SAVE 1998

Area: Rational use of energy in equipment

Study on water heating - labelling / standards

The foundation for the policy to be followed in creating an energy use information system for domestic hot water appliances

(SAVE program contract no. XVII/4.101/Z/98-092)

FINAL report

September 2001

Project coordinator: NOVEM (The Netherlands)

Participants: EVA (Austria), GASTEC (The Netherlands), DGC (Denmark), TU Graz (Austria), Armines (France), University of Athens (Greece), ECI (United Kingdom), BRECSU (United Kingdom), TNO-MEP (The Netherlands), Van Holsteijn en Kemna (The Netherlands), AFECI (Belgium)

Management Summary

Within the EU a considerable energy saving potential exist in the (primary) energy used for the production of domestic sanitary hot water. In order to utilize this potential an effective information system on energy use of these appliances is desirable. This study focussed on the main elements for such a system:

- tapping patterns, reflecting hot water use in practice
- test methods delivering realistic and reliable efficiency figures
- an evaluation scheme to identify the most efficient appliances

Regarding hot water demand in practice, little data was available. From the available field data a broad distribution emerges in both the consumption volume per person per day (average of 36 liter of water of 60 ^{o}C corresponding with an energy content of 7.5 MJ, with extremes from 20 liter to 63 liter) and in number of tappings per person per day (average of 8.3 taps, with extremes from 6 to 15 taps).

The hot water appliance market in Europe is dominated by combi boilers (instanteneous and storage) and electric storage water heaters. However, the sale of electric storage water heaters is declining since 1991 and this trend is projected to continue. Combi boilers are increasing share and are now the largest ‘sellers’ in the EU. This trend is expected to continue, especially with the increasing gas distribution network. Gas stand-alone water heaters are still a small part of the market, and are set to decline, whilst instantaneous gas water heaters are declining in sales rapidly, as combi systems become prevalent.

The technical-economical savings potential varies from 20 % for gas instanteneous water heaters to 34 % for gas storage water heaters. The technical potential alone is around 50 % for all types of water heaters considered.

During the study the prEN13203 standard for measuring performance aspects (including efficiency) of gas appliances was (further) developed. This standard contains several tapping patterns varying in energy content from 9 MJ per day to 88 MJ per day, and in number of tappings from 15 to 30.
For all kind of appliances it appears that with an increasing energy consumption the efficiency also increases. This means that if appliances are tested with tapping patterns with a higher energy content than the energy consumption in practice, the measured efficiency does not correspond to the efficiency in practice. For a correct information system it is therefore important to measure the efficiency with the tapping pattern the appliance is designed for.

In this study a transition model was developed which allows for calculation of the efficiency of an appliance using a limited number of appliance parameters.

The following is recommended to develop and implement labelling and other information systems for domestic hot water appliances:

- Because in practice a large variation in tapping patterns exists and different appliances are designed for different use, an EU labelling system and other information systems should use a range of tapping patterns. The efficiency of the appliance (and performance aspects) has to be determined at least at the tapping pattern that reflects (most) the function class the appliance is designed for.

- It is recommended to discuss with market parties whether to use one general rating scale or different rating scales per function class.

- It is recommended to determine the appliance efficiency to be used for the EU energy label by means of measuring the efficiency for a tapping pattern. In addition a limited number of appliance parameters are to be measured to be used in a model to calculate efficiencies for other tapping

patterns then measured. It is recommended to develop and define the calculation model on the EU-level.

- To cover a wide range of appliances with respect to the used energy source, a labelling system should use efficiency figures based on primary energy use. Therefore, such a system should include an electricity generation efficiency. Preferably this is defined on the EU-level, but since differences between countries exist, it can also be done at the level of (groups of) countries.
  The tapping patterns used for the labelling system should be the same for appliances designed for the same use, regardless the energy source of the appliance.

- The prEN13203 appears to be a suitable measurement method regarding the tapping patterns to measure appliance efficiencies. However, a Round Robin test is recommended to develop a Good Laboratory Practice (GLP) to improve the reproducebility of measurements carried out according to the prEN13203.

Content

Part I
Introduction

1. Overview of the study

It is known that within the EU a considerable saving-potential exists in the (primary) energy used for the production of domestic sanitary hot water. In order to utilise this potential an effective energy use information system for domestic hot water appliances with clear efficiency classes for comparison between different types of hot water appliances is desirable. The objective of such a system should be the decrease of primary energy use and emissions involved with hot water production.

Roughly spoken the following elements should therefore be known:

- Characteristics of the process of energy production as input for the appliances (gas, electricty and district heating)
- The market of hot water appliances and the technical potential for energy-saving improvements
- The current and future hot water demand in the EU
- The impact of changes in these elements on reduction of primary energy use and emissions

Having available these results a number of scenarios for reaching appliance improvement and market transformation can be set up. For each scenario the impact on the manufacturers, consumers and primary energy use and emissions can be defined. This will give clearness on the best policy to be followed for achieving the best environmental result with the highest support. This policy must afterwards be worked out (not part of this study) by means of a follow up proposal for an energy use information system for hot water appliances. The original set-up of the study is visualised in figure 1.1.

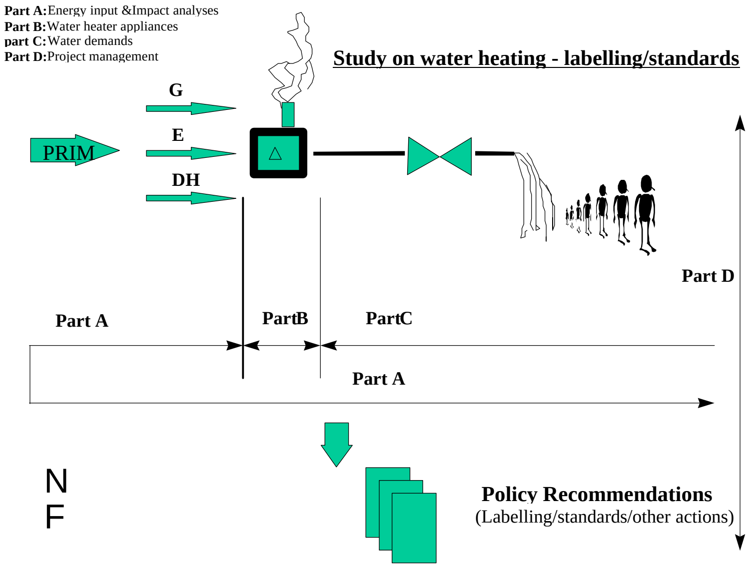


Figure 1.1 Overview of the study

The availability of an energy use information system will stimulate the development of low-energy domestic hot water appliances. The domestic hot water appliances that will be taken in to account in this study are gas fired types (storage, instantaneous and combi's), electric systems (storage, instantaneous and heat pumps), solar systems and systems based on district heating. In the longer run, these appliances will yield energy savings of over 10% in the field of hot water consumption giving an estimated energy saving of 30 PJ within the first 4 years.

2. Structure of the work programme

2.1 Introduction; original workplan

The original work program was divided in 4 parts and 7 tasks (see scheme of figure 2.1). For each task, a task leader was appointed, who was responsible for a detailed work program for each task and the coordination of the activities within the task. The overall coordination of the work program was Novem's task, supported by EVA. Before the start of the tasks, Task group 6 (impact analysis) described the expected results for each task. This document was discussed with all task leaders during a start-up meeting. The contacts and discussions with the European Commission, Industry, Consumer organisations and other interested parties were managed by Novem, with assistance from EVA.

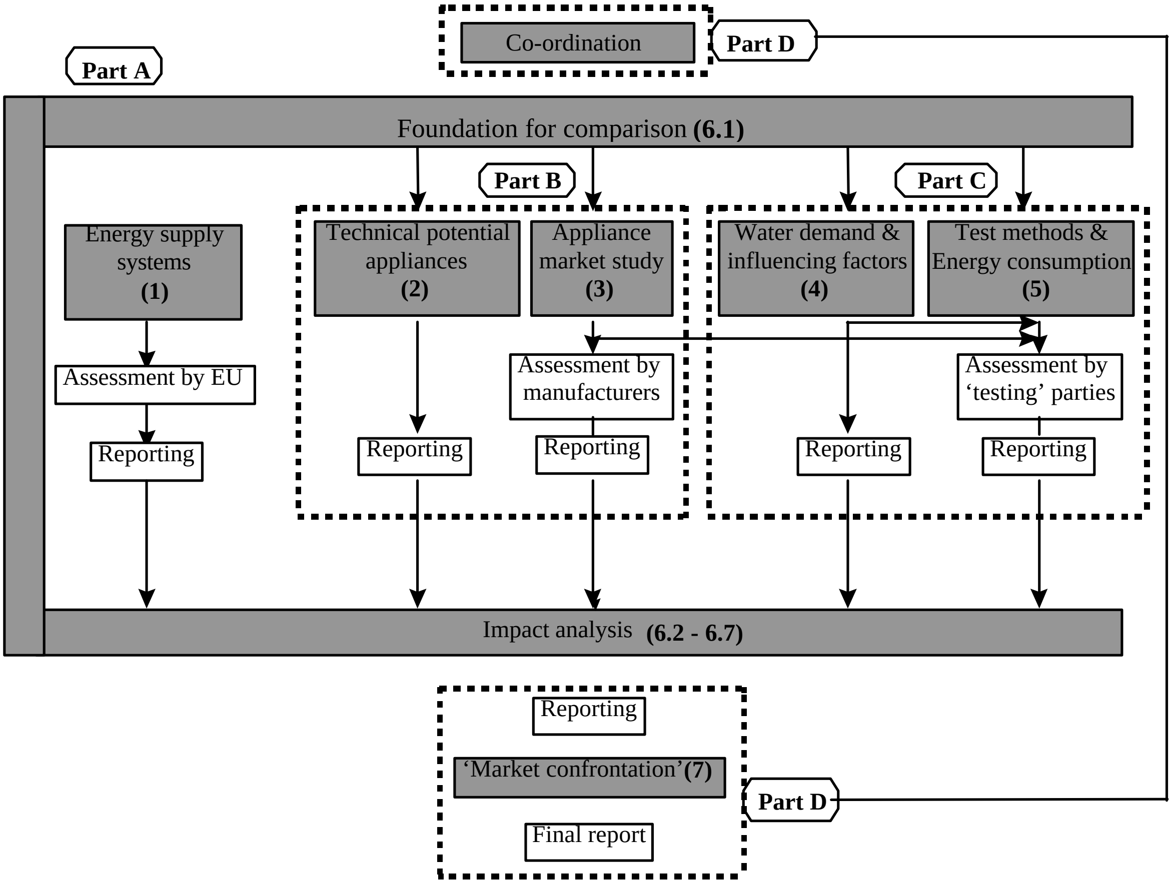


Figure 2.1 Structure of the orignal work programme

2.2 Changes in the workplan

During the project several fundamental changes in the workplan have been made, amongst others:

- excluding electrical heating appliances from the project
- termination of the study before the impact analysis could be carried out

The first change also implied that there has been no assessment by the EU of energy supply systems regarding the comparison between electricity and gas and an overall labelling or other information system for electrical heated, gas-fired and district heating water appliances.
The second change implied that no scenario calculations have been carried out. As a consequence the impact of changes on manufacturers, consumers and on primairy energy use and emissions is not covered by this report.

3. Objective and expected results

3.1 Objectives and outcomes

The objective of this study is to enable interested parties (especially EU) to change the water heater appliance market through the use of labelling, other information systems, minimum efficiency requirements and other policy instruments. The information gathered in this study will provide policy makers with a foundation for these policy instruments.

The outcomes of this study are:

- determination of typical values for CO_2-emissions, energy prices and availability
- an analysis of the technical potential of water heater appliances, with estimations of energy efficiency improvements and production and purchase price effects.
- an analysis of the European water heater appliance market, subdivided for different functional appliance categories and an analysis of market developments.
- an overview of water demands and household and installation types in different parts of the EU, and the determination of typical values for tapping patterns.
- an overview of test methods in use in member states of the EU and the development of a transition model for appliance efficiencies under different test methods (as a basis for the comparison of efficiency figures under different test methods).
- an analysis of real energy consumption of appliance categories, derived from combining tapping patterns and (already) measured appliance efficiencies under test methods through the transition model.

These results have been described in reports per task and are summarized in this report. Furthermore this report contains conclusions and recommendations.

3.2 Cost/benefit indication

It is hard to make a cost/benefit analysis beforehand without knowing the results which this proposed study exactly is looking for. However an idea of the benefit can be given.

Benefit indication
By providing rational information to customers that are in the process of buying a new hot water appliance, the purchase of energy efficient hot water appliances will be encouraged. Because of this an energy saving of 10% will be realistic in time.

The following assumptions are made:

•	number of hot water appliances placed in the EU	:142,000,000
•	number of hot water appliances replaced each year (15 years)	: 9,500,000
•	percentage of buyers who will choose for a less consuming appliance	: 20 %
•	savings potential	: 10 %
•	average appliance energy consumption for sanitary hot water	: 16 GJ
•	estimated average EU energy price	: 15 Euro/GJ

Then the annual energy savings will be:

9,500,000 * 0.2 * 0.1 * 16 GJ = 3.04 PJ corresponding with 45.6 MEuro

Cumulatively the savings (in PJ and in MEuro) are (see table 3.1):

Table 3.1 Cumulative savings

	Cumulative savings [PJ]	Cumulative savings [MEURO]
Year 1	3.04	45.6
Year 2	9.12	136.8
Year 3	18.24	273.6
Year 4	30.40	456.0

Costs

The costs of the study are about 0.5 MEURO. Before real energy savings will be achieved - of course - more effort for realising the energy use information system will be necessary. The total costs however will be a fraction of the potential savings.

4. Introduction to the final report

The final report presents the main findings of the study, including conclusions and recommendations. The task reports contain the detailed results of each task. Table 4.1 lists the available task reports.

Table 4.1 List of task reports

Task	Report	Participants
1	Energy Supply	Environmental Change Institute
2	Technical Analysis	Van Holsteijn en Kemna BV
3	Appliance Market Study	Environmental Change Institute, Armines
4.1	Inventory of existing tapping patterns	Gastec
5.1	Inventory of Existing Test Methods, Analysis of Existing Labelling Systems for Non-electric Appliances	Danish Gas Technology Centre
5.3	Measurements of Appliance Efficiencies under Different Test Methods	Gastec
5.5	Transition model for different test methods	TNO-MEP
5.6	Comparison of test methods with real tapping patterns	Danish Gas Technology Centre
5.7	Real life energy consumption per appliance category	TNO-MEP
	Domestic Electric Storage Water Heater (DESWH); Test Methods and Existing Labelling Systems Simulation and Transition Model	TU Graz

Part II
Water Demand, Appliances and Test Methods

5. Water Demand

5.1 Introduction

Objective

A clear view per country, group of countries and EU on the consumers hot water demand, expressed in terms of volumes, tapping frequencies and temperatures as well as factors which influence this demand.

Approach

The energy use of an appliance depends (logically) on its hot water demand. Characteristic for this dependence is the amount of hot water, the frequency of tapping and the desired temperature level. Other - external - factors like the temperature of the cold water supplied to the appliance, the amount of solar energy input for a solar boiler or the energy contents of ventilation air for a heat pump boiler, also influence the appliance energy use.
The hot water demand on the appliance depends on the hot water demand of the consumer at the different tapping points (kitchen / shower / bath) and the heat losses of the installation. So in order to have a clear view on the energy used by appliances for the production of hot water, the consumers hot water demand must be known, the external factors should be identified and quantified and the heat losses of the installation must be classified. To predict the future development in this energy use the trends occurring in these elements must be investigated as well.

5.2 Main results

Most figures on hot water consumption in practice were extracted from the Gastec report for task 4.1[1]. In the cases were the hot water temperature differed from 60 ^{o}C, the numbers were adjusted for the temperature difference, assuming a cold water temperature of 10 ^{o}C.

Table 5.1 Average domestic hot water (60 ^{o}C) consumption per person per day

Country	Average volume	1 person household	4 person household
Netherlands[1]	36	48	31
Denmark	36	63[3]	31
Germany[1]	38	51	32
Greece	22	27	20
United Kingdom	40	57	31
France[1]	41[2]	55	35
Average	*36*	*50*	*30*
Extreme values		27-63	20-35

[1] Only the average volume was known, the numbers for the 1 person household and 4 persons household were determined using the average of the ratios: 1 person household/average (=1.33) and 4 person household/average (=0.85) in the Greek and English situation.
[2] The French figures were only given as function of the number of rooms in a dwelling. An average of 3 persons per dwelling was assumed.
[3] Based on the observations in the other countries it was assumed that the category with the highest hot water usage per person belonged to the 1 person households.

Very little was reported on the real life tapping patterns. From the Dutch report "Praktijkonderzoek warm tapwater"[2], table 5.2 was extracted. It was not clear whether the tabulated tapping frequency is

[1] Testing methods for hot water appliances in Europe; an investigation of existing draw-off patterns in practice; Koot, Croonen, van der Loop; Gastec, Apeldoorn, 1999
[2] Gasunie, Groningen, June, 1997

the total tappings per person per day, or is the total at the kitchen tap point. Since the hot water tappings in the bathroom will be small (bath+shower = 0.7 tappings per person per day), it is assumed that the former is the case. The only data that is missing are the hot water tappings at washbasins.

Table 5-2 Tapping frequencies (Netherlands)

Appliance	**Country average [%]**	**Taps per person per day**
Instantaneous heater, kitchen	23.3	6.3
Instantaneous heater, bath	17.8	7.7
Instantaneous boiler	44.8	8.1
Storage boiler	10.8	12.7
Storage heater	3.3	14.6
Weighted average		*8.3*
Extreme values		6-15

The measured tapping frequencies vary between 1 and 51. However, the major part of the measured tapping frequencies is in the range of 3 and 20 tappings per person per day.

Time distribution
From the French data in the Gastec report it can be concluded that there are two peaks in hot water usage on weekdays, i.e. between 7 and 8 am and between 8 and 9 pm. At the weekend most water is used during the morning, and on Sundays between 10 and 11 am. Annually, most hot water is used in December. The French situation is probably illustrative for other European countries.

Distribution systems
This study focuses on direct systems. The distance between the most frequently used tapping point, the kitchen, and the appliance dominates the assessment of installation losses. Three situations are identified with a pipe length of 0, 5 and 10 m between appliance and kitchen tapping point.
In this study copper pipes of 10/12 mm are used as reference value.

For the given tapping patterns and distribution systems the worst-case distribution system efficiencies are given below. They can be even lower if tubes with larger diameters are applied or if a tapping pattern with smaller tappings is applied.
Installation losses can be lower down to 50 %, depending on the tapping pattern (clustering) and the useful temperature. In this case distribution system efficiency will be higher.

Table 5.3 Distribution system efficiency

	Tapping pattern	
	1 person	4 person
Tube length [m]	%	%
5	87.8	92.0
10	78.4	85.3

5.3 Conclusion

Although, the average values might seem not to differ that much, there is a very broad distribution in the field data. For this reason a low, medium, and a high hot water usage pattern is defined for evaluation purposes (see table 5.4 and table 5.5).

Table 5.4 Tapping pattern per *person* per day

	Low usage	**Medium usage**	**High usage**
Volume at 60 °C [l/pers/day]	18	36	54
Q[1] [MJ]	3.8	7.5	11.3
Q [kWh]	1.0	2.1	3.1
Number of tappings	4	8	12

[1] A cold water temperature of 10 °C and a hot water temperature of 60 °C, is assumed.

The medium usage situation is based on the Dutch situation and reflects the average values.
The field data in the Gasunie report suggest ratios of 0.5 (low usage/medium usage) and 1.5 (high usage/medium usage). This is valid for both the hot water usage as well as for the number of tappings. These ratios are a little bit larger than the ratios applied in table 5.1. One of the reasons, for this difference is that table 5.1 summarizes average values (for 1 and 4 persons households), so the extremes are already filtered out.
The same exercise can be done per household (see table 5.5). This table is based on the average values summarized in table 5.1.

Table 5.5 Tapping pattern per *household* and per day

	Low usage[2]	**Medium usage**	**High usage[2]**
Volume [l]			
1 pers. hhd.	25	50	75
4 pers. hhd.	60	120[1]	180
Q [MJ]			
1 pers. hhd.	5.2	10.4	15.6
4 pers. hhd	12.5	25	37.5
Q [kWh]			
1 pers. hhd.	1.4	2.9	4.3
4 pers. hhd.	3.5	7.0	10.4
Tappings[3]			
1 pers. hhd.	8	16	24
4 pers. hhd.	12	24	36

[1] medium usage = average value (table 5.1). For the four persons household the average value is multiplied by 4.
[2] The same distribution is assumed as in the Dutch field experiment: low/medium=0.5 and high/medium=1.5
[3] The low usage tappings for a 4 persons household is assumed equal to the lower boundary of the distribution of the tappings, i.e. 3. So the low usage tappings for a 4 persons household is 12.
The high usage tappings for a 1 person household is assumed to be equal to the higher boundary of the tappings distribution, i.e. 24.
Within the households, the same tapping distribution is assumed as in the Dutch field experiment.

6. Appliance Market Study

6.1 Introduction

Objective
A knowledge per country, group of countries and EU of the current and predicted future stock of appliances subdivided into functional distinguishable appliance categories.

Approach
In addition to the technical status and potential of different appliances it must be clear what the market for the different appliance types looks like. As a first step different functional distinguishable appliance categories will be defined (see also task 5). Different categories should be defined in order to create categories of comparable appliances. The reason for this is that the energy efficiency performance of appliances differs with different water demands and that appliances are designed for specific water demands. Therefore it is necessary to segment the appliance market into functional appliance categories before analysis, in order to prevent miscalculations.
Per functional category the number of appliances installed and currently sold will be identified. Next a prediction for the development of the appliance market within a number of years will be made, without the assumption of an EU energy consumption information system being developed and implemented in the market.

6.2 Results

6.2.1 Categorization of appliances

In this study the following categorization of water-heating appliances is used:

1. Electric instantaneous water heaters
2. Electric storage water heaters
3. Electric heat pump water heaters
4. *Gas instantaneous water heaters*
5. *Gas storage water heaters*
6. *Gas combi (room heating + water heating) instantaneous boilers*
7. *Gas combi (room heating + water heat.) storage boilers*
8. Gas heat pump water heaters
9. Oil (or coal) appliances (mostly all are oil combi boilers)
10. Solar water heaters
11. District heating appliances

Because of the exclusion of electrical heating appliances, the categories 1, 2 and 3 will not be treated in this study. It is expected that the categories 8, 9 and 10 and 11 have a relatively low market share, so the focus of the study will be on the (*italic* printed) categories 4, 5, 6 and 7.

Furthermore a classification in terms of size and capacity can be made (see table 6.1).

Table 6.1 Classification by size/capacity

		1 Single tap (kitchen/ washbasin)	**2** 2 taps (not simultaneous)	**3** 2 taps (1 shower) (simultaneous)	**4** 3 taps (bath) (simultaneous)	**5** > 3 taps (simultaneous)
Description of typical hot water needs						
(maximum flow rate for instantaneous systems, maximum daily hot water needs for storage systems)						
Flow rate	Litre/min (ΔT = 25 K)	<=5	5 - 10	10 - 13	13 -16	>=16
Daily hot water needs	Litres at 60 °C	15 –-30	30 -80	50 - 95	95 -150	150 - 250
Instantaneous water heaters						
Flow rate	Litre/min (ΔT = 25 K)	<=5	5 - 10	10 - 13	13 - 16	>=16
Power	kW	<=8.7	8.7 - 17.5	17.5 - 22.7	22.7 - 28	>=28
Storage water heaters						
Storage	Litre	15 or 30 (ST)	50 or 75 (ST)	75 or 100 (ST or DT)	100 or 150 (ST) 150 or 200 (DT)	150 or 200 (ST) 250 or 300 (DT)

ST = single tariff, DT = double tariff (for electric appliances, when available)

6.2.2 Market overview

From the country data some features of water heating in the EU do emerge. As central heating ownership has grown, the trend has clearly been towards water heating being linked to central heating boilers. This has taken two main forms:

- Instantaneous gas water heating using **combination boilers (combi instantaneous)** or "*combis*"**.** *Combis* have proved to be a convenient solution, especially for smaller properties, and especially where central heating has been installed in dwellings previously using instantaneous gas water heaters. The share of combis has grown in most of the countries studied, not only against dedicated water heaters but also, on balance, against indirect cylinders.
- **Combi storage (indirect cylinders)**, usually heated by a primary hot water circuit from the boiler. Quantification of this sector has been difficult. Except in the UK where the traditional copper cylinder has lost ground to the instantaneous combi, this has been a growing sector, with a trend away from instantaneous water heating towards the luxury of stored hot water. And even with combis (notably in Italy and the Netherlands and now France) there is a trend towards supplementary stored water. However, there are signs that the ratio of cylinders to boilers sold is now approaching saturation.

The aggregated sales data, shown in Figure 6.1 (which excludes the smaller electric water heaters), show some general trends, which are masked by particular circumstances in individual countries:

- the decline in sales of instantaneous gas water heaters in most countries was temporarily hidden by the rapid increase in demand from the former East Germany, which peaked in 1992 and fell dramatically from the end of 1993 onwards;
- the underlying growth in indirect cylinders is masked by the decline on the large copper cylinder market in the UK (which includes some versions other than indirect cylinders) and the peaking of the German market following the exceptional demand in 1991.

Overall, the sale of electric storage heaters is declining since a peak of 3 million in 1991 and this trend is projected to continue towards the year 2000 and beyond.

Combi boilers are increasing share and are now the largest 'sellers' in the EU (10 of the largest countries out of 15), approaching 3 million pieces per annum. This trend is expected to continue, especially with the increasing gas distribution network. Gas stand-alone water heaters are still a small part of the market, and are set to decline, whilst instantaneous gas water heaters, are declining in sales rapidly, as combi systems become prevalent.

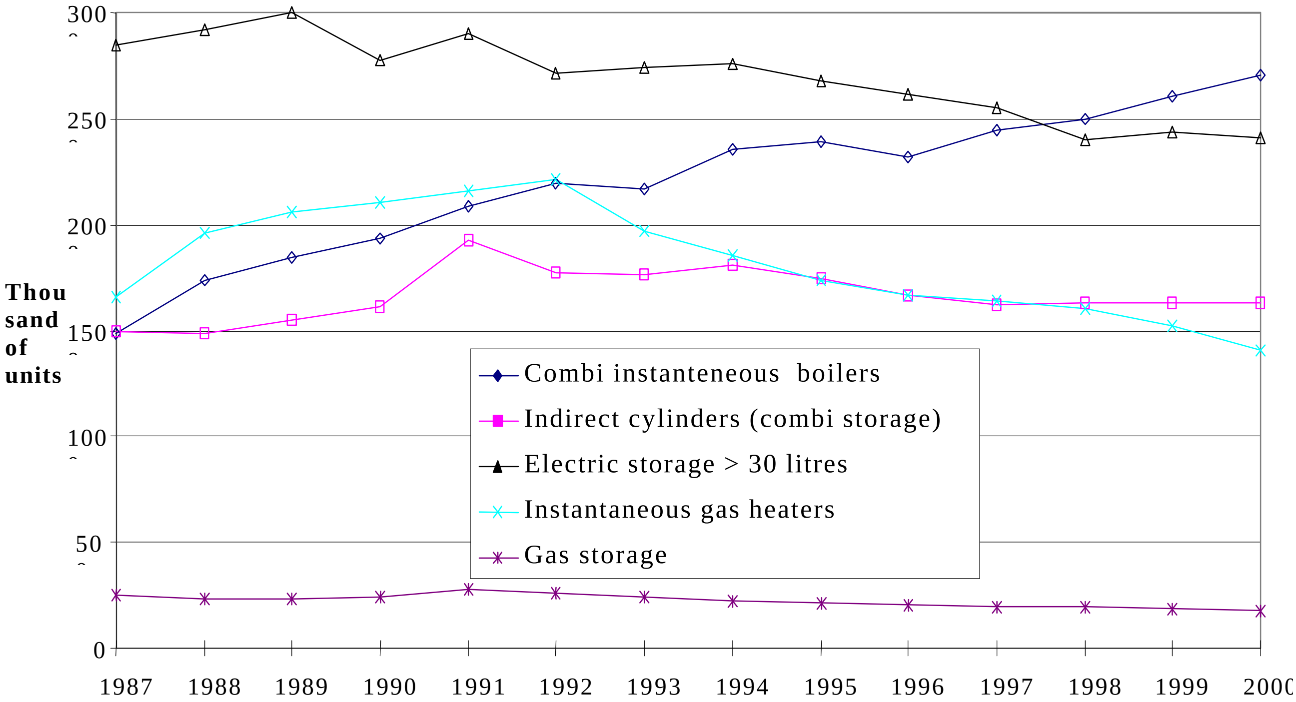


Figure 6.1 Sales trends in main water heating products 1987-2000 for 10 European countries

7. Technical Description and Savings Potential per Appliance Category

7.1 Introduction

Objective
The objective of task 2 is to get a clear view per appliance category on the technical possibilities for improvements of the energy-efficiency, and to get a clear view on related costs and benefits of these improvements.

Approach
In order to outline the technical potential for energy-saving improvements of hot water appliances, information about the technical potential for reducing the energy consumption of the different types of appliances will be collected. For each category of appliances (defined in task 3) an overview of possible improvements on the appliance will be given. The relative energy efficiency improvements will be calculated, and the effects on production cost and purchase price will be estimated.
Per appliance category, the possible improvements on appliances will be analysed with respect to the energy efficiency improvements and cost effects. This information will be used as input for task 6.

7.2 Results

After room heating appliances, sanitary hot water heaters are the largest energy consuming appliances in a household. The amount of primary energy that is needed to produce and supply the sanitary hot water for an average 3 person household, is roughly 3 to 5 times the actual energy content of the hot water that is drawn from the faucets. In other words, sanitary hot water supply systems have an overall system efficiency in the range of 20 to 35%. These losses are not only caused by the water heater appliance itself. The distribution system, the type of faucets and also the energy source that is used to heat the water, cause the energy losses that together result in an overall efficiency of 20 to 35% on primary energy.
This chapter reports only on the energy saving potential of the water heater appliance itself, and not on savings that can be realised in the other system parameters.

There are many different types of water heater appliances. They can be categorised by the type of their energy-source (natural gas, oil, electricity, coal, wood, lpg, district heating) and their heat-transfer principle (instantaneous, storage, combinations). For the consumer the most important water heater specifications are ‘waiting time’ and maximum (and minimum) ‘flow-rate’. The waiting time is the time one has to wait before the water heater actually delivers hot water at desired temperature. Depending on the type of water heater this can vary from a couple of seconds to almost one minute.
The maximum flow rate indicates the maximum flow (litres per minute) that can be drawn from he appliance. This can be used as an indication for the number of taps that can be used at the same time, and for the time it takes before the bath tub is filled with hot water.

The year efficiency of an appliance is defined here as the energy content of the yearly hot water consumption, divided by the energy input that was needed to produce this amount of hot water (water consumption is measured directly at the appliance).
The year efficiency of a water heater appliance is not only defined by appliance characteristics, but also by the tapping patterns that are applied. This relation with the actual tapping pattern (or consumer behaviour) is caused by the nature of the energy losses that occur.
Water heater appliances that have relatively large *standing losses* (storage type of water heaters, and water heaters with a pilot flame) have a lower year efficiency when small amounts of hot water are consumed. They have a higher year efficiency when large amounts of hot water are drawn from the tap.
Water heaters that have relatively large *start/stop losses* (heavy instantaneous water heaters) have a higher year efficiency when the number off draws is small and concentrated in a certain period of the

day. When a large number off draws is well divided over a day, the year efficiency of these appliances is a lot lower.

The saving potentials of the different type of water heater appliances are summarised in table 7.1 and are sorted according to the different type of energy losses that are applicable. The estimated savings are related to the energy consumption of an average 3 person household for sanitary hot water.

Table 7.1 Indication of saving potential per appliance category for the various design options (influence of combining technical options on savings is taken into account; savings are related to hot water consumption of an average 3 person household).

	Yearly average energy consumption for a 3 person household		Reduction heat capacity (weight & water content) with 25%	Replacing pilot-flame by electronic ignition	Reducing start/stop-losses with insulated cabinet	Reducing start/stop losses & standing losses by intelligent T-control	Reducing standing-losses storage tank by doubling the insulation	Reducing standing-losses storage tank with vacuum insulation	Reducing convection losses with flue-damper	Reducing convection losses with insulated pipe connections	Improving steady-state efficiency from 85 – 105 (lhv)	Reducing energy consumption by adding a heatpump to a storage tank	Reducing energy consumption by adding solar collector to storage tank
													*1
GIWH [kWh$_{pr}$] Gas Instantaneous Water Heater	**4040**	Savings	140	550	80				115		460		945
		Pay-back	*0*	*2.3*	*15.5*				*6.1*		*16.3*		*30*
GSWH [kWh$_{pr}$] Gas 150l. Storage Water Heater	**4815**	Savings		750		200		360	300	50	460	670	1250
		Pay-back		*1.7*		*8.3*		*4.6*	*2.3*	*5.5*	*16.3*	*26*	*18*
GCIWH [kWh$_{pr}$] Gas Combi Inst. Water Heater	**4449**	Savings	200	550	100	150	30		150	40	460		
		Pay-back	*0*	*2.3*	*12.5*	*6.4*	*8.3*		*4.6*	*6.9*	*11.7*		
GCSWH [kWh$_{pr}$] Gas Combi Storage Water Heater	**4508**	Savings	150	550	80	200	100		100	75	460		1000
		Pay-back	*0*	*2.3*	*19*	*4.8*	*6.9*		*6.9*	*7.4*	*11.7*		*23*
OSWH [kWh$_{pr}$] Oil Storage Water Heater	**4815**	Savings		750		200		360	300	50	460		1250
		Pay-back		*1.7*		*8.3*		*4.6*	*2.3*	*5.5*	*16.3*		*18*
OCSWH [kWh$_{pr}$] Oil Combi Storage Water Heater	**4508**	Savings	150	550	80	200	100		100	75	460		1000
		Pay-back	*0*	*2.3*	*19*	*4.8*	*6.9*		*6.9*	*7.4*	*11.7*		*23*
DHIWH [kWh$_{heat}$] District Heating Inst. Water Heater	**2445**	Savings	50		45								
		Pay-back	0		27								
DHSWH [kWh$_{heat}$] District Heating Storage Water Heater/	**2788**	Savings				150	160	170		100			
		Pay-back				11.1	5.2	9.8		5.5			

*1 figures based on an average solar input of 4.8 kWh/day for 2.8 m2 collector-surface

7.3 Conclusion

The economical and technical saving potential of domestic water heater appliances varies from 20 % for gas instanteneous water heaters to 34 % for gas storage water heaters, taking into account only the options that have a payback period of less then 10 years. The technical potential alone is around 50 % for all water heaters considered.
On the basis of the information given in table 7.1, it can be concluded that the saving potential on water heater appliances is impressive enough to convince the parties involved that further actions and policy instruments are useful and necessary.

8. Test Methods

8.1 Introduction

Objective
The objective of the task is to formulate a proposal for a well-described test methodology for hot water appliances of which the result gives a realistic representation of the energy consumption in practice.

Approach
For the creation of an energy consumption information system for hot water appliances a well-described, representative appliance test method is indispensable. This test method can vary for different appliance categories. In order to determine an appropriate European test method for water heater appliances, firstly existing test methods within the EU (including the proposed new test method from CEN/TC 109) will be analysed. The following appliance categories have been considered (see also section 6.2.1):

- Stand-alone gas water heater direct (strong in NL, IT, GE)
- Stand-alone gas (strong in IT) or oil (strong in GE) water heater storage
- Combi gas water heater direct (strong in NL, IT, UK)
- Combi gas (strong in IT, DK, UK) or oil (strong in DK, GE) water heater storage
- Solar heating appliances and combination with solar heating, wood burning boilers
- District heating
- Heat pumps

New technologies (fuel cells, domestic co-generation) were not considered, as no standard/labelling exists and, moreover, no data was available.

Secondly, the effect of changes in tapping patterns on appliances efficiency was investigated through a limited number of tests and experience of test institutes. The appliances were chosen based on efficiency results (average, minimum and maximum energy use) already known from existing (national) test methods.

Thirdly a transition model for appliance efficiency under different test methods was developed. This model was used to compare real tapping patterns throughout Europe (from task 4) and the determination (on the basis of real tapping patterns and the transition model for appliance efficiency) of real energy efficiency per appliance category (the calculation of appliances real performances will be carried out with “real life tapping pattern”). Combined with the inventory of existing test methods, existing (national and European) labelling systems for water heater appliances were analysed.

8.2 Main results

8.2.1 Test methods and existing labelling for non-electrical appliances

8.2.1.1 Overview of main results

- There are national standards and some guidelines on hot water appliances. Labelling systems are found in Denmark and in the Netherlands.
- In only a few countries national standards are mandatory: France, The Netherlands, Germany.
- In the case of gas, most of the national standards are in force until the European standards PrEN 26 and PrEN 89 become official. For combination boilers, there is already an official European standard (EN 625) available.
- In most cases there are different standards for instantaneous, storage and combined appliances.
- For oil, district heating and solar less standards are available. The standards are mainly on safety.

But in some cases, e.g. district-heating, there are national rules (Denmark).

- Besides the Dutch national standards and those of Germany, only the European standards require real efficiency rates. The other national standards are very much related to the proposed European standards.

8.2.1.2 Test methods: tapping patterns

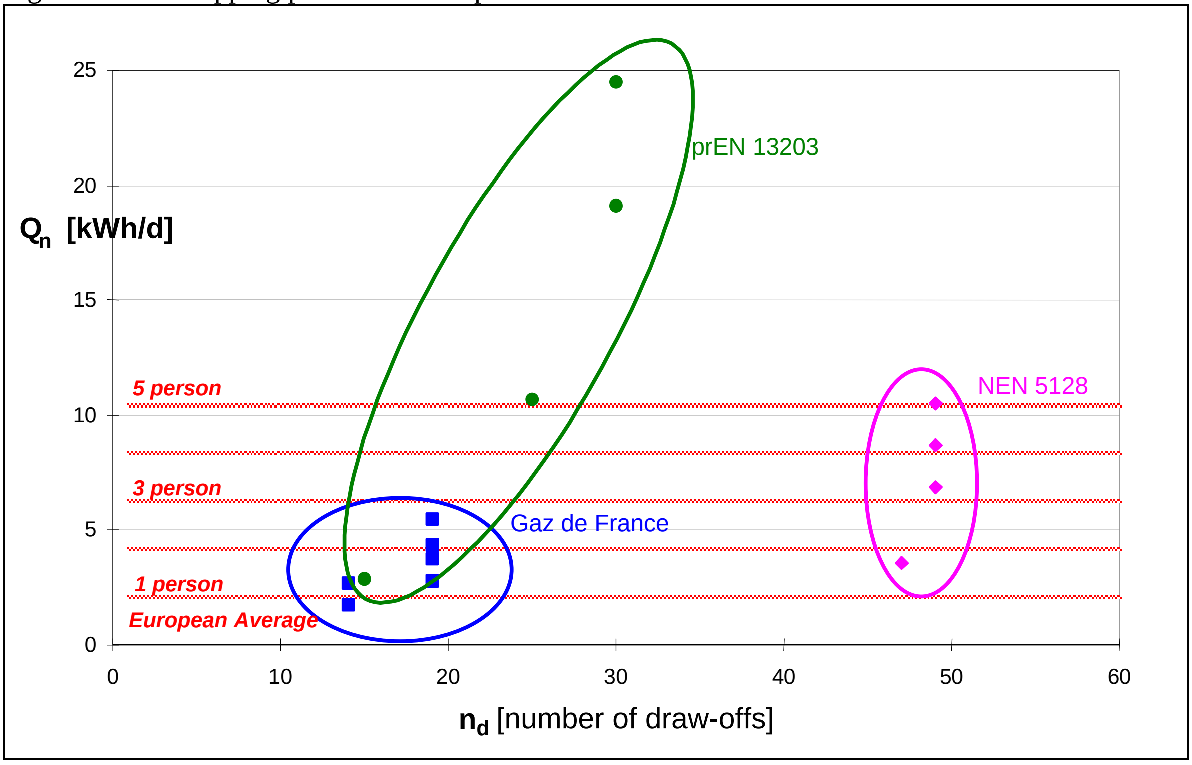
In most cases, the test methods are identical or very similar. But some of the parameters for the test, as for example the tapping pattern, are different from one standard to another.

Test based on tapping and standby loss measurement

In this case, the appliance to be tested is measured in a more or less "real" situation. This is typically a 24h test where the appliance is subjected to a tapping programme. The test is carried out in such a way that the energy content in the system is the same at the beginning and at the end. The results are expressed in an "efficiency" calculated on the basis of the heat output measured from the system (hot water) and heat input coming into the system (energy to generate the hot water tapped and energy to compensate the standby loss).
The tapping programme may be performed over the whole period to have a realistic simulation, or it may be concentrated in a short period of time (to make the testing easier).

Figure 8.1 provides an overview of tapping patterns available in European and national standards, characterized by the total energy content of the tapping pattern Q_n (kWh/day) and the number of tappings (draw-offs) n_d.

Figure 8.1 Tapping patterns in European and national standards



Test based standby loss measurement alone

In case the water tank is sold independently from the boiler, it can be tested for the losses alone. The measurement of the losses can be performed with an electric method. It consists in maintaining a

constant temperature in the water tank with an electric element mounted on a test rig (the losses of which are known).
Furthermore, the cooling time constant can be measured after the standby loss test by letting the tank cool down for a fixed period and measuring the temperature again after this time.

8.2.1.3 Evaluation of prEN13203; uncertainty of measurements

Although the measurement method in the prEN13203 standard applies to all gas appliances it seems more designed for direct heaters than for combination boilers with storage. As a result, a number of points would need further specification because the lack of details in the procedure will negatively influence the reproducibility of the measurement.
In general, the interpretation of the measurement procedure is a weak point in the method. Maximum uncertainties are given, but a number of important parameters is not taken into account. As a result, we expect that the measurement uncertainty without further specification of procedures is probably not better than 10%. DGC investigations indicated that if no correction applies for combination boilers with storage, the uncertainty may reach 15%. The results are to a certain extent confirmed by GASTEC's report (subtask 5.3).

All the individual measurement instruments have an uncertainty, which leads to a total uncertainty of the calculated energy contents of the water output and gas or electric input. However, as demonstrated by GASTEC, the overall uncertainty is not related to the measurement technology itself, but to the fact that the test procedure makes it difficult to measure exactly what needs to be measured.
According to GASTEC, the uncertainties of the individual instruments lead to a total efficiency uncertainty of +/- 1,4% at a temperature difference of 50K between cold and hot water.
But the strong influences are from other factors, as the uncertainty due to dynamic response in measurement, the external or ambient influences etc. Table 8.1 provides an overview.

Table 8.1 Overview of uncertainties in measurement

	Uncertainty in efficiency [%]	
Uncertainty factor	**Instantaneous appliance**	**Storage appliance**
Individual equipment	+/- 1,8%	+/- 1,8%
Dynamic response	+/- 1%	+/- 1%
External influences	+/- 1%	+/- 1%
Test method	+/- 1%	Variable with tapping pattern : 0 – 10%
TOTAL	***+/- 5%***	***+/- 10%***

According to DGC investigations on ***combi-boilers with water storage*** the following points have been identified:

- Repeatability of the appliance efficiency: ability of the system to keep the performance (efficiency) level constant.
  No reasonable estimation can be made at the time. The repeatability might very much depend on the system tested. (Thermostat position, interaction between the water tank and the boiler, etc.). The influence of the ambient conditions is also a factor to take into account.

- Repeatability of measurement.
  Some experiments have been carried out and have shown that the worst case was obtained with shorter tapping. In the experiments, the lowest number of tappings carried out was 12 tappings of each 0.48 kWh per hour. The standard deviation (experimental) obtained was 2.06%.

- Ability to retrieve the initial heat content in the system to be tested.

Only estimations are made for the time being, and more serious investigations should be undertaken.

- Problems related to the water temperature measurement.
  The response time of the hot water temperature measurement is linked to at least three different causes:
  1. The probe response time
  2. The heating of the part of the pipe where T_{out} is measured.
  3. The measured dead volume of water (between the real outlet of the tank and the probe).

  Calculations carried out show that 3) is negligible and 2) is in most cases counterbalanced when the tapping period is long enough for the outlet temperature to fall after having reached a peak. In addition, measurements carried out with a thermocouple show that the effect of 2) probably is not that important. The error due to the time constant (τ) of the temperature probe 1) is, therefore, the main factor here. As an example, when τ = 30 s the relative error can typically reach 10% for a 0.6 kWh tapping.

- Influence factors.
  Among the influence factors, which do not depend on the boiler/tank technology, the ambient conditions are probably the most important ones. The ambient temperature will change the energy losses of the water tank and, therefore, influence the standby losses. An accepted model for the standby losses is $SBY = k.(T_{water} - T_{amb})^n$ with n = 1.15.
  So the error due to the ambient temperature is mainly depending on the level of water temperature in the tank. One parameter difficult to know is the average temperature in the water tank, due to the stratification problems.

- Errors due to the testing procedures
  - Tolerance on the energy really taken from the tank
    The procedure states a fixed value of kWh, which shall be taken from the tank. In practise it is difficult to reach exactly the fixed value.
  - Setting of the boiler
    The setting of the thermostat has probably an influence, but it is not known (investigation is necessary). The influence shall be considered in combination with the influence of the temperature of the water in the tank and with the repeatability.
  - Starting point of the tapping
    The procedure should define more precisely when the first tapping shall start. The influence of the one-hour tolerance on this delay is not known, and again, investigations would be useful.
  - Calculation
    The calculation of the energy efficiency may depend on the standby period. A 24-hour test is generally not enough for testing a boiler with a tank, as the standby period (time between two re-heating times) can be up to 15 hours.
  - Sampling time
    The sampling time is an important factor especially for short tappings.
  - Peaks of flow
    When the tapping starts, the measured flow typically shows a peak of one or two seconds. It is not known if the peak is really due to a short time where the flow is so large, or if it has an electronic origin from the meter or acquisition chain. This should be investigated.

8.2.2 Measurements: appliance efficiencies under different test methods

The appliances tested were:

- Gas water heaters (instantaneous and storage)
- Electrical water heaters (instantaneous and storage)
- Combi gas CH boilers (instantaneous and storage principle)
- Combi gas CH appliances incorporating a solar energy connection

- Storage hot water heat pumps

On these appliances several tapping patterns and other specific tests were carried out. The tapping patterns used are already existing and described patterns such as Gaz de France, prEN 13203 and Gaskeur CW. The test results give information about the behaviour of several appliances under different tapping patterns opposed. For testing the several appliances some specific existing European tapping patterns are selected (see table 8.2).

Table 8.2 Overview of tapping patterns

Description of pattern	Class	Number of tappings	Energy consumption (kWh)
Gaz de France (GdF)	1s	14	0.86
Gaskeur	1	47	3.50
Gaz de France (GdF)	4s	19	3.70
Gaskeur	2	49	6.71
Gaskeur	3	49	8.54
Gaskeur	4,5,6	49	10.37
PrEN 13203_2	k/s (*)	25	10.74
PrEN 13203_2a (adj.)	k/s/b (*)	25	18.00
PrEN 13203_4	k/s/b/b+s (*)	30	24.52

(*) k=kitchen, s=shower, b=bath

Figures 8.2, 8.3 and 8.4 summarize the results of the measurements for stand alone gas water heaters, combi instanteneous water heaters and combi storage water heaters. The codes printed in bold, e.g. 21-B refer to specific appliances (see report task 5.3).

Figure 8.2 Efficiencies of stand alone hot water gas appliances

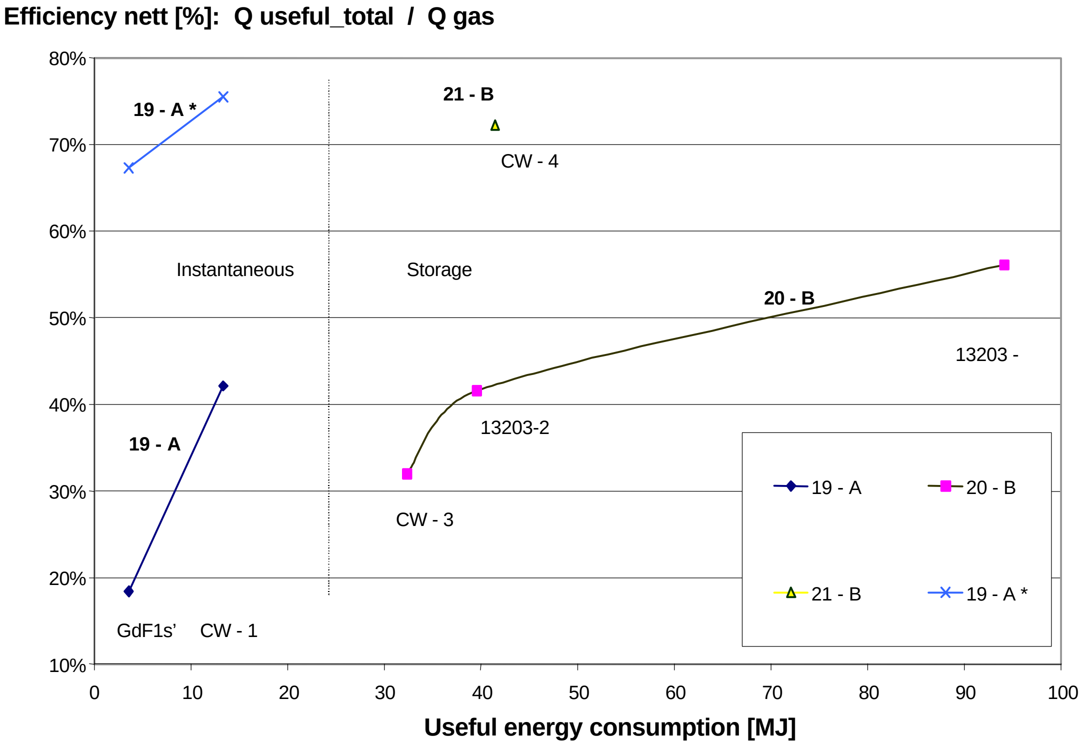


Figure 8.3 Efficiencies of instantaneous combi boilers

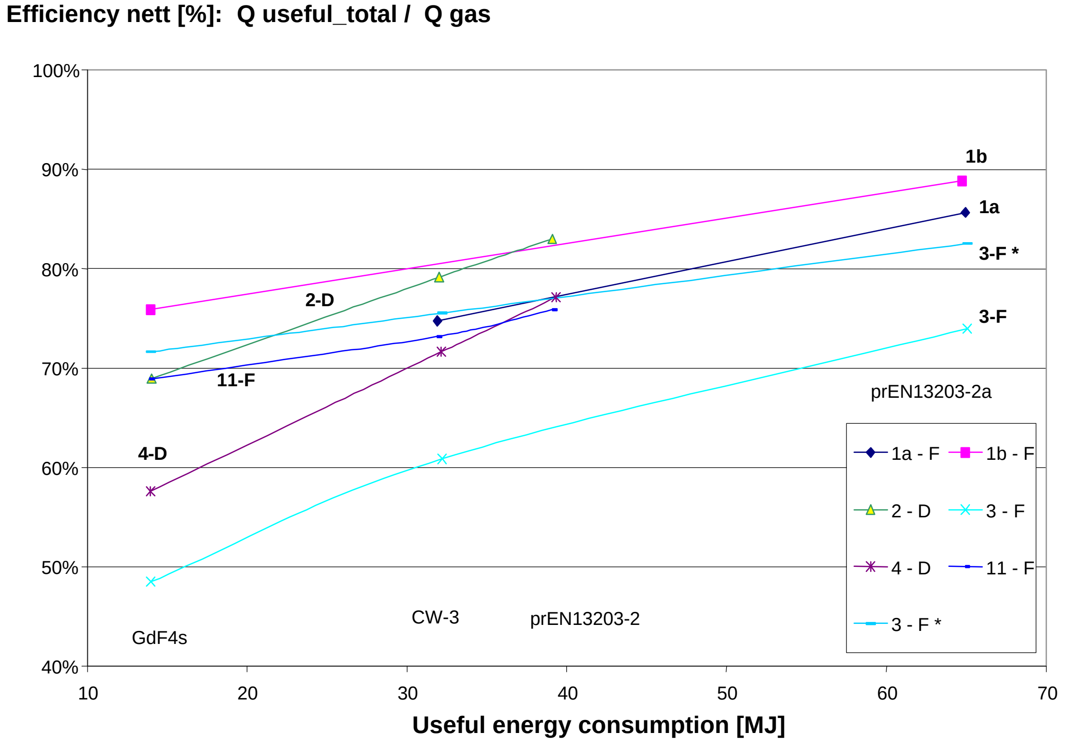


Figure 8.4 Efficiencies of storage combi boilers

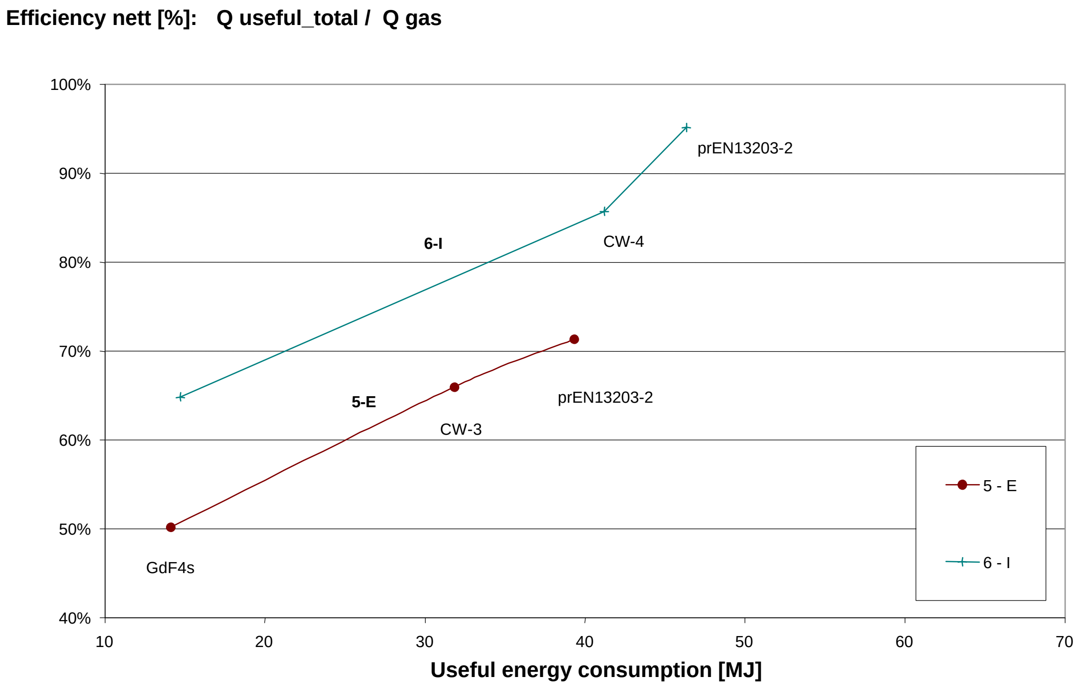
For all kind of appliances, it appears that with an increasing energy consumption there is a strong increasing of efficiency. The relative effect of the standby losses is becoming lower when the quantity of energy tapped is increasing. A simple explanation is that the efficiency is 0 when there is no tapping and the efficiency is almost the "direct hot water production efficiency" when the tapping is infinite (very large).

8.2.3 Transition model

8.2.3.1 General model considerations

The energy performance of the heating appliance is dominated by three effects: conversion efficiency, standby losses and start/stop effects. Some general model considerations and model formulas are given below:

- *Conversion efficiency*
  Cold water temperature may influence the efficiency. This effect is not taken into account. Conversion efficiency is in general related to water temperature. This is assumed to be constant, resulting in constant efficiency.
- *Standby losses*
  For combination boilers the standby loss due to a pilot flame can be related to the heating function during the winter season and to hot water function during summer season. Here only the summer situation is worked out.
- *Start/stop effects*
  Combi boilers show start/stop losses due to the capacity effect of the heat exchanger and water content of the internal circuit and a compact heat exchanger (instantaneous boilers). In the winter situation the heat in the heat exchanger is not lost but for the major part used for the heating function. Here only the summer situation is worked out.

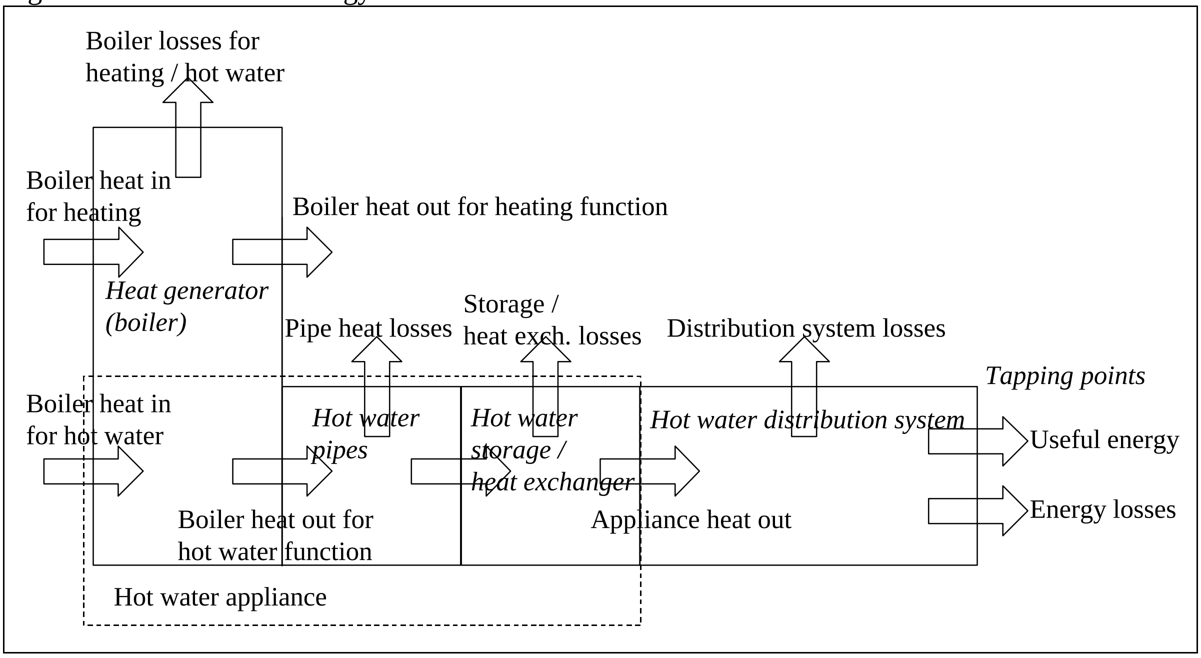


The auxiliary energy use for pump, fan and electronic controls is not taken into account.

8.2.3.2 General model formulas

Figure 8.5 gives a scheme of the general heat and energy flows in a heater or boiler. In heaters and instantaneous boilers with integrated heat exchanger, no section with "hot water pipes" is present.

Figure 8.5 Heat and energy flows



The following relevant efficiencies can be defined. Here "Boiler heat in" relates to the heat required for the hot water function at net calorific value.
The appliance efficiency for hot water production is defined by:

$$\eta_{app} = 100 * Q_{app,out} / Q_{app,in} \qquad [8.1]$$

with:

η_{app}	appliance efficiency for hot water production	%
$Q_{app,out}$	appliance heat out	MJ
$Q_{app,in}$	appliance net heat in	MJ

8.2.3.3 Result

The result of the transition model development are two models, one for all instantaneaous heaters and boilers and one for all storage heaters and boilers. The formulas are given below for instantaneous [8.2] and storage appliances [8.3].

$$Q_{app,in} = (Q_{app,out} + nt * Q_{b,loss,stst}) / \eta_b + P_{app,in,p} * 24 * 3600 / 10^6 \quad [MJ] \qquad [8.2]$$

$$Q_{app,in} = (Q_{app,out} + P_{st,loss} * 24 * 3600 / 10^6) / \eta_b \quad [MJ] \qquad [8.3]$$

where

$Q_{app,in}$	appliance net heat in	MJ
$Q_{app,out}$	appliance heat out	MJ
$Q_{b,loss,stst}$	average value of start/stop losses per burner action	MJ
nt	number of tappings	
η_b	average efficiency during burner on time	%
$P_{app,in,p}$	pilot flame power consumption	W
$P_{st,loss}$	storage losses	W

8.2.4 Comparison of test methods with real life tapping patterns

The total energy content of the tapping patterns of prEN13203 vary between 2,5 kWh (kitchen) and 25,4 kWh (kitchen, shower, bath, bath and shower). Even the kitchen/shower option is giving a daily tapping of 10.7 kWh.

The question of variation in the efficiency when the energy need is subject to variations is interesting for at least two reasons:

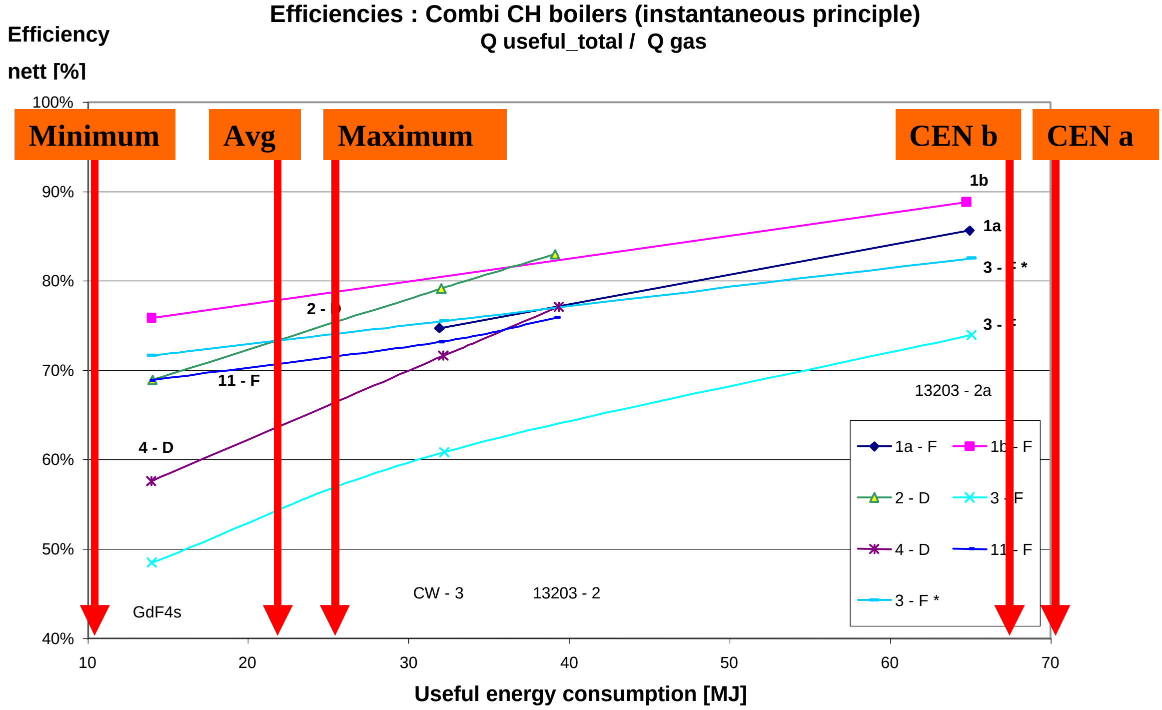
- It is of interest to know what is the advantage gained in the efficiency due to the fact that the energy need is overestimated in the standards.
- It is useful to estimate what might be the variation of the efficiency on an appliance, knowing that the consumer profile may be different and, therefore, the same appliance might have very different efficiency when installed in two different households.

The efficiency measured by GASTEC provides a basis for the comparisons. For the reasons explained above, we will consider the following points (see table 8.3). The real life tapping patterns and the average need is based on the results of chapter 5.Figure 8.6 shows the results for instantaneous combi boilers.

Table 8.3 Tapping patterns used to compare efficiencies

Tapping pattern	Energy content of tapping pattern	
	kWh	**MJ**
real life tapping pattern: minimum need	1.7	6.1
real life tapping pattern: maximum need	7.2	25.9
average need for a family	6.0	21.6
prEN 13203 k/s/b/b+s (point a)	24.5	88.2
prEN 13203 k/s/b (point b)	19.0	68.4

Figure 8.6 Comparison of efficiencies for various tapping patterns



For the instantaneous combination gas appliance the following remarks can be made:

- The effect on efficiency in the range maximum need to average need is in general very small (in the magnitude of 1% to 2%).
- Compared to the efficiency at average need, the efficiency at minimum need (obtained by extrapolation on the above graph) is from 5% to about 12% lower.
- Compared to the efficiency at average need, the efficiency according to the 19 kWh tapping in CEN prEN 13203 ("b" on the figure) is up to about 20% higher!
- Compared to the efficiency at average need, the efficiency according to the 24.5 kWh tapping in CEN prEN 13203 ("a" on the figure) (obtained by extrapolation on the above graph) is up to about 25% higher!

For the storage combination gas appliances, the data available are perhaps too few to conclude anything from, but for the two appliances tested, the trend seen above is much more evident. As the standby losses are larger (because of the tank), it is clear that the energy tapped from the system has a greater influence on the efficiency.

The comparison of hot water need in practice with the tapping pattern of prEN 13203 shows that the present standard overestimates the (average) hot water demand. As a result it can be concluded that the value of efficiency calculated/measured from prEN 13203 will lead to an overestimate of the efficiency in practice. The difference between the value given and the value in practice will be up to 20% for instantaneous heaters and even up to 30% to 40% for storage gas appliances.

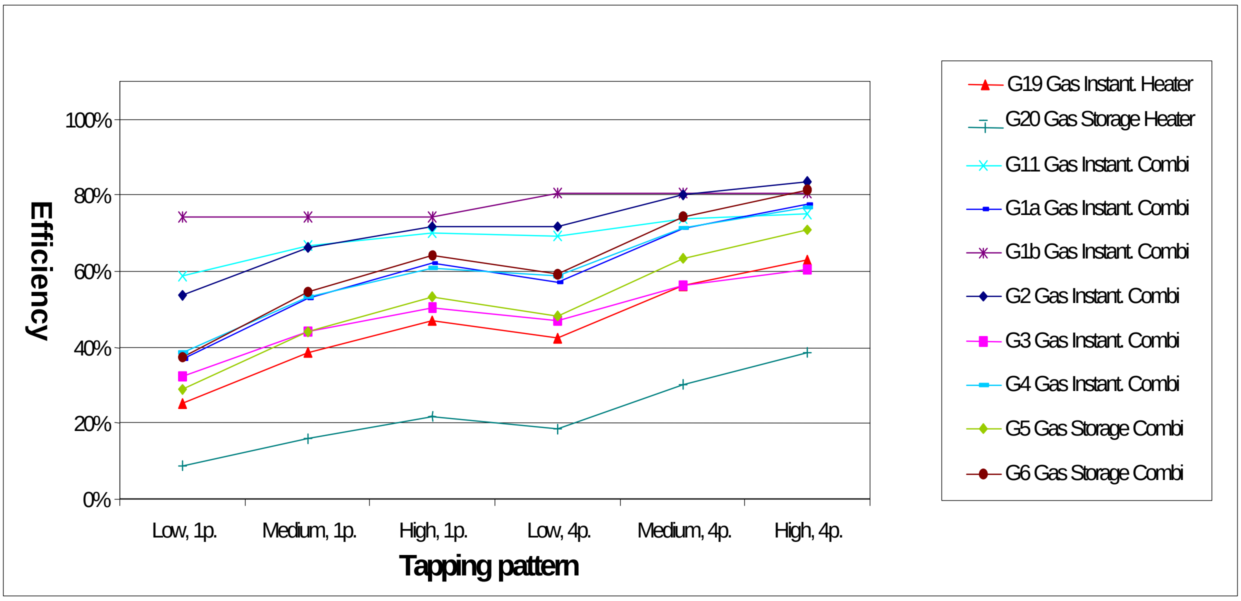
8.2.5 Appliance efficiencies for real life tapping patterns

For the (average) real life tapping patterns of table 5.4, table 8.4 and figure 8.6 indicate the appliance effiencies.

Table 8.4 Appliance efficiencies for real life tapping patterns

Appliance type				**Tapping pattern characteristics**						
				Name	Low, 1p.	Medium, 1p.	High, 1p.	Low, 4p.	Medium, 4p.	High, 4p.
ID	*Storage / instant.*	*Heater / combi*	*Appl. Cat.*	*Quseful [MJ/day]*	5,2	10,4	15,6	12,50	25,00	37,5
				nr. tappings/ day	8	16	24	12	24	36
G19	Instant.	Heater	1		25,3%	38,8%	47,1%	42,6%	56,2%	63,0%
G20	Storage	Heater	2		8,9%	16,1%	22,0%	18,6%	30,4%	38,6%
G11	Instant.	Combi	3		58,6%	66,7%	69,9%	69,3%	73,7%	75,3%
G1a	Instant.	Combi	3		36,8%	53,0%	62,1%	57,2%	71,3%	77,7%
G1b	Instant.	Combi	3		74,2%	74,2%	74,2%	80,7%	80,7%	80,7%
G2	Instant.	Combi	3		53,9%	66,4%	71,9%	72,0%	80,4%	83,6%
G3	Instant.	Combi	3		32,4%	44,3%	50,4%	47,2%	56,4%	60,3%
G4	Instant.	Combi	3		38,6%	53,3%	61,1%	58,9%	71,4%	76,9%
G5	Storage	Combi	4		29,1%	44,2%	53,5%	48,5%	63,5%	70,8%
G6	Storage	Combi	4		37,6%	54,6%	64,4%	59,1%	74,3%	81,3%

Figure 8.6 Appliance efficiencies for (average) real life tapping patterns



Part IV
Conclusions and Recommendations

9. Discussion on Information Systems

9.1 Introduction

The study on water heating presented in this report should provide the foundation for the policy to be followed in creating an energy use information system for domestic hot water appliances.
The study has identified and elaborated upon the following items as important building blocks for a labelling system or other information systems:

- tapping patterns
- test method (standard)
- the evaluation system (rating scale)

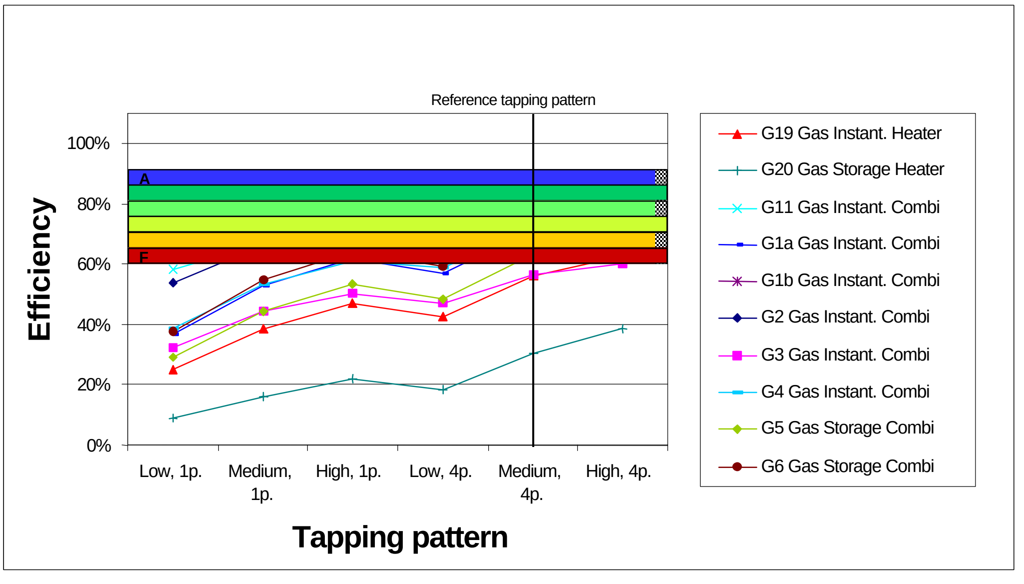
These 3 items are – of course - related. A tapping pattern, characterized by hot water volume and tapping frequency, summarizes the use of the appliance and is input for test methods. Test methods describe the procedures to determine performance and efficiency characteristics of the appliance. The evaluation system uses the results of the test methods to rate or rank various water heaters e.g. on the A to G scale used for EU-labelling.
An information system, e.g. a labelling system, is established by a combination of choices for the 3 items.
Furthermore, different choices can be made for each of the items. In the foregoing chapters of this report several of these choices have been identified, especially regarding the tapping patterns and the test method. In this chapter some basic choices for information systems for domestic hot water appliances will be presented and evaluated.

9.2 Basic choices for an information scheme

Regarding the tapping pattern and the rating scale the following types of label systems are distinguished.

1. ***One general rating scale, one general tapping pattern*** (see figure 9.1)
   The basic idea behind this approach is that all boilers have to fulfil equal requirements to allow good inter comparison.

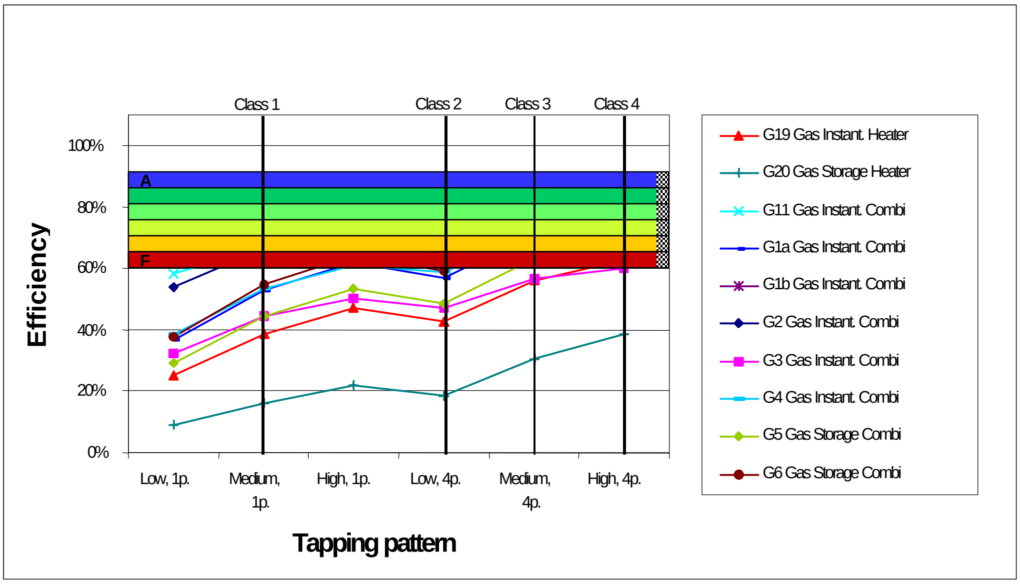
Figure 9.1 System 1: one rating scale, one test tapping pattern



2. ***One general rating scale, different tapping pattern (per function class)*** (see figure 9.2).

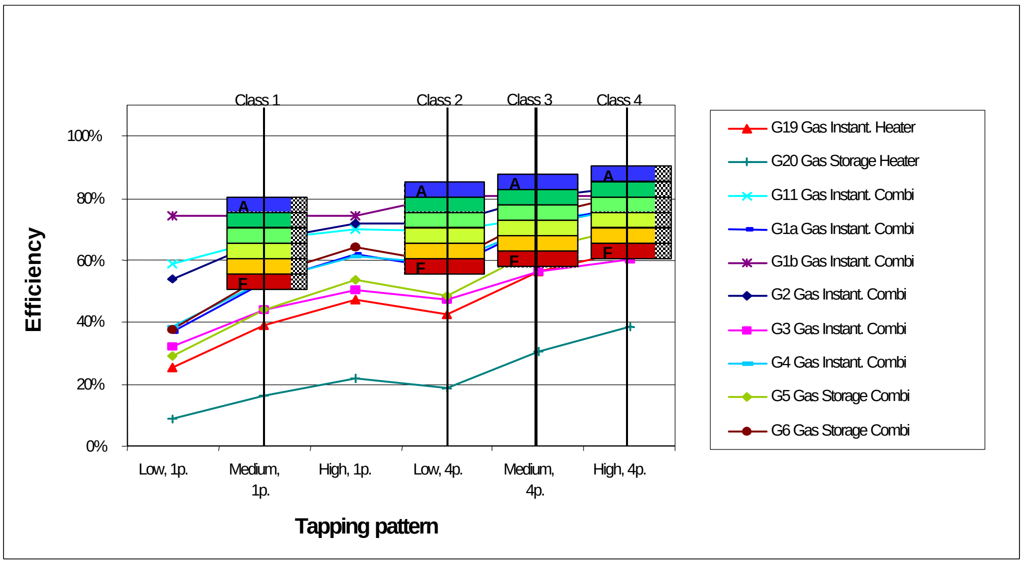
The basic idea behind this approach is that different boilers are designed for different use. Therefore the manufacturer has to indicate the comfort level a boiler is designed for. And the boiler is tested at a corresponding level (class). But for all function classes equal requirements are required to allow good inter comparison.

Figure 9.2 System 2: one rating scale, test tapping pattern per function class



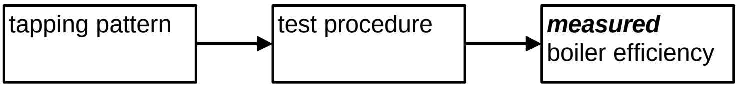
3. ***Different rating scales (per function class), different tapping patterns per function class*** (see figure 9.3)
The basic idea behind this approach is equal to that of option 2. But different rating scales are used since it is assumed that it is more difficult to achieve high efficiencies at low loads then at high loads, even if the appliance is designed for low loads.

Figure 9.3 System 3: rating scale and test tapping pattern per function class

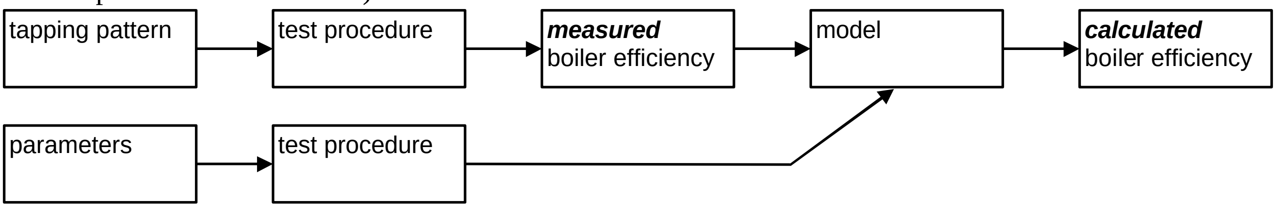


Regarding the methods for determination of boiler efficiency, the following are distinguished.

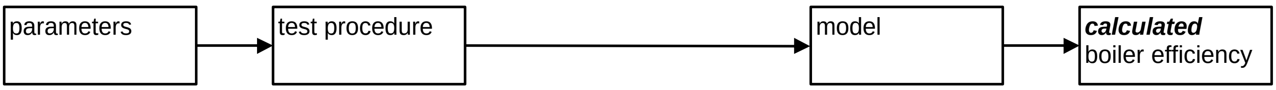
A Measurement of boiler efficiency for one or more tapping patterns



B Measurement of boiler efficiency for one or more tapping patterns and of some appliance parameters to be used to in a model to calculate boiler efficiencies (e.g. for other tapping patterns then measured).



C Measurement of appliance parameters to be used to in a model to calculate boiler efficiencies.



9.3 Criteria on information systems and determination of boiler efficiency

The criteria on an ***information system*** on the energy performance of hot water appliances are:

- Cover a wide range of appliances with respect to energy source.
- Cover a wide range of appliances with respect to function level.
- Easy to understand for consumer / installer / contractor.
- Realistic appliance ranking
- Realistic appliance efficiencies.
- Connect with current national and future European building energy performance calculation methods.
- Join in with existing European labelling systems.

Cover a wide range of appliances with respect to energy source

Appliances may use different energy sources like electricity, gas, oil and solar. Most gas and oil-fired appliances also use some electricity for auxiliary functions. There are also gas-combi-boilers in the market using an electric element to keep a small storage volume on design temperature. Maybe in the near future a storage vessel with an option for both gas fired heating at day and electric heating at low tariff during the night will show up.

All these developments enforce the development of an information system covering all energy sources. Fossil fuels can be compared directly at the level of primary energy consumption. For solar appliances with gas after-heaters the solar heat gains are expressed by the lower gas consumption of the whole appliance.

For electricity an equivalent primary energy consumption can be found using an electricity generation efficiency. This can be done at a European level but since there are some differences between the countries it can also be done at the level of (groups of) countries. In the latter case a European method will provide the information needed to determine labels at national level.

All 3 label systems of section 1 can be based on primary energy consumption.

Cover a wide range of appliances with respect to function level

Appliances are designed for a specific type of use. For instance, a small instantaneous heater is designed for kitchen use and a 300 l. storage boiler is designed to serve an installation with at least one bath. These differences in use type can be indicated by the *comfort* or *function* level of an appliance. For consumers this is relevant information that needs to be expressed in the information system.
It is well known that appliance performance is strongly linked to the level of hot water demand and to a lesser extend to tapping frequency. In practice there will be a correlation between hot water demand and the function level of an appliance. But in reality there is also a wide spread in hot water demand. Therefore an information system should give information on the appliance performance at an average hot water demand for the function level of that appliance. It should give additional information on appliance performance for other levels of hot water demand.
Label system 1 does not allow for differentiation by use, while label system 2 and 3 do.

Easy to understand for consumer / installer / contractor
Label system 1 seems to be the most easy to understand. But since it doesn't cope with the fact that some appliances will be tested at loads far higher or lower that they are designed for, unrealistic results may occur. As shown above this system illustrates the problems that might occur when we neglect the differences in function level.
Label system 2 and 3 apply the concept of "function class". This allows to link the design purpose of the appliance to its performance when tested for that purpose. Manufacturers are expected to indicate for what function class(es) there appliance is designed and has to be tested.
Label system 3 may be a little bit confusing to the consumer by applying different rating scales. However it takes into account the effect that most appliances show a drop in efficiency at low hot water demands.

Realistic appliance ranking
Realistic appliance ranking doesn't necessarily implies realistic efficiencies. If for instance a systematic error occurs the ranking will not change.
Label system 1 however introduces problems since the ranking is clearly depending on the tapping pattern used. Almost all appliances show an efficiency drop if the tapped water volume is diminished but some appliances are far more sensitive to this effect than others. So the ranking using one reference tapping pattern might be wrong for other tapping patterns.
Label systems 2 and 3 allow better comparison of appliances designed for the same function class. Appliances designed for a wide range of function classes may be tested at different tapping patterns and may have two or more labels (for instance: Function Class 3: B, Function Class 4: A).

Realistic appliance efficiencies
The points mentioned above even apply more strongly on the absolute level of appliance efficiency. Here label system 1 is only providing good information if the appliance is used in a situation with comparable tapping patterns as in the reference test. For all other situations the efficiency figures may be wrong for 10 percent or more.
As mentioned before label systems 2 and 3 allow better ways for realistic appliance efficiencies at different hot water demand levels.

Connect with current national and future European building energy performance calculation methods
In different European countries standards or guidelines are in use or development to asses building energy performance, including the hot water system. Attempts are done to develop a European standard as well.
These standards require rather detailed information on the energy consumption (fossil, electric or total primary energy) of the hot water appliance for all kinds of hot water demand. The information system should provide the basic information to support these standards.
An information system providing only the appliance efficiency at a given hot water demand (label system 1) makes it difficult to extend the results to lower and higher demand levels. The only way to extrapolate from these figures is to use conservative approximations on the efficiency change at lower

and higher demand levels. Label system 2 and 3 perform better regarding this criterion.

Join in with existing European labelling systems
This criterion is fulfilled for all three systems.

The criteria for discussing the methods for ***determination of boiler efficiency*** are:
- Accuracy.
- Usefulness and flexibility.
- Costs.

Accuracy
In general one can say that measured boiler efficiencies (method A and B) will give better accuracy then calculated boiler efficiencies (method C). Models need to be validated and therefore suffer in this validation from the same (in)accuracy as normal measurements.
Furthermore, the required models (especially for method C) will not be as simple as the models used in the study but need to be as complicated as the BoilSim-models. For instance they need to take into account:
- heat losses due to heating up and cooling down of the heat exchanger and the internal circuit (combi-boilers);
- cycling frequency of the burner for storage heaters and boilers;
- influence of water flow on boiler efficiency for instantaneous heaters and boilers using modulating burners;
- influence of demanded temperature on burner efficiency and storage losses.

A more fundamental point is that one is never sure that a specific model covers all effects that might occur in a new appliance type, so more or less permanent validation is required.

Usefulness and flexiblity (e.g. for building energy performance calculation methods)
The usefulness of method A is limited since a new measurement is required for each new tapping pattern. Only rough models and correction formulas allow efficiency prediction for other tapping patterns.
Method B and C have more flexibility since once the model parameters are established the appliance efficiency can be calculated easily for all required tapping patterns.

Costs
For all methods the appliance needs to be fixed in a test rig, connections and functioning need to be tested, etc. For method A one or more days of automatic testing are required, depending on the number of tapping patterns for which the efficiency needs to be determined.
For method B some additional tests need to be done to establish specific parameters required for the model.
For method C more additional tests need to be done than in method B.
Both method B and C require at least a standing-loss measurement during 48 hours. This requires a simple test stand with only fuel / electricity consumption measurement facilities.
The overall costs will be more or less equal for all methods, if the results for several tapping patterns are needed.

9.4 Other information systems and policy options

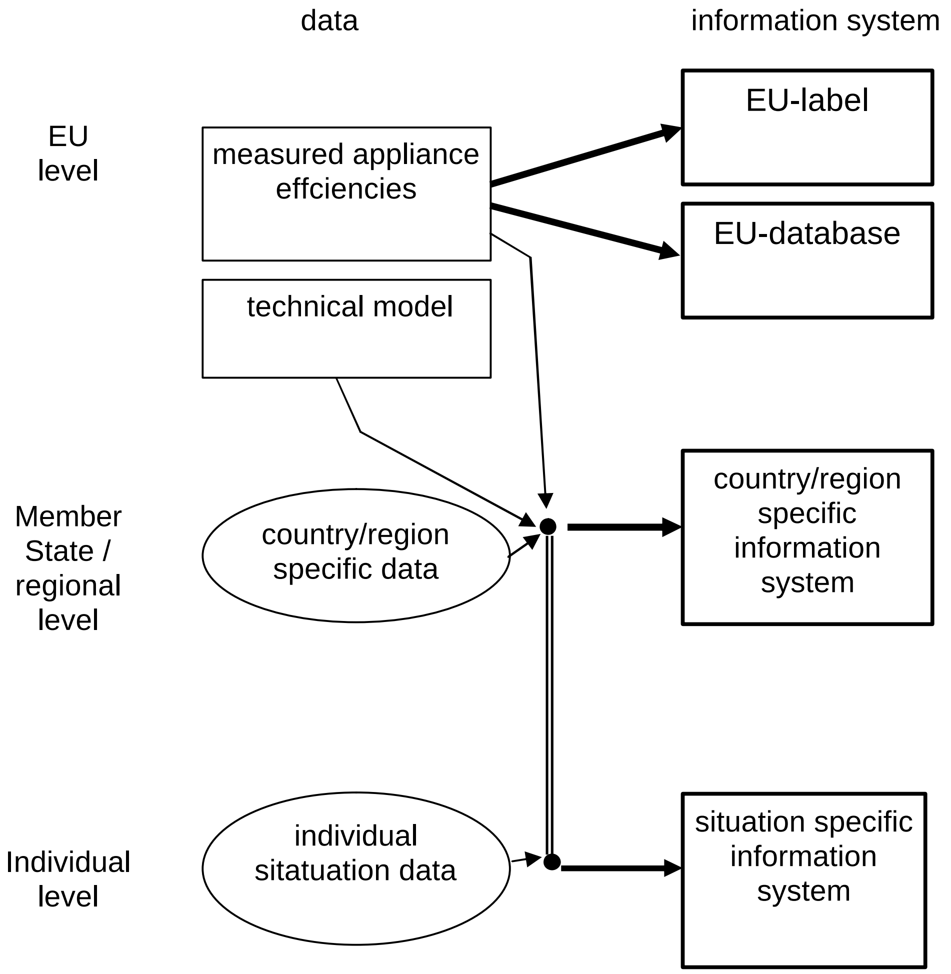
A (mandatory) EU-label is not the only policy option to transform the water heater market. Other policy options include minimum efficiency standards, integration in building energy performance calculation methods, and information systems other than labels, e.g. databases. However, for all of these options,

the building blocks as identified in the introduction are relevant and therefore the discussion in the foregoing sections is also relevant for other policy options.
Indeed, an EU-label and other information systems could or even should be complementary. It is well known that an EU energy label for installed appliances can not be implemented in the same way as the EU energy label for household appliances, because of the following reasons:

- Installed appliances are part of a building. Building characteristics and usage codetermine the energy consumption of an installed appliance to a large extent. However, the situation and conditions of use are not known before the appliance is sold and installed.
- The installer plays a central role in the market, and the appliance is in most cases not visible when sold. This makes it difficult to use the energy label as a "pull" instrument, i.e. consumers seeing the label and asking for an efficient appliance.

Figure 9.4 provides a framework for labelling and other information systems, showing how EU-labelling and other information systems can be complementary.

Figure 9.4 Framework for labelling and other information systems



The database contains basic data (including efficiency) measured in a standardized way on all installed appliances on the market in Europe. The technical model is a standardized model to calculate energy relevant information, e.g. energy consumption, life cycle costs from data in the database and other (situation specific) data. The database and the technical model should be defined on an EU-level, based on the EU labelling directive.

An EU energy label should display a selection of the data from the database. Furthermore on Member State level country or region specific information systems can be set up. However, these systems also (mandatory) use the data from the database and the EU technical model.
The third level is the level of the individual situation at a consumer. An information system for this level should also take into account the individual situation, e.g. construction, usage, climate. This level should provide situation specific information, to be used e.g. by installers advising a consumer on the most appropriate appliance.

9.5 Summary and conclusions

The table below summarizes the discussion of the label systems 1, 2 and 3 (tapping pattern and rating scale) and methods A, B, C (method for determination of boiler effiency) on several relevant criteria.

Table 9.1 Summary of discussion

		Label system: tapping pattern, rating scale		
		1: one tapping pattern, one rating scale	**2**: different tapping patterns, one rating scale	**3**: different tapping patterns, different rating scales.
Method for boiler efficiency determination	**A**: measured boiler efficiency	coverage functional level - appliance ranking - flexibility - accuracy + costs +	coverage functional level + appliance ranking + flexibility - accuracy + costs +	coverage functional level + appliance ranking + flexibility - accuracy + costs +
	B: measured and calculated boiler efficiency	coverage functional level - appliance ranking - flexibility + accuracy + costs 0	coverage functional level + appliance ranking + flexibility + accuracy + costs 0	coverage functional level + appliance ranking + flexibility + accuracy + costs 0
	C: calculated boiler efficiency	coverage functional level - appliance ranking - flexibility + accuracy - costs 0	coverage functional level + appliance ranking + flexibility + accuracy - costs 0	coverage functional level + appliance ranking + flexibility + accuracy - costs 0

The grey areas indicate the recommended situation for an EU-labelling system of which the results can also be used for other information systems.

Based on the assessment of the various possibilities for information systems, the following conclusions can be drawn:

1. To cover a wide range of appliances with respect to energy source a uniform information (labelling) system is required including an electricity generation efficiency. This can be done at a European level but since there are some differences between the countries it can also be done at the level of (groups of) countries. In the latter case a European method will provide the information needed to determine labels at national level.

2. To cover a wide range of appliances with respect to function level the manufacturer has to indicate the function level his appliance is designed for. The appliance performance is determined at a corresponding level of energy demand (function class).

3. Both label system 2 and 3 apply the concept of "function class". The pro's and con's of both systems need to be discussed more deeply with market parties before making a final conclusion.

4. Label system 1 introduces problems since the ranking is clearly depending on the tapping pattern used. Label systems 2 and 3 allow better comparison of appliances designed for the same function class.

5. Label systems 2 and 3 allow better ways for realistic appliance efficiencies at different hot water demand levels.

6. Appliance efficiency determination using method B seems the best way to fulfil all demands on the method (in label system 2 or 3). It allows a direct measurement of appliance efficiency with a tapping pattern related to its function class. It also provides additional data required for simple modelling, allowing extrapolation of the measured efficiency for other hot water demands, offering a good connection to all kinds of building energy performance calculation methods (flexibility).

10. Recommendations

Within the EU a considerable saving potential exists in primary energy used for the production of domestic sanitary hot water. In order to utilize this potential several policy options could be used. This study has focussed on the following items as important building blocks for policy options:

- tapping patterns
- test method
- evaluation scheme

The following is recommended to develop and implement labelling and other information systems for domestic hot water appliances:

- Because in practice a large variation in tapping patterns exists and different appliances are designed for different use, an EU labelling system and other information systems should use a range of tapping patterns. The efficiency of the appliance (and performance aspects) has to be determined at least at the tapping pattern that reflects (most) the function class the appliance is designed for.

- It is recommended to discuss with market parties whether to use one general rating scale or different rating scales per function class.

- It is recommended to determine the appliance efficiency to be used for the EU energy label by means of measuring the efficiency for a tapping pattern. In addition a limited number of appliance parameters are to be measured to be used in a model to calculate efficiencies for other tapping patterns then measured. It is recommended to develop and define the calculation model on the EU-level.

- To cover a wide range of appliances with respect to the used energy source, a labelling system should use efficiency figures based on primary energy use. Therefore, such a system should include an electricity generation efficiency. Preferably this is defined on the EU-level, but since differences between countries exist, it can also be done at the level of (groups of) countries.
  The tapping patterns used for the labelling system should be the same for appliances designed for the same use, regardless the energy source of the appliance.

- The prEN13203 appears to be a suitable measurement method regarding the tapping patterns to measure appliance efficiencies. However, a Round Robin test is recommended to develop a Good Laboratory Practice (GLP) to improve the reproducebility of measurements carried out according to the prEN13203.