SAVE II ACTION
Contract no. XVII/4.1031/ Z/99/283
Labelling and other measures for heating systems in dwellings

Appendix 4

VHK Stock model of residential heating systems

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The contents of this appendix, and revisions resulting from comments by the eight project partners, are the responsibility of the task authors.

Contents

1 Introduction

Any model can only be as good as its input data. In this context it is somewhat disappointing that despite large research projects in the area of energy consumption of space heating, there are still not enough input data to build a truly dynamic stock model of any of the components of the residential space heating system.

For most of the components mentioned in the technical analysis (Task 2.2), such as the Overall Demand Factor (comfort level), efficiency of emitters and controls, etc. we can only give a rough estimate at EU level, based on a calibration against totals and the study of anecdotal evidence.

Only for heat generators (CH boilers and local heaters) , the data that have been retrieved in Task 1 of this SAVE project give a rough indication of the stock and age distribution of heat generators in the EU mid 1990's (say 1995). This is a start, but it is far from sufficient to construct a time series.

In order to be able to build at least a static, linear stock model for the heat generator part, VHK had to extend the stock 1995 data with sales data from industry sources for at least two years: 1995 and 2005. A valuable contribution was made by *Consult GB (CGB)* , the most important market research agency in the CH-sector, that reviewed the original VHK data. *BRE* contributed regarding UK data, derived from its Boiler Model. Further contributions in data-review came from the Italian task-leader for Task 1, *Energie*, and the German *Wuppertal Institute*. The industry association *AFECI* contributed with data for the Belgian gas boiler market. Data were reviewed also by the Irish Energy Centre (IRE) and Omvarden(S).

With the contributions of these contractors it was possible to build a high-quality data-set as a basis for a linear stock model. This model thus allows at least the study of the energy saving of different efficiency levels for heat generators in time. This is done both on EU and Member State level.

The linear stock model, as opposed to dynamic stock models that VHK has developed for some white-goods sector, has limitations when studying the effects of fuel-switch and early replacement. Also the effects of unbalanced age distributions of certain types of heat generators in 1995 cannot be properly validated. Nevertheless, we believe that in this report we have made progress in the systematic analysis of the complex phenomenon of space heating and were able to provide a useful instrument for EU Energy Policy Support in this area.

2 Time series 1960-2020 of the average EU heating system

2.1 General

Following the methodology of the Technical Analysis (Task 2.2) the time series 1960-2020 for the residential EU Heating System model consists of the following basic parameters:

- Heat load of the house (at 100% system efficiency and ODF 100%)
- Overall Demand Factor 'ODF' (derived from both consumer behaviour and the technical possibilities of the heating system)
- Heat generator efficiency (seasonal efficiency, net calorific value)
- Emitter and distribution efficiency
- Efficiency of temperature control
- Efficiency of indirect energy sources (mainly conversion to electricity for electric space heating)

Especially regarding emitters, distribution and controls the term 'efficiency' is not an absolute physical parameter, but it is a factor measured against an ideal situation.

As mentioned in the previous chapter, only for the heat generator a linear stock model was constructed, all the other parameters were derived from desk research and calibrated against totals.

2.2 Heat load of the house

In 1999 the European Commission published its Shared Analysis[1], defining CO2 emission levels for all economic activities in some reference years (1990, 1995, 2010). Extending on this, the European Commission started its European Climate Change Programme in the summer of 2000, establishing Working Groups for many areas. For the energy demand in the building sector, Working Group 3, stakeholders from the sector were brought together to discuss the relative importance of the building sector (i.e. foremost space heating) for CO2 emissions. Many stakeholders brought forward documents and study results to contribute.
The figures below are based on the best consensus in the group and are now also adopted here as a basis for the specific heat load per average EU dwelling. Please note that this is the heat load at 100% heating systems efficiency and an Overall Demand Factor also of 100%, without the use of free energy (heat pumps, solar).[2]

Table 1 gives the figures in MtCO2 per dwelling and then –through the use of the average IPPC factors for the EU—converts these values into kWh values of energy demand. As an extra check, the kWh figures were then compared to data from literature sources.

[1] European Commission, DG Energy, '*Economic Foundations for Energy Policy, The Shared Analysis Project'*, Energy in Europe-special issue, 1999 (ISBN 92-828-7529-6)
[2] Definition of heat load: Total energy loss of a dwelling assuming a constant inside temperature of (at least) 21ºC for all rooms all year through.

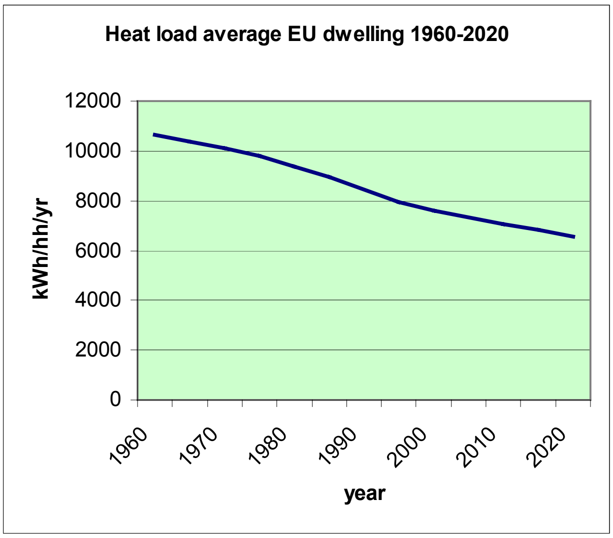


Table 1[3]

	tCO_2/hh/yr	kWh/hh/yr
1960	2.50	10638
1965	2.44	10383
1970	2.38	10128
1975	2.30	9787
1980	2.20	9362
1985	2.10	8936
1990	1.99	8468
1995	1.87	7957
2000	1.78	7590
2005	1.72	7339
2010	1.66	7065
2015	1.60	6815
2020	1.54	6564

The table 1 shows that there has been an improvement of approx. 30% of the average energy efficiency of the building shell (transmission and ventilation losses) over the 1960-2000 period, which is in line with historical trend lines found in Sweden and Austria. This is in spite of the increase in the size of the average house since 1960.

Estimated stock values range from 10,638 kWh/dwelling/yr. in 1960 to 6,564 kWh/dwelling/yr. in 2020. Despite this impressive improvement, we are still far from the optimum: New low-energy houses in moderate EU climate zones already reach values of 2,000 to 2,500 kWh/dwelling/yr.[4]

2.3 Overall Demand Factor (ODF)

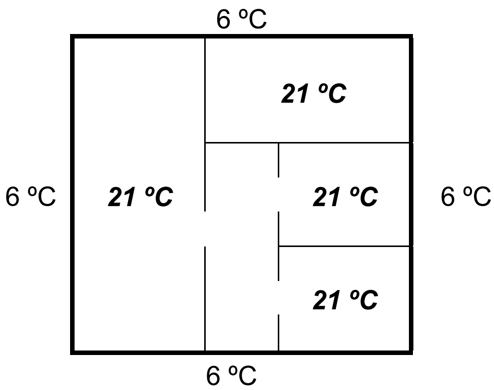
In task 2.2. the so-called 'Overall Demand Factor' (ODF) is defined in 5 discrete classes, ranging from optimal 'comfort' with low temperature floor/wall heating in all rooms down to low 'comfort' where there is just a local heater in the living room.
It should be remembered that the ODF is a new phenomenon in the description of space heating energy demand. It describes the extra energy demand that comes from an improved technical installation (e.g. the switch from a single local heater to a CH system with radiators in every room) and the consumer behaviour that follows these technical improvements. This consumer behaviour entails that the temperature of e.g. bedrooms rises and that the inhabitants tend to undertake more activities in all the rooms of the house rather than just in the kitchen and living room. And finally, when the inhabitants leave the rooms, they do not turn the radiators off. When trying

[3] Conversion: in tCO_2/hh;
avg. 17.8 tC/TJ ->65.2 tCO2 /0.277GWh--> 0.235 kgCO2 /kWh
gas 49%(net cal.) 15.3 tC/TJ, gas oil 25%->20.2, coal 8%->26-27.
11% is electric space at 0.5 kgCO2/kWh -> ***total avg. 0.265 kgCO2/kWh***
Please note that emission values are given for dry gas (i.e. lower heating value=net cal. value)
[4] Based on roughly 100-120 m2 per dwelling. Values exclude free energy and are for optimal comfort level (emitters in all rooms). Compare NL: EPC of 0.6 to 0.8. Compare AU: 26 kWh/m2/yr (source: NiedrigEnergieHäuser, OPET, Energie Tirol, 2000).

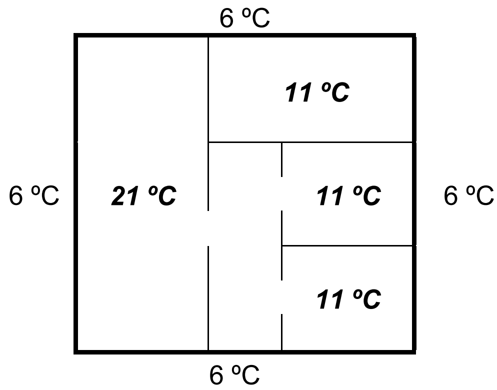
to quantify this phenomenon, which can also be seen as the ***'rebound-effect'*** of improving the heating system, we are definitely treading new ground.

For the purpose of the time series it was chosen to convert the 5 discrete classes into indices. These indices are on one hand based on the average indoor temperature (assumed avg. optimal 21 ºC) versus the average outdoor temperature (assumed avg. 6 ºC), related to the volume of the dwelling (see Fig. 1).

Optimal comfort (fig.1a)



Minimal comfort (fig. 1b)

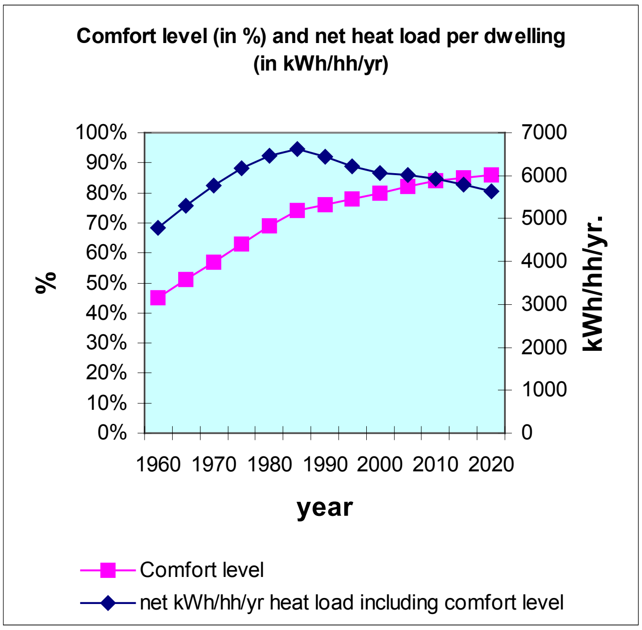


Another way to calibrate the ODF quantitatively is looking at specific phenomena in the past, when local heaters were replaced by central heating in the 1960's and 70's, or the present, e.g. when local heaters are replaced by CH heating systems in the UK ('fuel poor') and Germany (Eastern Germany). Despite the fact that the efficiency of the heat generators improved considerably (e.g. from 60 to 80%), the energy consumption of the houses increased.[5]

Based on the above the following graph could be drawn up, showing not only the tentative index of the comfort level, ranging from 45% in 1960 to 86% in 2020, but also how the heat load of the building shell is actually affected by the comfort level. Heating discomfort from relatively primitive local heater arrangements thus 'saves' considerable amounts of energy.

[5] Only with the help of better controls, thermostatic valves, building insulation, etc. the energy consumption was brought to decrease again. But the efficiency improvement of the CH system alone was not enough to offset the encreased consumption through the increase in heating comfort in all rooms.

Table 2.



	ODF	net kWh/hh/yr heat load including ODF
1960	45%	4787
1965	51%	5295
1970	57%	5773
1975	63%	6166
1980	69%	6460
1985	74%	6613
1990	76%	6436
1995	78%	6207
2000	80%	6072
2005	82%	6018
2010	84%	5935
2015	85%	5792
2020	86%	5645

2.4 Heat generator efficiency

The stock model of the heat generator efficiency will be described extensively in the next chapter. Here we will merely present the EU-totals for 1995 and beyond from the stock model (see Table 3).

Generator efficiencies range from 45% in 1960 (typically coal stoves) to around 80% (mostly CH systems) at present.

The definition of heat generator efficiency in this report is **not** the ***nominal efficiency*** as measured according to national or EU standards and published in manufacturer's brochures, but the ***seasonal efficiency*** which takes into account the real-life energy use at part load situations throughout the year. In this report we will assume, pending input from the BRE subtask on the subject, that the seasonal efficiency is around 10% lower than the nominal efficiency.

Furthermore, the efficiency relates to the ***Net Calorific Value*** of the fuel (also called 'lower heating value' or –for gaseous fuels—the 'dry gas' value).[6]
And finally, it has to be kept in mind that we are talking about the efficiency of the main heating system. Auxiliary heaters, often single electric radiators, are not taken into account.

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[6] **Calorific value:** The measure of the heating content of a fuel, usually expressed as the available heat resulting from the complete combustion of the fuel. If the term gross calorific value is used this relates to the heat of condensation of the water vapour in a hydrogen fuel being included. If it is excluded the calorific value is called net.

For instance, the Gross Calorific Value ('upper heating value') of NL natural gas is 35,2 MJ/m³, whereas the Net Calorific Value ('lower heating value') is 31.8 MJ/m³ (conversion factor 0.902). If the efficiency on Net Calorific Value is e.g. 100%, then the efficiency on Gross Calorific value is lower, namely 90.2% in the case of Dutch natural gas.

The terminology in this report may differ from the one adopted elsewhere in this SAVE study. BRE proposes a distinction between room heating, dwelling heating, block heating and district heating. We use 'local heating', 'individual central heating', 'collective central heating' and 'district heating'. For electric heating systems no distinction between local and central heating is made, because the different definitions per country may cause confusion.

2.5 Efficiency of emitters and distribution

These efficiency values relate to heat losses of piping in not-inhabited areas of the house plus excessive local transmission losses through the building fabric at places where emitters are positioned. Distribution and emitter losses are estimated to be relatively minor (<10%), based on the estimated savings from insulating pipes and local insulation measures (e.g. aluminium foil and insulation behind the radiator) (see table 3)

2.6 Efficiency of control.

These efficiency values relate to heating losses through heating of rooms at times when there are no people and heating losses through temperature overshoot. Based on the experience with houses using sophisticated control systems as compared to houses with no or only very simple control systems, the saving potential of this option is considered to be quite substantial (see Table 3)

2.7 Indirect energy generation efficiency

This relates to efficiency in the ***electric power generation*** multiplied with the part of the total space heating requirement in the EU through electric heating systems. Average power generation efficiency in the 1960's is estimated to be below 30%, increasing to a present level of 45% overall (Net Calorific Value[7]). For the stock model the use of ***average*** efficiency value's for power generation and distribution is found most adequate. For more detailed analysis in specific countries/situations the ***marginal*** efficiency, which at present is around 54 %, might be more appropriate. But no such analysis is undertaken in this report.

The use of electric heating, in the 1960's mainly through storage heaters, occurred already in the 1960's as a means to utilize surplus power generation at night, but became very popular in the 1970's e.g. linked to the rise of nuclear energy. Present level of electric heating is around 13-14%. At present, electric heating systems are diminishing in cold and moderate climate zones[8], whereas they are becoming popular in warm climate zones in Southern Europe as a cheap way to generate heat in a very short heating season and/or as the 'the other side' of reversible air-conditioners.
In Scandinavia, where electrical heating traditionally holds a strong position, they are replaced by district heating or (still electrical) heat pumps. Overall the trend in ownership of electrical systems is declining

[7] The conversion between efficiency on gross and net calorific value depends on the fuel mix per country and can range from 0.9 (methane) to 0.948 (heavy fuel oil). In the Netherlands the conversion factor is 0.923.
[8] Except perhaps in electrical floor heating systems when renovating bathrooms and kitchens in existing stock.

In principle we also have to calculate with the ***efficiency of heat delivery for district heating***. This value is often based on political rather than technical arguments. As in most building performance codes, this efficiency is set around 100%.

2.8 Heating system total efficiency

Table 3 below shows the total heating system efficiency built from the efficiency types described in the previous paragraphs. The table distinguishes between system efficiency with and without considering the ODF ('comfort level').

Table 3

	heating system efficiency incl. ODF	ODF	**heating system efficiency excl. ODF**	generator efficiency	emitter efficiency	control efficiency	indirect energy conversion (e.g. power generation)
1960	**58%**	45%	**26%**	45%	92%	69%	91%
1965	**57%**	51%	**29%**	49%	92%	71%	91%
1970	**55%**	57%	**31%**	53%	92%	72%	89%
1975	**52%**	63%	**33%**	57%	92%	73%	86%
1980	**54%**	69%	**37%**	62%	93%	74%	87%
1985	**56%**	74%	**42%**	67%	94%	76%	87%
1990	**63%**	76%	**48%**	73%	95%	78%	88%
1995	**69%**	78%	**53%**	79%	95%	80%	89%
2000	**70%**	80%	**56%**	81%	96%	81%	89%
2005	**72%**	82%	**59%**	83%	96%	82%	90%
2010	**73%**	84%	**61%**	85%	96%	83%	90%
2015	**74%**	85%	**63%**	87%	96%	84%	90%
2020	**76%**	86%	**65%**	89%	96%	85%	90%

2.9 EU total energy consumption of space heating systems (BaU)

Using the heating system efficiency corrected for the ODF in table 3, the gross heat load of the average EU house in table 1 and the total number of dwellings[9] we can now estimate the total energy consumption per dwelling and the total energy consumption for the EU.

For the latter we arrive at around 1.6-1.7 PWh in 1995. At the target levels set for the various heating system components (see also next chapter) this is estimated to arrive at a level of 1.4 PWh in 2020. This is an energy saving of around 12%. This may seem disappointing, given that the heating system efficiency increases by around

[9] Total number of dwellings is set equal to the total number of households according to Eurostat. As far as the total number of houses is concerned there are two 'schools of thought': Most government statistics only count the first house and arrive at less houses than there are households, because part of the households live in larger communities (share dwelling, live in homes). Building constructors' statistics like Euroconstruct also count the second homes. As 8% of the EU population claims to have a second home (sometimes shared) Euroconstruct arrives at more houses than households. These second homes also use energy, but of course to a much lesser degree because they are much less inhabited. As a compromise between the two approaches we therefore propose to use the number of households as a yardstick for the number of dwellings in terms of space heating requirement.

25% (from 53% to 65% in table 3), but at the same time it is clear that roughly half of the saving effort has been offset by the increased level of heating comfort.

In the relevant first Kyoto period ahead, between 2000 and 2010, it is foreseen in this Business-as-Usual scenario that the energy efficiency (including comfort) increases from 70% to around 74%.

Fig. 2 shows the total EU energy consumption and the energy consumption per average house. Please note that auxiliary electricity consumption for pump, fan and boiler control is not included in these calculations.

Table 4

	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**

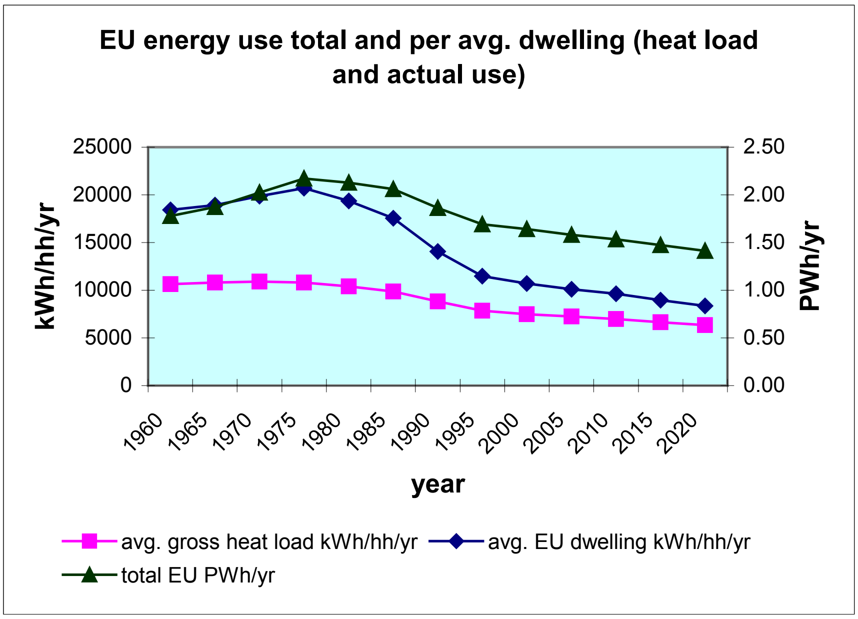

fig. 2

3 Stock model heat generators

3.1 Parameters

This chapter briefly explains the stock model for heat generators (CH boilers, district heating and local heaters). Tables for this stock model can be found in the annex.

The linear stock model is based on inputs for

- ***stock data 1995***
- ***sales data 1995*** and
- ***sales data 2005***

The main output of the model is the

- ***stock data 2005***

Originally, VHK presented stock and sales data for 1995 and 2005 from figures in the Task 1 report and their own industrial ***sources***. A very valuable contribution was made by *Consult GB (CGB)* , the most important market research agency in the CH-sector, that reviewed the original VHK data. *BRE* contributed regarding UK data, derived from its Boiler Model. Further contributions in data-review came from the Italian task-leader for Task 1, *Energie*, and the German *Wuppertal Institute*. The industry association *AFECI* contributed with data for the Belgian gas boiler market. Figures were read and approved by the Irish Energy Centre (IRE), CED (F) and Omvarden (S).

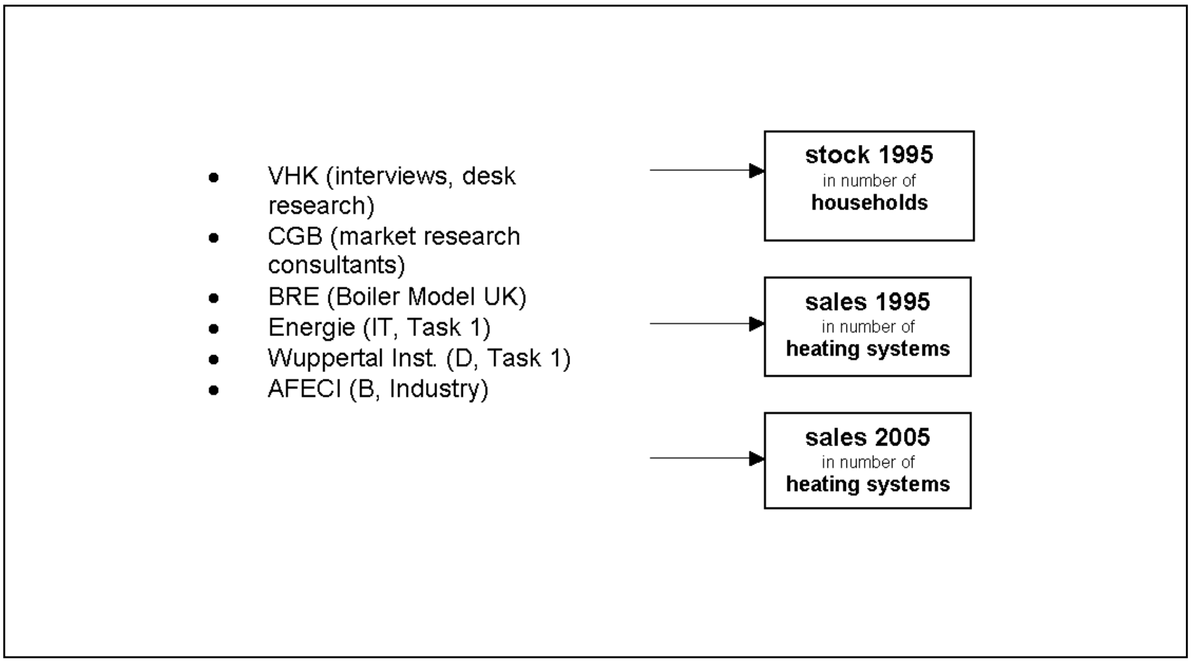

Fig. 3. Data sources and base data for model [Tables A1 to A3]

The heat generators were subdivided by type:

- ***local heating systems (room heating)***
- ***individual central heating (CH) systems (dwelling heating)***
- ***collective CH systems (block heating) and***
- ***district heating***

and by the fuel type used:

- ***gas (incl. LPG)***
- ***oil***
- ***solid (wood, coal, peat, etc.)***
- ***district heat***
- ***electricity (no distinction between local heaters and centrally controlled systems)***
- ***multi-fuel (e.g. boilers used with both oil and electricity)***
- ***miscellaneous (usually referring to heat pumps, heat storage, etc.)***

The categories 'multi-fuel' and 'miscellaneous' were quite small (1% of total stock each) and therefore no distinction was made between local and central heating systems. With electric heating systems the definition of 'central' or 'local' heating depends per country. In order not to create confusion, also here no such distinction was made.

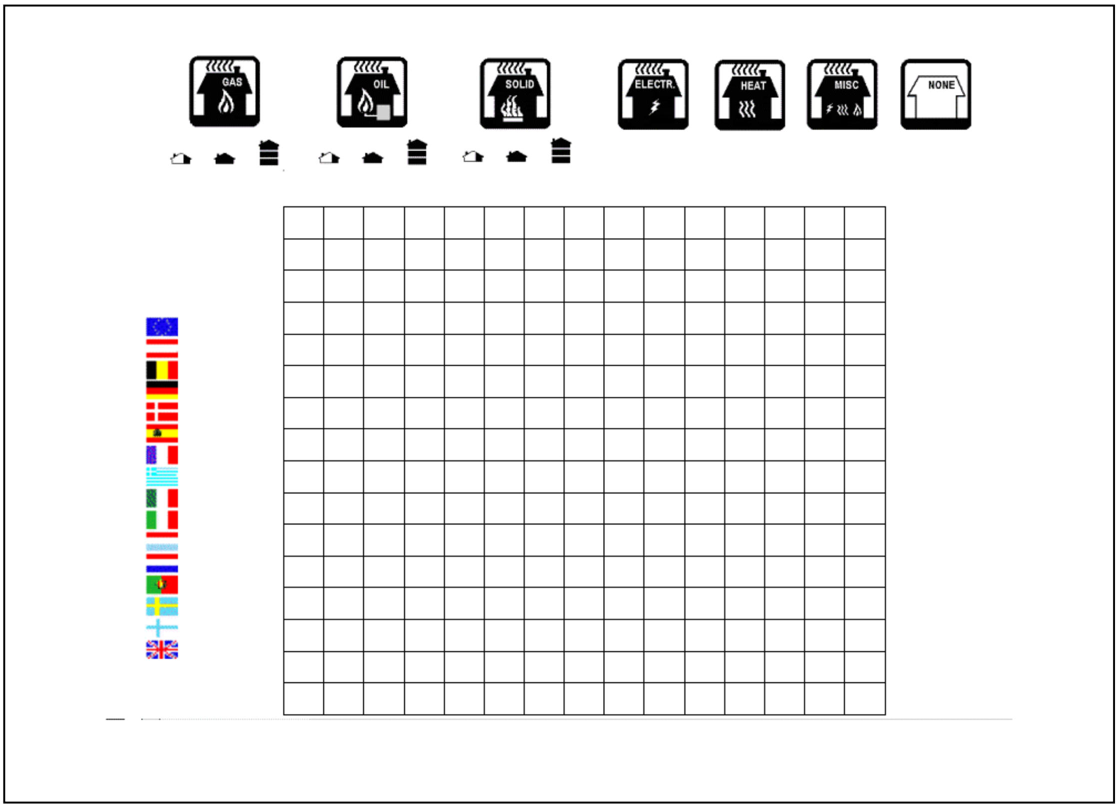

Fig. 4. Basic format of data tables: 15 Member States + EU total (rows) and 16 segments of heating systems market by fuel and type (columns): '*gas'* (incl.. LPG), *'oil', 'solid'* (incl. coal, browncoal, peat, wood, other biomass) all subdivided by '*local heating* '(room heating), '*individual central heating'* and '*collective central heating*'. Furthermore --not subdivided—'*electric', 'district heating', 'multi-fuel', 'miscellaneous* '(incl.. heat pumps) and '*no'* heating system.

The raw data on the type of heating system and fuel came in two forms:

- ***per household or dwelling (usually from statistical sources) and***
- ***per unit/heating system installed or sold (from industrial market research).***

The former usually related to stock data and the latter to sales data. The conversion between these two proved to be quite difficult, as it required an estimate of the

- ***share of individual versus collective heating systems***
- ***average number of dwellings/households served by the average collective heating system***

Please note, that there is a difference between stock 1995 and the sales for these parameters. Over the last two decades central heating has increased. The relative share of collective heating systems within that segment has decreased in most Member States, as has the number of households per collective heating system. The 'multiplier' in fig. 5 takes this into account.

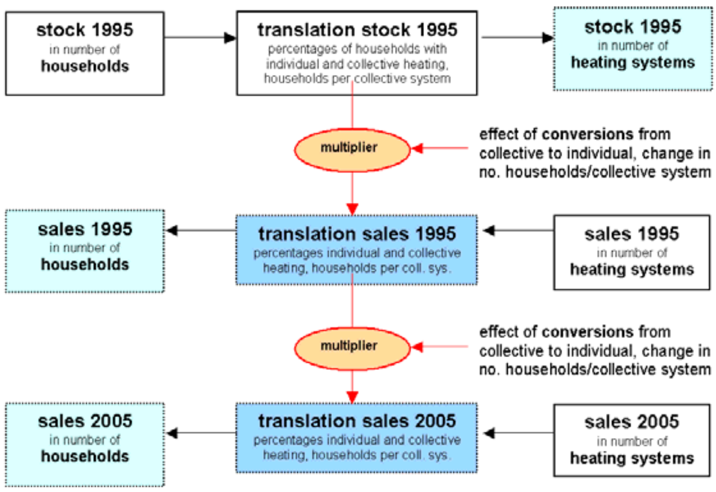

Fig. 5. Initial completion of data set by translating ownership data in number of households into data in number of heating systems (for stock data) and vice versa (for sales data). Translation tables B1 to B4 in Annex I. Derived stock and sales in tables C1 to C3 and J1.

Comparison between stock data 1995 and sales data 1995 gives an estimate of the typical average ***1995 product life*** of the heat generator per country. The values found –around 17 years average product life for the whole of EU heating systems stock—are in line with values in literature. For ***2005 product life*** was slightly altered. There is an ongoing trends, notably the replacement of floorstanding boilers with a product life of around 20-25 years by wall-hung boilers with a product life closer to 15 years which led to minor adjustments. Furthermore, there is the influence of legislation, notably in Germany, where the Energie-Einsparverordnung (EnEV) is expected to temporarily increase replacements; this is taken into account by shortening product life.

Note, that ownership rates in Spain, Portugal, Greece and Italy are not 100% and therefore the product life is based on average values.

From data on the ***stock 1995*** and the ***product life 1995*** the ***replacements 1995*** were calculated. That is to say, these are –per type—the replacements 1995 that should take place to keep the composition and size of the stock unaltered. But of course things change.

To study this change, the ***replacements 1995*** were then subtracted from the total ***sales 1995***, resulting from market research, to yield the 'apparent non-replacement sales 1995'.
These apparent non-replacement sales can be negative when particular types of fuels (e.g. coal) or heating systems(e.g. local heaters) are phasing out (no longer replaced).
The model identifies these 'negative apparent non-replacement sales 1995' per type and defines them as the sectors where fuel switch (or switch from local to CH systems) is taking place. The 'negative apparent non-replacement sales 1995' now have to be filled in with the new types of heating systems that are replacing the ones phasing out. For this, the model identifies the 'positive apparent non-replacement sales' and fills in the total 'negative apparent non-replacement sales 1995' proportionally to these.

To complete the picture, data on newly constructed houses, that are the basis for the ***new sales 1995*** and the ***new sales 2005*** were taken from Eurostat.[10]

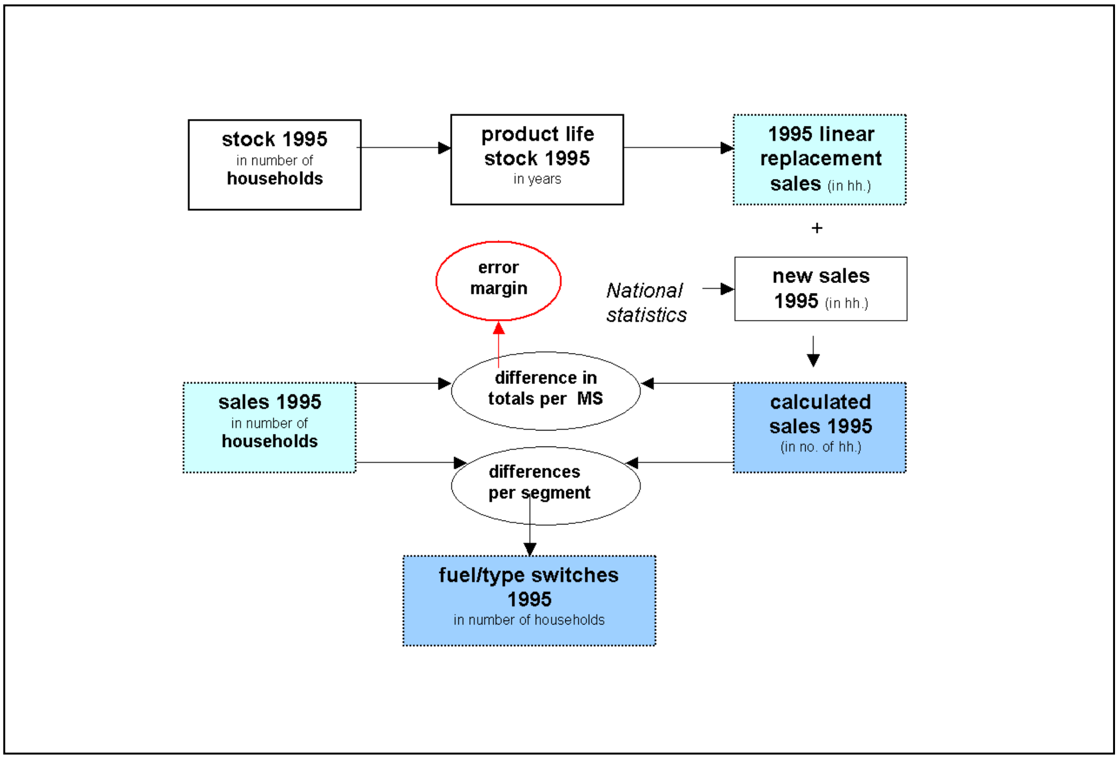

Fig. 6. Calculation of linear replacement sales (per segment and Member State), minimum fuel/type switches and the maximum error margin. (diagram is an illustration, for actual calculation sequence see text)
Product life in tables D1 and D2. Linear Replacements in E1 and E2. Fuel/type switches in F1 and F2. New sales in tables G1 and G2. Error tables are H1 and H2 (Annex I).

[10] Eurostat Annuario '97.

Please note, that the calculated fuel switches are a minimum value, derived from a calculation with linear replacements. In reality, taking into account dynamic stock built-up, the share of fuel switch replacements versus real replacements could be higher.

Another issue that is illustrated in figure 4, is the maximum error margin that comes from comparing the 1995 sales data per Member State as supplied by the data sources with the 1995 sales data that could be calculated. It goes without saying, that the multipliers (see 'translation' tables in fig. 3) and product-life estimates were used to calibrate the calculated sales in order to minimize the ***error margin*** (maximum error smaller than 10% on country totals and smaller than 15% for individual segments). The largest positive deviations in outcome occurred in countries (i.e. Italy around 200,000 per year and the Netherlands up to 50-80,000 per year) where there was a significant conversion in the last decade from collective to individual heating systems for existing dwellings. This gives some idea where at least part of the error may come from.

In a similar manner as for 1995, also the replacement sales, fuel switches and new sales for the period 1995-2005 could be identified, leading up to a the ***stock 2005*** data.

The original data set of ***sales 2005*** played a key role in this, as it indicated the share of fuel switching taking place. However, once the stock 2005 data were calculated, there proved to be a high discrepancy between the total calculated stock 2005 data and the total number of households per country that are foreseen by ***national statistics*** for the year 2005. The former were much higher than the latter, indicating that sales predictions for 2005 were far too optimistic in absolute numbers. Obviously the industry is underestimating the decline in newly built dwellings that is to be expected in the coming years.

Table 6
Number of households EU
(source: National statistics, Eurostat 1997)

	2005	2000	2005	2010
A	3,1	3,1	3,2	3,2
B	4,0	4,2	4,2	4,3
D	36,2	37,0	36,8	36,6
DK	2,5	2,7	2,7	2,8
E	12,0	12,4	12,9	13,5
F	22,8	23,4	24,3	25,2
G	3,4	3,5	3,5	3,6
I	20,4	21,2	21,8	22,5
IRL	1,1	1,2	1,3	1,3
L	0,2	0,2	0,2	0,2
NL	6,4	6,8	7,0	7,1
P	3,3	3,4	3,4	3,5
S	4,0	4,1	4,2	4,3
FIN	2,1	2,2	2,3	2,3
UK	23,8	25,7	26,1	26,6
EU15	**145,7**	**151,6**	**154,6**	**157,6**

In the model, the application of a ***correction factor*** (multiplier) of around 75% was used for 'sales 2005' in most countries in order to keep the maximum ***error margin*** in a range lower than 10%. This correction factor may be pessimistic, as e.g. it is not certain how various governments are going to deal with the crises in their national construction industry, but nonetheless the model can only deal with outcomes that are consistent with the bigger picture of the EU population almost coming to a standstill and the number of EU households (showing a declining number of persons per household) rising only very slightly.

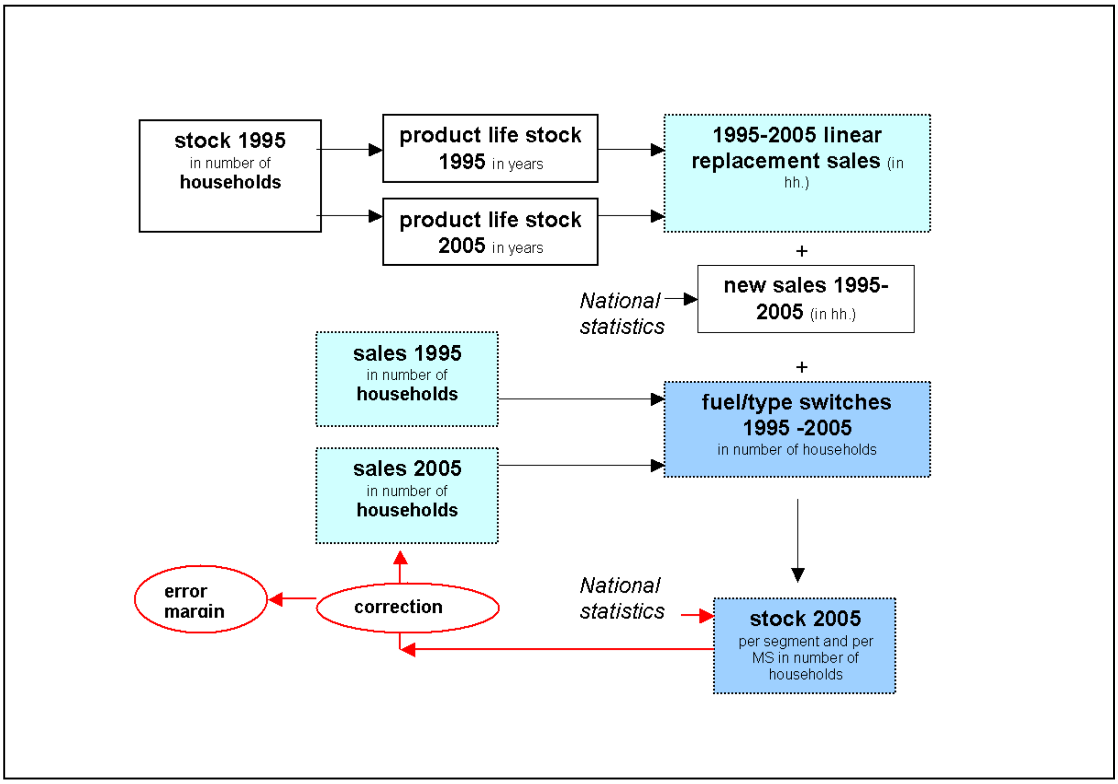

Fig. 7. Illustration of calculation of the built-up of stock 2005.
Annex I: Corrected sales 2005 in table A4. Stock 2005 ownership figures in tables I1 and J1 (Annex I)

The ***efficiency values for the stock 1995*** of various heat generators were estimated on the basis of the outcome of task 1. European averages of 1995-stock efficiency were compared on the basis of ownership rates and on the basis of estimated (through degree days[11]) share in total energy consumption. BRE contributed with data on the share of condensing boilers. (see table 5) which served to estimate efficiencies of gas- and oil-boilers for stock 1995, sales 1995 and sales 2005. ***Efficiency 2005*** values were estimated on the basis of ongoing trends. Please note, that the values are estimates of seasonal efficiency (Net Calorific Value) to be validated in another task.

[11] Regarding the definition of degree days there seems to be no consensus on what is to be taken as the EU average outdoor and indoor temperatures. In this report we assumed the degree days as defined in the MURE model which uses an indoor temperature of 20ºC and no heating treshold, but a table composed by BRE shows some different results coming from the Eurostat 'Energy Monthly' statistics, that use an indoor temperature of 18 ºC , a temperature threshold of 15ºC and meteorological data over a long time period.

Table 5 (source: BRE on the basis of CGB data)

	Gas condensing as % of Gas CH Sales 1995	Stock 1995	Sales 2005
A	34%	24%	71%
B	0,0%	0,0%	17%
D	15%	3,6%	74%
DK	9,5%	1,3%	58%
E	0,0%	0,0%	1,8%
F	0,5%	2,1%	1,4%
G			
I	0,1%	0,0%	5,6%
IRE	0,1%	0,0%	2,7%
L			
NL	47%	17%	100%
P			
S	0,7%	1,4%	2,1%
FIN			
UK	2,0%	0,4%	19%

Table 6. Efficiency values used in model (stock '05 is output)

	CH Gas	**Local Gas**	***Total Gas***	**CH Oil**	**Local Oil**	***Total Oil***	**DH**	**CH Solid**	**Local Solid**	***Total Solid***	**Total Electr.**	**Multi Fuel CH**	**Misc.**	**Non %**	**Avg. EU**
stock '95	80%	65%	*78%*	74%	63%	*73%*	100%	60%	60%	*60%*	100%	70%	78%		**78,8%**
sales '95	85%	70%	*84%*	79%	68%	*78%*	100%	65%	65%	*65%*	100%	75%	82%		**83,8%**
sales '05	90%	75%	*89%*	84%	73%	*83%*	100%	70%	70%	*70%*	100%	80%	87%		**88,7%**
stock '05	86%	69%	*85%*	79%	68%	*78%*	100%	64%	64%	*64%*	100%	75%	82%		**84,4%**

3.2 Main Results EU

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.[12]

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 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).

[12] 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.

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.[13]

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, which serve as an input into subtask 3.2, give an indication of the inertia of the market.(tables in ***Annex I***)

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***.

3.3 Recommendations for further study

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 to the Commission to develop a more detailed and dynamic stock model that will be more accurate and more adequate for energy policy support.

[13] 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 e.g. natural gas. Overall, the seasonable efficiency at Net Calorific Value should be comparable to the nominal efficiency at Gross Calorific Value.