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Labelling and other measures for heating systems in dwellings

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- Innovation Energie Developpement, Paris, France
- Irish Energy Centre, Dublin, Ireland
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APPENDICES 1 to 8 (separately bound) provide more detailed information.

1. Overview

1.1. Aims

This project, funded under SAVE II, aims to substantially improve knowledge and understanding of the stock of heating systems in EU member states, their energy-critical components (mainly boilers), and the markets for these.

The information is then used to explore the scope for developing labels and other activities, so as to promote more efficient domestic heating systems in the EU.

1.2. EU-15 energy consumption of heating systems

The following estimates of energy consumption for heating systems in dwellings, includes both individual dwellings, and groups of dwellings (district or community heating).

Eurostat 'Energy Consumption in Households, 1995' (table 2.7.4) gives a space heating total of 6033 PJ (1676 TWh), but there is no data for Italy. Adding a 1998 value for Italy (provided by our Italian partner) gives an estimated:

- **EU15 space heating total, of 6760 PJ (1880 TWh).**

This project focuses on heating systems that use boilers for heat generation. An approximate energy consumption estimate can be made from analysis of Eurostat, table 2.2.1, indicating that 66% of dwellings have central heating (excluding electric heating). Central heating energy consumption per household is generally greater than for non-central heating, *so this method is an underestimate*, but gives:

- **EU15 central heating (excluding electric) total, of 4470 PJ (1240 TWh).**

In addition, the heat generator for many central heating systems provides hot water as well as space heating. Improvements to these heat generators will reduce the energy consumption for hot water, as well as for space heating. Analysis of Eurostat tables 2.2.1 & 2.3.1 (excluding electricity) indicates that an average of about 67% of dwellings with central heating, have their water heating connected to the central heating. Energy consumption for water heating is about 1/4 of that for space heating in existing dwellings. This leads to an estimate (*again an underestimate*) of:

- **EU15 hot water energy where connected to central heating 753 PJ (209 TWh)**

The above estimates do not include electricity used by central heating systems (discussed in this report in 'Electrical consumption of gas and oil fired central heating'). Estimates of pumps, fans, and other associated electrical equipment gives:

- **EU15 electricity use associated with central heating of 148 PJ (41 TWh).**

It should be recognised that the carbon emissions per PJ delivered energy can be about 2 or 3 times greater for electricity than for oil or gas. This depends of course on the electricity generation; for example, for nuclear and hydro, carbon emissions can be considered minimal, whereas for coal-fired generation the factor can be as high as 5 or 6.

1.3. Definitions

It is apparent that a number of commonly used names for heating systems have different meanings in member states. In this project, it was agreed that the use of the following names would improve understanding.

- District heating - a heating system using distributed hot water, for dwellings in an area or district
- Block heating - a heating system using distributed hot water, for a block of dwellings, or a number of blocks situated close together
- Dwelling heating - a heating system using distributed hot water, for an individual dwelling
- Room heating - heating using individual room heaters

It should also be noted that energy consumption, and hence boiler efficiencies, are based on the 'net calorific value' or 'lower heating value' of fuels, in most European work. In the UK the 'gross calorific value' or 'higher heating value' is used.

The maximum possible gross (hhv) efficiency is 100%, whereas net (lhv) efficiency values can be greater than 100%. Conversion from net to gross efficiency is achieved by multiplying by 0.901 for gas, and 0.937 for oil.

2. Characterisation of heating systems and their markets

(See Appendix 1 for a full description of this task, undertaken by EnergiE sas, Italy).

2.1. Introduction

The data focuses on the nine EU countries Denmark, Finland, France, Germany, Ireland, Italy, Netherlands, Sweden, and the UK. They are represented by, or have close links with, the partners for this project.

All partner data was checked where possible with other sources, and for consistency with other partner data. However, although all data sources can be considered as reputable, discrepancies between data sets were often present, and sometimes these were significant. Therefore, though a coherent qualitative picture has been developed, care should be taken regarding the accuracy of any single figure.

2.2. Energy Consumption

The nine partner countries account for nearly 90% of the space heating energy consumption in all fifteen EU countries. Total energy use for space heating in the nine countries under study is in the region of 1.5 to 1.7 PWh/year (considering the five year period 1995-2000). Germany accounts for 30% of the nine country total, France 22% and the UK 16%. Energy consumption for space heating accounts for close to 70% of total household energy consumption in most of these countries. (Moreover, water heating from central or other heating systems is additional to this).

Indications are that growth in energy consumption for space heating is limited, if not contained. Though household numbers, heating system penetration rates and household wealth (the main structural drivers) have continued to increase over thirty years, this has been offset by technical improvements; particularly household insulation levels and the introduction of improved boiler technologies (e.g. condensing boilers).

Over the 20 year period 1975 to 1995, total space heating energy consumption was reduced by 25% in Denmark, 11% in Sweden, and remained approximately constant in the Netherlands. A 17% increase was registered in Germany, however, this may be due to different accounting practices before and after unification.

However, despite the trend in containing energy consumption, a potential for notable reductions in energy consumption is also reported. For example in Denmark the DEA. estimates that adequate insulation could reduce present heat demand per square meter by up to 40% (this is in spite of the country having the lowest unit energy consumption).

2.3. Normalisation by Floor Area and Degree Days

The trend of containing total space heating energy consumption, and the increase in total household floor area, has resulted in a decrease of the energy consumption per unit floor area (kWh/m^2) by some 30 to 40% in partner countries over the twenty year period 1975 – 1995.

Average consumption per unit floor area and degree day[1], for the nine countries under study is 0.056 kWh/m^2/degree day. However, there is a variation between countries, with Germany and Ireland (0.07 kWh/m^2/degree day) using 84% more energy per m^2/degree day than Sweden (0.038 kWh/m^2/degree day). Denmark and Finland have comparable consumption figures (within 20%) of Sweden.

2.4. Heating systems

Across the different countries, 85% of homes use dwelling, block or district central heating systems. Here 'central' includes electrical heating emitters, installed in the majority of rooms in the home, which may or may not be centrally controlled. The definition is ambiguous and elsewhere such systems maybe identified as room heaters.

The severity and length of the winter is an important factor determining the level of investment in space heating systems that households are willing to undertake. Penetration of central heating systems is greatest in Sweden (100% of households) with a long and cold winter, and lowest in Italy (70%) where the southern and coastal regions enjoy a mild Mediterranean climate (though central and northern regions too have severe, if not long winters). The use of room heaters as the main means of providing space heating is still important in Ireland (25%), France, Italy and Germany (18%). Italy is unique in the countries studied, in that 11% of households have no form of space heating.

Penetration rates of central heating systems have increased substantially since 1970, growing from roughly 30% to over 80% in the UK, and with similar increases in Germany, Italy and France. Rates of penetration increase are now slowing down, which also may be another factor helping to stabilise energy consumption.

Dwelling central heating systems are important in all countries, principally in the UK (87% of households), Netherlands (76%), and Ireland (73%). The relative importance of block systems has decreased in Italy over the last 30 years, from 31% of households in 1970 to 24% in 1998. Block systems are also important in France (15% of households) and Germany, though no precise figures are available. With standard heat generator technologies , the larger multi-dwelling block systems (> 35 kW) are generally more efficient than smaller single dwelling systems (20-30 kW). However, with the introduction of new modulating burner heat generators, the relatively higher efficiency of larger block systems is not so pronounced.

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[1] 'Degree days' is the time and extent (in degrees) that the external temperature is below a certain value, and thus can be related to the heat requirement of dwellings over a given period of time. It is used here to normalise, i.e. to remove the effect of differences in climate.

2.5. Energy sources

Together gas, oil and electricity are the energy sources for well over 90% of dwelling and block systems, for example,

- gas in the Netherlands (84% of households), the UK (71%), Italy (48%), Germany (37%), and France (30%)
- oil in Denmark (23%) ,and Ireland (28%).
- electricity in Finland (21%), and Sweden (19%).

Wood, a renewable energy source, is a significant fuel in Finland and Sweden (some sources indicate about 10% of households), also France and Austria. Bio-diesel is finding a market in Italy, though its use is still only marginal.

Over the last thirty years there has been a significant shift from fuel oil and coal to natural gas. In Italy the share of gas in households with heating systems rose from 10% in 1970, to 66% in 1998. In Denmark, the share of gas was nil at the beginning of the 1980's and rose to 18% by 1997, and in the UK natural gas rose from 33% of the total of centrally heated dwellings in 1970 to over 76% in 1996.

The growth in the use of gas has reflected the progressive extension of the gas network in partner countries over the same 30 year period. The gas network now extends to 99% of homes in the Netherlands, 93% of households in Germany, 87% of households in Italy, 82% of households in the UK, and 72% of households in France. In Germany , France and Italy a notable portion of households reached by the network still do not use gas as the space heating fuel source.

In Sweden the gas network reaches just 0.5 % of households, and expansion is currently being investigated. In Sweden the share of electricity increased substantially from 1970 to 1990. Electricity is now the most common form of space heating in detached houses.

The proportion of homes using electricity is increasing in Finland, and reached 24.7% in 1997. Generally the choice of electricity over other fuel sources is often justified in terms of its relatively low initial investment costs. More stringent installation and maintenance standards for gas and oil systems can also present a barrier to the uptake of these fuels.

2.6. Heat generator and efficiency

Across the different countries, average nominal power efficiency of installed oil and gas heat generators can be estimated at 87%, (with respect to lower heating value of the fuel). However cyclic switching of generators during the heating season and associated standby losses leads to reductions of about 15% of the nominal efficiency rating. Consequently the seasonal efficiencies of the stock of installed gas heat generators (dwelling and block) is estimated to be about 72%, and for oil heat generators 71%. (See section on seasonal efficiencies for further information).

Improvements to gas and oil heat generator technology over the last 30 years have led to improvements in nominal efficiency of new equipment in the region of 20-25%. New high efficient gas generators offer nominal efficiencies of 91% and condensing boilers of up to 108% which probably represents the ultimate limit for combustion heating technologies. The seasonal efficiency of new gas condensing boilers (which use modulating burners), can be in the region 104-107%, though in traditional radiator configurations seasonal efficiencies of 98% might be more typical.

The Netherlands represents the largest market for condensing boilers; 36% of installed gas systems and 60% of the heat generator market. In the Netherlands, condensing boilers were first introduced in the 1970s. At first they were not popular because they were difficult to control. However subsidy programmes throughout the 80's and 90's, and training for installers improved the situation.

Outside the Netherlands, the penetration of condensing boilers is negligible, from 1 to 2% of households in partner countries. The market is expected to show a slight increase in the short term, to 15% of heat generator sales in Italy (by 2005) and 50% in Germany (2000).

2.7. Heat pumps

Performance coefficients of electric compression heat pumps vary from 2.5 to 5 (efficiencies of 250 to 500% with respect to delivered energy). Though a mature technology, their diffusion is probably greatest in Germany, but even here it does not extend beyond 1%.

Air sourced heat pumps are the most common. Ground water and ground pumps, though more efficient, are more expensive and can present difficulties in siting. Though air to air pumps might offer an efficient means of heating in mild climates where winter temperatures are generally above 5°C (COP 2.5 – 3), efficiency gains in heating (compared to alternative combustion technologies) may readily be lost if air to air reversible heat pumps units are used to provide space cooling in summer.

2.8. District Heating

District heating central heating is used by 55% of households in Denmark, 48% in Finland and 41% in Sweden. Of this, respectively 70, 80 and 30% of distributed heat is generated within CHP systems. The high proportion of homes connected in northern countries might be explained by the fact that high investment costs are better justified in colder climates with much higher annual operating hours than in warmer climates.

In the Netherlands, 90% and Italy, 75% of distributed heat is generated within CHP plants, though networks in these countries reach respectively only 3% and 1% of households. The average efficiency of CHP plants in Europe in 1994 was 76%.

2.9. Heat generator sales

Gas heat generators are on average 3 to 9 years younger than oil heat generators, reflecting the general shift from oil to gas over the last thirty years. The average age of gas generators varies from 10 to 14 years, compared to oil 13 to 23 years. The average age of oil systems in Denmark is 21 years and in Sweden 23 years. In particular in Denmark 60% of oil generators are more than 20 years old and 30% more than 30 years old. In Sweden nearly 50% of oil generators are more than 30 years old.

Annual sales of heat generators for heating systems are in the region of 3-7% of total household numbers. Thus considering the 120 million households in the nine partner countries, annual sales are in the region of 3.6 to 7.2 million units a year.

2.10. Heat emitters

Hydronic (water) high temperature (e.g. 60/80°C) "radiator" systems prevail. Marketing of low temperature (30 to 40°C) floor heating and radiant panels, first introduced the 1950's (though then at higher temperatures) is increasing, though the actual number of installations is limited (estimate < 5%).

Electric central heating systems employ principally convective heaters. Storage heaters are predominant in the UK and Germany, and are also significant in France. In Sweden a third of electric systems are hydronic, that is they use water to distribute the heat from the central electric heat generator.

2.11. Heating system controls

Most heating systems employ at least an indoor thermostat; in the Netherlands 95% of households and in the UK, 73%. The use of outdoor thermostats is significant in countries with a significant presence of block systems; this avoids the need to identify a single indoor space which is representative of all the households serviced in the block. In Germany 30 to 40%, and in Italy 20 to 30% of households use outdoor thermostats. To achieve uniform temperatures across all spaces requires precise calibration, and assumes that heat emitters are sized correctly. Due to the inertia of the building and heating system there can be wide fluctuations in indoor temperature.

At least half of thermostats are integrated into programmable units, allowing daily and weekly variation in temperature set points. Their diffusion is greatest in Germany, 90% of households (all heating systems), Italy 70% of households (all heating systems), and roughly half of heating systems in France and the Netherlands.

The use of thermostatic valves , allowing individual room temperature control, is significant in Germany, 90% of households, the UK, 37% of households, in France 25% of households, and the Netherlands (all new housing in the last 15 to 20 years). The penetration is less in the Italy (estimate < 10% of households).

3. Standards governing design and installation of heating systems

(See Appendix 2 for a full description of this task, undertaken by IED, France)

3.1. Introduction

This review of standards describes partner countries' national standards for improving energy efficiency governing design, installation & maintenance of heating systems in dwellings. This description distinguishes between existing and new buildings.

3.2. Existing buildings - design, installation and maintenance procedures

Design and installation procedures are required In Italy and Germany.

Germany - Qualified companies are normally involved in replacement heating systems. As a result, low-temperature or condensing boilers are usually installed. If a standard boiler is installed, a calculation of the building energy requirement is obligatory. Depending on building type, a signed certificate of compliance is obligatory. The regulations are enforced by 'chimney sweeps'.

Italy - A Presidential Decree requires that any significant restructuring of buildings must include aiming to reduce energy consumption. A technical report confirming compliance must be submitted, and sizing of heat generators must follow the procedure set down by presidential decree.

Maintenance procedures required in EU countries depend, in general, on the size of the boiler. Where the checks described below fail requirements, they must be corrected.

Germany - Regulations require regular testing of the efficiency of heating systems with domestic boilers. Heating systems bigger than 50kW have to be serviced twice a year, by qualified personnel, including a check of the combustion efficiency.

France - For energy installations greater or equal to 1 MW, a Decree requires that a periodic check must be effective for 3 years. In addition, the correct functioning of control systems, distribution systems, and combustion of the boilers, must be verified.

Italy - A Presidential Decree requires, for heat generators under 35kW, cleaning and a generic check of the generator. For heat generators over 35 kW, cleaning, checking of thermostatic control, combustion efficiency, and regulation of the burners, once a year if under 350 kW, twice a year if over 350 kW. In addition, Local Authorities must check all heat generators over 350 kW at least every two years, check all heat generators over 35 kW where self-certification has not been received, and make a random check of 5% of all heat generators. These checks include an efficiency check.

Netherlands - Regulations require, for boilers over 130kW, inspection and service every year. For boilers under 130 kW, guidelines encourage yearly maintenance, which if neglected can negate the manufacturers product liability. The servicing includes checking combustion products.

3.3. Existing buildings - qualification of installers and maintenance staff

Netherlands - Boiler replacements are mainly done by small companies. Business licensing requires business, and technical qualifications. Several certificates qualify (Intermediate Technical School, Technical College, and others), as well as several separate vocational training courses. Most installers have general knowledge about the efficiency classes of boilers, and experience of installing and servicing condensing boilers, which have been on the Dutch market since 1980. Installers can establish special interest groups; for example a Solar Energy group has been established at the request of the installers. However, there is no training or procedure for evaluating the energy-efficiency of the overall heating system in the residential sector. Only when heating systems do not function adequately and consumers complain, is the overall heating system re-evaluated and modified.

Italy - Installations of new systems, and significant restructuring (this excludes only a boiler replacement) must be carried out by installation companies registered in the craftsmen's guild. This requires at least one member of the company staff to have a specified academic qualification and/or a specified number of years experience (depending on the level of the academic qualification).

Germany - Installers must have a minimum qualification within the German system of craftsmanship, which is divided into specific fields. This requires a specified academic qualification and/or a specified number of years experience (depending on the level of the academic qualification). Installations must be done by a qualified company (Meisterbetrieb) who must have at least one leading master (Meister) qualified in this field. DIY work is legal, but must certified by a qualified company.

As regards servicing, in all nine partner countries, people who work on gas fired equipment must be suitably trained and have a certificate in gas servicing. Generally there is no similar restriction on people maintaining oil or solid-fuel fired boilers.

3.4. Existing buildings - heating system components

With regard to energy efficiency, the boiler is generally the only component of heating systems which is regulated, as required by the EU Directive 92/42/EEC. In general, in existing buildings, the complete heating system does not have to comply with regulations. However, in some countries such as Italy and the UK, compliance with new building regulations is required when there is significant restructuring of the building. Only in Germany is there an efficiency standard applied to circulation pumps of warm-water heating systems and sanitary hot water. In all other European countries, there are no minimum standards and/or measures for retrofitting old systems.

Germany - Energy saving laws require that installed boilers are, with a few exceptions, low-temperature or condensing boilers. Warm water circulation pumps must have a timer so that it can be turned off overnight (but may not always be used). Heating systems controls for pumps and fans are required. However improvements to the regulations would be needed to ensure pumps and fans are turned off in all cases when there is no demand for heat. Pumps for heating systems over 50 kW must be sized correctly.

France - For boilers between 400 kW and50 MW, a 1998 Decree specifies minimal energy efficiency and equipment.

3.5. New buildings

All EU countries have regulations relating to thermal insulation, which are applied to new buildings, or extensions to existing buildings. (See Appendix 2 for a detailed summary). In general, regulations are applied to the complete heating system (that is, the boiler, control system, ducts & pipes, heat emitters). and they also define the design and installation procedure. But the regulations do not relate to maintenance procedures.

The legislation for minimum boiler efficiency is the EC Directive 92/42/EEC, although some countries have set a higher minimum efficiency.

3.6. European regulations and standards

GENERAL REGULATIONS

Directive 89/106/EEC, concerning energy efficiency and thermal insulation, requires that the building and its installation (heating, air conditioning and ventilation) must be designed so that the energy consumption is moderate, considering the climatic local conditions, without prejudice to the occupants comfort.

Directive 90/396/EEC, concerns energy efficiency relating to appliances which burn gaseous fuels.

BOILERS

Directive 92/42/EEC of 21 May 1992 specifies the efficiency requirements for new hot-water boilers fired with liquid or gaseous fuels, with a rated output of no less than 4kW and no more than 400kW. Boilers must comply with minimum efficiency requirements, specified according to boiler type, power, and fuel, and which are established from efficiency tests undertaken (a) at rated output and (b) at part load (30% of full load). The efficiency requirements are set out in the Article 5 of the Directive.

4. Technical improvements and technological change

(See Appendix 3 for a full description of this task, undertaken by VHK, Netherlands)

4.1. Objective

The objective of this task is to analyse the scope for technical improvements regarding the energy efficiency of heating systems commonly used in the EU. This overview should lay down a basis for ranking of heating systems, possibly for labelling purposes.

Energy efficiency of heating systems can be defined as the amount of energy needed in order to fulfil a certain unit of performance. The difficulty lies in establishing a simple but versatile unit of performance. This is because performance is determined not only by the type of heating system, but also by the level of comfort desired by the user (which is influenced by the type of heating system in conjunction with the thermal properties of the dwelling). Therefore this task starts off by establishing a common ground for comparing the performance of heating systems which includes some notion of the comfort level of the heating system. This approach does not necessarily represent the views of the EU Commission but stands wholly for the views of the authors.

4.2. Proposed approach

Part of the proposed method is based upon the nominal efficiency of heating systems (that which can be measured on a test rig, independent of user preferences). The bulk of the task describes this efficiency of heating systems, and ways to improve upon them. Given the immense variety in heating systems (ranging from simple open fireplaces to advanced central heating systems) it proved necessary to split up these systems into: those using indirect energy sources (such as electricity, heat), dwelling based heating systems (with a further split up into components) and room based heating systems. The following observations were made:

1) Indirect energy sources (such as electricity, district heating and co-generation) must show high efficiencies, for both electricity and heat production, in order to outperform separate generation (above 40% for both).

2) Dwelling based heating systems are split up into components: boiler, distribution & emitters, control system and auxiliary energy use.

- For boilers obvious improvements are the introduction of condensing boilers and increased use of renewable energy (e.g. heat pumps). Aside from that, more room for improvement is shown in the area of reducing dynamic losses (“start-stop losses”).

-Energy efficiency of distribution and emitters can be improved by carefully balancing the flow through the individual emitters and by applying low temperature heating (floor and wall heating).

- Control of boiler water temperature is made more efficient by using modulating burners and weather dependent control. Control of room temperature can be improved by making use of automatic room thermostats or thermostatic valves.

- Auxiliary electric energy use can be reduced significantly through use of energy efficient circulation pumps and fans (See separate section that deals this issue in more detail).

3) Room based heating systems are a very diverse group of heating appliances ranging from simple open fireplaces and local gas heaters to sophisticated electric heaters. However the room for improvement of these appliances appears to be limited.

The study concludes with a draft of a possible method for ranking of heating systems, taking both (nominal) energy efficiency and comfort levels into account. It also gives an overview of technical design options that might improve on energy efficiency of heating systems is provided.

The Annexes provide more detailed technical information on heating systems.

5. Heating system stock model

(See Appendix 4 for a full description of this task, undertaken by VHK, Netherlands)

5.1. Time-series space heating energy demand EU 1960-2020

This task entails the construction of a stock model for EU residential heating systems, taking into account the parameters listed in the task 'Technical improvements and technological change':

- nominal heat load of the dwelling (ventilation and transmission losses of the building shell at a fixed indoor temperature)
- overall demand factor (factor taking into account that –also depending on the type of heating system—such an indoor temperature will not be reached in all rooms at all times)
- heat generator efficiency
- efficiency of emitters and CH circuit
- efficiency of the temperature control and
- efficiency of the power generation for electric heating

Due to lack of data, a dynamic and complete stock model per EU member state could not be built at this stage. However, we were able to construct

- a first time series for the EU as a whole
- a simple method for estimating the seasonal efficiency of boiler systems in each of the 15 EU countries on a comparable basis (needs further refinement)
- a detailed linear stock model for the heat generators (local heaters, CH boilers, district heating, etc.).

These may serve as input to a scenario analysis.

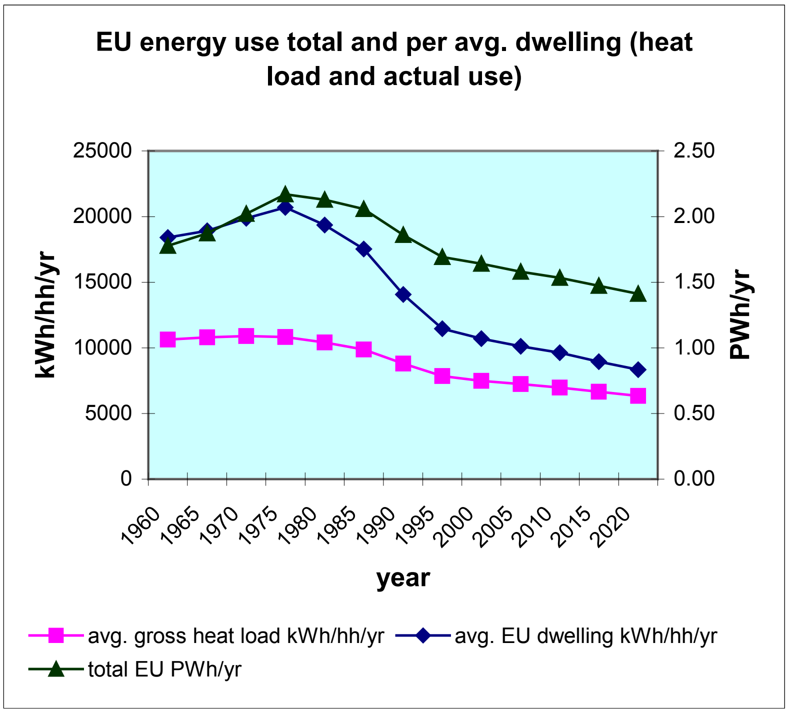
The table below gives the energy balance for the space heating of an average EU household in 1995 and 2005, two reference years that are used throughout this report.

	1995		2005		saving 1995-2005 (BaU)	
	kWh		kWh		kWh	%
nominal heat load building *(transmission and ventilation losses at 18 °C indoor temperature, 100% heating system efficiency and ODF 100%)*	**7857**		**7250**		**607**	*7,7%*
overall demand factor ODF *(takes into account that indoor temperature will be lower than 18 °C in some rooms and at certain times)* ***78%/82%***	**-1728**		**-1305**		**-423**	*-24,5%*
Subtotal Net Heat Load		***6129***		**5945**	**184**	*3,0%*
heat generator losses (eff. 79%/83%)	**1967**		**1445**		**522**	*26,6%*
emitter & circuit inefficiencies (eff. 95%/96%)	**468**		**340**		**128**	*27,4%*
control inefficiency (eff. 80%/82%)	**1874**		**1530**		**344**	*18,3%*
Subtotal direct heating system losses		**4309**		**3315**	**994**	*23,1%*
Subtotal indirect losses (power generation electric heating only)		**1031**		**850**	**181**	*17,6%*
Subtotal direct and indirect heating system losses		***5340***		***4165***	**1175**	*22,0%*
Total annual energy consumption/household		**11469**		**10110**	**1359**	*11,9%*

The table shows that over the 1995-2005 period an energy saving of almost 12% is reached in a Business-As-Usual (BAU) scenario. Over the same period the number of households will grow by some 6% (from 146 to 155 million), so the net saving on residential space heating will be around 6% or rather 0.6% per year.

The table and graph below give the complete 1960-2020 time series. Please note that over the Kyoto reference period the total EU energy consumption for residential space heating is projected to drop from 1.86 PWh/yr to 1.53 PWh/yr (17.7%). This is in a Business-As-Usual scenario, taking into account only present policy.

	avg. gross heat load per dwelling	**heating system efficiency incl. ODF**	**avg. EU dwelling energy consumption**	**EU dwellings**	**total EU energy consumption for space heating residential**
	kWh/hh/yr	*%*	*kWh/hh/yr*	*million*	***PWh/yr***
1960	10638	58%	18416	97	**1.78**
1965	10807	57%	18923	103	**1.87**
1970	10892	55%	19870	109	**2.02**
1975	10817	52%	20701	116	**2.17**
1980	10419	54%	19366	122	**2.13**
1985	9870	56%	17539	130	**2.06**
1990	8816	63%	14076	138	**1.86**
1995	7857	69%	11468	146	**1.69**
2000	7496	70%	10697	152	**1.64**
2005	7250	72%	10110	155	**1.58**
2010	6982	73%	9622	158	**1.53**
2015	6658	74%	8963	161	**1.47**
2020	6343	76%	8345	164	**1.41**



5.2. Stock model heat generators 1995-2005

With the help of market research consultants Consult GB (CGB), the BRE Boiler Model (UK data), the inputs from Energie (task 1 leader) , Wuppertal Institute (Germany data) and industry association AFECI (Belgium data) we were able to build a database of stock and sales data 1995 as well as projected sales data 2005 for heat generators (local heaters, CH boilers, district heating, etc.). From this database, which is probably the most detailed available in the public domain, it was possible to build a stock model not only for the EU but also each EU member state. Sales and stock data are given both in number of heating systems sold/installed and in number of households served. The model comprises 50 large tables (300 cells per table), which are shown in the annexes to appendix 4.

In 1995 there were around 120 million heating systems installed in the EU. Around 5.1 million heating systems were collective central heating systems, providing the heat for an average of 5.1 dwellings/system. Central heating systems, both collective and for individual households, were approx. 61% of the 1995 stock. In total, space heating was provided for over 140 million households.[2]

In 1995 around 11.3 million households acquired 7.3 million new heating systems. (including individual, collective and district heating). Given an average product life of around 16 years, the number of households that *replaces* their heating system is some 8.8 million. Around 1.3 million of these households do not keep their old type of system, but *switch* from electricity (0.6 million), room oil heaters (0.1 million), solids (0.3 million) and room gas heaters (0.25 million) to gas-fired Central Heating systems (1.2 million), oil-fired CH and district heating (both 0.05 million).

Also contributing to a new fuel mix for the EU are the sales of heating systems for the 2.08 million ***newly built houses*** in 1995, which is completely different (e.g. 73% gas-fired) from the 1995 stock (e.g. 46% gas-fired).

Furthermore, there will be a slight increase of sales, beyond replacements and new sales, due to ***conversions*** from collective to individual CH systems. This is significant in Italy (0.25 million) and the Netherlands (0.05 million) in 1995, but is expected to decline towards 2005. Also, the average number of dwellings served by one collective heating system is expected to decline to around 4.1. Please note, that this only influences unit sales of heating systems, but not the number of households served.

The ***sales trend*** over 1995-2005 is heavily influenced by the declining housing market in most EU Member States. From around 2 million new houses in 1995 the market is expected to fall to 740,000 new houses in 2005, on the basis of demographic forecasts by the national statistics offices.

The largest uncertainty in this forecast for 2005 is the way governments and the market will handle this decline. Can and will this trend be reversed by increased

[2] Around 2.2 million households in Southern Europe reportedly did not own any heating system in 1995. The stock model assumes that this number is reduced to zero in 2005.

renovation and refurbishment projects or legislative measures? In Germany, for instance, where sales declined in 1995-2000 but are expected to pick-up in 2001-2006. This should following the adoption of legislative measures forcing boiler-replacement, such as the Energie-Einsparverordnung (EnEv), but no one really knows to what extent and at what pace this is going to happen.

If we compare the industry forecasts with what the model calculates in a 'Business-as-Usual' scenario (BaU) following the national statistics, then the industry is around 20-25% too optimistic. Industry estimates sales to rise from 7.1 million to 8.4 million between 1995 and 2005, with the occasional dip in between. The BaU-scenario envisages a decline in sales to a little over 6 million units in 2005, with sales of gas-fired CH-systems stable at 3.7-3.8 million units and all other unit sales declining.

The stock model calculates that in 2005 already 60% (*compare '95: 46%*) of the 155 million dwellings have heating systems that are gas-fired, 20% will be oil-fired (*'95: 22%*), 8-9% electric (*'95: 14%*), 7% solid ('95: 8%) and 7% on district heating (unaltered).

The average ***seasonal efficiency*** of the 2005 stock of heat generators will have increased from 79% in 1995 to 83% (Net Calorific Value) if we do not take into account the indirect energy for power generation. The stock model for heat generators, however, does take this into account and then the increase is much more: from 71% in 1995 to 77.8% in 2005.[3]

This is calculated on the basis that the average efficiency of the heat generators sold will be 5% higher than the efficiency of the stock in 1995. In 2005 it is assumed that the efficiency will again be 3% higher than the efficiency of the units sold in 1995.

In terms of primary energy, the saving from the heat generator alone (including power generation, but not counting the influence of the other factors) in a BaU-scenario is estimated at 129 TWh annually in 2005 with respect to 1995. The savings in CO2-emissions are around 30 MtCO2 per year over the same period. Other scenario's will be elaborated in Subtask 3.2.

These figures give an indication of the inertia of the market.(tables in ***Annex I*** *of Appendix 4*)

Furthermore, a ***sensitivity analysis*** of the model shows the effect of some policy measures. The interface and a first evaluation is shown in ***Annex II*** *of Appendix 4*.

[3] Calculated at power generation efficiency of 45%. All heating system efficiencies are seasonal efficiencies for the Net Calorific Value of the fuels. It is assumed that the seasonal efficiency is 10% lower than nominal efficiency. The Net Calorific Value is around 9% lower than the Gross Calorific Value for natural gas. Overall, the seasonal efficiency at Net Calorific Value should be comparable to the nominal efficiency at Gross Calorific Value.

5.3. Recommendation

Overall, the linear stock model is a good first approximation of trends to be expected within a margin of ± 10-20% for individual segments. The high-quality data set allows for a good consistency.

However, non-linear phenomena such an uneven stock built-up or the temporary influence of legislative measures cannot be fully taken into account and they cause a large part of the error. Furthermore, for certain segments, such as heating with renewable energy sources (biomass, heat pumps, solar) the model lacks sufficient detail as these segments are still relatively small. The same goes for the segments of auxiliary heating systems, such as the ever more popular electric floor heating which might have a significant impact on the EU's residential energy bill. For this it is recommended that the Commission should develop a more detailed and dynamic stock model that will be more accurate and more adequate for energy policy support.

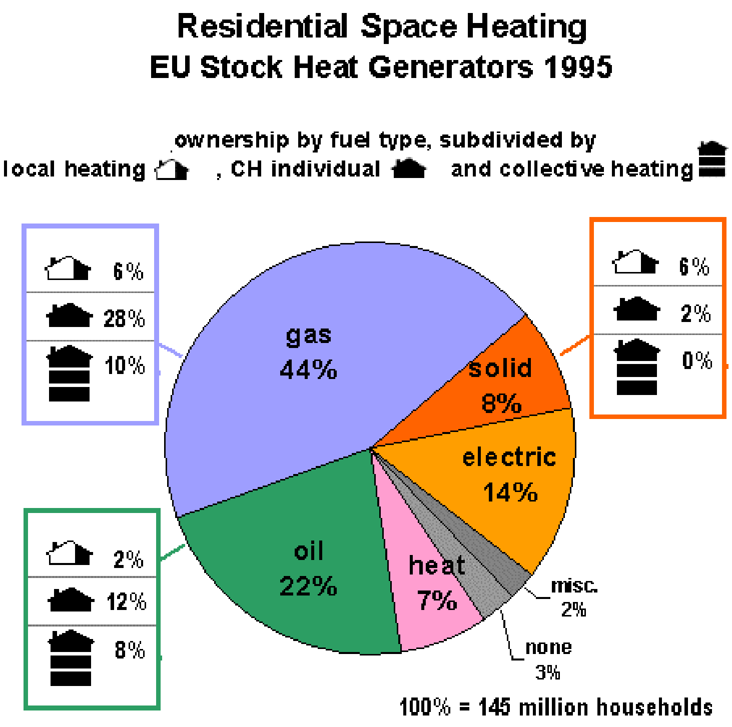


Fig a. Residential Space Heating Ownership 1995

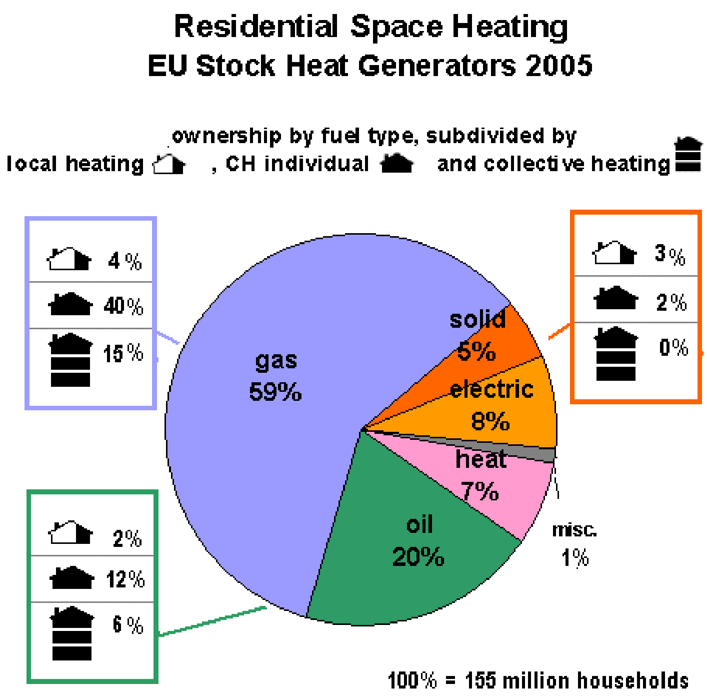


Fig b. Residential Space Heating Ownership 2005

6. Scenario Analysis

(This task was undertaken by ECI, UK)

6.1. Introduction

To estimate the likely effects of current and potential decisions on future consumption one has to perform scenario analysis. Using a stock model to estimate energy consumption and emissions, from which it is possible to create different future scenarios by changing the input data of the model, does this.

The most important scenario to construct is a reference case or baseline, which can be used to estimate the likely impact of other scenarios. This Reference Case (RC) scenario is a projection of consumption that is likely to happen without any further intervention by policy makers. This scenario is sometimes known as the Business as Usual scenario, and has been presented in the previous task.

To maintain simplicity only two energy-saving scenarios will be presented though it is relatively easy with the numbers presented to estimate others. The first energy-reducing scenario is one that should be realisable with action at the EU-level alone in the short term, based on known and proven technology. The second energy-saving scenario is the maximum potential saving that can be achieved by improving the heating system in EU households. The level of saving is based on the technical improvements identified earlier in this study, see the section and appendix “Technical improvements and technological change”. However, it may be difficult to ensure that householders take up these technical options in the near term.

Thus, the main scenarios to be produced for this study are:

- a reference case (RC),
- a short term policy scenario to reduce consumption and emissions (Sc1),
- a longer term theoretical maximum potential reduction (Sc2).

Heating systems and their components have long life times (boilers in excess of 15-20 years on average). So in order to see the effects of changes in new products, consumption will be estimated to the year 2020. Values for 1990 and 2010 will also be included, as these are useful for climate change negotiations – ‘Kyoto’ targets are based on reducing emissions from 1990 levels by 2010 (strictly 2008-12).

6.2. Reference case or Business as usual

Using the model described earlier, a reference case projected into the future can be described. The input data are listed in Table 1. The emitter, control and generator efficiency data are from page 9 of the appendix “VHK stock model of residential heating systems”. In particular, the average generator efficiency is calculated using the detailed stock model of EU heating systems. The ownership and number of households are also described in this appendix.

Table 1: Input data for estimating RC by EU domestic heating systems

	Households (million)	Ownership (%)	Generator Efficiency (%)	Control (%)	Emitter Efficiency (%)
1990	138	93	73	78	95
1995	146	94	79	80	95
2000	152	95	81	81	96
2005	155	97	83	82	96
2010	158	97	85	83	96
2015	161	97	87	84	96
2020	164	97	89	85	96

Note: The efficiency of the generator is discussed further in Section 7

Using these input data and a model to estimate the effect of the turnover of the stock of new appliances, an estimate of consumption of domestic heating systems can be made. Energy consumption in 1995 is estimated to be 1,676 TWh of delivered energy per annum, which represents a majority of the (delivered) energy use in EU households. However, this figure is declining slowly due to increases in the thermal insulation levels of houses and the increases in system efficiency, which are more than offsetting rises in the ownership of heating systems per household, more households, and higher levels of comfort being demanded.

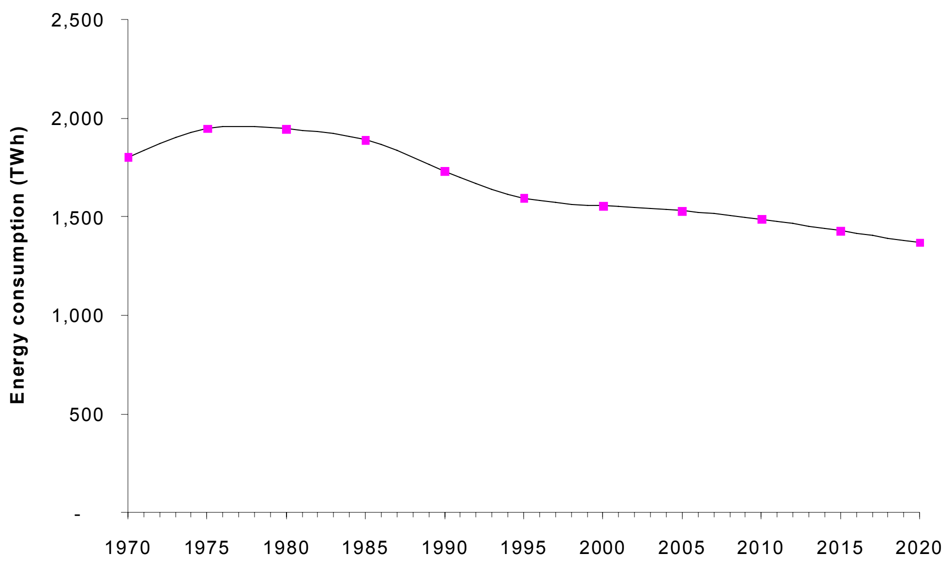


Figure 1: Estimated energy consumption by EU space heating, RC, 1970-2020

The model estimates consumption at 5-yearly intervals. These have been interpolated to give smoothed figures between these years. Note also that this model does not take into account variable climate conditions – these have been 'smoothed out'.

The average financial cost to the consumer can also be estimated by using an average price of 3 cents/kWh for domestic fuel costs (an average derived from the SAVE study on water heating labelling/standards). With this figure and the estimated consumption figures, means that in 2000, EU household spent approximately 47 billion Euros on heating their homes. This consumption is also responsible for the emissions of greenhouse gases, either in the home for gas and oil systems or at power stations for the electricity used. The most significant green house gas is carbon dioxide (CO_2), and the emissions of this gas were approximately 350 MtCO_2 in 2000. Converting between consumption and emissions is done using an average conversion factor for each year, which takes into account the relative proportion of each supply fuel which have different emissions per delivered kWh. (Note that carbon emissions can be quoted either in terms of carbon dioxide or carbon – to convert from CO_2 to C divide by 44/12).

At an EU-level, householders are, on average, spending 324 Euros and are responsible for the emissions of 2.5 MtCO_2 each year.

Table 2: Consumption by heating systems in EU, Reference Case

	1990	1995	2000	2010	2020
Energy (TWh)	1,731	1,676	1,555	1,487	1,368
Energy (Mtoe)	149	144	134	128	118
Emissions (MtCO_2)	407	375	365	350	322
Running costs (MEuro)	51,941	50,280	46,648	44,622	41,050
Energy/hh (kWh)	13518	11,652	10,792	9,727	8,622
Emissions/hh (tCO_2)	3.18	2.74	2.54	2.29	2.03
Cost/hh (Euro)	406	350	324	292	259

Due to improvements in efficiency of the heating systems and the thermal characteristics of the housing stock, energy costs and emissions are falling. Using the above assumptions these will continue to fall with the effect of past efficiency improvements filtering through as well as the affect of additional new efficiencies in the reference case. It should be noted at this point that prices might not stay at the low level they are at present, and are most likely to increase over the next 20 years. If this is the case then heating running costs may not decline further and additional efficiency improvements will become cost-effective to the consumer. This RC scenario, presented in Table 2, is now used as the basis for estimating potential future savings.

6.3. Potential for reduction

There are three broad areas where consumption by heating residential space can be reduced – these are:

- improve the thermal characteristics of the dwelling;
- reduce the level of heating;
- improve the efficiency of the heating system.

By improving the thermal insulation of the building (new and retrofitting existing), the heating required to maintain the temperature of the building can be reduced. This is usually a cost-effective way to reduce energy consumption but is outside the scope of this study. This area is receiving the attention of policy-makers at a national level, with building codes and is being more actively covered at the EU-level. The European

Commission's current 'buildings directive' proposal will aim to improve the 'efficiency' of buildings, and depending on coverage, may include some domestic buildings.

Where homes are over-heated, reductions in consumption may be possible. Indeed there are campaigns by Member States advising householder to turn down their heating thermostat (controls) to save energy and money. Eliminating the over-heating (or even decreasing the level of heating from the system) will reduce consumption. Turning the thermostat down by 1°C will usually reduce consumption by around 5-10%.

However, the primary aim of the current study is to promote the uptake of efficient heating systems. It is possible to reduce the consumption by domestic heating systems in several ways:

- Increase efficiency of heat generator (boiler);
- Increase efficiency of heat emitter (eg radiator);
- Improve the control of the system

All of these measures will improve the energy efficiency of the heating system. There are two other technical options to improve the 'carbon efficiency' of heating systems. Firstly, switching fuel sources for heat generators (eg from existing electricity where there is a high carbon intensity to gas or oil). Secondly, it is possible to improve the efficiency and/or reduce the carbon content of the electricity generated and used in heating systems. Included in this there is the possibility to use the 'waste' heat in electricity production. The heat from these combined heat and power plants (CHP) can displace domestic boiler energy consumption and thus represent an improvement in overall efficiency. These issues are considered as (important) supply-efficiency improvements, and are not pursued further in this study.

An earlier task in this study examined possible technical improvements that could be made to the various heating systems in the EU. The basis for producing these design options was based on minimising the cost of the heating system to the consumer.

Table 3: Potential improvements in heating system efficiency

	Existing	**Potential improvement**
Efficiency of generator (%)	85 (conventional)	Up to 111 – condensing up to 140 – heat pump
Efficiency of control (%)	83	<10 improvement
Efficiency of emitter (%)	96	<10 improvement

Source: Task 2.2 of this study

Using these potential improvements in efficiency levels of new equipment it is possible to generate future scenarios of consumption based on these improvements. The two scenarios will be a realistic short-term policy based scenario (Scenario 1), and a longer-term maximum theoretical potential savings (Scenario 2).

Scenario 1 – assumes all heat generators sold by 2005 are 10% more efficient, which is equivalent to half of all EU sales being condensing boilers by this year.

Scenario 2 – assumes all new products by 2010 are 'optimal'. It would not be desirable for all new heat generators to be gas heat pump – this scenario assumes they reach the same level of efficiency.

Figure 1 shows the improvement in efficiency of new heat generators for the Reference Case and the two energy reduction scenarios into the future.

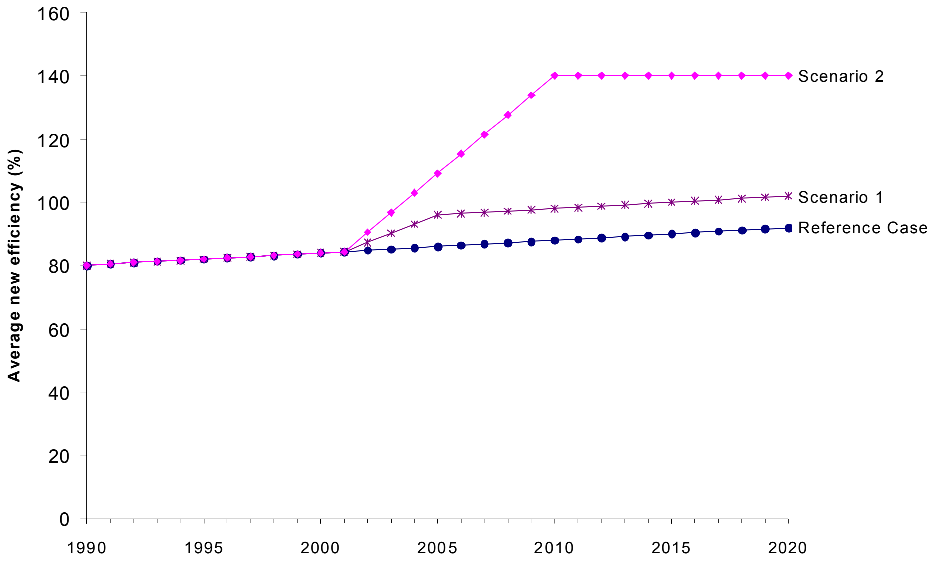


Figure 1: Average efficiency of new EU heat generators (% lhv)

Since heat generators can last on average between 15 and 20 years, it will take longer than this for the full effect to filter through to the whole of the heating stock. The time delay for the effect on the average efficiency in people's homes of improved new heat generating products is shown in Figure 2. In this case the heat generators are assumed to last for 15 years, as there is some evidence that boilers are not lasting as long as they use to (ie the average lifespan is declining).

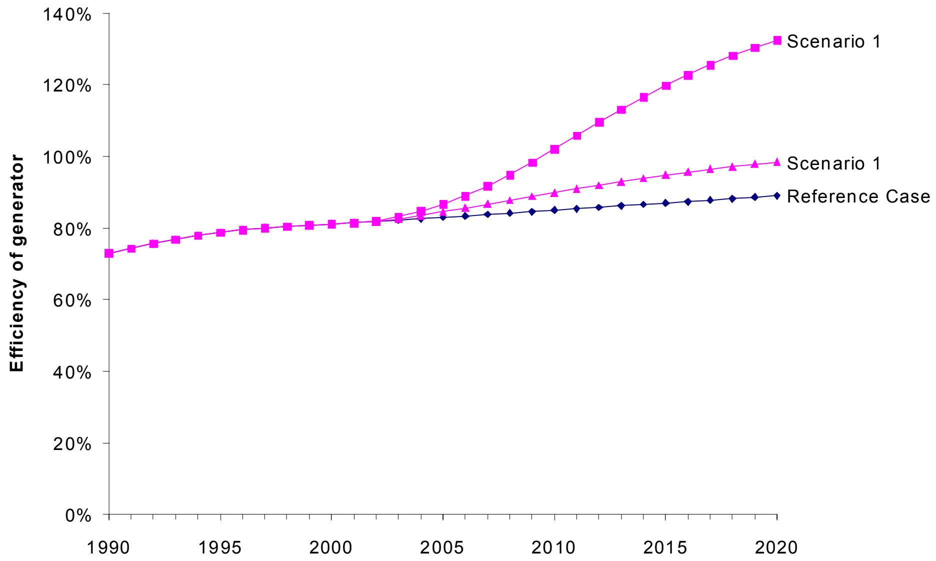


Figure 2: Average efficiency of EU heat generators (in stock)

6.4. Policy-based (short-term) reduction

There are a variety of policy measures that governments (EU and Member State) can introduce to improve the efficiency of domestic heating systems. To-date, much of the policy to reduce consumption has been at the Member State level, which was considered appropriate since houses are not traded across boundaries, and ambient climatic conditions, and thus good practice and appropriate measures, vary considerably across EU. Building codes and regulations and test methods were at the Member State level. The major intervention by the EU has been the 'boilers' directive and the SAVE directive. The boilers directive is appropriate at the EU level since boilers are traded goods within a single EU market. Any product-based regulation should be at the level of the unified market.

At an EU level, the European Commission can introduce information systems and regulation to remove the most inefficient technologies. The efficiency of installed heat generators can be increased either through a new 'boilers' directive or by a negotiated agreement between the EU Commission and the appropriate industry associations.

Table 4:
Energy consumption, emissions and costs for Reference Case and Scenario 1

	Annual	RC	Sc1	RC-Sc1
EU	Energy (TWh), 2000	1,555	1,555	-
	Energy (TWh), 2010	1,487	1,407	81
	Energy (TWh), 2020	1,368	1,237	131
	Emissions ($MtCO_2$), 2000	365	365	-
	Emissions ($MtCO_2$), 2010	350	331	19
	Emissions ($MtCO_2$), 2020	322	291	31
Household	Energy (TWh), 2000	11,652	11,652	-
	Energy (TWh), 2020	8,622	7,797	825
	Cost (Euro), 2000	350	350	-
	Cost (Euro)2020	259	234	25

Policy measures to improve the efficiency of heating systems in the EU are explored further in Section 9 of this report, whilst some of the likely impacts on stakeholders are examined in Section 10.

6.5. Maximum (theoretical) reduction

The largest potential increase would occur if all new heat generators to be installed were at the highest efficiency level identified earlier. In addition the efficiency of the heating system can be further improved by increasing the 'efficiency' of new emitters and controls. All of these efficiency improvements are included in Scenario 2.
To reach these levels of efficiency improvements would mean that all new installations would have to be of heat-pump type or a similar level of efficiency.

This is a theoretical scenario that assumes that this level of efficiency of installation can be achieved by 2010. It is unlikely that this level of efficiency could occur without significant intervention by policy makers, at EU and Member State level, but will provide a notional maximum for potential savings for the heating system. Using the input data already described the potential reductions in energy, emissions and costs are given in Table 5.

Table 5:
Energy consumption, emissions and costs for Reference Case and Scenario 2

	Annual	RC	Sc2	RC-Sc2
EU	Energy, 2000 (TWh)	1,555	1,555	-
	Energy, 2010 (TWh)	1,487	1,213	274
	Energy, 2020 (TWh)	1,368	901	468
	Carbon, 2000 (MtCO_2)	365	365	-
	Carbon, 2010 (MtCO_2)	350	285	65
	Carbon, 2020 (MtCO_2)	322	212	110
				-
Household	Energy, 2000 (kWh)	11,652	11,652	-
	Energy, 2020 (kWh)	8,622	5,675	2,947
	Cost, 2000 (Euro)	350	350	-
	Cost 2020 (Euro)	259	170	88

6.6. Potential savings

The potential future scenarios of energy consumption are shown graphically in Figure 3. Clearly significant reductions in energy can be achieved by short-term policy that improves the efficiency of heat generators by 10% (Scenario 1). However, there is still the potential to deliver much larger savings (Scenario 2).

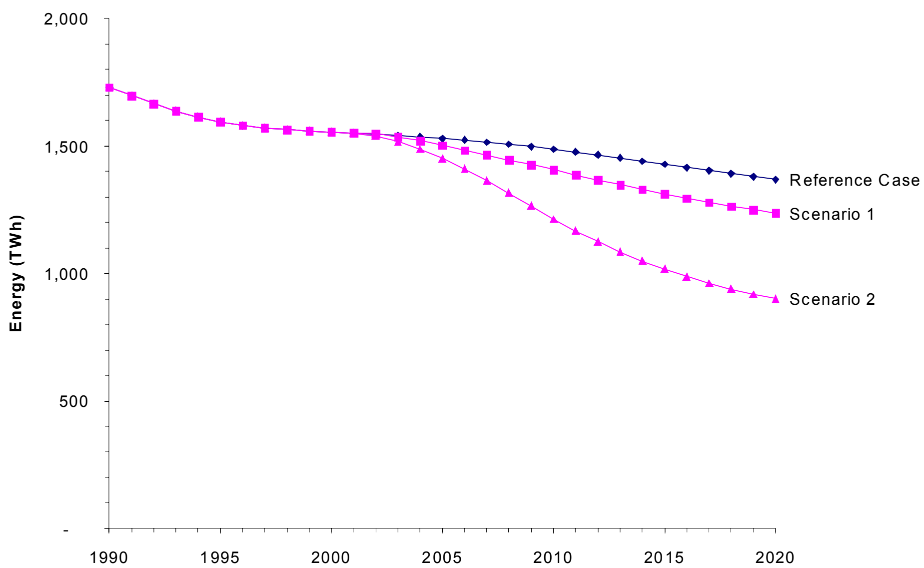


Figure 3: Annual energy consumption by EU space heating, RC and potential reductions, 1990-2020

Consumption by EU domestic space heating is declining and by 2020, could reduce to 1,368 TWh without further intervention by policy makers. However, with some intervention and support, energy consumption could be reduced significantly over the next 20 years. Following realistic short-term policy measures, 131 TWh of energy could be saved by 2020, and is cost-effective for the consumer to do so. Realising all the cost-effective potential savings, though difficult to achieve, would increase the level of savings to 468 TWh. All of these scenarios are based on consumers replacing their heating systems every 15 years. Any shortening of this lifespan would decrease energy consumption by this end-use further.

6.7. Conclusions

The amount of (delivered) energy required to heat homes in the 15 Member States of the EU amounts to around 1,676 TWh annually, making it the largest domestic end-use. This level of consumption is however, declining due to improvements in the housing stock and the efficiency of heating systems, and by 2020 consumption could be at 1,368 TWh without any further intervention by policy makers.

If the efficiency of heat generators where to increase by 10% above the reference case by 2005 and continue to improve at the same rate, then energy consumption could be reduced by 81 TWh by 2010 and 131 TWh by 2020. This equates to reduction in carbon emissions of 19 $MtCO_2$ (31 $MtCO_2$) by 2010 (2020) - shown by Scenario 1 in Table 6.

A 10% increase in the efficiency of heat generators, given by Scenario 1, should be realisable by information systems coupled with a revised 'boilers' directive in the short term.

Table 6: Potential improvements in heating system efficiency

	Annual	RC	Sc1	Sc2	RC-Sc1	RC-Sc2
EU	Energy (TWh), 2000	1,555	1,555	1,555	-	-
	Energy (TWh), 2010	1,487	1,407	1,213	81	274
	Energy (TWh), 2020	1,368	1,237	901	131	468
	Emissions ($MtCO_2$), 2000	365	365	365	-	-
	Emissions ($MtCO_2$), 2010	350	331	285	19	65
	Emissions ($MtCO_2$), 2020	322	291	212	31	110
						-
Household	Energy (kWh), 2000	11,652	11,652	11,652	-	-
	Energy (kWh), 2020	8,622	7,797	5,675	825	2,947
	Cost (Euro), 2000	350	350	350	-	-
	Cost (Euro), 2020	259	234	170	25	88

There are still further efficiency improvements, which could be made by upgrading controls, and also improving emitters. These have not been included in Scenario 1.

Including the potential savings from emitters and controls with a theoretical 'optimal' level for heat generators will deliver savings shown in Scenario 2. However, these will be more difficult to realise. 'Retro-fitting' controls and emitters to existing heating systems will require actions and measures at a Member State level, in addition to EU activity (principally information and minimum standards of efficiency)

In the EU, many space-heating systems are combined with the water heating function, so any efficiency improvements of new boilers should also result in reduced energy consumption and emissions from this end-use. So, the potential savings presented here are under-represented in this respect.

In the short-term there are significant energy and emission reductions that can be made by domestic heating at no (or negative) financial cost to the consumer.

6.8. Annexe - Comments on model

The model used in this study has been termed a linear stock model. It contains detailed stock data of good quality for 1995 and 2005, however, it assumes linear changes, which limits its accuracy in assessing trends and scenarios. This could be improved by the development of a dynamic model using further data that are available.

The stock is disaggregated by heating system type and Member State, though time and resource limitations prevented the disaggregation of estimates of energy consumption. Energy consumption and emissions cannot therefore be disaggregated to the Member State level in this work, and are thus presented as a European aggregate. Further development of the model would allow such disaggregation, and more detailed assessments, For example, it would enable assessment of the effect of improvements to particular types of heating systems, or improvements in certain countries, including the carbon intensity of electricity generation in individual countries. In addition the trends and effects of changes to the fuel used by householders could be assessed.

The fuel mix has been assumed to be constant during the modelling period, which will provide a source of error on the absolute level of emissions into the future, though will have less of an effect on the level of emission reductions.

Electricity consumption by auxiliary components (pump, fan, and controls) is excluded from this model. Circulation pumps make up the majority of the auxiliary energy - this forms a separate task in this project, which was carried out in parallel to another SAVE study on this subject. From the outset of this study, the energy used in central heating systems for water heating is also excluded from this work, and was also previously covered by a separate SAVE study. It would be valuable to include both of these areas in future development of the model and scenarios.

7. Seasonal efficiencies of heating systems

(This task was undertaken by BRE, UK)

7.1. Meaning of efficiency

Although often used more loosely, the term “efficiency” is used here as the ratio of useful heat output from a heat generator (e.g., a boiler, or heating appliance) to the energy supplied to it. For a boiler, the heat lost from the casing and in flue gases discharged from the building is not regarded as useful. Efficiency is a non-dimensional number, expressed as a percentage. The importance of heating system efficiency in energy modelling is that it links delivered to useful energy, and allows one to be calculated from the other.

Efficiency is affected by the calorific value of the fuel burned, which is commonly measured in two ways: “gross calorific value” (GCV) is the full amount of heat which can theoretically be extracted whereas “net calorific value” (NCV) excludes the quantity of heat needed to evaporate water present in the fuel during the combustion process, and is always a lower figure. In energy modelling it is essential to know whether efficiency figures are based on GCV or NCV, and to ensure that subsequent calculations use figures for fuel cost and carbon intensity on the same basis.

Efficiency calculated on a GCV basis always has a theoretical upper limit of 100%. On a NCV basis, however, this is not so and the upper limits are about 111% for natural gas, 108.6% for LPG, and 106.7% for oil. It is very important to be aware of this when efficiency figures are quoted and compared.

7.2. Efficiency tests

There are many different tests to determine heating appliance efficiency, defined in national and European Standards. They have to be carried out under carefully controlled conditions, usually in laboratories. For boilers the most relevant are the European standard (EN) tests for full-load efficiency (FLE) and part-load efficiency (PLE) which are used to demonstrate compliance with the European Boiler Efficiency Directive (Council Directive 92/42/EEC). The Directive prescribes different test conditions for different types of boiler and fuels, so quoted results are not comparable unless boiler type and fuel are the same.

7.3. Seasonal efficiency

The results from standard FLE and PLE tests are not, on their own, adequate as a guide to the average efficiency of a boiler once installed in a heating system in a dwelling. Many other factors influence installed efficiency, such as boiler type, household occupancy, the pattern of heat demand, controls, weather conditions, system design, whether the boiler is used for hot water service as well as space heating, and, if so, whether used through the summer as well as winter. But seasonal efficiency is important for estimating fuel usage in heating systems in real conditions, as required for energy modelling. The concept is less important for room heating appliances than for central heating systems, as individual appliances are not normally capable of delivering widely variable quantities of heat according to demand under different conditions.

There are a number of methods to measure or estimate seasonal efficiency for central heating systems with boilers, and two which make use of the standard European FLE and PLE test results are BOILSIM and SEDBUK.

BOILSIM was developed as a European project under the SAVE programme, and calculates efficiency for a particular heating installation, taking account of the thermal performance of the building, type of heating system, and controls used. It also requires an additional test to be carried out on the boiler. BOILSIM results may be quoted on either a GCV or NCV basis.

SEDBUK (Seasonal Efficiency of Domestic Boilers in the UK) is a less precise method than BOILSIM as it does not take into account the characteristics of individual buildings or call for additional boiler test information. It is intended to discriminate between boilers only, using the standard FLE and PLE test results and a number of simple characteristics such as boiler type, fuel used, burner control, ignition method, and size of internal hot water store if fitted. The method assumes that the boiler will be installed in typical UK conditions, making reasonable assumptions about factors such as intermittent usage, composite heating and hot water, common control regimes, and the nature of the UK housing stock and climate. Consequently it is not applicable in other conditions – notably conditions in other European countries – without some adaptation to allow for different climates and national installation practices.

SEDBUK figures are always quoted on a GCV basis, with a theoretical upper bound of 100%, although the method imposes practical limits for different fuels and boiler types that are somewhat lower; eg, about 82% for a non-condensing gas boiler and about 91% for a condensing gas boiler. SEDBUK has been used successfully to support government policy initiatives for more efficient domestic heating within the UK, and a database of SEDBUK figures for both current and obsolete boilers has been created which may be seen on the Internet website www.boilers.org.uk.

7.4. UK national boiler energy model

The national boiler energy model for the UK has been built using population figures for different boiler types. Each type is ascribed different SEDBUK values for past and future years, typical of products of that type sold in each year. The same approach, adapted for other countries but with certain simplifications, has been used for European modelling within the current project, described below.

7.5. European heating system energy model

The European heating system energy model that has been developed in this SAVE project provides a good first approximation of trends in energy consumption in residential heating systems. The model includes estimates of seasonal efficiency which take account of conditions in different European countries, albeit in simple terms. Further work is required to refine the national variations assumed in the model.

Seasonal efficiency is preferred for large scale energy modelling, to provide a better estimate of energy consumption. It allows the model to be checked against national statistics of fuel consumption, improves robustness, and increases the confidence that can be placed in the trends indicated. The method adopted here is a variation of SEDBUK, described below.

7.6. Seasonal efficiencies of domestic boilers in Europe

Seasonal efficiency equations for 15 EU countries, compatible with SEDBUK, have been developed and applied to three space and hot water heating options, for the two most common types of boiler,

(a) non-modulating regular (ie, not combination) boilers, and
(b) modulating instantaneous combination gas boilers

The general form of the equations is:

$$0.5 \times (E_{full} + E_{part}) + k - 4p$$

where:

'$E_{full} + E_{part}$' are the full and part load efficiency test results, as required to establish compliance with Council Directive 92/42/EEC. Test results must be converted from a NCV basis (on which they are measured) to GCV before using them in the equations.

'k' is known as the boiler type characteristic, and is a constant depending on the type of boiler (eg, -2.5 for non-condensing non-modulating regular gas boilers in the UK, used for hot water service throughout the year as well as space heating during the heating season)

'p' = 1 if the boiler has a permanent pilot light, otherwise 'p' = 0

The result is seasonal efficiency on a GCV basis.

It is important to note that significant simplifying assumptions have been made, and that the method is worthy of further refinement (beyond the scope of the current project). The assumptions in the method and the European boiler energy model are listed below, and though they provide values sufficient for the current project they should be reviewed and revised in any future development of this work:

- the average number of heating hours/day is the same in all EU countries
- the internal design temperature is the same in all EU countries
- the effect of a permanent pilot flame is ignored (p=0)
- all regular boilers are assumed to be on/off (non-modulating)
- all combination boilers are assumed to be modulating
- the load factor for each country has been determined from the number of degree days, design temperature difference, and number of heating hours; this implies that the boiler sizing method is the same throughout Europe
- the boilers are assumed to provide hot water service all year in addition to heating, except in Ireland (market research information from Consult GB indicates that EU15 countries have about 20% or less of systems supplying hot water separately, except for Ireland where the figure is about 90%)

k-values for EU Countries

	Degree-days Sept to May °C days[4]	Outside design[5] temperature °C	Load factor	*Load factor UK load factor*	k for regular boilers % gross	**k for combi boilers** % gross
Portugal	1278	4.0	0.72	0.668	-3.4	-2.8
Greece	1458	1.0	0.69	0.641	-3.5	-2.9
Spain	1543	1.0	0.73	0.678	-3.4	-2.8
Italy	1887	-1.0	0.81	0.750	-3.1	-2.6
Ireland	2480	-2.5	0.99	0.920	-2.6	-2.2
France	2565	-4.2	0.96	0.885	-2.7	-2.3
Belgium	2753	-7.0	0.92	0.850	-2.8	-2.3
UK	2757	-3.0	1.08	1.000	-2.5	-2.1
Netherlands	2834	-5.0	1.02	0.945	-2.6	-2.2
Germany	3117	-10.4	0.92	0.854	-2.8	-2.3
Luxemburg	3154	-7.0	1.05	0.974	-2.5	-2.1
Denmark	3270	-7.0	1.09	1.010	-2.5	-2.1
Austria	3494	-12.0	0.98	0.909	-2.7	-2.2
Sweden	3740	-13.0	1.02	0.944	-2.6	-2.2
Finland	5134	-18.0	1.22	1.125	-2.3	-1.9

[4] Degree-days are from Eurostat Energy Monthly Statistics; these values are averages of a number of years, and are computed from the AGROMET database
[5] Average of cities given in Table 2, ASHRAE Handbook, 1993, Fundamentals, SI Edition

k-value for different space and hot water heating loads across Europe

	Space heating and hot water heating all year		Space heating only (ie no hot water heating)		Space heating and hot water heating in the winter only	
	k for regular boilers % gross	**k for combi boilers** % gross	k for regular boilers % gross	**k for combi boilers** % gross	k for regular[6] boilers % gross	**k for combi[7] boilers** % gross
Portugal	-3.4	-2.8	-3.6	-3.3	-2.5	-2.4
Greece	-3.5	-2.9	-3.8	-3.4	-2.6	-2.5
Spain	-3.4	-2.8	-3.6	-3.2	-2.5	-2.4
Italy	-3.1	-2.6	-3.2	-2.9	-2.2	-2.1
Ireland	-2.6	-2.2	-2.5	-2.4	-1.7	-1.7
France	-2.7	-2.3	-2.6	-2.5	-1.7	-1.8
Belgium	-2.8	-2.3	-2.7	-2.6	-1.8	-1.9
UK	-2.5	-2.1	-2.2	-2.2	-1.5	-1.6
Netherlands	-2.6	-2.2	-2.4	-2.3	-1.6	-1.7
Germany	-2.8	-2.3	-2.7	-2.6	-1.8	-1.9
Luxemburg	-2.5	-2.1	-2.3	-2.3	-1.5	-1.7
Denmark	-2.5	-2.1	-2.2	-2.2	-1.5	-1.6
Austria	-2.7	-2.2	-2.5	-2.4	-1.7	-1.8
Sweden	-2.6	-2.2	-2.4	-2.3	-1.6	-1.7
Finland	-2.3	-1.9	-1.9	-2.0	-1.3	-1.4

These values can be used to adjust SEDBUK values that have already been derived for the UK. The UK national boiler energy model is based on stock and sales information, together with SEDBUK seasonal efficiency values. Average seasonal efficiency values for stock and sales in any particular year are calculated in this model, and values can be calculated for future years based on scenarios. The following tables show 1995 stock and sales values, and 2005 values based on a 'business as usual' scenario.

6 On/off boilers are the most common
7 Modulating boilers are the most common – modulating is variation of the fuel burning rate in response to air or boiler water temperature.

Gas - average UK seasonal efficiencies
(based on gross calorific value, divide by 0.901 to convert to net efficiency values)

	Non-condensing boilers	Condensing boilers	All gas
Stock 1995	65.0%	86.7%	65.1%
Sales 1995	73.2%	87.4%	73.4%
Sales 2005	77.0%	89.8%	78.3%

Oil - average UK seasonal efficiencies
(based on gross calorific value, divide by 0.937 to convert to net efficiency values)

	All oil
Stock 1995	69.6%
Sales 1995	78.2%
Sales 2005	86.5%

These values can be modified for other EU countries using the method above. The modified seasonal efficiency values could then be used in the stock model, to provide improved estimates of the consumption of fuels in residential heating systems. It would then be feasible to check the model against national statistics of fuel consumption for heating, improve robustness of the results in the model, and increase confidence in the trends that it shows.

8. Electrical consumption of gas and oil fired heating systems

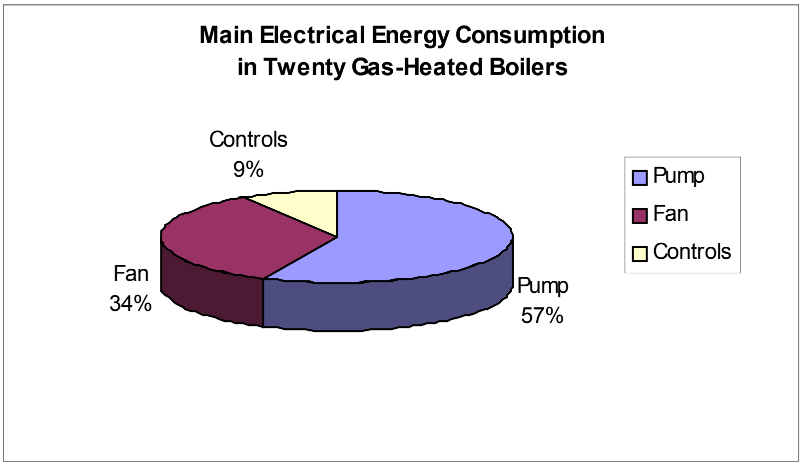
(See Appendix 5 for a full description of this task, undertaken by OMV, Sweden).

Circulation pumps are responsible for most of the electrical energy consumed by boilers, as can be seen in the table and figure below. These have been the subject of another SAVE II study, *Promotion of Energy Efficiency in Circulation Pumps especially in Domestic Heating Systems (Grundfos with ECI and VHK, June 2001)*. Analysis carried out by this study results in an estimate for household central heating systems in the EU15 of 41TWh, made up of
- 87 million pumps less than 250W, consuming 33TWh
- 0.29 million pumps greater than 250W (district/block heating), consuming 8TWh.

This study included scenarios that showed electricity consumption in 2020 in a reference case of 45.6 TWh, compared with an ETP (Economic Technical Potential) case of 13.9 TWh, a 70% reduction. Four options were considered to be effective and reasonably achievable, as follows: (1) The current housing could be improved by optimising its design for individual motor sizes. (2) Automatic speed control would avoid the need for the pump to be drawing full power all the time that the pump is on. (3) Permanent magnet motors, which are inherently more efficient, could be used. (4) Lastly, a seasonal switch could be introduced in systems that run the pump all year, so that it is turned off in summer.

Some recent studies have indicated that a speed controlled pump can give heat savings (for example, gas savings in gas central heating systems) as well as electricity savings. However, this is strongly doubted by some experts, who can see no clear physical cause that would result in significant heat savings. Discussion is currently taking place about this issue, and further research is needed to determine the presence of these additional heat savings.

Equipment	Effect	Estimate of time in use
Electrical trace heating	a few watts	rare
Boiler gas valves	a few watts	frequent
Programmers	a few watts	frequent
Thermostats	a few watts	frequent
Motorised valves	a few watts	frequent
Stand-By Equipment	5-10 watts	frequent
Boiler fan	60-150 watts	frequent-very frequent
Circulator pump	40-250 watts	frequent-very frequent


Main Electrical Energy Consumption
in Twenty Gas-Heated Boilers
Controls
9%
Fan
34%
Pump
57%
Pump
Fan
Controls

The figure also shows that fans and controls are estimated to represent 43 % of the electric energy consumption. There are opportunities to reduce the electrical energy consumption dramatically by using available technology in this area, as well as for pumps, and these should not be neglected.

The design of the fan assembly, including the motor, its control circuitry, and the aerodynamic design of the fans and airways has a significant impact on electrical energy consumption. Some savings could also be achieved by using motorised valves which only draw power when in transit, rather than being continuously powered when they are in an active position. Programmers and time switches draw power continuously, and this can be considered as 'standby' power. This could be added to a list of household appliances (such as microwaves or video players), for which standby power should be limited.

It should be noted that the saving in carbon emissions as a result of each TWh of delivered energy saved, can be about 2 or 3 times greater for electricity, than for oil or gas. This factor, of course, depends on the method of electricity generation. For example, for nuclear and hydro generation the carbon emissions can be considered minimal or zero, whereas for coal-fired generation they can be as high as 5 to 6 times greater per unit of delivered energy saved, than is the case for oil or gas.

Moreover, pumps and fans are produced by only a few large suppliers, so that voluntary agreements may be a cost effective method of reducing the electricity consumption of these components. Alternatively, separate labelling, and/or minimum efficiency standards may be considered.

9. Market barriers and opportunities

(See Appendix 6 for a full description of this task, undertaken by IED, France).

For heating systems based on oil and gas boilers, efficient technologies are mature and available. However, their dissemination does not reflect the potential for efficiency that is possible. Various policy measures have been implemented by EU member governments to promote efficient technologies. The situation is very different between member countries, due to different climates, policies, and levels of concern. These variations make it difficult to construct common policy measures which are compatible across all EU countries.

Installers, architects, building developers and consumers are the main actors in the heating market, particularly the decision process for individual heating systems in dwellings. For new buildings, architects and building developers are the main actors, and their choice is influenced to a large extent by energy suppliers and/or manufacturers. For existing buildings, the consumer is influenced by the installer, who generally does not consider energy efficiency a first priority. The consumer usually has little information about energy use, so that in general he is unable to consider this in his decision, even though he will be the user of the heating system.

The economic barrier of higher cost for efficient technologies is well known, and treated through the use of subsidies and fiscal incentives. In the past, a number of subsidy programmes for efficient heating systems, particularly efficient boilers, were developed by national governments. At present there are no national subsidies, however some countries use fiscal incentives such as tax reductions, or subsidies from energy suppliers. District heating, CHP, and switching fuels are promoted by subsidies in a few EU countries.

The principal regulations relevant to energy efficiency of heating systems are

- the European Directive 92/42/EEC which applies to liquid and gaseous fuelled boilers, and
- the National Thermal Regulations or Building Codes which are applied to new buildings, and which include the European Directive on boilers.

Manufacturers are now making products of a higher energy efficiency standard than the minimum required in the European Directive. It would therefore be feasible to define a new minimum level.

Except for a few countries where efforts have been made to enforce the installation of condensing or low temperature boilers, there are no regulations concerning procedures for installing or replacing boilers in existing buildings. This is particularly unfavourable to the proper sizing of a boiler according to the heat requirement of the dwelling, and also to determining the correct replacement and installation of other components of the heating system.

A general barrier in all countries is lack of information available to the main actors in the market chain, particularly to the final consumers. As mentioned, the final user rarely decides by himself the system to be installed, and those who influence the decision do not pay the fuel costs which are a consequence. This is clearly a major market constraint to the uptake of efficient heating systems. Two options which are available to authorities to overcome this barrier are

- enforcing efficient heating using norms and standards
- providing information so that the consumer can evaluate energy consumption, which then creates pressure on the market actors to improve efficiency.

These options can be used to complement each other, with regulations to enforce a minimum efficiency, and information to encourage even better efficiencies. In this context, the development of a label to provide the information is attractive;

- it gives the required information to the user
- labels are already developed for a variety of household appliances, and the 'A to G' scale is generally accepted and understood by EC consumers.

However, while in most EU countries heating systems represent the largest share of energy consumption in a building, at present they have no labelling system. Labelling for heating systems is more difficult than for most other appliances because;

- there is a wide range of systems, with different fuels, configurations, and sizes
- heating systems are more complex than single appliances, making it more difficult to define and evaluate a criteria for efficiency
- a label at an EU level must be suitable for the large range of climates, and for the variety of national regulations, that are present across the EU.

Even for boilers only, these difficulties have been encountered in the implementation of the four stars labelling scheme, which is part of the European Directive.

Two current EU projects concern the Energy Performance of Buildings, and Sanitary Hot Water. In addition, labelling schemes for buildings are implemented or under study in several EU countries at a national level. These projects should be taken into account in further discussions on the labelling of heating systems in dwellings.

This discussion indicates a number of conditions as a basis for considering a label;

- the field should be limited initially to heating systems with gas and oil boilers. This could be extended in the future to other heating systems and fuels.
- the information to be delivered should be the system efficiency
- the basis should be a label on the efficiency of the system, although experience from the European Directive four star labelling scheme show that design of such a label will need careful consideration. The method may take into account other components of the heating system, as well as installation of the boiler.

In the future, a label for boilers and the heating system could be extrapolated to, and integrated with a procedure for the whole building.

Such a label for heating systems would be compatible with other policy measures that could support it where the market is not able to promote efficient products by itself, for example subsidies. In addition, specific attention may be given to consumers who are financially unable to invest in efficient products themselves.

In addition to individual dwellings, consideration should also be given to labels for block and district heating, even though this will have particular difficulties where the consumers interest is indirect due to payment methods. For district, and more complex heating systems, a wider view of the system, the buildings, and the information that is relevant, will be necessary.

10. Stakeholder impact analysis

(See Appendix 7 for a full description of this task, undertaken by Wuppertal Institute, Germany).

In Task 5.2 'Stakeholder Impact Analysis' the impacts of a labelling scheme for heating systems and other possible measures for improving energy efficiency in this sector are evaluated. A main point of this work included theoretical analysis and research aimed at estimating the effect on manufacturers. The theoretical research is mainly based on different market analyses carried out in other Tasks of the project and supplied by independent market research companies. It further included a series of structured interviews with selected manufacturers and the organisations representing manufacturers and a questionnaire that was sent out to 35 manufacturers in eight countries representing more than 60 percent of the European market for heating systems[8]. Responses to our questionnaire were received from 14 companies of all sizes and from five different countries, representing more than 30 percent of the EU market. By inviting the relevant market associations to a meeting and talking to their representatives we also tried to include the common position of the industry[9].

The network of actors who determine the choice of a heating system sustains of three main stakeholder groups. All three are involved in the decision-making process for the installation or replacement of a heating system in a dwelling First are the customers who have to be subdivided into owner occupiers, tenants and landlords. The second group are the installers who sell and install the heating system and who have a great influence on the relevant decision-making processes when a new heating system is purchased and installed. The last but not least group are the producers of heating systems. All three groups would more or less be affected by policies trying to transform the market of heating systems in the EU and especially by the introduction of a labelling scheme for boilers.

The consumers will be able to make sounder purchasing decisions and to take an active role in the decision. The relation between costs and benefits of the measures proposed will mainly determine further effects for the consumers. These aspects are discussed in depth in Task 5.1 'Cost Benefit Analysis' of this study.

The installers bear the main task of informing consumers about efficiency measures such as labels, etc. To take over this task installers will need to improve customer communication skills. Together with the important role they have in the decision-making process, it is clear that they are crucial for the success of most policies and especially a labelling scheme for energy efficiency of heating systems. In general introducing a labelling scheme and other measures for improving energy efficiency tend to increase their economic opportunities.

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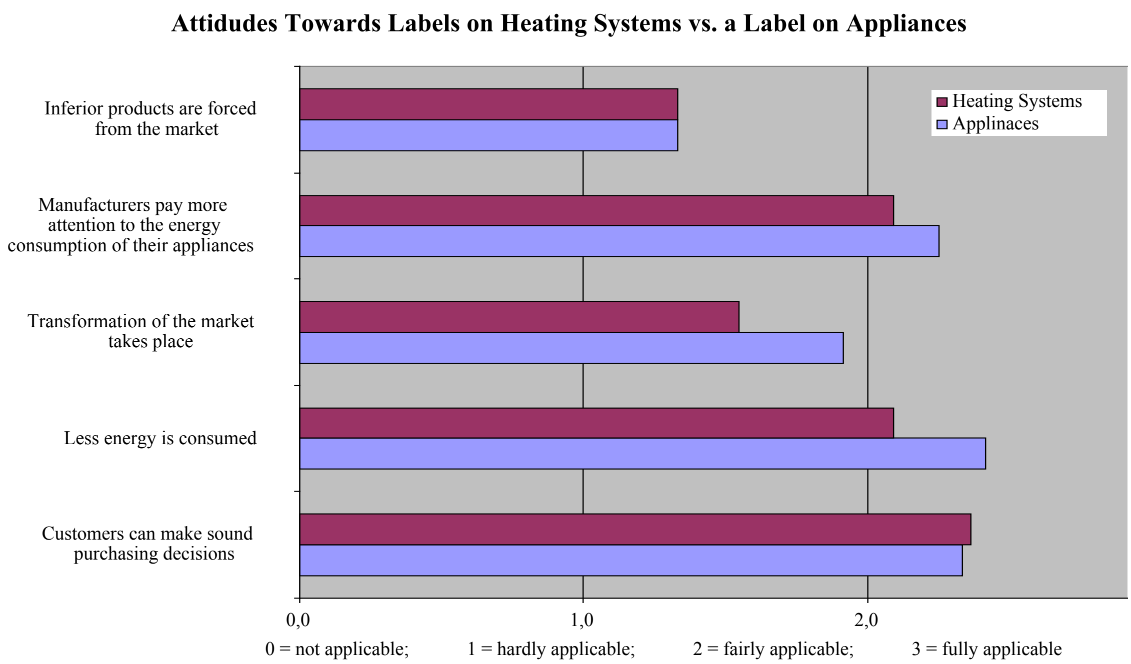
8 However, with the time and budget given a really representative survey of the total European heating systems industry was not possible. All results are therefore to be interpreted with appropriate care.

9 The results of the questionnaire and especially the talks we had with industry were very helpful for us and we would like to thank all those people who used their time and provided valuable information for their co-operation.

The focus group of this Task is clearly the manufacturers of heating systems. On the one hand they are important players influencing the efficiency of heating appliances. On the other hand it is their products and their market at which a labelling scheme and other measures are targeted.



In the following text this market is analysed in detail to find out which companies could be harmed and which could profit from the proposed measures. The analysis is underpinned by a survey that tried to find out the attitudes of the industry towards a labelling scheme for heating systems and their expectations regarding potential effects on the markets and the companies.

Generally our survey brought out that heating systems manufacturers regard energy efficiency labels for heating systems as slightly less effective than the labels on other household appliances that are existing in the EU. However, it is believed that customers can make sounder purchasing decisions because of the availability of a label and therefore responders think that energy savings will be achieved. Most companies regard a label as a good instrument to use in their companies marketing campaign.

In contrary to this opinion the possible transformation of the market is estimated as not very significant – and certainly lower than for other appliances. That inferior products would be forced from the market is – as for appliances in general – hardly believed. In line with these views is the expectation of responders that manufacturers will pay just fairly more attention to the energy consumption of their appliances.

Companies could imagine that the prices for heating appliances could rise and that ecologically sound appliances will become more economical. A second possible result of a label could be that it would support the ongoing integration process of the European market – especially if national labels were removed.

Potential problems to the introduction of a labelling scheme are not perceived as very high. It is hardly believed that industry will experience problems with sales. Respondents also have no big fears that product cycles will be shortened or small companies will be forced from the market. They anticipate neither loss of sales, nor high costs for converting production. Consequently, changes of location and reductions in workforce are not regarded as possible consequences of a label. The majority of companies estimate their ability to adapt to the changed market conditions above average and see themselves as winners of the introduction of a labelling scheme. Most other companies claim an average position.

However, companies producing electric heating systems did have a differing point of view. They do in fact fear losses in sales and to a certain degree also high costs of converting production if their products are included in an integrated labelling scheme. Consequently they also expect problems with a reduction in workforce but no consequences regarding the location of companies. The opposite effect is feared by some producers of fossil fired systems. They mentioned that separate labels for all energy carriers could mean a disadvantage for gas and oil fired systems in southern European markets. And therefore have possibly unwanted substitution effects in favour of electric systems.

Most manufacturers of heating systems seem not to expect very severe consequences of a labelling scheme. Also most of the companies that responded to our questionnaire see themselves as winners of such a scheme. Nevertheless we tried to theoretically analyse special market segments and groups of manufacturers that could possibly be affected by an energy efficiency label. The possible direction and extent of effects was estimated using market information and information gathered by the survey. The results therefore have to be regarded more as plausible estimates than as real hard facts.

For this purpose we derive some hypotheses on which groups of companies might be affected by a possible label. The real effects will of course be closely connected to the total effectiveness of the label and its concrete design. The hypotheses about effects of a label are:

- Companies producing only or mainly low-standard boilers could be forced from the market by labelling and subsequent legal measures.
- Companies which produce heating technologies that have lower rankings in an integrated labelling scheme compared to competing energy carriers could also be affected. This would probably apply to electricity as an energy source for heating and to a far lower extent to oil. Other energy carriers like biomass and solar systems and even electric heat pumps are more likely to profit from such effects.
- Small and medium-sized producers could be affected because they might have administrative problems applying for a label and because of a lack of capacity to follow the market trends promoted by the label.
- By introducing energy efficiency labels and other measures, concentration trends on the market for heating systems could be promoted.

The first hypothesis is of course obvious in theory. But we did not find much evidence in our survey that it is a real problem. Regarding the bulk of the market we looked at the top 5 European producers of heating systems, which sell together more than 40 % of all heating systems in the EU and more than 50 % of all gas-fired heating systems. All of them do have condensing boilers in their assortment. Their share of sold numbers is between some 10 to 50 %. Only for Riello this technology has a much smaller dimension. From this point of view among the big 5-heating producers higher standards do not form a bigger obstacle to economic development. Only the British market leader Baxi faces bigger changes in product range because the inefficient types of back-burners and cast-iron wall hung heaters make about 75 % of sales. Analogous is the situation for the medium sized companies. Many of them are active in the segment of more efficient products and most would be able to produce systems with higher efficiency. A survey of all British producers found out that all manufacturers make condensing boilers and suppliers could meet a much higher demand for condensing boilers if they had to (Sharpe 2001). Today’s market share of condensing boilers is about 5 % in the UK. Similar judgements we got in our own survey regarding south European producers.

Producers of electric systems brought up the second hypothesis that substitutions of energy carriers might have negative effects on some companies. Generally a quick look at the markets for electric heating systems shows that the sales of conventional electric systems could be affected by the introduction of an integrated labelling scheme based on primary energy efficiency. This could be a source of trouble for those producers who are typically not active in the segment of fossil-fired boilers. But it also seems to be clear that regarding their main segment, the replacement market, substitution of an electric heating system by a fossil-fired one always needs a decision for a completely new system. This fact will prevent the market at least in the short and medium term from radical changes. Producers of electric heat pumps, however, could also be among the winners of a labelling scheme, as our interviews showed.

In contrary a separate labelling scheme and other measures only targeted at fossil systems could make them more expensive and therefore less competitive against electricity in the warm climates of southern Europe, namely Spain and Portugal and possibly also in the south of Italy and the south France. In these cases an integrated label would not have negative substitution effects on oil and gas, which separate labels, could possibly have.

The first result of market analysis in the case of substituting oil by gas is that most companies produce gas and oil-fired appliances. If the market concentrations are looked at, it is evident that the market for gas-fired appliances is more dominated by the big producers than the market for oil-fired ones. An effect could thus be a strengthening of the ongoing concentration processes in the industry. For most individual producers, however, an adaptation strategy would be possible for usually both types of devices are produced.

Biomass fired and solar heating systems[10] are currently niche-products. But in some markets as e.g. Austria, Germany and Sweden their markets are rapidly emerging. In most cases these systems are more efficient or emit less than fossil fired technologies. As technologies marking a step into the politically wanted direction of a renewable energy system some member states and a lot of communes support these technologies. Usually well-informed and environmentally aware customers purchase these technologies. Therefore they could clearly profit from a label that shows their high efficiency in terms of primary energy consumption and/or emissions.

The third hypothesis is that the some hundred small and medium producers of heating systems could have administrative problems applying for a label and also not have the capacity to follow the market trends promoted by the label. Because this group is very big and has extremely diverse structures it is not easy to really verify this hypothesis. One result of our survey was that companies with niche products and small flexible companies are expected to profit a little more from a label than others.

However some possible problems of a labelling scheme apply especially to small and medium-sized companies: The first is bureaucracy and the costs of a possible label which is more of a problem to medium-sized companies. They are active on several national markets and in this case have to compete with the market leaders. Small companies usually operate in restricted national or even regional markets and thus usually do not have the problem of different legislation and/or labels.

Another problem is that small companies doubt whether a neutral label would give them a better opportunity to prove that their products are of comparable quality. In their view the reason for this contradiction is that the main problem is not to convince installers and consumers of the quality of their products, but merely to become known as an alternative to the dominating brands.

The fourth hypothesis is that by introducing energy efficiency labels and other measures, concentration trends on the market for heating systems are promoted. The

[10] Solar heated water used for heating as well as domestic hot water.

background for this hypothesis is the fact that about three-quarters of all heating systems are supplied by the 47 leading producers. The biggest five companies supply 41 percent of the total market. The most concentrated market segment is that of the condensing boilers of which the five biggest companies sell 72 percent. Very flat concentration structures dominate on the other hand in the market for solid fuel boilers, for which the leading producers hold only one third of the market. With these market patterns, it would appear that policy measures targeting at higher shares of more efficient devices could support the still existing trends to higher market concentrations. On the other hand, it seems to be clear that actions promoting higher efficiency must not necessary be harmful to smaller companies. On the contrary, solar systems, heat pumps, biomass, etc., are niche technologies that bring market opportunities for innovative smaller companies.

Regarding this we can conclude: Our survey and interviews as well as the existing market analysis have the same result. Companies belonging to the problem groups mentioned above seem not to be very widespread or very important in industry. We also did not find evidence that possible effects will be really severe. This conclusion is strengthened by the expectation of industry that a label will have positive but quite limited effects.

The worst fears concerning the introduction of an energy efficiency labelling scheme expressed by the responding companies are:

- That a new label will produce new costs for testing, approval, placement of labels and advertising.
- That this label will be difficult to understand for consumers and will just be an additional label to national labels.
- That testing and approval will not be objective. Here companies stated especially the fear of cheap and bad testing procedures in some countries of the EU.

Advantages are being expected in:

- Energy savings and reduction in emissions.
- A Europe-wide harmonised performance scale to compare products.
- Better information for the customers.
- Better prospects for energy-efficient and innovative products.

11. Definition of possible labels

(See Appendix 8 for a full description of this task, undertaken by IED, France).

11.1. Proposal described in Appendix 8

This section discusses possible ways of implementing a labelling scheme to improve the energy efficiency of heating systems in dwellings. A four step process is considered as follows.

1. A label for new gas or oil boilers, based on laboratory efficiency tests

2. A label for new heat generators, all fuels, based on laboratory efficiency tests

3. A label for existing heating systems, of all fuels, based on an audit by an expert

4. A label for buildings, which would include the heating system, based on an audit by an expert

Options 1 and 2 would involve evaluation of the heat generator efficiency by independent laboratories. Each fuel would have its own scale, so that comparison between fuels would not be possible, (this would be clearly stated on the label). The label would have an associated information sheet, describing best practice concerning such aspects as the installation, maintenance, use, and control system. (This would allow the labelling scheme to promote energy efficiency for the whole heating system, without a complete evaluation of the whole system).

Suggested information to be included in the information sheet is as follows.

- Presence and configuration of control systems (e.g. thermostat, boiler interlock), and the quality and performance of the emitters and distribution system, and auxiliary equipment.

- Installation procedure, including the method of sizing the boiler to the heat requirements, and the adjustment of the water circulator.

- Maintenance procedures and frequency, in particular for control systems, and for safety as well as for maintaining efficiency

- User information for efficient operation, e.g. use of temperature control, and timers.

Options 3 and 4 would require an audit to evaluate the whole heating system, or building. These options would need to be developed by exploring ways in which such labelling schemes could be made consistent with current National Thermal Regulations and Building Codes in EU countries, and using or adapting existing nationally recognised calculation procedures and tools. This would allow a consistent framework for both new and existing buildings, with a 'good practice' level based on regulations, and the label encouraging better efficiencies.

However, as a first approach, such an option would be difficult to implement. The quantification of all the parameters required in the calculations could require considerable work, particularly for an old building, with a consequently high cost for implementing the label. For this reason it may be better to explore a less detailed approach which evaluates the quality of design, equipment, installation, and maintenance. In this less detailed case, additional information could still be delivered to the user about possible improvements to the heating system or building, and their respective costs. The cost of implementing such a label would, of course, depend on the level of detail.

It is clear that a labelling scheme for heating systems in dwellings involves many complex issues, including:

- how to compare different fuels, that is, whether on the basis of CO_2 emissions, costs, primary energy, or some other parameter
- how to deal with auxiliary energy (usually electricity)
- households heated to different standards, particularly the differences between room heaters and central heating
- block and district heating, and apportioning energy use, particularly where CHP is involved
- dealing with regional climatic differences
- how to treat biofuels such as wood from renewable sources

For this reason it would be advisable as a first step to develop a label for new gas and oil boilers, based on their efficiency. This is a natural development of the European Directive 92/42/EEC which defines a minimum efficiency for gas and oil boilers.

11.2. Modified proposal

A modification of steps 1 and 2 as described above was also proposed, as a result of our German partner's industry contacts, also from normal practice in Germany under the new Energieeinsparverordnung for comparing different fuels and including auxiliary electric consumption of heating systems (e.g for pumps etc.).

Many of our German partner's industry contacts express a wish for a single label on all fuels (including electric heating) based on primary energy. This could be achieved by following the principles of a norm that exists in Germany for comparing different energy sources in a comprehensive way. This norm uses average primary energy values (European, rather than German, average primary energy values would, of course, be used).

Importantly, this would enable the auxiliary electricity used by central heating systems to be included in the label. (This can be significant, especially for new houses with high insulation standards, as high as 5 to 10 % of the total primary energy used by a heating system).

Steps 1 and 2 would therefore be modified to be a single label for all fuels on a primary energy basis (using European average primary energy values). This has the important advantage that the potential benefit of switching fuel for heating a dwelling is indicated by the label. Although separate labels for each fuel is easier because it avoids some difficult issues, indicating the potential benefits of switching fuels is an important issue. As soon as adequate testing standards are available the electric consumption of the heating system could also be included in the label.

The label would have an associated information sheet as described in the first proposal, above, to ensure best practice, and to promote energy efficiency for the whole heating system. In addition the label would include information on the energy consumption of auxiliary electrical components, for example, those in gas and oil central heating systems.

11.3. Discussion with industry at partner project meeting

Industry representatives from AFECI, EHI (formerly EBA) and Marcogaz joined one of the partner project meetings, and identified a concern that a label for a boiler on its own was insufficient to ensure that the heating system would provide the performance indicated by the label. To meet this concern, a label scheme for a boiler should have an associated information sheet, describing best practice concerning such aspects as the installation, maintenance, use, and control system. This would have many benefits, including allowing a boiler labelling scheme to promote energy efficiency for the whole heating system. It is suggested that a further project would develop the detail of such a labelling scheme, and the specific information to be included as part of such a scheme.

11.4. Main issues

The main issues that have arisen from consideration of labelling are as follows.

- Whether to label separately for each fuel (for example using net or gross efficiency), or use one label for all fuels. The basis for a single label for different fuels could be primary energy since this corresponds approximately to CO_2 emissions. However, there may need to be exceptions to this, for example, where the energy source is primarily electricity generated from renewable sources.

- How to include water heating where this is heated from the same heat generator

- What items should be included on an information sheet

- How to include auxiliary energy (for fans, pumps)

- How to include standby energy (i.e. energy used 24hrs/day)

12. Conclusions and recommendations

The tasks defined for this project are wide ranging, and the scope of the work ambitious. This is appropriate given the significant energy consumption of heating systems in EU dwellings (see section 1.2), and the resulting importance of this sector in aiming to reduce associated CO_2 emissions, and also to reduce dependence on external supplies. The key findings of the study are as follows.

- In EU15, residential space heating is estimated to consume 6760 PJ (1880 TWh), water heating produced by central heating systems at least 753 PJ (209 TWh), and electricity used by central heating (pumps, fans, etc.) 148 PJ (41 TWh).

- Space heating energy consumption has risen little, if at all, over the last ten years, as growth in number of households and improving heating standards has been balanced by improvements in heating system efficiencies and insulation standards.

- A ranking of heating systems has been developed which aims to take account of level of comfort as well as heating type and efficiency. The large variety and components of heating systems have been assessed for potential as regards energy efficiency improvement, particularly central heating boilers, and their auxiliary electricity consumption.

- A stock model of heating systems in 1995 and 2005, of good quality data and consistency, has been constructed. From this, and preliminary development of estimates of the seasonal efficiency of heating systems, approximate energy trends and scenarios have been generated. These indicated that if the efficiency of new generators were to increase by 10% (consistent with 50% of new boilers being as efficient as condensing boilers) by 2005, then around 80 TWh could be saved by 2010 and 130 TWh by 2020. This equates to a carbon reduction of 19 MtC in 2010. (These should be treated as approximate estimates given the present development of the energy modelling).

- Market barriers and opportunities have been assessed, concluding that for existing buildings, the consumer is strongly influenced by the installer. Also the consumer has little information about energy efficiency when purchasing a heating system.

- Stakeholder impact analysis of interviews and other information indicated that possible effects of introducing labelling will, in general, not be severe.

- A label for new gas and oil boilers, based on their efficiency, would be a natural development of European Directive 92/42/EC which defines a minimum efficiency. Alternatively a single label for all energy sources including electricity could be developed, based on a norm that already exists in Germany.

- There was concern that a boiler label on its own may be insufficient to ensure efficient operation of the heating system. Any scheme should therefore include an information sheet describing best practice for such aspects as installation, maintenance, use, and control systems.

We believe that the information in this report will be useful in improving understanding of energy use of this sector, and for informing the debate about how to control it, particularly in relation to measures such as labelling. The chapters in this report covered a wide range of subjects, including both discussions and information in text, and analytical information in numbers.

With a project of this scope it is inevitable that there are a number of issues which we would have liked to have worked on, but were unable to include within the budget and resources. We believe it would be valuable to develop the work described in this report, particularly in the following areas.

- The linear stock model of heating systems that has been developed in this project is a good first approximation of trends, and is a consistent data set of high quality. Using further data that we now know is available, it would now be possible to develop a more detailed dynamic model, and generate scenarios, that would take account of non-linear changes and smaller, but significant, sectors such as biofuels, heat pumps, electric floor heating.

- The energy estimates resulting from the heating system stock model and scenarios do not include energy consumption for hot water, which was the subject of another SAVE study. However, many central heating systems provide hot water as well as space heating (see estimates in section 1.2). As a result of this, central heating system efficiency improvements will give water heating energy savings in addition to space heating energy savings. It would be possible to include this, to give more comprehensive estimates, in the energy, carbon and cost saving calculations described in 'Heating system stock model' and 'Scenario analysis' in this report. Consideration should also be given to the electrical energy consumption of central heating systems.

- The heating system stock model used only approximate estimates of seasonal efficiency. These could now be significantly improved using the methods described in the section 'Seasonal efficiencies of heating systems'. In addition the energy consumption estimates in the model should be disaggregated by country and by heating system. This would allow the model to be checked against member country and EU energy statistics, improving the consistency of the model, and developing it into a valuable heating energy use stock model. This would be a powerful tool for estimating future trends, and examining the effects of improving different aspects and sectors of heating systems.

- Labelling of heating systems involves many complex issues, due to the variety of types of heating, and the various energy sources that can be used. These issues have been discussed in detail in our meetings, one of which included industry representatives. This has been described in this report, with suggestions for future developments, including the development of a label for boilers with an associated information sheet which describes best practice for other parts of the heating system, and thus promotes energy efficiency for the whole heating system.

As a result, we recommend the following future work.

1. Development of the heating system stock model to a dynamic model, that includes the effect of heating improvements on hot water energy savings, incorporates improved estimates of seasonal efficiency, and improved methods for dealing with electricity use and its generation. This would significantly improve the accuracy and robustness of the model and scenarios generated from it, so that it would be a valuable tool for policy support.

2. Consideration of a revision to the current minimum standard for the efficiency of heat generators.

3. Development of the detail of a labelling scheme for heating systems, in particular for central heating boilers/heat generators, and the specific information that should be associated with it, such 'best practice' information about the electrical consumption, controls, maintenance, and installation of central heating systems.