Foss : Gas
E : Renew : Solid
E : Renew : Liquid
E : Renew : Gas
E : Nuclear : Heat
E : Renew : Elec
EH : Foss : Solid
EH : Foss : Liquid
EH : Foss : Gas
EH : Renew : Solid
EH : Renew : Liquid
EH : Renew : Gas


Electricity supply : Spain : Carbon15
700
600
500
400
300
200
100
0
PJ
1990
1995
2000
2005
2010
2015
2020
E : Foss : Solid
E : Foss : Liquid
E : Foss : Gas
E : Renew : Solid
E : Renew : Liquid
E : Renew : Gas
E : Nuclear : Heat
E : Renew : Elec
EH : Foss : Solid
EH : Foss : Liquid
EH : Foss : Gas
EH : Renew : Solid
EH : Renew : Liquid
EH : Renew : Gas


Electricity supply : France : Carbon15
PJ
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1990
1995
2000
2005
2010
2015
2020
E : Foss : Solid
E : Foss : Liquid
E : Foss : Gas
E : Renew : Solid
E : Renew : Liquid
E : Renew : Gas
E : Nuclear : Heat
E : Renew : Elec
EH : Foss : Solid
EH : Foss : Liquid
EH : Foss : Gas
EH : Renew : Solid
EH : Renew : Liquid
EH : Renew : Gas


Electricity supply : United Kingdom : Carbon15
PJ
1400
1200
1000
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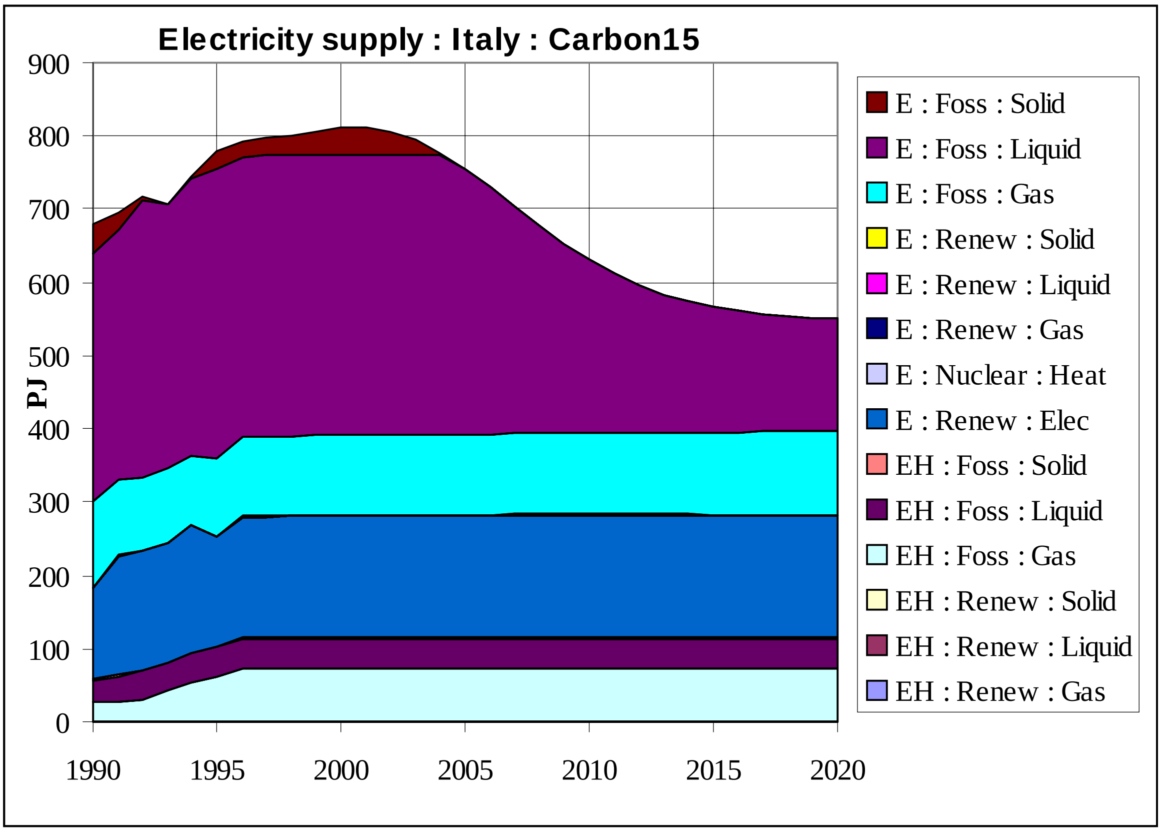
0
1990
1995
2000
2005
2010
2015
2020
E : Foss : Solid
E : Foss : Liquid
E : Foss : Gas
E : Renew : Solid
E : Renew : Liquid
E : Renew : Gas
E : Nuclear : Heat
E : Renew : Elec
EH : Foss : Solid
EH : Foss : Liquid
EH : Foss : Gas
EH : Renew : Solid
EH : Renew : Liquid
EH : Renew : Gas



4 DISCUSSION

4.1 Feasibility of scenarios

The feasibility of the scenarios may be assessed from a number of perspectives: technical, economic and behavioural.

Technical aspects. In most countries the measures are not implemented to the maximum and therefore, if the maxima are approximately correct, the scenarios are technically feasible from this perspective. The rate of introduction of the measures is to a degree not a technical issue, since extra expenditure can increase the rate of implementation over the ‘natural rate’. It has been observed that total EU gas consumption does not increase much beyond current levels and therefore the availability should not be problem in the shorter term.

Economic aspects. ***ScenaGen*** contains no information about costs. However the assumptions about demand management and efficiency are based on estimates which do at least assess the cost-effectiveness of these measures against supply. Since the quantities of energy supplied do not change as much as in scenarios with more energy demand, the low carbon scenarios should engender lower marginal and total fuel costs than high demand scenarios.

Behavioural issues. Key to the Carbon15 scenarios are assumed changes to the stocks of consumer technologies in terms of efficiency and fuels used. This implicitly assumes certain consumer behaviour in terms of technology and fuel choice. The means for inducing such changes, such as regulation or fiscal instruments, are not described.

Policy. Central to the Carbon15 scenarios is the assumption that measures are introduced in 2000. This would require substantial and rapid changes to the current policy stance in most, if not all EU countries. Currently most debate is about policies for meeting the Kyoto commitments.

4.2 Limitations of model

4.2.1 Energy demand

The demand for useful energy is the foundation of any energy scenario. The model changes the demand for useful energy according to functions based on per capita GDP and population. At present these functions do not account for factors such as:

- Decreasing household size. Some energy demands are more related to the number of households rather than population.

- Age structure and activity of population.

- The saturation of certain segments of demand due to factors such as full appliance ownership or the reaching of adequate indoor temperatures.

- Changes in expenditure pattern. The energy intensity of many goods and commodities purchased at the margin can decrease as wealth increases: once people have houses and cars, further marginal ‘optional’ expenditure may go into less carbon intensive goods and services such as electronic goods; alternatively it may go on carbon intensive goods or services such as luxury cars or long distance holidays. Such changes in final consumption also tend to be reflected in a restructuring of the economy such that an increasing proportion of value added is realised in the tertiary or services sector, and a decreasing proportion in primary and secondary industrial sectors. For many, but not all, goods and services produced by the sector the energy consumption per value added is less than in heavy industries.

- Demand management and efficiency potential. The estimates of the savings to be made through demand management and efficiency are based on specific and general studies. Some of these studies are quite old, and some countries are not covered.

These issues require further careful analysis. If the simple growth functions assumed in the model are used, energy demand increases inexorably in the long term after the potential technical savings are fully taken up. This can only be avoided by increasing the use of non carbon renewable and nuclear energy.

4.2.2 Other issues

Electricity generation. There are operational considerations which are not included in the simple electricity module of ***ScenaGen.***

Renewable energy. Surveys of the potential of the different renewable energies are required.

4.2.3 Data and consistency problems

A number of difficulties have been encountered with the IEA statistics. Perhaps most important of these are problems accounting for energy inputs and outputs to cogeneration.

4.3 Further development and applications of the ScenaGen model

The ***ScenaGen*** modelling system has been developed by SENCO for specific purposes. Like all models it has strengths and weaknesses.

Its principal strengths are:

- It can be used to rapidly identify the technical potential of different policy options.

- It can be used to generate scenarios for any country for which there are IEA data, which is all major countries of the world. Since the IEA data are published annually, the model always has a recent fuel use database to base projections on. There are a number of problems with the IEA energy database, but these are gradually being ironed out. Furthermore, the IEA collate a number of other statistical series which are useful inputs to the modelling process.

- The model can be used to rapidly explore the effects of different programmes in energy strategies for many countries in any geographical or political grouping. The profile of programmes, in terms of change in fuel use and the time and rates of change can be easily altered. The programmes can be applied in any combination and thus the effect of each can be isolated and analysed separately.

- The output of ***ScenaGen*** can be automatically converted into the files and formats required by IIASA's RAINS model.

Its principal weaknesses are:

- Its growth projections based on population and GDP use simple functions which do not include detailed market processes such as saturation.

- It does not calculate the costs and prices of energy or of the technologies incorporated in the programmes.

- It does not incorporate the responses of economic agents to costs and prices with elasticities.

- It does not include consideration of how technical changes to the energy system might be brought about by instruments such as taxation or regulation.

The further development of the model would therefore best be aimed at correcting these weaknesses depending on the required application. The most obvious next development would be to calculate the costs of the energy technologies and energy supplied. These costs could then be added to emission control costs calculated in the RAINS model, so as to arrive at the total cost of reaching a set of environmental objectives encompassing targets for greenhouse gases, acidification and ozone.

5 REFERENCE MATERIALS

Some reference materials are given below. Many of these were used in a previous similar study for the Stockholm Environment Institute in 1994. These include other energy strategies and scenarios; some country and sector specific references used, and a list of references. The scope of this study has been such that there has not been a comprehensive collation of more recent materials.

5.1 Other European energy strategies

5.1.1 IPSEP's "Energy Policy in the Greenhouse" project

Since 1987, IPSEP has carried out an on-going research activity under the working title "Energy Policy in the Greenhouse." So far, the project has occurred in two phases.

Phase I

> The first phase (1987-1989) focused on the science of the greenhouse issue, modeling of needed reductions in global greenhouse gas emissions to stabilize the

climate, issues of international equity and burden sharing; and reduction goals for fossil carbon emissions and other greenhouse gases that industrialized countries should adopt if climate stabilization is to be achieved in an equitable and risk-minimizing manner. The Climate Protection Commission of the German Parliament and several delegations to the UN- sponsored Intergovernmental Negotiating Committee (INC) have drawn from this work in preparing and evaluating proposals for international greenhouse gas reduction protocols. The report was distributed to all delegates of the 1991 Second World Climate Conference in Geneva.

Phase II

The second phase of the IPSEP project began in 1989 and has focused on economic and energy policy issues. This research is presented in ten scholarly reports comprising a total of 1500 pages, as well as a number of additional reports, summaries and articles. Recent topics of IPSEP's research include:

- Quantification of zero or negative net cost ("no regrets") emission limits and reduction objectives for cutting carbon emissions in Western Europe and other OECD countries;
- A comparative assessment of recent modeling analyses for the U.S., Western Europe, and other industrialized countries;
- Methodological critiques of top-down and bottom-up modeling studies on the economics of climate change mitigation;
- A review of important feedback effects of climate protection policies on fuel and technology prices, rates of technology innovation, energy supply security, and economic growth and international competitiveness.
- Comparisons of the economics and effectiveness of energy taxes, emission caps, other non-price policy instruments, and of combinations of these policy options;
- Economics and effectiveness of innovative market transformation programs for increasing energy efficiency;
- Impacts of utility deregulation on the cost of electricity services and on efforts to reduce carbon emissions;
- The roles of energy efficiency improvements, renewable energy sources, low-carbon fossil power generation, and cogeneration of heat and power in a least-cost strategy for averting climate change;
- Evaluation of nuclear growth and nuclear phase-out scenarios in terms of their impacts on electricity costs and power sector carbon emissions.

- An in-depth scenario-based case study of costs and policy requirements for cutting carbon emissions in Western Europe;

- State-of-the-art discussions of technology options and end-use data for the transportation, utility, building, and industrial sectors.

Key findings

The core findings of IPSEP's economic and energy policy research to date challenge the widely held notion that climate stabilization will unavoidably impose economic burdens on society and thus place narrow limits on achievable reductions. Among other things, the "Energy Policy in the Greenhouse" study finds that

- Over the next 30-50 years, industrialized countries could reduce their carbon emissions by more than 50 percent below current levels using mainly technologies that are already available.

- The critical technological resources for bringing about low emissions are investments in more efficient energy use. If these are emphasized, large reductions could be achieved in a timely and cost-efficient manner even as renewable energy sources are still undergoing commercial development and as problematic low-carbon resources such as nuclear power lose market share.

- Contrary to the assumption of macroeconomic models, a large pool of money- saving "no regrets" options currently exists. Major market and institutional barriers in the form of high transaction costs, asymmetric information, uncertainty, inefficient utility regulation, and lack of secondary markets prevent an effective competition between energy efficiency investments, cogeneration, renewables, and conventional energy supplies. Externalities and various subsidies further distort the economic playing field. As a result, a large pool of money-saving efficiency investments remains currently unrealized in the world's economies.

- As carbon constraints and other policies stimulate innovation, the pool of low- cost, low-carbon technology options will increase further. However, because of the large backlog of unrealized investments in already existing, presently cost-effective technology options, a policy of delayed action would result in lost opportunities and would be economically inefficient.

- The economic savings from implementing money-saving "no-regrets" options are potentially so large that they could more than offset the costs of market creation programs for renewable energy sources that are still somewhat more expensive than fossil-based energy. Potential savings from profitable energy efficiency investments are up to two orders of magnitude larger than the funding required to accelerate the development of low-cost renewable energy sources.

- A number of proven policies exist for mobilizing these "no regrets" resources in a cost-effective manner. However, strategies that mainly or exclusively rely on broad-brush energy taxes are not the most effective or cost-efficient ways of mobilizing money-saving efficiency investments. Narrow emphasis on cross- cutting taxes or emission rights trading schemes alone may cause unfavorable economic impacts.

- Favorable economic impacts could be realized in an integrated approach that strategically combines emission caps, energy taxes, tax shifts, and a range of market transformation policies. If these measures are emphasized, and if the revenues from new energy or carbon taxes are ear-marked, in part, to directly finance incentives for low-carbon investments, OECD countries could achieve substantial emission reductions at a zero net cost or at an economic profit.

- Rather than being undermined by accelerated fossil fuel use in developing nations ("leakage" effects), an aggressive carbon reduction strategy by the OECD countries can be expected to trigger a beneficial "spillage" effect: the faster diffusion of low-carbon and low-cost energy efficiency, cogeneration, and renewables options into the energy infrastructures of developing countries. This "spillage" effect would, on balance, result in significant capital savings and other economic benefits for developing countries. They could be enhanced by deliberate international technology transfer programs.

5.2 Energy scenarios for a changing Europe. Integration versus Fragmentation

Author(s):
Oostvoorn, F. van; Pellekaan, W.; Aaserud, M.; Brubakk, L.; Harmelen, T. van; Stoffer, A.

ECN report number:
ECN-C--95-075

Note:
This study is a result of cooperation between Statistics Norway in Oslo and ECN in Petten

Abstract:
At the moment the effects of a further integration in Western Europe on the economy and energy markets are far from clear. Obviously the degree of integration will influence the scope and effectiveness of national and European Union energy and environmental policy decisions, together with different prospects for economic growth and energy prices. In

order to analyze consequences of these different impacts two 'extremely' different scenarios have been developed, one representing ongoing integration in Western Europe (IS), and another describing fragmentation of Western Europe (FS). To analyze two different socio-economic scenarios an energy demand model for Western Europe (SEEM), has been developed to project primary energy demand per country in the Industry, Services, Households, and Transport sector. In order to cover almost all primary energy demand the electricity production sector was included in the model, too. Resulting long run (2020) primary energy demand for both base-scenarios differs substantially, and is much higher in an integrating Europe, due to higher economic growth and lower energy prices. The effect of energy tax harmonization is rather limited on a European level, but is significant for some countries and fuels. CO_2 emissions increase significantly in the base scenarios, and a CO_2 tax of $100 per ton carbon (about 10 $/barrel) results in a decrease of CO_2 emission of about 14% in 2020 relative to the reference scenario IS, which is by far too low to meet reduction targets, for example stabilization.

5.3 Sector and country references

The next two Tables gives some sector and country references.

Table 1 : General references

Sectors	**General references**
Domestic	(Herring, Evans; 1991)
Industry	(Langley; 1984)
Commercial	(Herring, Hardcastle, Phillipson; 1988)
Transport	(Martin, Shock; 1989)
General	(Fisher; 1990): (Grubb; 1990): (Schipper, Meyers, Howarth, Steiner; 1991)
Regions	
World	(IEA; 1992)
EC	(COHERENCE; 1991): (EC; 1991a,b): (JOULE; 1990): (Mickle C, Brown I; 1991)

Table 2 : Country references

Countries	**References**
Belgium	EC:
Denmark	EC:
Finland	(MTI; 1990)
France	EC:
Germany	EC:
Greece	EC:
Italy	EC:
Netherlands	EC:
Portugal	EC:
Spain	EC:
Sweden	(Boeryd; ??)
UK	EC: (Chandler; 1990): (Grubb; 1991): (Leach,Nowak; 1990)

5.4 REFERENCES

Boeryd A: Options for Constraining the Emissions of CO_2 in Sweden, Including the Role of Forestry Biomass: National Energy Administration, Stockholm, Sweden.

Chandler WU(ed): 1990: Carbon Emissions: Control Strategies: WWF/Conservation Foundation, Advanced International Studies Unit of the Battelle Memoria Institute, Pacific Northwest Laboratories, ISBN 0-942635-19-1.

COHERENCE: 1991: Synthesis Report, EC programme Cost-Effectiveness Analysis of CO_2 Reduction Options: JOULE Programme, Models for Energy and the Environment, COHERENCE for CEC-DGXII.

EC: 1991a: Country Reports, EC programme Cost-Effectiveness Analysis of CO_2 Reduction Options: JOULE Programme, Models for Energy and the Environment, European Commission.

EC: 1991b:Energy for a New Century: The European Perspective: Energy in Europe Special Issue July 1991, European Commission.

Fisher D (ed): 1990: Options for Reducing Greenhouse Gas Emissions: Stockholm Environment Institute, Stockholm Environment Institute, ISBN: 91-88116-18-2.

Grubb M: 1990: Energy Policies and the Greenhouse Effect: Volume 1: Policy Appraisal: Royal Institute of International Affairs, 10 St James' Sq, London SW1Y 4LE, Dartmouth, ISBN 1 85521 175 0.

Grubb M: 1991: Energy Policies and the Greenhouse Effect: Volume 2: Country Studies and Technical Options: Royal Institute of International Affairs, 10 St James' Sq, London SW1Y 4LE, Dartmouth, ISBN 1 85521 175 0.

Herring H, Evans R: 1991: Energy Use and Energy Efficiency in UK Domestic Sector up to the Year 2010: Energy Efficiency Series 11, Department of Energy, Energy Technology Support Unit, HMSO.

Herring H, Hardcastle R, Phillipson R: 1988: Energy Use and Energy Efficiency in UK Commercial Public Buildings up to the Year 2000: Energy Efficiency Series 6, Department of Energy, Energy Technology Support Unit, HMSO.

IEA: 1999: Country Energy Statistics: International Energy Agency, OECD, 2, rue Andre-Pascal, 75775 PARIS CEDEX 16, France. An electronic database of energy statistics for most countries.

IIASA, January 1999, Seventh Interim Report: Cost-effective Control of Acidification and Ground-level Ozone, International Institute for Applied Systems Analysis, A-2361 Laxenburg, Austria. E-Mail: info@iiasa.ac.at

JOULE: 1990: Energy and Environment: Methodology for the Assessment of Acid Air Pollution in Europe: General Directorate for Science, Research and Development, Commission of the European Communities.

Langley KF: 1984: Energy Use and Energy Efficiency in UK Manufacturing up to the Year 2000: Volume I; Executive Summary and Main Report: Energy Efficiency Series 3, Department of Energy, Energy Technology Support Unit, HMSO.

Langley KF: 1984: Energy Use and Energy Efficiency in UK Manufacturing up to the Year 2000: Volume 2; Sector Reports containing the detailed analyses of the industries, their Energy Use and Potential Energy Savings: Energy Efficiency Series 3, Department of Energy, Energy Technology Support Unit, HMSO.

March Consulting Group: 1990: Energy Efficiency in Domestic Electric Appliances: Energy Efficiency Series 13, Department of Energy, ISBN 0-11-413424-3.

Martin DJ, Shock RAW: 1989: Energy Use and Energy Efficiency in UK Transport up to the Year 2010: Energy Efficiency Series 11, Department of Energy, ISBN 0 11 412956 8.

Mickle C, Brown I: 1991: A Study of EC Policy Options Aimed at Reducing Carbon Dioxide Emissions in the Electricity Production Sector: Association for the Conservation of Energy, 9 Sherlock Mews, London, W1M 3RH, UK.

Ministry of Trade and Industry, Energy Department: 1990: Finnish Energy Economy up to 2025 - some development paths: Ministry of Trade and Industry, Energy Department.

Schipper L, Meyers S, Howarth RB, Steiner R: 1991: DRAFT Energy Efficiency and Human Activity: Past Trends, Future Prospects: International Energy Studies Group, Energy Analysis Program, Applied Science Division, Lawrence Berkeley Laboratory, University of California, for Stockholm Environment Institute, Berkeley, CA 94720, USA.