Preparatory Study on

Eco-design of Boilers

Task 3 Report (FINAL)

Consumer Behaviour & Local Infrastructure

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1 INTRODUCTION

1.1 Scope

This is the draft interim report for Task 3 of the preparatory study on the Eco-design of Central Heating Boilers for the European Commission, in the context of the Ecodesign of Energy-Using Products Directive 2005/32/EC.

Task 3 consists of two subtasks:

1. Identification of possible barriers to eco-design innovations due to social, cultural or infra-structural factors;
2. User-defined parameters that influence the environmental impact during product-life and that are different from the Standard test conditions as described in Task 1.

The following section describes these tasks in more detail, using the text of the Tender as reference. After this the structure of the report is explained, showing how the required items are covered in the underlying report.

1.2 Identification of possible barriers to eco-design innovations

The tender requires the contractor to assess:

- cultural and social aspects relating to purchase, use and disposal of the product. Including an estimate of the e.g. second-hand market, repairs and product life, etc.
- local infra-structure related to the product. E.g. reliability of the electric grid and how consumers deal with it. Special tariffs and consumer behaviour. For installed appliances: Penetration of gas-grid, logistics of oil/coal/peat/wood storage, chimney renovation costs, etc...

The main barrier for Ecodesign is the fact that the buyer of the CH boiler is not the user and therefore is not confronted with the energy costs. This is certainly true for new buildings, where the purchase of a boiler is simply a part of the building costs. Especially in countries with low energy tariffs and/or a low awareness of the potential house-owners of the energy bill, the energy efficiency of the boilers will not serious affect the price of the building as a whole, practically allowing builders and specifiers to prescribe the cheapest solution that the legislator will allow.

But also for boiler-replacements in existing buildings the main influencer of the purchase decision is not the user. Installers –as advisers of the house owner—play an overriding role as the average consumers do not judge themselves expert enough to go against such an advice.

The motives and training level of these specifiers and installers will be a major theme in our study. Also here, there are considerable differences between countries.

The local infra-structure is another major issue. First of all, the penetration rate of e.g. the gas-grid, the availability and infra-structure costs of other fuels (oil, biomass, coal, district heating) is a very important consideration in the legislation and therefore in the study proposed here. Furthermore, the infra-structure would also include the house and certain technical provisions, like chimneys. As an extension on our work in the MEEUP project, we intend to look installation costs for chimneys that are appropriate for condensing boilers in some other countries besides the Netherlands.

1.3 User defined parameters

Quantification of user-defined parameters relating to the product, e.g. :

- load efficiency (real load vs. nominal capacity),
- temperature- and/or timer settings,
- characteristic of use.

The load efficiency of a CH boiler depends only partly on the user. Other important factors are the dimensioning and control-features of the boiler, the characteristics of the heating system (radiator, convector, tubing, valves, floor/wall heating, etc.). These "other important factors" will be investigated in the subtask on systems analysis.

Major user-related concerns the desired indoor temperature and the control behaviour.

For the room temperature and the control behaviour relevant parameters are the:

- Desired indoor temperature when there are people present;
- Whether the temperature control takes place through a central room-thermostat and/or whether there is a local control per room through thermostatic valves;
- Whether the control device is programmable in time (24h, weekdays, Saturday, Sunday) and –if so—what a typical timer- and temperature setting is.

Furthermore, regarding the boiler temperature it is important to know:

- Whether it is manually- or weather-controlled, i.e. adjusted dynamically according to the outside temperature and;
- How the setting is of the manual control (temperature) or the weather control (angle of heating curve).

Finally, the fraction of boiler-owners that is actually shutting off the boiler outside the heating season needs to be established.

Specifically for boilers running on liquid and solid fuels (coal, biomass, etc.) the consumer is also an important factor in determining the fuel-quality and the storage conditions (humidity).

1.4 Report structure

The barriers mentioned in the first subtask "Identification of possible barriers to ecodesign innovations" fall into two categories: The first category are the social, cultural barriers which are related to the influence of the installer and other stakeholders on the process of specifying boilers. The second category of barriers are the technical constraints related to the energy infrastructure and the characteristics of houses that are also partly shaped by climate, cultural and social aspects.

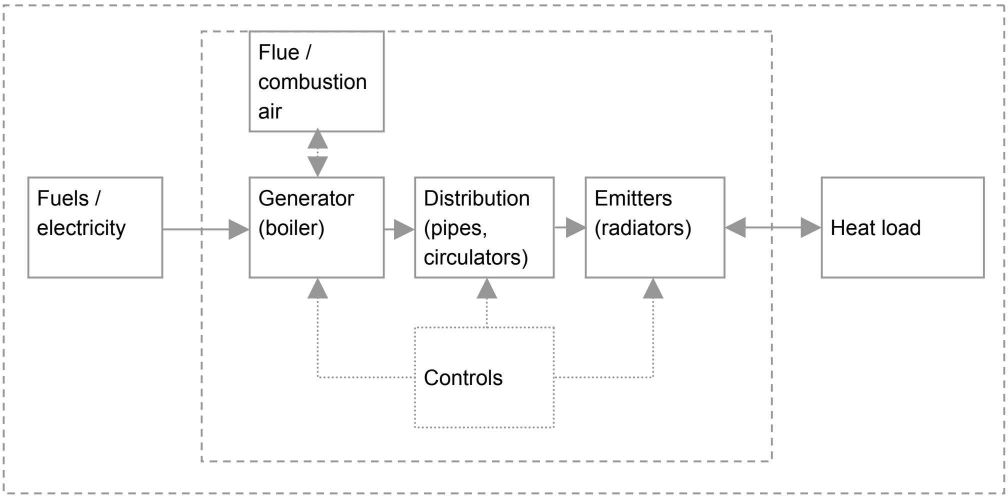
These items are covered in the report as follows:

- Chapter 2 describes cultural and social aspects relating to purchase, with a focus on the role of the installer;
- Chapter 3 describes the climate and housing characteristics per Member State;
- Chapter 4 describes the energy infrastructure per Member State and the consequences at local level;

The second subtask of Task3 is to quantify relevant user defined parameters that influence the environmental impact.

These parameters are described in Chapter 5 following a structure based upon central heating system components.: (siting of) boiler, distribution, emitters and controls. Chimneys and flues are extensively covered in Chapter 6.

The inner box in the figure below indicates the components of the central heating system (Chapter 5 and 6). The outer box indicates elements described in Chapter 3 and 4).



Please note it is not the intention to describe the functioning of the boiler and the rest of the heating system - that is the subject of Task 4, Product and System Analysis.

The outputs of Task 3 (and Task 4) will be used in Task 5 (Basecase) in which a model is constructed describing the average EU boiler.

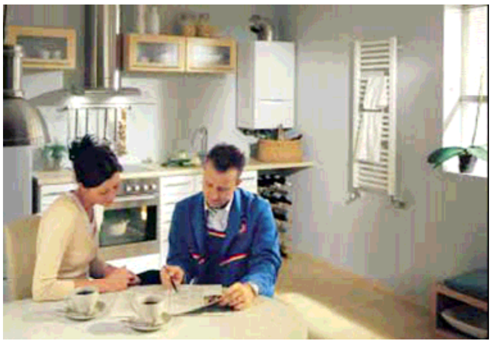
2 CONSUMERS, INSTALLERS AND OTHER STAKEHOLDERS

This Chapter deals with the process of specifying central heating boilers which appears fore mostly a task for the installer. Besides installers also the role of the householder or housing developers, as the ones often initiating the contact and ultimately paying for the system and other stakeholders such as manufacturers and housing authorities is described.

2.1 Survey: How households choose their boiler

Most of the information in this section is based upon the 1999 study Lower Carbon Futures: Appendix C [1] which presents the findings of a very detailed study of motives and behaviour of actors involved in the process of specifying boilers. Although it mainly focuses on the residential sector of the UK the findings are so recognisable that they are deemed relevant for the rest of the EU as well, although the percentages presented of course will be different given the spread in legislative environments and market characteristics in other Member States. The study was based upon lengthy interviews with eleven households who recently bought a new boiler/installation or gas water heater, backed up by telephone interviews by GfK with a much larger group of households. Furthermore a group of installers, manufacturers, trade associations, developers, housing associations and local authorities were contacted as well.

Figure 2-1: householder consulting an installer [2]



2.1.1 Householders

The householders were asked what motivated them to decide for the installation of a boiler. The unprompted - the first answer that sprung into their minds - showed that approximately 2 out of 3 installations are motivated by boiler breakdown or concerns related to that.

[1] Banks, N.W., Appendix C: The UK Domestic Heating Industry - Actors, Networks and Theories (Background paper for Lower Carbon Futures study), ECI, Oxford, 1999

[2] Source: www.waermewasserluft.de

Table 2-1. Reason for new installation

	percentage
Fault or breakdown	49
Old installation prone to breakdown (but still working)	14
Reorganisation due to other building project	7
New requirements (e.g. more capacity, combi functions)	7
New kitchen	6
No heating before	6
Efficiency concerns	4
Safety	2
Extension	2
Wasting money concerns	1
Comfort / level of service concerns	1
Other	3
Total	100

Other important motivators are refurbishments, home improvements or other building reorganisation projects. This includes the "new kitchen" as reason which is typical for the UK (and Italy), where over 50% of boilers are installed between or next to the kitchen cupboards. The report mentions that some 22% of new boiler installations are related to a kitchen refit. Only 5 tot 7 percent mention "changing needs / other requirements" as main reason (e.g. need for boiler with more output or combi-functionality). Some 4-5 percent mention energy efficiency/running costs.

The study also revealed that some 23-29% of respondents have a service contract for their boiler

The respondents were then asked who did the installation. A large majority (over 80%) used an unknown (no friend/relative) professional installer. Some 10% relied on a known installer and 8% had a known, non-professional installer (friend/relative/him-/herself) doing the job.

Table 2-2. Who installed the system

Who installed the system	percentage
Professional installer	82
Professional installer who is friend or relative	10
Friend or relative	4
Me, spouse or partner	4

The study also makes an important remark about trust in installers. It revealed that some 60% of the respondents would not trust an unknown installer. This is flagged as a potential disincentive in taking initial steps to improve heating systems - especially where one has no pool of objective advice to call on to judge whatever the professional installer may say.

This apparent lack of trust is also recognised by the sector itself, a.o. in publications by the EETB and the European Commission [3].

Householders were also asked how they decided on which installer/installation to use. In case the householder had time to gather information before installation he/she obtained quotes from a number of installers. Over a half of the householders obtained more than one quote, allowing a comparison.

Table 2-3. Number of quotes

	none	1	2	3	4	5 or more

[3] Competitiveness of the Construction Industry, DG ENTERPRISE, Education, Training and Image Working Group, Bruxelles, December 2000 (http://www.ceetb.org/docs/Reports/training.pdf)

percentage	12	35	18	25	6	4

This also shows that the other half of respondents apparently rely on the installer to suggest what he/she thinks fit.

Some 35% of the respondents described the boiler replacement situation as an emergency, whereas 70% felt they had the time to gather information prior to work being done.

When asked whether the respondent was interested in energy efficiency a large majority indicated they were.

Table 2-4. Are you interested in energy efficiency?

	agree strongly	agree slightly	neutral	disagree slightly	disagree strongly
percentage	36	42	8	6	8

A similar response was prompted by the question whether one was interested in reducing home energy use.

Table 2-5. Are you interested in reducing home energy use?

	agree strongly	agree slightly	neutral	disagree slightly	disagree strongly
percentage	45	26	12	12	5

A large majority of householders appeared prepared to spend significantly to heat the home in an environmentally friendly way

Table 2-6. Are you prepared to spend significantly to heat the home in an ...

	agree strongly	agree slightly	neutral	disagree slightly	disagree strongly
percentage	42	40	12	4	2

Interpretation of the above however is somewhat difficult since householders may also refer to changing the origin of their fuel instead of replacing/upgrading their system (e.g. buy green power).

It does however indicate some leeway for installers not to come up with the cheapest solution every time. An option for installers would be to give at the minimum two quotes - one more efficient, one conventional package. Householders can then choose and the installer does not risk losing the business.

Surprisingly, when asked for their interest in heating domestic water in a more environmentally friendly manner, the responses were much more spread evenly with some 40% indicating no interest in this.

Table 2-7. Are you interested in heating domestic water in a more env ...

	agree strongly	agree slightly	neutral	disagree slightly	disagree strongly
percentage	31	18	11	8	32

Even more disinterest was noted regarding the application of innovative heating techniques, with only 19% showing a positive attitude and 70% showing a negative attitude.

Table 2-8. Are you interested in innovative heating techniques?

	agree strongly	agree slightly	neutral	disagree slightly	disagree strongly
percentage	9	10	11	33	37

Whether this expresses a certain conservatism towards actual application of such techniques or just a casual lack of interest in the technicalities involved is not described. Fact is that adoption of an innovation has always been confined to a minority at first, requiring a personal risk and a strong motivation.

The householders where then asked what information they used in the decision process.

Around 71% had used only the information supplied by the installer for choosing their boiler. The remaining 29% actively sought information from other sources; most common were builders / plumbers merchants (20%), local energy centres (17%) and word of mouth (17%). TV and/or general advertising were rarely mentioned.

The actual decision for a new boiler is not always solely in the hands of the installer. In approximately 46-51% of the cases the decision was made by the installer together with a person from the household. The other cases were decided by either the installer alone (27%) or by a member of the household (22 to 27%).

Around one third of the householders responded that the manufacturer or model were considered important. Half of the householders considered it of little to no importance.

This also becomes evident when people are asked why they opted for a certain brand or make. For over half of the households it is that the installer recommended it.

Table 2-9. Selection of brand or make

	1994	1995	1996	1997	1998
Recommendation by installer	50	50	54	61	65
Well known make/brand	10	11	9	8	10
Price	9	7	6	7	10
Fuel savings / running costs	7	6	8	5	5
Appearance	5	4	5	6	4
Other	19	22	18	13	6

The influence of installer on householder also stretches out to providing the options from which the householder can choose. In only one/fifth-one/fourth of the cases the householder decided by him-/herself.

Table 2-10. Alternative options considered

	System choice	Make and model choice
I left it up to him	56	50
He gave me a few choices and I chose between them	10	13
I decided and he gave some options	7	7
I decided	20	23
Other	7	7

The statements above indicate a strong influence of installers on the type of boiler fitted. This could be a hindrance in case the installer has a conservative attitude towards new technologies and some interviewees have witnessed such reticence and obstruction from the installers when they were opting for condensing boilers.

The study furthermore suggests that many people put up with boilers and heating systems that are barely functional, indicating a resilience for poor heating performance and the heating bills that might go with this [4]. Some households remain reluctant to changing their heating system or boiler because of concerns over higher heating bills or that the introduction of new technology requires a change in lifestyle (e.g. no drying of clothes in airing cupboard now that the old boiler has gone) which is not always appreciated.

[4] Poor heating performance or poor heating comfort may also lead to low heating bills (e.g. if only a limited number of rooms is heated adequately due to poor system performance). Heating bills should not be seen separate from the heating comfort that is achieved.

As mentioned in many other studies, an excellent opportunity to inform people regarding improvements in energy performance is when they are planning refurbishments, kitchen refits, extensions, etc. in their existing home or new home.

2.1.2 Installers

Specification of boilers by installers (selecting output, type, brand/model) differs depending on whether the installer is self-employed or working for a larger company. The former situation often has the installer specifying the boiler, often using his/her experience, general guidelines and/or rules-of-thumb. In the latter situation it is often a heating engineer or other desk-bound individual who specifies the boiler and the rest of the heating system.

The specification process also differs depending on whether the installation is new build or in existing properties.

New build

Larger housing developers often specify exactly the type and make of the boiler to be installed. The responsibility of the installers lies in supplying the specified system and installing it.

Smaller builders and housing developers leave more to the installer himself who often employs a heating engineer to specify the system.

Existing homes

In the context of existing homes the installer has a lot of control over the specification of the boiler. Many installers make an effort to fit the system that is most appropriate for the preferences and lifestyle of the occupants, but much depends on the individual qualities and preferences of the installer. The price quote by the installer can be influenced by the amount of work available to him/her - if there's enough work, then the price quote obviously will not be rock bottom.

When specifying boilers the personal experience of the installer with a certain brand or model is very influential. Reliability is paramount, since no installer wants to be called back for repair of a recently installed boiler. Many boilers also require specialised tools, spares and knowledge and there's a limit to the number of boilers an installer has detailed knowledge of.

This loyalty to a certain brand and/or models is also fostered by manufacturers, offering incentives such as point schemes for gifts for each boiler sold, comprehensive after sales service and courses at training centres.

The positive side of such loyalty is of course a better familiarity with and support for the specific product. At the down side one can mention that installers remain rather conservative and wary of new or innovative products, especially if they are made by an unfamiliar manufacturer.

The condensing boiler

In general the installer has a positive attitude towards energy efficiency. However many misconceptions and myths around condensing boilers remain, e.g. that they only work best during the coldest time of the year, that they are not financially viable, that customers do not want them, etc. [5]

Most installers think more gains are to be achieved in better control of the system. Accordingly thermostatic radiator valves and electronic controls were often mentioned, both with their merits and drawbacks. Other items mentioned to improve efficiency are combi-boilers ("they only heat the water you need") and a reduced distance to the draw off point.

[5] The survey is from 1999. It would take another 6 years before the condensing boiler would become mandatory for most applications (Part L of Building Regulations).

Fact remains that installers are rarely asked to focus on energy efficiency by their customers: "Most of them just want something that heats the house."

Conclusions

- Installers are broadly responsible for the specification of heating systems in existing housing;
- Installers are conservative in their approach towards new and innovative techniques. Reasons are:
  - a preference for expanding depth of knowledge, tools and experience for a limited array of boilers;
  - relations that exist between installers and manufacturers (ranging from credit schemes to visits to training centres);
  - installers do not want to be called back for a job on a recently installed boiler - it costs them money and reputation - and therefore prefer to install trusted, "reliable" technology;
  - that new technologies like the condensing boiler are perceived to give marginal energy savings and are significantly more expensive;
  - that installers do not feel there is a strong demand for e.g. condensing boilers;
- There is anecdotal evidence that installers have even discouraged interested customers in installing a condensing boilers;
- That this situation of lack of trust by installers and lack of demand from customers is likely to continue until the "chicken-and-egg-situation" is resolved (Authors: and this has happened in the UK by the introduction of Part L in the Building Regulations prescribing condensing boilers as of 2006).

An argument against efficient condensing boilers (not made by the survey but often heard as anecdotal evidence) is that with retrofitting condensing boilers (that work with lower heating system temperatures) the radiators are sized too small. Although this might be true in principle (in the UK system temperature of 90-70°C are customary, whereas in other EU countries this is often lower) it should not be presented as a obstacle for putting in condensing boilers. What is overlooked is that in many cases radiators are oversized to begin with (a quote from an installer is: "if the radiator looked too small they'd fit the next larger one") and that condensing boilers can run just as hot as conventional boilers delivering just as much heat to the house but with better efficiency, even in non-condensing modes, due to its larger heat exchange surface. During part load operation (the larger part of the year). radiator sizing is also less critical.

The average age of installers is also an aspect often overlooked, but closely linked to installer attitude towards newer technologies and the level of experience with these. It is known that the UK suffered from a shortage of plumbing skills early 2000 [6]. The Government and the trade associations tried to overcome this with the introduction of NVQ qualification schemes and many schools started apprentice courses. More on this aspect in section 2.4 of this Chapter.

2.1.3 Manufacturers

The principle marketing target for manufacturers is the installer, who is essentially the one "pulling the product from the merchants shelf". Brand loyalty of installers is sought, by a.o. providing educational facilities with free products (so that the apprentice-installer gains experience with their products), point-schemes, sophisticated web-sites, promotions in trade press and at builders and plumbers merchants.

The latter is seen as not that effective since most installers already know what they want before they go to the merchant. It is believed only 10% of installers can be influenced on

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[6] APHCL News Release, "There isn't a shortage of plumbers say APHCL", January 16, 2006 (APHCL = Association of Plumbing & Contractors Ltd.)

the shop floor. To influence installer preferences merchants do run promotion schemes or offer complete 'heating kits'.

Manufacturers know that it is the installer rather than the householder or merchant who specifies the boiler, but at the same time feel that installers make poor ambassadors for their products. Manufacturers would like to see installers becoming better salesmen and improve the quality of their installations - call backs may affect the reputation of the brand (many faults develop because of the quality of the installation rather than the product itself). That's why training installers to work with their products is an important item, which goes well with efforts in promoting energy efficiency. The CHIC (Central Heating Information Council, funded by manufacturers), together with the EST (energy Saving Trust, funded by Government) have developed training material for installers as the key to greater efficiency.

2.1.4 Housing developers

In the UK the building sector is a fiercely competitive sector dominated by cost reduction efforts. Developers feel that, location aside, the price is most influential on housing choice. Therefore there is an overriding need to reduce construction costs both to gain a price advantage over competitors and to increase the profit on each house sold. Additional costs which cannot be directly added to the price of a new house are eating directly into the profit margin and are consequently discouraged. It seems to be the industry view that energy efficiency improvements beyond regulated requirements fall into this category.

What developers do to minimise installation costs is to buy in bulk (for larger projects) and settle prices with manufacturers directly. The sub-contractor (installer) is by-passed and the rebate flows directly from manufacturer to developer. Some developers engage in an even tighter relationship with manufacturers by having the manufacturer specify the heating system, based upon drawings and plans supplied by the developer. Such arrangements are called solus-arrangements. When developers are building for housing associations or local authorities the specification might lie in the hands of these parties.

The practice in the UK (and also in Italy and possibly other Member States as well, red.) of producing homes with pre-fitted kitchens - which often includes the boiler - can limit the number of boiler options, sometimes to only those that can be fitted with a fascia. Chances are these are not the most efficient.

Developers are generally not happy with off-standard specification of installations e.g. to improve energy efficiency. It is perceived as something that can create a lot of problems. Despite this many developers feel that there could be a market or at least an interest in energy efficient housing, especially when compared to existing housing with higher heating bills. The difficulty remains that energy efficiency often is not tangible and therefore hard to sell.

As regards solar panels and other innovative technologies the common feeling is that these technologies are too expensive and that only a small group of people would be interested ("solar is something for technophiles or cranks"). The survey mentions that another reason probably is the lack of familiarity of developers with such technologies that. A solution would be to have more local projects with efficient technology to get more people - including building management - acquainted with it.

Another suppressor of innovation in building practises are lenders (those who issue mortgages or lend money for development). If they feel they would not be able to resell the project - in case a mortgage goes bad - they won't lend the money in the first place. It is thought that lenders are extremely conservative in their tastes, making it difficult to introduce visible energy efficiency options like solar panels. The fact that many other efficient technologies are barely noticeable or not visible at all, is often disregarded.

The examples above are classic examples of "split-incentives": the stakeholder responsible for the investment in the boiler is not responsible for paying the heating bills. As long as developers don't see how they can pass on the investment to home-buyers the investment will not be made. The survey suggests introduction of labels, indicating energy efficiency of boilers (or whole heating systems/houses) as a means for installers and developers to "sell" the higher investment costs.

2.1.5 Local authorities

The survey highlights the difficulties, such as lack of funding and resources, local authorities have in putting to practice energy efficiency initiatives from central government. Local authorities also perceive a lack of co-ordination between government schemes and local actors such as local energy advisory centres, leading to a profusion of schemes and inconsistent messages.

Despite such problems local authorities are recognised as perfect in place for giving advice when planning applications come in and alerting applicants for additional funding for weatherisation or other efficiency improvements.

2.1.6 Conclusions

- The three main reasons for a change of boiler or heating system are breakdown, upgrading or changing household needs.
- In almost three quarters of boiler installations for private households the installer has (large) influence on the type of boiler to be installed;
- Some households remain reluctant to change their heating system or boiler because of concerns over higher heating bills or a forced change of habits;
- Installers tend to produce one quote with the least expensive option, whereas over 80% of householders are prepared to invest in a more efficient heating system;
- Installers are (seen as) not the best ambassadors for energy efficiency for several reasons:
    - Installers have a strong preference for sturdy, "reliable" and proven technology, to avoid call backs;
    - Installers like to work with a select range of models which they have experience with and tools and spares available;
    - Installers have relations to certain manufacturers (for gifts, promotion, training) making them wary for (new) products of other manufacturers;
    - Installers think energy efficient technologies do not deliver enough benefits for householders and see no demand for these from households;
- Manufacturers do not see a commercial conflict between their commercial business and promotion of energy efficiency;
- Manufacturers do consider installers as conservative and invest in training facilities and programs to improve installer awareness and experience with new technologies;
- Developers who specify heating systems are seriously hampered by 'split incentive' problems e.g. not being able to pass on higher costs Other stakeholders, e.g. lenders, also take a very conservative approach to housing.
- Local authorities can play a major role due to their involvement in both private and commercial projects by sensitising the specifying parties to energy efficiency issues at a natural moment.

The survey concludes that an enthusiastic installer is potentially the key to more efficient heating installations. To improve current installer attitudes training schemes, targeting both actual installation as well as the skills to sell efficient boilers to the public, have been developed. The development of an A-G level for boilers would help to raise awareness of efficiency as an issue with installers. Such a label would also assist other specifiers such as architects, local authority housing officers and (the small number of) householders who do take a more active role in specification.

2.2 Sizing of boiler

The previous section underpinned the importance of the installer as specifier of the home heating system. It also mentioned guidelines and rules-of-thumb applied by installers to specify the system. This section describes some of these 'tools' [7].

Like-for-like

The simplest form of boiler sizing is in the case of "like-for-like" replacement. Here the installer just copies the specifications of the previous boiler and replaces it by an equally sized, sometimes identical model. It is evident that in such cases no attempt is made to optimise boiler specifications to the actual heat demand.

Guidelines / rules-of-thumb

In case there is no previous installation, or demands have changed, the installer must at least be able to make an educated guess. This is were guidelines and rules-of-thumb are applied. Some examples are:

- In case of existing dwellings the installer may simply add up the capacity of the radiators installed and size the boiler accordingly.
- The installer may calculate on basis of the floor area or the volume of the dwelling and default values the needed output of the boiler:
  - Example from the Netherlands [8]: A dwelling needs 45 W output per m³ floor area (for a 100 m² dwelling with room height of 2.5 m the volume is 250 m³ is 11.25 kW);
  - Example from Germany [9]: For multi-family housing the dwelling needs 0.07 kW of boiler output per m² floor area (100 m² dwelling is 7 kW). For single-family / detached housing this is 0.10 kW per m² (100 m² dwelling is 10 kW).

The German values are derived from the now outdated HeizAnlagenVerordnung from 1994, the current EnergieEinsparVerordnung does not contain these references anymore.

It is clear that such guidelines totally disregard the spread in actual heat demand, which depends on many aspects (notably transmission and ventilation losses). The graph below [10] shows the range where the most upper diagonal describes a poorly insulated old dwelling and the bottom diagonal a dwelling according the latest Building regulations in Germany.

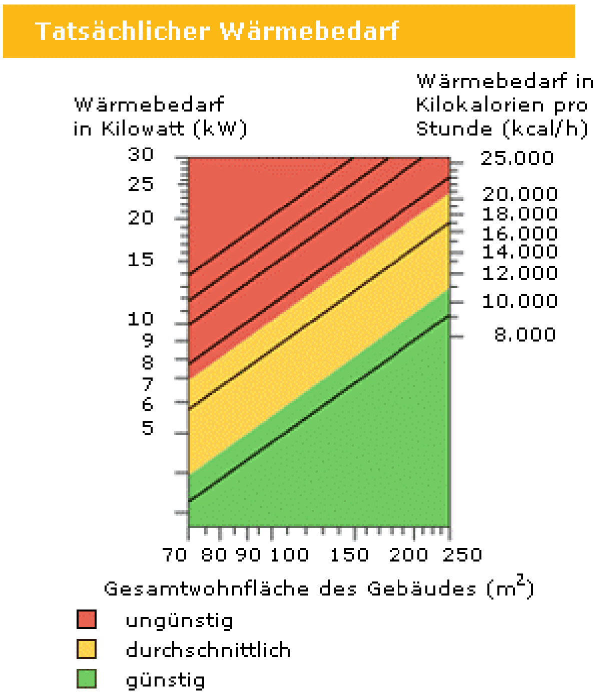
[7] http://www.centralheating.co.uk/index/fuseaction/site.articleDetail/con_id/5173

[8] http://www.cvkoopjes.nl

[9] http://www.wasserwaermeluft.de/b2c/sparen/ressourcensparen/00466/index.html

[10] from http://www.erdgasinfo.de/contents/gasheizung/index.html

Figure 2-2: Similar sized dwellings show considerable differences in average energy consumption per sq.m. floor, depending on insulation level, etc. [11]



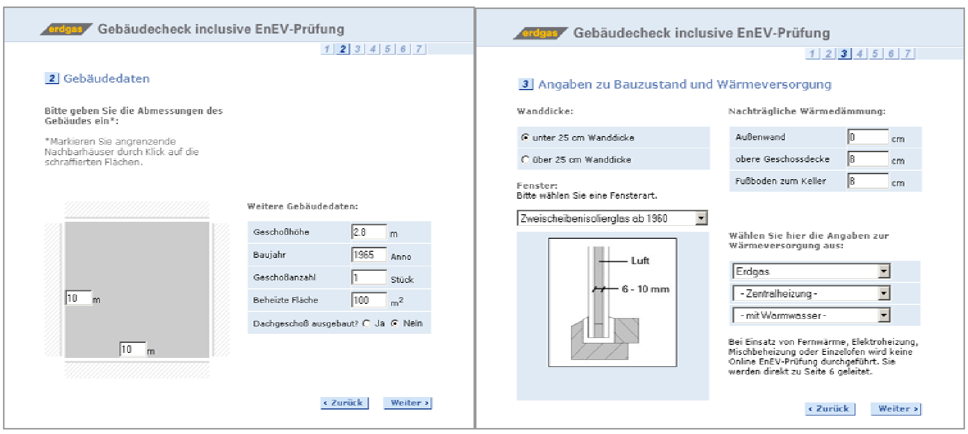
Of course the installer must also take into account other demands like whether the household wants to combine the heating with hot water facilities and, if so, what kind of hot water demand would be expected (a large family would probably require a large storage tank or high hot water flow rates, whereas this is not the case for an elderly person).

Heat loss calculation

The third option is to make a calculation of heat loss which includes an assessment of current levels of insulation (including windows) and infiltration air. Most of these methods are identical or rely heavily on existing Building Codes and the standards that apply in those. In case of combi-boilers the hot water demand should be taken into account as well for which many methods apply default values that can differ significantly per Member State (see also Task 1 of the parallel preparatory eco-design study on Water Heaters).

On many websites (from trade associations and manufacturers) installers and competent self-builders can download software to calculate heat losses of the dwelling.

Figure 2-3: Simple pages allow entering of basic dwelling data. The third page shows the calculated heat demand[12]



[11] Source: www.erdgasinfo.de

[12] http://www.erdgasinfo.de/contents/gasheizung/index.html

Another example is found on www.centralheating.co.uk, the website by the Heating & Hot Water Industry Council (UK's association of manufacturers of central heating equipment) which also contains explicit warnings against over sizing:

from www.centralheating.co.uk:

The correct sizing of a boiler is important, whether it is required as a replacement, or for a new installation. An oversized boiler costs more to purchase, generally operates less efficiently resulting in higher running costs and increased emissions to the atmosphere.

Boiler size is often established on the basis of existing radiator output. This nearly always leads to substantially oversized boilers and is not a recommended practice.

The determination of boiler output, other than for a combination boiler, is related directly to the 'heat loss' of the property, plus additions for domestic hot water requirements, losses from pipe work not used as useful heating surface and an allowance for intermittent heating.

For the vast majority of domestic dwellings, the heating output of combination boilers far exceeds the needs of the property, because such boilers are sized to meet the greater demands of the hot water requirements. (Most combis are fitted with a 'range rate' device enabling their 'heating output' to match the needs of the property)

Other than for large dwellings, with higher than normal occupancy and, therefore, heavy hot water use, boiler size is normally arrived at in the following way :
- heat loss of the whole dwelling including extensions.
- 10% for intermittent heating
- up to 5% for pipe work losses
- 2 kW for hot water

This, of course, assumes that a cylinder is used to provide hot water and that the cylinder is heated by the boiler.

The method of sizing for condensing boilers is no different to that of any other type of boiler.

For an accurate assessment of heat losses, the calculation would usually be carried out 'long hand'. For further information on calculating heat losses and boiler sizes, please use the Heat Loss Calculator.
...

The Heat Loss Calculator is software that can be bought for 23 euro which helps the installer (or competent consumer) to calculate the size of radiators and boilers. It contains a list of 900 gas, oil and LPG boilers and sixteen alternative styles and patterns of radiators from seven radiator manufacturers.

The software allows a fairly detailed input of the dwelling and system characteristics as shown by the example pages below.

Figure 2-4: Entering characteristics room by room [13]

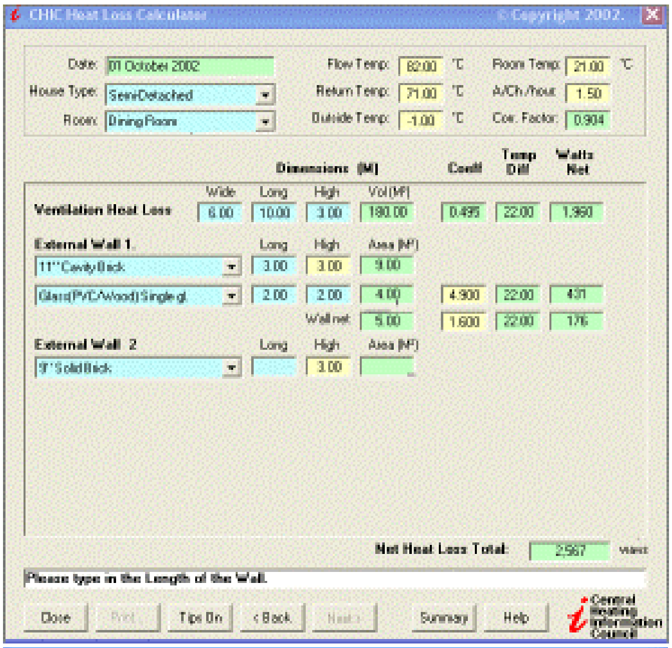


Figure 2-5: Choosing type of radiator

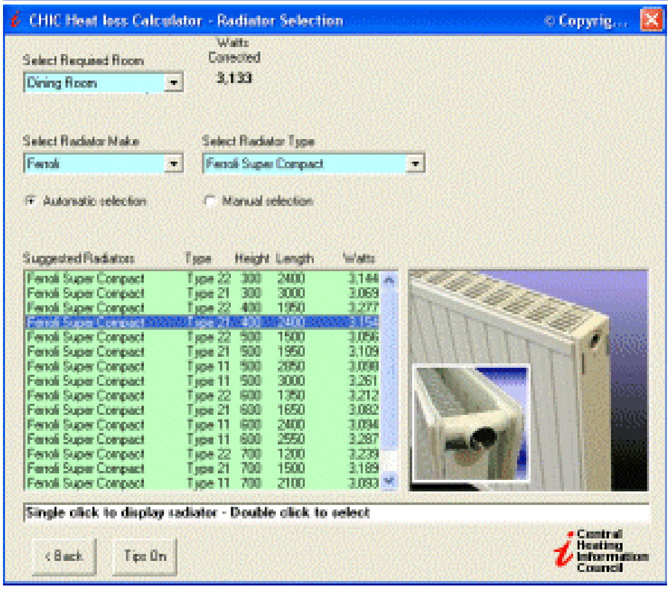
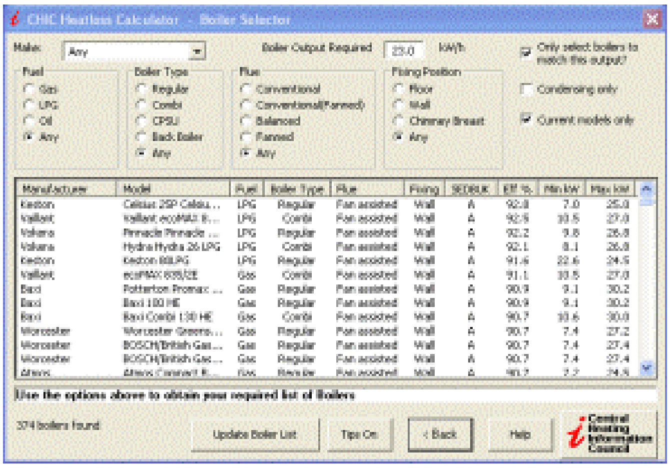


Figure 2-6: Selecting type of boiler



Common causes for oversizing

- But even such sophisticated software cannot avoid a very common cause for oversizing, namely the (instantaneous) combi-boilers, specified to deliver a

[13] Source: http://www.centralheating.co.uk

comfortable hot water output. This output is in most cases much higher than the maximum output needed for space heating;

- An other issues the software cannot avoid is that in case of replacement, boiler options are also limited by existing flues, pipework, etc. (or the householder must be prepared to invest in a different layout). In existing homes a " like-for-like replacement" is often the simplest form of replacement and therefore probably preferred by installers, disregarding actual heat losses;
- In some cases it is the sheer urgency of boiler replacement that there is not enough time to go through a lengthy, well-balanced decision process. A broken down boiler in winter time needs fast replacement without fuss;
- And finally it is known that most people, both installer and householder/specifier, adhere the "better-safe-than-sorry principle" and permit oversizing.

Noteworthy in this context is the UK campaign "skills for business" which aims to train some 70.000 heating fitters in advising and installing more efficient appliances and equipment. Similar campaigns exist in other Member States as well (see www.managenergy.net, supported by the European Commission).

Given the pivotal role of installers in the process of specification of boilers and heating systems the following section describes in more detail the size and organisation of the installer work force and presents examples of installer education in three countries.

2.3 Size and organisation of the sector

2.3.1 Size [14]

Statistical information on the sector of installers is covered by classification NACE 45.3 "Installation work", which in turn is subdivided into four classes: Installation of electrical wiring and fittings (NACE class 45.31); Insulation (NACE class 45.32); plumbing (NACE class 45.33) including all water and gas supply, drainage, heating and ventilation work; and other building activities (NACE class 45.34). Note that the installation of industrial equipment (for example the installation of industrial furnaces and turbines) is excluded. According Eurostat some 2.9 million people where employed in sector 45.3 in the EU25 in 2002 and generated 88.7 billion euro of value added. As such the installation sector as a total made up nearly a quarter of the overall contraction sector (NACE 45) contributing 23.9% of the workforce and 23.1% of the value added.

The largest contributing Member States to the overall performance of the sector 45.3 are the United Kingdom (19.8% of value added in the EU25), Germany (19.2%), France (15.4%) and Italy (12.8%). Other Member states shows shares below 10%. As regards EU25 employment Germany leads (with 17.6% share of EU25 employment), followed by Italy (14.9%) and Spain (14.1%).

A more detailed analysis of the subsector (unfortunately excluding Member States as Spain, Belgium, Czech Republic, Greece and Malta, Netherlands incomplete) shows that plumbing contributes 40.1% tot the total of value added by the sector, second to electrical wiring and fittings (48.2%).

When looking at the size of companies (for the same subset of Member States as above) involved there is no detailed breakdown for the plumbing sector but the installation sector as a whole consists of 35.5% micro-enterprises (1-9 persons employed), 32.9% small enterprises (10-49 persons employed) and 31.6 medium to large enterprises (50-249 and 250+ persons employed).

2.3.2 Organisation

Installers are organised on European level through the CEETB, founded in 1976 as the joint European association of electrical, heating, air conditioning, ventilation and plumbing contractors. CEETB has 25 membership countries and represents about

[14] European business, Facts and figures Data 1995-2004, Eurostat, 2005.

450,000 specialist building contractors with 2,400,000 employees in the European Union and beyond. According CEETB these companies have a combined overall turnover of about 200 billion Euro.

The CEETB itself is composed of the organisations AIE (International Association of Electrical Contractors), the GCI (International Union of the Associations of Heating Ventilating and Air-Conditioning Contractors) and the UICP (International Union of Roofing and Plumbing Association). Of these the GCI is of course the organisation representing the installers and most relevant here. GCI's 15 member organisations represent 80,000 contracting businesses with a total workforce of more than 500,000. The member organisations of GCI at national level are indicated in figure xx below.

However not all installer companies operating in a country are members of such organisations. As an example the Dutch UNETO-VNI claims there are some 12.300 companies active in the installation sector, employing 120.000 persons and producing an annual turnover of some 12 billion euro. However only 5.000 companies are member of UNETO-VNI (realising a turnover of some 10 billion euro turnover indicating it is mainly the larger companies that are member). A similar situation can be expected in other member states indicating a significant group of companies that are not represented by national trade associations. Furthermore these organisations listed below may be represent ting trades besides that of plumbing / installation work.

Table 2-10. Installers professional organisations

MEMBERS GCI at country level		# of members or companies(if indicated on website)	
Austria	B.S.H.L.	Website: http://www.shk.at/	
	VZHL	Website: www.fmmi.at	
Belgium	F.B.I.C. - L.B.I.S.	Website: http://www.lbis-fbic.be	
	UBIC	Website: www.ubic.be	40% of employees
Denmark	DANSK VVS	Website: www.tekniq.dk	
Finland	LVI-Tekniset UrakoitsijatLVI-TU ry	Website: http://www.lvitekniseturakoitsijatlvitu.fi ; http://www.lvi-tu.com	
France	UCF	Website: www.ucf.fr	4600 companies, 55,000 employees, 40 billion francs turnover
Germany	BHKS	Website: http://www.bhks.de	600 companies 45,000 employees
	ZVSHK	Website: http://www.wasserwaermeluft.de	50.000 companies, 300,000 employees
Ireland	M.E. & B.S.C.A.	Website: http://www.cif.ie	3000 members
Italy	ASSISTAL	Website: www.assistal.it	1500 companies
Luxembourg	Fédérations des Installateurs en Equipements Sanitaires et Climatiques	Website: http://www.federation-des-artisans.lu	
Netherlands	UNETO-V.N.I.	Website: www.uneto-vni.nl/ www.vni.org	5000 companies
Norway	N.R.L. - VVS	Website: http://www.nrl.no	
Portugal	AECOPS	Website: http://www.aecops.pt	
Spain	CONAIF	Website: http://www.conaif.com	
Sweden	Platslageriernas Riksförbund	Website: http://www.plr.se	
	VVS - Installatörerna	Website: http://www.vvsi.se	1400 members
Switzerland	Suissetec	Website: http://www.suissetec.ch	3200 members of which
United Kingdom	APHC	Website: http://www.aphc.co.uk	
	HVCA	Website: http://www.hvca.org.uk	
	SNIPEF	Website: http://www.snipef.org	

AFFILIATE MEMBERS		
Australia	AMCA	Website: www.amca.com.au
Bulgaria	NIS	Website: http://www.nisbg.org
Canada	Mechanical Contractor Association of Canada	Website: http://www.mcac.ca
Cyprus	Mechanical Contractor Association of Cyprus	Website:
Czech Republic	Czech association of mechanical, electrical and plumbing contractors	Website: http://www.amf.cz
United States	MCAA	Website: http://www.mcaa.org
	MCA	Website: http://www.ncmca.net

2.4 Training / certificates / qualifications

Installers carry great responsibility in keeping up to standards the energy efficiency and safety of the heating park and of new installations. For this it is essential that adequate training is followed, often communicated to the public through certification (or qualification) of expertise.

Each Member State has its own set of requirements for installers in order to be allowed to work with gas, electrical and other potentially dangerous goods and equipment. In certain Member States certification or qualification schemes for installers are mandatory. Certification often is only valid for certain specific areas in plumbing. A gas installer is not automatically certified for making oil or electrical installations. In some cases certifications schemes are still in its infancy stage, e.g. for the installation and commissioning of heat pumps and/or solar panels.

Since it is not feasible (not within budget nor time scope of the study) to describe all possible training / certification / qualification schemes existing in all 25 Member States some national schemes are highlighted to serve as an example of approaches found.

2.4.1 Example UK

Education

Becoming a heating system installer in the UK starts with basic skills at two or four GCSEs (A-C)/S grades (1-3) levels (school diploma) or an appropriate Intermediate GNVQ/GSVQ level II or equivalent. After this students (often at age 16-18) can either choose to work as apprentice and attain NVQ levels (NVQ = National Vocational Qualification [15]) through learning at the job combined with part-time training or continue with full-time education. The apprentice route is very popular and leads to relevant NVQ qualification level 1 to 3 in a period of 2 to 4 years [16,17].

Heating installations

In the UK homeowners are required to inform their Local Authority Building Control if they realise new electrical, gas, oil or other installations or make significant changes to existing ones. The Regulation requires such changes to be inspected, possibly by third party involvement. In order to take away some of this burden from homeowners and

[15] http://www.qca.org.uk/14-19/qualifications/index_nvqs.htm

[16] http://www.wakefield.gov.uk/JobsAndCareers/ApprenticeshipsandAdvanced/GasFitter.htm

[17] http://www.eaifhe.ac.uk/New%20Courses/Jobskills/JS%20Plumbing.htm

the local authorities the Regulations also introduced a register of Competent Persons, who can do he necessary installation works themselves and notify this to the authorities directly.

Depending on the type of work different registrations apply:

- Electrical: BRE, BSI, ELECSA, NAPIT and NICEIC
- Gas: CORGI
- Oil: OFTEC
- Solid fuel: HETAS
- CORGI and OFTEC also allow certification including minor electrical works (like realisation of sockets for boilers).

Gas equipment

For people working on gas fittings and appliances CORGI registration is a legal requirement.

The Gas Safety (Installation and Use) Regulations 1998 placed specific duties on gas users, installers, suppliers and landlords. Installers of gas equipment are obliged to be CORGI [18] registered. CORGI is charged by the Health and Safety Executive (HSE3) to maintain a register of competent gas installers in Great Britain, Northern Ireland and the Isle of Man. Gas equipment owners are not allowed to have non-CORGI registered installers to work on gas appliances. CORGIS visits each installer before completion of registration.

Installers who have opted into CORGI's Building Regulations Self-Certification and/or those registered with the OFTEC Competent Person Scheme, are able to certify that their work complies with Building Regulations. The NVQ/SVQ in Gas Service Installation and Maintenance is the only gas qualification that allows for CORGI registration.

For new installations (and replacement) this means that all equipment is installed by qualified personnel. For existing installations gas equipment owners have to ensure that Gas fittings (appliances, pipework) and flues are maintained in a safe condition. CORGI recommends safety checks on an annual basis: for home owners-occupiers these are not enforced [19], but for landlords these checks are mandatory (the Declaration that goes with it will be legally required from 2007) and tenants have the right to ask for proof of recent checks. CORGI also states that the safety check is not sufficient to provide effective maintenance and vice versa.

The regulations also place a number of restrictions on gas appliances installed in bathrooms, shower rooms and bedrooms which are detailed and prescriptive. For instance it is now illegal to install instantaneous water heaters, which are not room sealed or fitted with a safety device that automatically turns the gas supply off before a dangerous level of poisonous fumes builds up. CORGI installers also have a duty to report any unsafety regarding gas appliances if they encounter these during their work.

LPG

For the installation of LPG equipment the installer has to be CORGI registered, followed by a specialised training which requires a steep entry level and may cost up to 2 years to complete.

The investment costs for CORGI registration are almost 600 euro for registration and 300 euro for annual membership fee. Including the expense of the NVQ and further Accredited Certification schemes for LPG, the total cost of becoming an LPG installer could easily be between three to five thousand pounds.

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[18] Confederation for the Registration of Gas Installers

[19] http://www.corgi-gas-safety.com/section_gas_law/house-owner.asp

Oil

OFTEC (Oil Firing Technical Association) is a trade association and maintains the Government register of 'Competent Persons' who are qualified to work on oil fired heating and cooking appliances. Although it is not explicitly mentioned that the installer working on the installation should be OFTEC registered, OFTEC mentions evident benefits of hiring OFTEC registered installers since they may notify the works by themselves, avoiding costly inspection by third parties. The client (homeowner / landlord) receives a certificate confirming that the work done meets the relevant Building Regulations and has to keep the certificate in a safe place since it may be needed when Home Information Packs become mandatory for England and Wales in June 2007. The installation itself must follow strict guidelines from Building Regulations.

OFTEC recommends an annual service and safety check including the flue, but also points to manufacturers service schedules as some boilers may require servicing more often than others. When installing a new/replacement equipment the OFTEC Registered Technician is required to ensure as far as is reasonably practicable that the flue liner should last the life of the appliance and may decide for relining of the chimney with a stainless steel flue liner.

If a new/replacement is reconnected to existing stainless steel flue liner, the existing stainless steel flue liner may spilt (allowing products of combustion to escape) when it is disturbed without the technician knowing it.

Training requirements for installing and servicing oil boilers are regulated by OFTEC. The investment for OFTEC registration by an installer is 60 euros per year for an individual and 670 euro for a company for 5 years. Furthermore the installer must have a Public Liability insurance cover, minimum 1.5 million euro. The necessary courses (there are several modules: for oil storage tank installation, boiler installation, pressure jet and/or atomising burner commissioning and servicing, etc.) take half a day to one day to complete. Each installer is visited and accompanied by an OFTEC inspector every 5 years.

Electrical [20]

Applications for any electrical work must be made before work starts, unless it is to be carried out by a 'Competent Person' who is on an Approved Register, and who is capable of 'self certifying' their own work. In cases where a Competent Person is used, Building Control Section will receive notification after completion of the works.

The scope of the electrical work covered (Part P of Building Regulation) that may affect private homeowners includes:

- New Installations, plus;
- Alterations
- Additions
- All electrical work in Kitchens (except accessory changes)
- All electrical work in bathrooms (except accessory changes)
- Power supplies to Sheds, Greenhouses, other Detached Buildings
- Floor and Heating systems
- Extra Low Voltage systems
- Generators
- Swimming pools
- Saunas
- Photovoltaic systems (Solar Panels)

[20] http://www.havant.gov.uk/havant-4145

- Power Supplies in gardens (outside lights, pond pumps etc)

There are certain works that are excluded from the scope of the new regulations, and are considered 'Minor Works'. These include minor repairs to existing fittings, or adding extra sockets or light fittings to an existing circuit.

(Please note: any electrical work in kitchens/bathrooms or other wet areas is not considered minor work, see above)

Any installer on the approved list wishing to self certify their work must use BS 7671:2001 as the standard by which compliance with Part P can be achieved. Any deviation from this standard will require a Building Regulation application to be made.

If a person chooses to use the Councils Building Control Department, the applicant/building owner will be requested on completion to supply an installation and commissioning test certificate completed by a person competent in respect of the inspection and testing of such installations as required by British Standards 7671.

Any person who undertakes work on domestic electrical installations to which Building Regulations applies and fails to follow one of the above procedures may:

- Potentially put their health and safety and that of others at risk
- Be liable for a fine
- Possibly invalidate the home insurance
- Encounter problems with any future sale of the property.

If people are considering DIY electrical work, they should be aware that this new Regulation is equally applicable to that work.

2.4.2 Example NL

Education

In the Netherlands one becomes a heating system installer by following education or courses relevant for the trade (full-time or part-time). Completion of such courses entitle the person to set up a business (Chamber of Commerce checks credentials) [21] .

As regards installer certification / qualification: In addition to what is stated above three voluntary certification schemes exist today: "KOMO-Instal" (which is primarily of interest for installers for large commercial projects and includes heat pump installation), "erkende installateur" by Sterkin [22] and "erkend installatiebedrijf / EVI 2004" by SEI [23] (the latter two are more oriented towards installers aiming at the residential market).

Sterkin certifies according the REG, REI and RES regulations, that have been drafted by EnergieNed and Gastec and describe the way the installer acquires and maintains his/her certification plus some other procedural guidelines. REG applies to gas installations, REI to electrical installations and RES to comfort heating (includes fires, stoves, hearth, etc.). The quality of the installer is periodically checked through inspections of work on-site. The installer pays an annual fee for certification of 55 euro per annum plus costs for inspection. Certification through SEI (set up by UNETO-VNI and VEWIN) is very much alike as described above. Cost for SEI certification are minimum 35 euro per year (excluding VAT and extra costs for inspections).

The nature of these schemes is voluntary leaving it up to the consumer to look for and appoint " certified" installers and be certain that the works are performed by a capable company.

[21] http://www.ez.nl/content.jsp?objectid=17330

[22] http://www.stichtingsterkin.nl/installateurs/index.html

[23] http://www.erkendinstallatiebedrijf.nl/

Heating installations

Inspection of heating installations in the Netherlands is entirely different from what is now common practice for the UK. The Building Regulations do not specify certification requirements for installers. It does however ask for the whole house including the installation to be conform the requirements of the Building Regulations. For existing installations homeowners are not required to hire a certified professional to do the necessary work on installations.

As regards safety of gas and electrical installations the house-owner bears the responsibility to ensure adequate safety [24]. Communities bear secondary responsibility and are required to make sure the house-owners fulfils his/her task. How this is enforced in practice remains unclear, leading to proposals for a mandatory periodical safety check of installations in dwellings. Although this periodical safety check still is a proposal, a Technical Guideline NTA 8025 [25] has been produced to facilitate those wanting to perform such checks today on voluntary basis.

Heat pumps

For heat pumps there may be a requirement for the installer to be STEK-certified, meaning the installer has the mandatory certificate needed for working with cooling systems with a capacity over 500 W and/or over 3 kg of coolants. The STEK regulation [26] was put into practice following concerns over emissions from ozone depleting substances from mainly air-conditioning systems. If the installation of heat pump requires a connection to be made in the coolant circuit a STEK certified installer is obliged. However certain heat pumps are hermetically sealed and the only connections to be made are with the heat source side (often a brine solution, water or air) and the central heating or sanitary water side and may be installed without STEK certification. So it kind of depends on the installation at hand whether STEK certification is required.

2.4.3 Example Germany

Education

Like in the Netherlands an installer starts his/her career by following the relevant education or course, who provides the basic knowledge of the trade (Berufsausbuildung Anlagemechaniker etc.). Such courses take in general some 3.5 years to complete. In order to be able to set up a business of his own an installer must become a master in plumbing-, heating- and air-conditioning/ventilation systems ("Meister für Sanitär-, Heizungs- un Klimatechnike"). The SHK Master title can be combined with elementary qualifications for electrical installations (e.g. to place a wall outlet for a boiler installation). It takes at least 10 months to become a Meister. Another route is through a form of apprenticeship (Geselle), which builds upon training in practice (to be completed with courses regarding business and management). This "on the job" route to becoming a Meister can take 6 years.

Inspection of heating installations

Periodical safety and efficiency checks are mandatory for heating installations in Germany. The Erste BundesImmisionsSchutzVerordnung (1. BImSchV) prescribes maximum emissions of NOx (type testing only), soot and chimney losses (%) and the periods between checks. This legislation is harmonised at National level.

Next to the BImSchV there is the KüO (Kehr und Überprüfungsgesetz = KüO, Schornsteinfegergesetz) which prescribes checks of soot formation and other emissions (a.o. carbon monoxide), the siting of the boiler (are ventilation requirements met etc.) and the flue system (check and sweeping if necessary). The implementation of the KüO can be different in the number of checks required in each Bundesland (region).

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[24] http://www.vrom.nl/pagina.html?id=11506#5

[25] http://www2.nen.nl/nen/servlet/dispatcher.Dispatcher?id=194420

[26] http://www.stek.nl/

Together the BImSchV and KUO are the Regulations that underpin the works of the chimney sweepers (Schornsteinfeger) who must be allowed to inspect the heating installation, possibly clean the chimney and must be reimbursed fur such inspections/work according a harmonised tariff scheme. The Schornsteinfeger also bear a responsibility to check the compliance of heating installations with the EnergieEinsparVerordnung which prohibits continuous use of appliances commissioned in 1978 and before.

Depending on the Region the KUO might require two checks per year for oil or solid fuel installations (the regulation does not allow to combine certain checks in one visit), whereas for gas installations the checks may be bi-annual. For bivalent systems (gas or oil in combination with heat pump or solar energy) measurement of chimney losses by the Schornsteinfeger is not required. Measurement of soot (under 1.BimSchV) and/or carbon monoxide however remains responsibility of schornsteinfeger, so these systems will be checked regularly as well.

This structure of mandatory checks by Schornsteinfeger are currently subject of much debate among house owners who prefer alternative (and cheaper) ways of ensuring correct and safe functioning of appliances. The structure is also discussed in the light of the free market of services in the European Union.

Electrical

In Germany inspections of electrical installations in new buildings or after alterations of existing ones are not compulsory [27]. The electrical installer ("Elektromeister") is deemed competent enough to realise installations of sufficient quality. Since 1996 there is a voluntary certification scheme for electrical installers, called E-CHECK, for which the Elektromeister have to complete an exam to become an member of the association. With E-CHECK the installations should fulfil current standards regarding electrical installations (VDE 0100). Benefits of E-CHECK can be the recognition by certain insurance companies who may offer a discount.

[27] Desmet, G. at al, Overview of Regulations for Electrical Safety in European Residential Buildings, Proceedings 3rd IEEE Benelux Young Researchers Symposium in Electrical Power Engineering, April 2006, Ghent, Belgium

3 HOUSING CHARACTERISTICS

3.1 Introduction

This chapter deals with housing data for system analysis (Task 4), the definition of the basecase (Task 5) and impact analysis (Task 7). It concerns demographics (par 3.2), climate (3.3), physical characteristics (3.4), expenditure (3.5) and financing (3.6). Finally two extensive paragraphs deal with the existing studies (3.7) and a VHK update (3.8) on the average EU heat load of dwellings.

Statistics of housing present a number of problems and it is not uncommon to find several authorative sources using slightly different data. To an extend this is due to the fact that many data are retrieved at local and regional level (cities, villages, provinces, regions) and have to be aggregated a number of times –using slightly different interpretations of definitions- to arrive at a national level. And of course between the Member States the definitoions of buildings and building characteristics are also not harmonised.

Furthermore, there are some very volatile parts of the housing market related to second homes, vacant homes , hotels, trailers/caravans, etc. where data are scarce and not very reliable. This was true for the EU-15 and for the EU-25 the situation certainly hasn't improved.

Finally, mix-ups occur when researchers and analysts start using official statistics and citing their original source and each other incorrectly. The most frequent mix-ups are between 'dwellings' and 'households' (10-15% difference), lower and upper heating values of fuels (5-10% difference), combustion values of fuels in statistics and in engineering, almost-metric units (1 ton= 907 kg or 1000 kg), etc..

In the following paragraphs we have tried to use a limited number of reliable sources. The most comprehensive of these is the 'Housing Statistics of the European Union 2004', compiled by the National Board of Housing, Building and Planning in Sweden (Boverket) and the Ministry for Regional Development of the Czech Republic. These two have retrieved from Eurostat and national statistics a valuable collection of data that also –for the first time in the series that is prepared for the EU Mininsters of Housing—includes the 10 new Member States. Also the authors have outlined the different definitions of housing and housing characteristics in the Member States in great detail. In this chapter we can not reproduce the complete report, but provide the most important data in a series of summary tables. Only on a very few occasions we have added information from other sources, such as the PRIMES model that is used for long-term projections in the EC DG TREN, data from ESTIF on the thermal solar market and climate data from Eurostat (degree days) and the JRC Ispra database (data on temperatures and solar irradiation for EU capitals).

Besides these 'official data' where direct information is available, the last two paragraphs of this chapter also discuss the subject of 'heat load' where only indirect sources are available. This means that the values are calculated/estimated through a 'bottom-up' model based on engineering data, a 'top-down' approach where higher aggregated figures are the basis for a split-up or a combination of both.

All in all, we believe that the data in this chapter are not perfect, but they represent the best available at the current time.

3.2 Demographics

Data on EU-25 population, households and household size are shown in Table 3-1.

Main findings are:

- Currently, the EU-25 has 456 million inhabitants and is hardly growing (0,15%/year). In some countries like Italy, Portugal, Hungary, the Czech Republic and the Baltic States the population is expected to decrease. Fastest grower is Ireland, which expects 18% more inhabitants in 15 years from now.
- The number of households, where 'household' may have slightly different definitions per Member State but in general is equal to the number of primary dwellings, is growing faster, i.e. at around 1% per year. Depending on the source, the 2003 number is estimated at 184 (Boverket) or almost 190 mln. (PRIMES).
- The growth of the number of households is mostly due to families becoming smaller in size. Currently 60% of households have 1 or 2 persons. In the Northern Member States and Germany this can increase to over 70% of the households. Also in the South family size is shrinking.
- On average the EU-25 household size in 2003 is 2,5 persons per household. In 1990 this was 2,7 persons per household. The largest average household size is found in Cyprus (3 pp/hh), followed by Spain, Portugal and Poland (all 2,8 pp/hh or above).

3.3 Climate

The European climate data are given in Table 3-2. The most important indicator forn the heat demand of the house for space heating are the degree-days. They indicate the temporal temperature difference between the average daily outdoor temperature and an assumed indoor temperature.

Eurostat's degree days are calculated as:

$$(18°C - T_m) * d$$

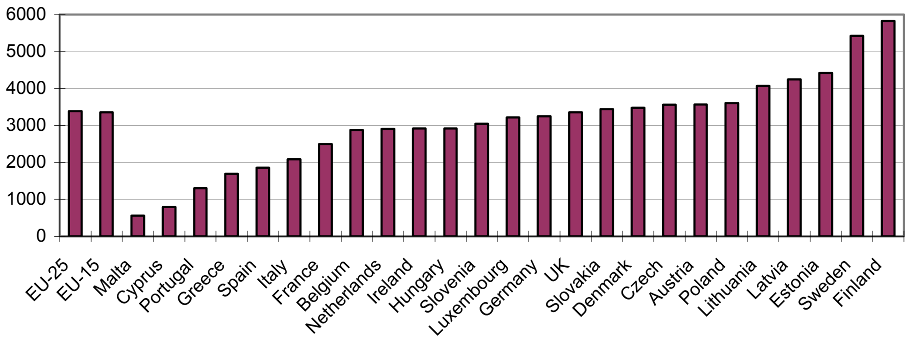
if Tm is lower than or equal to 15°C (heating threshold)

and are nil

if T_m is greater than 15°C, where T_m is the mean ((T_{min} + T_{max})/2) outdoor temperature over a day (d=1)

The figure (usually annual degree days) is a graphical display of the data in Table 3-2, relating to the long term average (1980-2004). thus indicates the relative coldness and thus the heat load of dwellings in that particular country.

Figure 3-1. Heating degree days per country (Eurostat)



Using the degree-days as a parameter, we can also make an estimate of what used to be called the heating season: Heating season in hours = (degree-days + 2000). Heating season in months = rounded (12* heating season in hours/8760).

However, it must be mentioned that boilers are now more and more also hot water suppliers –as a combi or with an indirect cylinder—and therefore the concept of a heating season where the boiler is 'on' and an 'off' season is disappearing: The boiler has to be 'on' all year round.

Table 3-1 also shows the yearly average of the daily solar irradiation on a horizontal surface and at an optimal collector-angle in Wh/m²/day. These data come from the JRC Ispra database and are relevant for solar-assisted boilers and water heaters.

Also relevant are the average daily temperatures (day and night) per month, not just for the space heating but also for hot water appliances. The yearly average daily temperature is a rough approximation of the soil temperature in a region (heat pump) and the average of this soil temperature and the outside air temperature is an approximation of the cold water temperature.

Main findings are:

- The EU-25 average (weighted by dwelling stock) number of degree days in 2003-'04 is around 3240, which is some 4% lower than the long-term (1980-2004) average of 3386.
- The warmest Member States are Malta (564 degree days long term) and Cyprus (787), with a heating season of 4 months and the coldest are Finland (5823) and Sweden (5423), with a heating season of 10 months. Around 80% of the EU-25 population has a heating season of 6-8 months.
- The yearly average of the daily temperature outside an EU dwelling is 11,7°C, with the coldest month being January (3,5°C) and the warmest August (20,7°C). At the level of country capitals, the coldest month is in Helsinki (FIN) in February (-4,5°C) and the warmest is Lanaca (CY) in August (27,3°C).
- The EU-25 average solar irridiation is 3235 Wh/m²/day on a horizontal surface. With a collector at an optimal angle (typically 35-40°) this increases by 14% to 3700 Wh/m²/day.
- The sunniest countries are Cyprus, Spain, Portugal, Greece and Italy (Rome) with over 4000 Wh/m²/day on a horizontal surface. But the rest, even the colder Scandinavian countries all are in a very narrow bandwidth of between 2554 (Helsinki) and 3357 (Budapest) Wh/m²/day irradiation on a horizontal surface and some 13-14% more at an optimal angle.
- The country with the highest number of solar collector surface –Germany (Berlin)— has a solar irradiation of around 2700-2800 Wh/m²/day on a horizontal surface, which can rise to around 3100-3200 Wh/m²/day at the best collector angle.

3.4 Physical housing characteristics

Table 3-3 gives an overview of the EU-25 dwelling stock, split by primar/secondary, single family/multi-family and year-of-built for the year 2003 (or earlier as indicated in the table). The split-up between primary dwellings (approximately equal to the number of households) and secondary dwellings is accompanied by a line explaining which types of secondary homes are included in the dwelling stock of a Member State. The average age was estimated using the median age per year-of-built class, assuming – from anecdotal data on the Netherlands, that buildings <1919 were built on average in 1880.

Furthermore, the table reports on newly built housing in 2003 and 1990, the number of houses demolished, the floor area of houses in stock and newly built, the number of rooms and the presence of central heating (as opposed to local heaters or no heaters, includes wet/dry/collective central heating), running hot water and the market penetration of solar collectors (% of dwellings). This last figure is a VHK estimate, based on the ESTIF data on stock and sales given in the last lines of the table combined with an estimate of the collector area per Member State.

Main findings are:

- Boverket reports an EU-25 stock of 205 million dwellings in 2003, of which 19% in Germany, 14% in France, 13% in Italy, 12% in the UK and 10% in Spain. If we also include Poland (6%), there are 6 countries that make up three quarters of the EU-25 dwelling stock. The other countries each make up 3,3% (NL) or less of the total.
- Primary dwellings, the principle dwellings where families live, are around 184 million. Around 20,5 secondary dwellings are reported which represent a heterogenous mix of second homes, vacant homes, etc..
- Remarkable in this context is e.g. that
  - Germany does <u>not</u> include vacant homes in its dwelling stock, whereas most countries do.
  - France[28] includes hotels in its dwelling stock figure.
  - Ireland, France and Poland also include mobile dwellings such as ships and/or permanent caravans (US.: 'trailers').
  - Collective homes are reportedly included in the dwelling stock statistics of Belgium, Cyprus, Lithuania, Luxembourg, Poland and Sweden. This could have a negative effect on the primary dwelling stock, because these dwellings house multiple households.
  - With the possible exception of Spain, the reported figures on the stock of second homes, winter and summer habitations, etc. after subtraction of the vacant homes are very unlikely. Despite the efforts of Boverket this will probably remain a grey area.
- Vacant homes, waiting to be sold, renovated or demolished, are the most substantial part of what is reported as 'secondary homes'. In 2003 some 18 million homes were identified as such. If we exclude the German vacant homes, we find that almost 15 out of the 20 million 'secondary homes' are in fact 'vacant homes'. The remainder are mostly second homes reported by Spain, whereas of course also in many other countries there is a vast –but not reported—stock of weekend/winter/summer cottages.
- Single- and two family homes account for 54% of the dwelling stock and multi-family homes for 46%, of which some 16% are high rise buildings with more than 4 storeys. In some countries, notably Germany, a distinction is made in the statistics between single-family and two-family houses, where the latter are slightly less than half of the total. But some countries just count two-family dwellings as (semi-detached) single family homes. Please note that the figures represent the number of dwellings (not the number of buildings).
- Every year the EU-25 builds some 2,2 million new dwellings, this is true in 1990 and in 2003. Effectively, given the rise in population and the smaller household size this means that there has been a negative growth rate in many countries, notably in Germany (-16%), Baltics (around -75%), Scandinavia (>-50%), whereas also in Slovakia, Czech Republic and Hungary the new 2003 dwellings are only half of what they were in 1990. The most dramatic increases took place in Ireland (+245%) and in Spain (+63%).
- Reporting on demolished dwellings is incomplete, so the figure of 133000 dwellings removed from the 2003 stock is a minimum figure.
- The largest fraction of older buildings in the EU-25 can be found in the UK, Denmark, France and Italy, where buildings from before 1919 make up 19-21% of the total stock.

[28] and in principle also Poland, but the figure presented in the table only includes primary dwellings.

- These countries also have the highest average dwelling age of 56-57 years. The youngest building stock can be found in Portugal and Finland (33 years), followed by Ireland, Spain and Greece (35 years). The Netherlands has relatively built the most new dwellings (30% of total) in the period since 1981.
- The average EU floor area for existing dwellings is 87 m² or 35 m²/person. For new dwellings this is 103 m² per dwelling. The largest existing houses can be found in Cyprus (145 m²), Luxembourg (125), Denmark (109) and Ireland (106). The smallest existing dwellings (avg. 55-60 m²) can be found in the Baltic States and some countries in Central Europe. However, new dwellings in the Baltics and Central Europe are on or above the EU-average.
- Existing dwellings have approx. 4 rooms per dwelling, wheres new dwellings have 4,5. This excludes the hall(s), cellars, etc.. Whether the kitchen is counted as a 'room' depends on the country. Many countries use a definition with a minimum number of square meters. Austria, Denmark, France and Lithuania do not usually count the kitchen as a room. From the number of rooms the number of heat emitters can be estimated to be 6-7 heat emitters per dwelling (including the hall and 2-3 radiators in living room + kitchen).
- Around 78-79% of the dwelling stock –or some 160 million dwellings—are reported to have some form of central heating (wet/dry/district) and running hot water for showers or baths. In friendly climates like Malta (3%), Portugal (4%), Cyprus (27%) the occasional stove is probably enough for space heating. For hot water we find the lowest penetration (60-70%) in the Baltic States and Portugal. In general, the reliability of these figures should not be overrated because it is usually left to the imagination of the people filling in a questionnaire to determine whether they have 'central heating' or not.
- Around 2,5% of the EU-25 dwellings are estimated to have a solar collector mostly for hot water preparation and occasionally space heating. The estimated average collector areas range from 6 m² (Austria) to 2,5 m² (Cyprus, Greece, Spain, Portugal) per dwelling. The total collector area in the EU in 2005 is 15,5 million m²of which over 2 million m² was sold in 2005. Around 89% of the collector sales (in m²) are flat plate glazed types. Unglazed types are 4%, whereas the more expensive vacuum tubes are apparently becoming more popular (6%), especially in Central Europe and Germany. Data are from ESTIF.[29]

3.5 Housing Expenditure

Table 3-4 gives an overview of the expenditure on housing as a percentage of the total household consumption in the EU-25 and per Member State. Furthermore, the housing costs are subdivided in energy costs, building maintenance, water supply and miscellaneous services, as well as the costs of the actual rent and –for owner-occupied dwellings—the imputed rent (interest plus mortgage pay-off). These figures, which are an important check for actual life cycle cost calculation in Task 5, are given per household, for the EU-25 as a total and as percentages.

Main findings:

- The average EU-25 housing costs are € 6.039 per household or 16,4% of total housing expenditure of € 36.872 in 2003. This is an average in straight money terms, however for most households a figure of around 23,4% (weighted by dwelling stock) will sound more familiar. For the whole of the EU-25 the housing costs represent € 1.112 billion (10^9 €).
- The costs for electricity, gas and other fuels in the house amount to € 1006 per household in 2003. For the whole of the EU this is € 185 billion, of which the boiler and water heater energy costs are a substantial part (see also Task 2 report).
- Building maintenance and repairs account for € 316 per household per year, whereas € 413 goes to miscellaneous services. In the whole of the EU this is € 58

[29] www.estif.org

and € 78 billion respectively. The statistics are not clear but probably the latter figure includes the repairs and maintenance of the boiler and water heater , whereas the former figure could include replacement of the CH-boiler and larger water heaters.

- The rest of the housing costs – a total of € 792 billion or € 4.303 per household in 2003—goes to actual and imputed rent. As the boiler and the primary water heater are usually part of the house, a small part of this is paying off at least the very first boiler and water heater.

3.6 Housing Ownership and Financing

The investment in a heating installation, whether it is a heat pump, solar system or a boiler/water heater, involves what most people would call a 'substantial sum' which isn't paid in cash but financed through a mortgage or a loan. This is certainly true for new owner-occupied dwellings, where boiler and water heater are usually part of the building costs and included in the mortgage. But also a replacement can be financed through an extension of the mortgage or a loan.

In case of rental apartments and houses, i.e. where the user and the one paying the energy bill is not the same as the owner, an extra difficulty arises to adopt the most efficient technology. A case in point is the situation in Switzerland, where the '*Minergie*' efficiency standard is very popular with owner-occupied dwellings but where the government has a very hard time to convince landlords and owners of apartment buildings to invest in energy saving measures. In other words, this is another aspect to be taken into account, e.g. in the impact analysis.

Finally, there is the issue of 'affordability' for low income groups, where perhaps Ecodesign measures should be accompanied by lateral measures to help these groups. The statistics define 'low-income' if the income is lower than 60% of the median equalized income in a country.

The main findings, which are presented in full in Table 3-5, are:

- Around 61% of the dwelling stock is owner-occupied and 35% is rental. The 4% remainder is owned by a co-operation or there is another ownership situation. The information is not complete, but assuming that these percentages are valid throughout, it means that 124 million dwellings are owner-occupied and 72 million are rental.
- The household size varies with the ownership situation. In public rental dwellings the household size is 2,4 persons per household, in private rental it is only 1,8 persons and in owner-occupied houses it is 2,7 persons per household. The average—as mentioned before—is 2,5 persons per household.
- The rent index (not corrected for inflation) has risen to 122 in 2003 (1996=100). Roughly over the same period the index of the single family house –also not corrected for inflation— has gone up to around 190 (1995=100). The real price index of the house prices—corrected for inflation (PPS)— went to 178 over the same period. This is a very rough estimate. The EU-25 data are not complete and that is why no estimate is given in the table.
- From the ratio of the outstanding residential mortgage to GDP (Gross Domestic Product) it is clear that the Dutch are the biggest lenders and that the houses are in fact fully mortgaged and the loan-against-value ratio is on average 112%. The reason is a tax regime which favours maximum mortgaging, as can be see from the line 'Mortgage related interest relief ' and banks that have very few reservations. On the other side of the spectrum we find Italy, Greece and Central European countries where mortgages are (far) lower than 20% of GDP.
- The typical length of the mortgage contract is 20 years with some countries going upo to 30 years. The typical mortgage rate in the EU-25 in 2003 was around 5%.

- Around 15% of the households can be classified as 'low income' according to the definition mentioned earlier. For most EU-15 Member States this means an income of less than 6.000-9.000 PPS per household/year. For some new Member States, especially the Baltic States, this can be as low as around 2.400 PPS per household/year.
- Nonetheless, the ownership situation amongst the low income groups is not very different from the rest: in most countries one third is paying rent and two thirds is owning the house.
- In most countries that are reporting on the issue there is a state subsidy for the low income groups. In Denmark, Finland, France, Sweden, the Netherlands and the UK this subsidy covers more than 14-20% of the total population, i.e. the whole of the low income group. The statistics do not reveal the level of support.

Table 3-1. EU Demographics (source: VHK compilation of 'Housing Statistics of the European Union 2004', Boverket 2005 and PRIOMES 2006)

	Parameter	*unit*	EU-25	A	B	CY	CZ	DK	EST	FIN	F	D	GR	H	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	SK	SLO	E	S	UK
	EU population (Boverket 2005)																											
2	population 2003	k#	**453684**	8067	10356	715	10203	5384	1356	5206	59630	82537	11018	10142	3964	57321	2331	3463	448	397	16193	38219	10407	5379	1995	40683	8941	59329
3	population 2005	k#	**456342**	8128	10370	821	10227	5392	1297	5230	60900	82780	11017	9797	4079	57306	2272	3412	466	399	16343	38562	10094	5418	1981	41348	8917	59786
4	population 2010	k#	**459971**	8125	10478	858	10201	5449	1236	5285	62527	83094	11085	9593	4326	56759	2184	3339	497	406	16733	38553	10129	5457	1965	41774	9014	60904
5	population 2015	k#	**462989**	8123	10578	895	10151	5498	1177	5342	64037	83426	11106	9402	4585	55903	2096	3274	526	417	17071	38538	10125	5487	1945	41992	9115	62180
6	population 2020	k#	**465565**	8132	10681	928	10083	5554	1117	5390	65402	83818	11075	9217	4811	54903	2007	3204	560	424	17400	38425	10089	5510	1918	42012	9237	63668
	No. of households (PRIMES 2006)																											
7	households 1990	mln	**167**	3,0	3,9	0,1	3,6	2,2	0,6	2,0	22,5	33,8	3,3	4,0	1,0	21,5	1,0	1,3	0,1	0,1	6,0	12,3	3,3	2,1	0,6	12,3	3,9	22,5
8	households 1995	mln	**176**	3,1	4,1	0,2	3,8	2,3	0,6	2,2	24,0	35,3	3,5	4,1	1,2	23,0	1,0	1,3	0,2	0,1	6,4	13,1	3,5	2,3	0,6	13,2	4,0	23,9
9	households 2000	mln	**186**	3,2	4,2	0,2	3,9	2,4	0,6	2,3	25,5	36,7	3,7	4,2	1,3	24,4	0,9	1,3	0,2	0,1	6,8	13,8	3,6	2,5	0,6	14,0	4,1	25,3
10	households 2005	mln	**195**	3,4	4,4	0,2	4,1	2,5	0,6	2,4	27,1	38,3	3,9	4,3	1,4	25,6	0,9	1,4	0,2	0,2	7,3	14,4	3,8	2,7	0,7	14,6	4,3	27,0
11	households 2010	mln	**205**	3,5	4,6	0,2	4,2	2,6	0,6	2,5	28,7	39,8	4,1	4,3	1,5	26,8	0,9	1,4	0,2	0,2	7,8	14,9	4,0	2,8	0,7	15,2	4,5	28,6
12	households 2015	mln	**211**	3,6	4,8	0,2	4,2	2,7	0,6	2,6	30,1	40,7	4,2	4,3	1,6	27,8	0,9	1,5	0,2	0,2	8,2	15,0	4,2	2,9	0,7	15,6	4,7	30,1
13	households 2020	mln	**218**	3,6	4,9	0,2	4,2	2,8	0,6	2,7	31,5	41,5	4,3	4,3	1,7	28,7	0,9	1,5	0,2	0,2	8,6	15,1	4,3	2,9	0,7	16,0	4,9	31,6
	Household sizes 2003 (Boverket 2005)																											
14	1 person	%	**30**	31	32	16	30	37	31	39	30	37	20	26	22	25	24	29	29	15	34	25	17	26	22	20	47	31
15	2 persons	%	**30**	29	31	27	28	33	31	32	33	34	28	29	26	27	30	26	29	23	33	23	29	22	23	25	28	34
16	3 persons	%	**17**	17	16	17	19	12	18	13	15	14	21	20	18	21	23	20	17	23	13	20	25	18	21	21	11	16
17	4 persons	%	**15**	15	14	22	17	12	14	10	14	11	20	16	17	19	15	17	16	26	14	18	20	21	23	22	10	13
18	≥ 5 persons	%	**8**	8	7	18	6	5	6	6	8	4	11	9	18	8	8	8	9	12	6	14	9	14	11	12	4	6
	Persons/household (Boverket 2005)																											
19	persons/household 1990	#	**2,7**	2,6	na	3,2	2,6	2,3	na	2,4	2,6	2,3	3	2,6	na	2,8	na	na	2,6	na	2,4	3,1	3,1	2,9	3	3,4	2,1	2,5
20	persons/household 1995	#	**2,6**	2,5	na	3,2	na	2,2	2,4	2,3	2,5	2,2	na	na	3,3	2,6	na	2,8	na	3,1	2,4	3,1	na	na	na	3,2	2	2,4
21	persons/household 2000	#	**2,55**	2,4	2,4	3,1	2	2,2	2,4	2,2	2,4	2,2	2,8	2,6	3	2,6	2,5	2,6	2,5	3	2,3	na	2,8	2,6	2,8	3,1	2	2,4
22	persons/household 2003	#	**2,5**	2,4	2,4	3	na	2,2	2,4	2,2	na	2,1	na	na	2,9	2,6	2,5	2,6	na	3	2,3	2,8	na	na	na	2,9	1,9	na

Table 3-2. EU Climate characteristics for buildings 2003 (source: VHK compilation of misc. sources)

Parameter	*unit*	**EU-25**	**A**	**B**	**CY**	**CZ**	**DK**	**EST**	**FIN**	**F**	**D**	**GR**	**H**	**IRL**	**IT**	**LT**	**LIT**	**LUX**	**MT**	**NL**	**PL**	**P**	**SK**	**SLO**	**E**	**S**	**UK**
1. Dwelling stock****	k#	**204663**	3280	4820	299	4366	2561	624	2574	29495	38925	5465	4134	1554	26526	967	1292	176	127	6811	11764	5318	1885	785	20947	4351	25617
Degree Days* **																											
2 2003	#	**3247**	3474	2711	728	3455	3287	4421	5658	2361	3135	1732	3078	2665	1971	4245	4076	2953	583	2766	3602	1261	3458	3039	1770	5227	3084
3 2004	#	**3239**	3561	2798	763	3472	3274	4306	5536	2480	3186	1567	2872	2730	2010	4213	4047	3172	500	2774	3518	1368	3387	3049	1915	5268	3075
4 Long term avg. 1980-'04	#	**3386**	3569	2882	787	3559	3479	4420	5823	2494	3244	1698	2917	2916	2085	4243	4071	3216	564	2905	3605	1302	3440	3044	1856	5423	3354
Avg. Solar Irridiation (in country capital)**																											
6 Horizontal, Wh/m²/d	Wh	**3235**	3123	2642	4724	2817	2669	2620	2554	3068	2748	4305	3357	2605	4021	2730	2731	2832	4843	2702	2766	4474	3018	3234	4496	2575	2699
7 Optimal angle, Wh/m²/d	Wh	**3700**	3554	2978	5245	3171	3115	3131	3068	3489	3157	4771	3835	3013	4583	3200	3150	3192	5491	3089	3165	5105	3464	3697	5148	3105	3097
Avg. Daily Temperature (in country capital)**																											
8 Jan	°C	**3,5**	-0,8	3,4	11,8	-1,2	0,7	-3,0	-4,0	4,1	0,4	8,9	-0,8	5,7	8,6	-2,6	-3,8	1,7	na	3,2	-2,1	10,7	-0,7	1,0	6,3	-1,4	5,0
9 Feb	°C	**5,0**	2,4	5,2	12,0	1,5	1,5	-3,4	-4,5	5,8	2,7	9,3	2,0	6,3	8,6	-2,1	-2,2	3,8	na	4,8	0,0	11,9	2,3	3,2	7,9	-1,3	6,1
10 Mar	°C	**7,2**	5,7	7,3	13,7	4,3	2,8	-0,8	-1,6	8,3	4,6	10,5	5,8	7,2	10,9	0,5	0,6	6,4	na	6,6	2,5	14,3	5,7	7,2	11,1	1,0	7,4
11 Apr	°C	**10,3**	10,5	9,7	16,7	8,9	6,6	4,6	3,9	10,1	9,4	13,8	11,4	8,6	13,0	6,7	7,7	9,1	na	9,3	8,5	15,2	10,7	11,0	12,6	4,7	9,3
12 May	°C	**14,8**	16,2	13,8	21,2	14,4	10,9	9,4	9,1	14,3	14,6	19,2	17,1	11,2	17,9	11,7	12,8	13,8	na	13,2	14,1	17,7	16,3	16,5	16,6	9,2	12,5
13 Jun	°C	**18,2**	18,9	16,4	24,8	16,9	14,6	14,9	14,8	17,3	17,1	23,9	20,0	13,4	21,8	16,0	16,4	16,6	na	15,7	16,8	21,0	19,0	20,0	22,0	14,6	15,3
14 Jul	°C	**20,2**	20,4	18,2	27,3	18,5	17,0	17,7	17,6	19,1	19,1	26,2	21,6	15,6	23,8	18,4	18,6	18,2	na	17,7	18,8	22,9	20,5	21,0	24,4	17,5	17,6
15 Aug	°C	**20,7**	20,7	19,0	27,3	19,0	17,9	16,8	16,5	20,1	19,7	25,7	21,6	15,9	24,7	17,5	17,4	19,1	na	18,6	18,4	23,3	20,8	21,6	24,3	17,6	18,4
16 Sep	°C	**16,3**	15,1	15,2	24,8	13,9	13,9	12,0	11,5	15,6	14,7	22,0	15,9	13,8	20,4	12,3	12,0	14,3	na	15,2	13,1	21,1	15,3	15,9	19,7	12,8	15,2
17 Oct	°C	**12,4**	10,7	11,4	21,6	9,6	9,4	6,8	6,2	12,2	10,2	17,8	11,3	11,2	17,2	7,3	7,1	10,5	na	11,3	8,6	18,0	10,8	12,1	15,1	7,6	11,8
18 Nov	°C	**7,4**	4,9	7,0	17,4	3,7	4,7	1,5	0,9	7,2	4,4	13,7	5,4	8,2	13,0	1,8	1,3	5,5	na	7,2	2,8	13,8	5,1	6,5	9,5	3,0	8,1
19 Dec	°C	**3,8**	-0,4	3,8	13,6	-0,7	1,1	-2,7	-3,6	4,7	0,3	9,9	-1,0	5,9	9,5	-3,2	-4,4	2,5	na	3,5	-2,6	11,3	-0,6	1,6	6,5	-0,8	5,3
20 Year*	°C	**11,7**	10,4	10,9	19,4	9,1	8,4	6,1	5,6	11,6	9,8	16,7	10,9	10,3	15,8	7,0	7,0	10,1	na	10,5	8,3	16,8	10,4	11,5	14,7	7,0	11,0
21 Heating season, months		**7**	8	7	4	8	8	9	11	6	7	5	7	7	6	9	8	7	4	7	8	5	7	7	5	10	7

*= A rough approximation of the year-round soil temperature is the average daily temperature over a year in a region. This is relevant for ground source heat pumps. To approximate the real cold water temperature take the average of this soil temperature and the air temperature in a month.
= source JRC Ispra ; http://re.jrc.cec.eu.int/pvgis/solradframe.php?en&europe ; *= Eurostat, *Statistics in Focus, Statistical Aspects of the Energy Economy 2004*, 2005.; ****= source Boverket, used as reference for weighting

Table 3-3. EU Housing Characteristics 2003 (source: VHK compilation of 'Housing Statistics of the European Union 2004', Boverket 2005)

	Parameter	*unit*	**EU-25**	**A**	**B**	**CY**	**CZ**	**DK**	**EST**	**FIN**	**F**	**D**	**GR**	**H**	**IRL**	**IT**	**LT**	**LIT**	**LUX**	**MT**	**NL**	**PL**	**P**	**SK**	**SLO**	**E**	**S**	**UK**
1.	Dwelling stock**	k#	**204663**	3280	4820	299	4366	2561	624	2574	29495	38925	5465	4134	1554	26526	967	1292	176	127	6811	11764	5318	1885	785	20947	4351	25617
2	Primary (= ca. # households)	k#	**184166**	3280	4325	239	4216	2481	566	2378	24525	38944	3674	3863	1382	22004	915	1346	171	129	6996	13337	3651	2072	685	14187	4454	24346
3	Secondary	k#	**20497**	0	495	60	150	80	58	196	4970	-19	1791	271	172	4522	52	-54	5	-2	-185	-1573	1667	-187	100	6760	-103	1271
4	Secondary types, included in dwelling stock*			WSV	WSC VN	WS CV	SVN	V	na	SVN	WSH MV	S	WSV	WSV	WSm VN	WSV	WV	CN	CHM	WSN	V-	SCH MVN	WS VN	V	WSV	WS VN	CV	WSV
5	Vacant dwellings	k#	**18083**		na	72	537	128	68	237	2006	*3192*	514	347	182	5199	58	*48*	*4*	na	150	623	564	219	79	2912	74	871
6	One/two family dwellings	%	**54**	48	75	na	44	61	32	42	57	46	59	66	91	25	29	39	71	na	69	37	77	49	72	53	48	81
7	Multi-family dwellings	%	**46**	52	25	na	57	39	68	58	43	54	41	34	9	75	71	61	29	na	31	63	23	52	28	48	52	19
8	of which high-rise (> 4 storeys),	%	**16**	na	4	na	34	10	na	na	16	6	na	23	na	23	na	na	16	na	7	39	22	38	12	31	na	2
9	New built 2003 (completed)	k#	**2174**	42	41	6	27	24	2	28	334	268	128	*22*	69	*178*	1	5	2	na	60	163	82	14	7	459	24	190
10	New built 1990 (completed)	k#	**2169**	42	43	8	45	27	8	65	336	319	120	44	20	176	13	22	3	na	101	134	66	25	8	281	58	205
11	Demolished/removed	k#	**133**	16	2	0	2	*8*	1	3	21	*22*	na	5	11	na	3	0	na	na	18	5	1	1	0	16	2	15
12	Year of built <1919 *[VHK 1880]*	%	**15**	19	15	na	11	20	9	2	20	15	3	14	10	19	11	6	12	15	7	10	6	3	15	9	12	21
13	Year of built 1919–1945	%	**12**	8	17	7	15	17	14	9	13	13	7	13	8	11	14	23	15	11	13	13	9	7	8	4	20	18
14	Year of built 1946–1970	%	**32**	27	29	17	26	28	30	31	18	47	32	26	16	41	28	33	27	29	31	27	23	35	28	34	33	21
15	Year of built 1971–1980	%	**20**	16	15	21	23	18	22	23	26	11	25	22	18	20	23	18	15	17	19	18	18	26	24	24	17	22
16	Year of built >1980	%	**22**	12	9	27	16	10	20	20	10	15	19	18	16	10	21	14	12	16	30	19	44	21	16	14	10	19
17	of which, year of built >1990	%	**13**	18	15	|	8	7	5	14	12	|	14	7	32	|	4	6	17	12	|	13	|	7	9	16	7	|
18	Avg. age dwellings *[VHK est.]*	yr	**49**	49	50	28	46	57	45	33	52	53	35	48	35	56	46	47	45	48	40	43	33	36	47	39	52	56
19	Floor area/dwelling (stock)	m²	**87**	94	86	*145*	76	109	60	77	90	90	83	75	104	90	55	61	125	106	98	68	83	56	75	90	92	87
20	Floor area/dwelling (new 2003)	m²	**103**	101	119	198	105	112	89	90	113	114	125	94	105	82	194	106	120	*106*	116	99	89	118	114	96	128	83
21	Floor area/person (stock)	m²	**35**	38	36	*48*	29	51	28	36	38	40	*30*	28	35	*35*	24	23	*50*	34	41	22	*30*	26	30	*31*	44	44
22	Number of rooms (stock)	#	**4,0**	4,1	4,3	5,4	2,9	3,8	3,6	3,6	4	4,4	3,8	na	5,6	4,1	2,4	2,5	5,5	na	4,2	3,7	4,3	3,2	2,8	5	4,2	4,7
23	Number of rooms (new built)	#	**4,5**	3,5	5,8	6,1	3,9	3,4	4	3,8	3,9	5,1	3,1	4	5,6	3,8	4,3	3,5	5,2	na	3,9	4,2	4,9	3,1	3,4	5,4	4,2	4,5
24	persons/household (stock)	#	**2,5**	2,4	2,4	3	2,4	2,2	2,4	2,2	2,4	2,1	2,8	2,6	2,9	2,6	2,5	2,6	2,5	3	2,3	2,8	2,8	2,6	2,8	2,9	1,9	2,4
25	Central heating (wet & dry)	%	**79**	90	73	27	82	92	59	92	91	91	64	53	59	79	65	72	92	3	90	78	4	74	79	42	100	94
26	Bath/shower (hot water)	%	**78**	98	96	99	96	95	67	99	98		98	87	94	99	67	70	94	100	100	87	66	93	92	99	100	99
27	solar sys.penetration, % dwell.***	%	**2,5**	11,8	0,5	66,9	0,3	2,6	0,0	0,1	0,4	3,4	22,3	25,4	0,2	0,6	0,1	0,0	1,5	6,0	1,5	0,2	1,2	0,7	2,6	0,8	1,0	0,3
28	solar collector stock***	000m²	**15573**	2318	68	500	66	337	1	14	396	6554	3047	5250	11	516	3	2	13	19	304	138	161	64	102	527	208	197
29	estimated collect area/hh	m²	**3**	6	3	2,5	5	5	5	5	3	5	2,5	5	3	3	5	5	5	2,5	3	5	2,5	5	5	3	5	3
30	total solar collector sales 2005	000m²	**2073**	240	28	50	19	21	0	2	164	980	221	1	4	72	1	1	2	4	39	28	16	7	5	107	35	28
31	of which glazed collector sales	%	**89**	97	73	100	70	99	100	100	93	87	100	100	100	96	100	100	100	100	48	85	97	88	94	95	49	64
32	unglazed coll. sales	%	**4**	3	27		17				4	3									52	0						
33	vacuum tube sales	%	**6**	1			13	1			3	10				4						15	3	12	6	5	16	36

* = W=Winter or summer habitation; S=Second homes; C=Collective homes; H=Hotels; M=Trailers & ships; m=Trailers; V=Vacant homes; N=Non-permanent habitation; na= no data available; | = data included in line above; **= dwelling stock data year CY: 2002; FI: 2001; FR: 2002; GR:2001; HU: 2001; LU: 2002; MT: 1983; PL: 2002. PT: 1999 most recent, 2003 is estimate; In other lines, italic font indicate older reference years
***= solar sales and stock data from ESTIF (www.estif.org). Collector area per household estimated by VHK on the basis of general recommendations by authorities for 4-person household.

Table 3-4. EU Housing Expenditure 2003 (source: VHK compilation of 'Housing Statistics of the European Union 2004', Boverket 2005)

	Parameter	*unit*	**EU-25**	**A**	**B**	**CY**	**CZ**	**DK**	**EST**	**FIN**	**F**	**D**	**GR**	**H**	**IRL**	**IT**	**LT**	**LIT**	**LUX**	**MT**	**NL**	**PL**	**P**	**SK**	**SLO**	**E**	**S**	**UK**
1	Primary (= # households)	k#	184166	3280	4325	239	4216	2481	566	2378	24525	38944	3674	3863	1382	22004	915	1346	171	129	6996	###	3651	2072	685	14187	4454	24346
Expenditure per household €/yr																												
2	Total, of which	€	36872	31690	32542	29285	9498	28031	8384	30256	33759	27082	27893	10055	42211	35350	6512	27317	64815	22340	23699	8806	20987	7849	19259	11286	26856	39877
3	Housing, of which	€	6039	6053	7680	6267	2232	8017	1920	7836	8136	6798	4379	1820	9118	7176	1400	4261	14000	2100	5072	2184	2204	2080	3794	3544	7762	7258
4	Electricity, gas & other fuel	€	1006	1077	1432	996	798	1682	520	635	1249	1110	614	553	1266	1167	352	1502	1426	na	948	810	546	848	982	339	1746	957
5	Building maintenance & repair	€	316	349	163	322	28	364	34	0	439	135	195	60	169	460	189	300	778	na	355	414	42	165	77	260	81	598
6	Water supply, misc. services	€	413	792	423	293	161	589	159	91	608	650	112	151	42	495	85	300	648	na	332	167	147	133	327	214	0	319
7	Rent, Imputed rent , of which	€	4303	3834	5662	4656	1244	5382	1207	7110	5840	4902	3459	1056	7640	5055	775	2158	11148	na	3436	793	1469	934	2407	2731	5935	5383
8	*Actual rent*	€	*1282*	*887*	*1595*	*674*	*313*	*1906*	*193*	2088	1587	2248	*614*	*70*	*1097*	848	26	109	*1944*	*na*	*1303*	*159*	*231*	*78*	*347*	*181*	*2337*	*1635*
9	*Imputed rent (owner-occupied)*	€	*3020*	*2947*	*4068*	*3983*	*940*	*3476*	*1014*	5023	4220	2654	*2845*	*985*	###	*4242*	*749*	*2021*	*9204*	*na*	*2133*	*634*	*1259*	*801*	*2061*	*2528*	*3572*	*3748*
Expenditure EU total (bln. €/yr)																												
10	Total, of which	10^9€	6791	103,9	140,7	7,0	40,0	69,5	4,7	71,9	827,9	1054,7	102,5	38,8	58,3	777,8	6,0	36,8	11,1	2,9	165,8	117,5	76,6	16,3	13,2	160,1	119,6	970,8
11	Housing, of which	10^9€	1112	19,9	33,2	1,5	9,4	19,9	1,1	18,6	199,5	264,7	16,1	7,0	12,6	157,9	1,3	5,7	2,4	0,3	35,5	29,1	8,0	4,3	2,6	50,3	34,6	176,7
12	Electricity, gas & other fuel	10^9€	185	3,5	6,2	0,2	3,4	4,2	0,3	1,5	30,6	43,2	2,3	2,1	1,8	25,7	0,3	2,0	0,2	na	6,6	10,8	2,0	1,8	0,7	4,8	7,8	23,3
13	Building maintenance & repair	10^9€	58	1,1	0,7	0,1	0,1	0,9	0,0	0,0	10,8	5,3	0,7	0,2	0,2	10,1	0,2	0,4	0,1	na	2,5	5,5	0,2	0,3	0,1	3,7	0,4	14,6
14	Water supply, misc. services	10^9€	76	2,6	1,8	0,1	0,7	1,5	0,1	0,2	14,9	25,3	0,4	0,6	0,1	10,9	0,1	0,4	0,1	na	2,3	2,2	0,5	0,3	0,2	3,0	0,0	7,8
15	Rent, Imputed rent , of which	10^9€	792	12,6	24,5	1,1	5,2	13,4	0,7	16,9	143,2	190,9	12,7	4,1	10,6	111,2	0,7	2,9	1,9	na	24,0	10,6	5,4	1,9	1,6	38,7	26,4	131,1
#	*Actual rent*	10^9€	236	2,9	6,9	0,2	1,3	4,7	0,1	5,0	38,9	87,5	2,3	0,3	1,5	18,7	0,0	0,1	0,3	na	9,1	2,1	0,8	0,2	0,2	2,6	10,4	39,8
#	*Imputed rent (owner-occupied)*	10^9€	556	9,7	17,6	1,0	4,0	8,6	0,6	11,9	103,5	103,4	10,5	3,8	9,3	93,3	0,7	2,7	1,6	na	14,9	8,5	4,6	1,7	1,4	35,9	15,9	91,3
Expenditure in % *																												
18	Total, of which	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
19	Housing, of which	%	16,4/ 23,0	19	23,6	21,4	23,5	28,6	22,9	25,9	24,1	25,1	15,7	18,1	21,6	20,3	21,5	15,6	21,6	9,4	21,4	24,8	10,5	26,5	19,7	31,4	28,9	18,2
20	Electricity, gas & other fuel	%	2,7/ 4,2	3	4,4	3,4	8,4	6	6,2	2,1	3,7	4,1	2,2	5,5	3	3,3	5,4	5,5	2,2	na	4	9,2	2,6	10,8	5,1	3	6,5	2,4
21	Building maintenance & repair	%	0,9/ 1,4	1	1	1	0	1	0	0	1	1	1	1	0	1	3	1	1	na	2	5	0	2	0	2	0	2
22	Water supply, misc. services	%	1,1/ 1,6	2,5	1,3	1,0	1,7	2,1	1,9	0,3	1,8	2,4	0,4	1,5	0,1	1,4	1,3	1,1	1,0	na	1,4	1,9	0,7	1,7	1,7	1,9	0,0	0,8
23	Rent, Imputed rent , of which	%	11,7/ 15,8	12,1	17,4	15,9	13,1	19,2	14,4	23,5	17,3	18,1	12,4	10,5	18,1	14,3	11,9	7,9	17,2	na	14,5	9	7	11,9	12,5	24,2	22,1	13,5
#	*Actual rent*	%	*3,5/ 4,4*	*2,8*	*4,9*	*2,3*	*3,3*	*6,8*	*2,3*	*6,9*	*4,7*	*8,3*	*2,2*	*0,7*	*2,6*	*2,4*	*0,4*	*0,4*	*3*	*na*	*5,5*	*1,8*	*1,1*	*1*	*1,8*	*1,6*	*8,7*	*4,1*
#	*Imputed rent (owner-occupied)*	%	*8,2/ 11,4*	*9,3*	*12,5*	*13,6*	*9,9*	*12,4*	*12*	*16,6*	*12,5*	*9,8*	*10,2*	*9,8*	*16*	*12*	*12*	*7,4*	*14,2*	*na*	*9*	*7,2*	*6*	*10*	*10,7*	*22,4*	*13,3*	*9,4*

*= Two EU averages are given: the first is the straight money average, the second is the average percentage weighted by no. of households

Table 3-5. EU Housing Financing 2003 (source: VHK compilation of 'Housing Statistics of the European Union 2004', Boverket 2005)

Parameter	*unit*	EU-25	A	B	CY	CZ	DK	EST	FIN	F	D	GR	H	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	SK	SLO	E	S	UK
1. Dwelling stock	k#	204663	3280	4820	299	4366	2561	624	2574	29495	38925	5465	4134	1554	26526	967	1292	176	127	6811	11764	5318	1885	785	20947	4351	25617
Ownership																											
2 Rent, % of occupied dwellings	%	35	39	31	na	na	40	na	34	38	55	20	7	18	na	21	na	26	26	45	24	na	na	9	11	39	31
3 Owner-occupied, % occ. dwell.	%	61	58	68	na	na	53	na	63	56	45	74	92	77	na	79	na	67	70	55	58	na	na	84	82	46	69
4 Co-operative, % occ. dwell.	%	2	na	na	na	na	7	na	0	na	na	na	na	na	na	0	na	na	na	na	18	na	na	na	na	15	na
5 Other ownership, % occ. dwell.	%	2	3	2	na	na	0	na	3	6	0	6	1	5	na	0	na	7	4	0	0	na	na	7	7	0	0
Persons/hh by ownership																											
6 Public rental , pp/occ. dwell	#	2,4	2,0	2,2	2,5	2,5	1,9	na	1,9	2,6	1,9	na	2,6	3,1	2,7	2,6	na	na	2,8	1,9	na	na	3,0	2,6	3,2	1,7	2,2
7 Private rental , pp/occ. dwell	#	1,8	|	1,9	|	|	1,7	na	1,7	2,1	|	|	0,4	2,4	2,7	2,4	na	1,2	|	1,7	na	na	|	2,6	|	1,6	2,1
8 Owner occupied , pp/occ. dwell	#	2,7	2,7	2,6	3,3	2,8	2,5	na	2,4	2,5	2,5	2,9	2,7	3	2,8	2,7	na	2,3	3,2	2,7	na	2,9	3,3	3	3,4	2,7	2,4
9 TOTAL persons/occ. dwelling	#	2,5	2,4	2,4	3,1	2,6	2,2	na	2,2	2,4	2,2	2,8	2,7	3	2,8	2,5	2,8	2,5	3,1	2,4	na	2,1	3,2	2,9	2,8	2,1	2,3
Indices Rent/Houses																											
6 Rent (1996=100)	ndx	118	122	113	122	122	120	135	123	112	110	143	134	152	128	201	99	121	110	124	288	120	248	136	136	112	122
7 House nominal price (1995=100)	ndx	na	na	138	na	na	172	na	184	162	na	na	na	268	143	na	na	na	na	205	na	na	na	na	225	175	235
8 House real price (1995=100)	ndx	na	na	120	na	na	146	na	159	143	na	na	na	207	117	na	na	na	na	167	na	na	na	na	178	153	210
Mortgage																											
9 Ratio mortgage/GDP (res.)	%	na	na	27	na	3	88	na	36	25	54	17	8	45	13	8	na	33	na	100	5	51	na	na	42	50	70
10 Typical mortgage interest rate	%	na	5,3	6,2	na	na	5,0	4,6	3,4	4,6	5,0	5,5	na	3,6	4,6	na	na	na	na	4,5	8,0	4,4	na	na	3,1	4,1	4,7
11 Usual length of contract	yr	na	na	20	na	15–20	30	na	15–20	15–20	≤30	15	na	na	10–25	10–20	20–25	20–40	30	≤30	na	25–30	20	na	24	30–50	na
12 Average loan-to-value ratio	%	na	60	80–85	na	70	80	na	70–85	66	70	60	na	60–70	na	≤ 85	70–90	≤80	68	112	na	70–80	70	na	83	90–100	70
13 Tax on imputed rent	Y/N	na	N	Y	na	N	Y	na	N	N	N	Y	na	N	Y	Y	Y	Y	N	Y	na	N	19	na	N	N	N
14 Mortgage related interest relief	Y/N	na	na	Y	na	Y	Y	na	Y	N	N	Y	na	Y	Y	N	Y	Y	Y	Y	na	Y	N	na	N	Y	N
15 Indirect taxes (VAT)	%	na	10–20	21	na	5	25	na	22	19.6	16	11–13	na	13.5	4	18	18	3		19	na	0	19	na	7	25	0
Low income groups (<60% median equalized income)																											
16 total	%	15	13	na	8	11	18	11	15	11	20	10	21	19	16	17	12	15	11	15	20	5	11	19	10	17	15
17 renting	%	na	10	na	7	6	17	8	12	7	21	9	17	17	14	17	8	11	7	15	19	na	11	18	6	12	na
18 owner	%	na	28	na	8	24	26	23	25	16	15	16	44	30	24	26	24	na	20	16	25	na	na	23	18	32	na
19 60% median eq. Income in PPS	PPS	na	9468	9286	na	4045	10197	2440	7680	8765	9492	5443	3369	7934	7044	2301	2346	14376	5510	8309	2859	4967	3649	6795	6527	7679	8984
20 % all hh receiving allowances	%	na	na	na	na	na	21	na	20	20	7	1	na	5	na	6	na	na	na	14	6	na	1	1	12	16	19

3.7 Heat load: Existing studies

3.7.1 Introduction

As known, the statistics do not offer sufficiently detailed building data to make a direct assessment of the heat load of the EU-25 dwellings. This would require detailed information on the insulation-levels (U and R values) of walls, floors, roofs, windows etc., as well as average orientation, ventilation requirements and the park of (heating) appliances.

Hence, there are only indirect ways to make an estimate of the heat load. For this there are basically three approaches:

'Bottom-up' whereby on the basis of a simplified technical model and anecdotal data an assessment is made of U-values in the dwelling stock. Recent example: Ecofys studies for Eurima (European Insulation Manufacturers Association). The advantage is that the effect of a specific measure –e.g. extra insulation— can be quickly assessed. The disadvantage can be that there is no reality-check whether the totals of all these measures would add up. Another limitation lies in the fact that all parts of the technical model must be balanced and correct, e.g. an underestimation of the ventilation losses or an overestimation of the boiler efficiency both would lead to an increased relative importance of insulation measures.

'Top-down' whereby the basis is the total average energy consumption or CO_2-emission per household in a Member State, which is then partitioned between the various functions (heating, hot water, electrical appliances, etc.) in the household also according to a simple technical model. Example: PRIMES model by the University of Athens which is used by the European Commission for long-term projections. The advantage is that the starting points are the totals and the modelling concerns the split-up. This allows a reality-check and can –at least visually—suggest detailed data per Member State. The disadvantage may be that this more economical model for the partitioning can only be as good as the technical understanding of the total energy balance of the house. A frequent mistake in this context is e.g. that the real-life boiler efficiency —which is substantially lower than the nominal efficiency—is overestimated.

Both 'bottom-up' and 'top-down', whereby on one hand the economical data on energy consumption per household are taken as a basis for partitioning and on the other hand there is an extensive technical modelling of the whole energy balance of all energy consuming products in the house (not just the heat load). This was done in the so-called 'stakeholder-approach' for the European Climate Change Programme (ECCP) of the European Commission, where each discussion partner and expert claimed a piece of his/her savings and emission-reduction 'cake' but with the restriction that the total figures need to be consistent. This is a considerable advantage, where e.g. SAVE-studies from all sectors –including the 2002 BRE-study on boilers and the 2001 SenterNovem study on water heaters—were brought to the table and a match had to made with official statistics. This considerably reduces the risk of all too great errors in partitioning. A possible disadvantage is the complexity and the amount of both economical and technical data that is required. It is not a single simple model, but in fact a compilation of models, measured data and estimates to arrive at the most realist assessment possible.

All three approaches, by way of their examples, will be explained in the followings sub-paragraphs.

3.7.2 *Ecofys/Eurima*

Ecofys has performed two studies for Eurima: One for the EU-15 and one for new and aspiring Member States in Central and Eastern-Europe. [30] We will discuss the model for the EU-15.

For this simplified model, the EU-15 was split into

- Three climate zones (cold, medium, hot)
- Dwelling floor area (in m²) and form factor (A/V) per climate zone and three classes of building age (<1975, 1975-1990, >1990)
- Technical data on two types of buildings (single family home and apartment in a 16-family building)
- Insulation levels (U-values) for floors, roofs, walls, windows per climate zone (3) and per 8 classes of building-age/renovation (<1975, <1975 retrofit, 1975-1990, 1990-2002, 2003-2006 new, 2003-2006 retrofit, >2006 new, >2006 retrofit).
- Efficiency levels for CH boilers overall (Basis: Standard boiler 85% efficient. Best: 97%)

The modelling of ventilation losses was not explained in the Ecofys report. The following tables give the main input data used. Ecofys' output data are mainly limited to the saving potentials of insulation and boiler replacement.

Table 3-6. Degree days for the three climate zones distinguished by Ecofys 2006

Cold	Moderate	Warm
Finland, Sweden	Austria, Belgium, Denmark, France, Germany, Ireland, Luxemburg, The Netherlands, United Kingdom	Greece, Italy, Portugal, Spain
4500	3500	1800

The actual method for calculation of these Ecofys degree days could not be traced, but the figures are quite similar to that of Eurostat.

Table 3-7. Floor area per type, age and climate (Ecofys 2006)

Climate	Building age	Total	one-family	apartment small	apartment large	small office	large office
	year	(mio m²)	(mio m²)	(mio m²)	(mio m²)	(mio m²)	(mio m²)
cold	<1975	534	220	109	59	55	92
	1975-1990	154	63	31	17	16	27
	>1990	120	31	26	14	18	30
moderate	<1975	9145	4607	1242	669	780	1848
	1975-1990	2551	1290	348	187	216	511
	>1990	1708	670	181	97	226	535
warm	<1975	3116	1197	769	414	319	416
	1975-1990	1945	748	480	259	199	259
	>1990	1175	399	256	138	166	216

Together with average U-values (below) and a form factor describing the total surface area in relation to the floor area the transmission losses of the stock can be calculated.

Table 3-8. U-values per age and climate (Ecofys 2006)

[30] Ecofys GmbH, Mitigation of CO2 - Emissions from the Building Stock, Eurima / EurACE, 2006, Brussels

Uvalues [W/m²K]	< 1975 no retrofit	< 1975 retrofit	1975-1990	1990-2002	newly built 2003-2006	retrofit 2003-2006	newly built > 2006	retrofit > 2006
Cold								
Roof	0.50	0.20	0.20	0.15	0.15	0.15	0.13	0.13
Facade	0.50	0.30	0.30	0.20	0.18	0.18	0.17	0.17
Floor	0.50	0.20	0.20	0.18	0.18	0.18	0.17	0.17
Windows	3.00	1.60	2.00	1.60	1.42	1.42	1.33	1.33
Moderate								
Roof	1.50	0.50	0.50	0.40	0.25	0.25	0.23	0.23
Facade	1.50	1.00	1.00	0.50	0.41	0.41	0.38	0.38
Floor	1.20	0.80	0.80	0.50	0.44	0.44	0.41	0.41
Windows	3.50	2.00	3.50	2.00	1.84	1.84	1.68	1.68
Warm								
Roof	3.40	1.00	0.80	0.50	0.50	0.50	0.43	0.43
Facade	2.60	1.40	1.20	0.60	0.60	0.60	0.48	0.48
Floor	3.40	1.00	0.80	0.55	0.55	0.55	0.48	0.48
Windows	4.20	3.50	4.20	3.50	3.04	3.04	2.71	2.71

3.7.3 Assothermica

Similar to the Eurima study, the Italian association of heating appliances Assothermica has conducted a study with engineering office EdilClima to calculate the heat load of residential buildings in 3 different climate zones (Milan, Rome, Palermo). The scope of the study is in the title 'Energetic and Economic Evaluations for Operations of Energy Saving' and outcomes of this study are also used for planning in a wider European context (European Heating Industry Association). The study is interesting for more aspects that will be discussed in Task 7 (Sensitivity Analysis), but here we will focus on the heat load of the buildings and heating systems selected.

As a basis, the study uses the heat load of 3 buildings/heating systems:

- An apartment building, reportedly typical of the 1960's in Italy, with 16 apartments and collective heating (one boiler for all apartments). The built volume of the building is 4423 m³ and the average floor area per apartment is approx. 96-98 m².
- The same apartment building but now with an individual (combi-)boiler for each apartment
- A single family house ('villa') with a built volume of 948 m³, which equals around 330 m².

For each of these buildings the energy consumption and the payback times for 3 types of heating systems are assessed: conventional, condensing, condensing & better control. The net heat load of the dwelling –which is the parameter we are after— is the same with all three. The Table 3-9 shows the net heat load of the dwellings (in MJ, kWh, kWh/m²). Also in all cases the calculated heat demand for hot water is the same (3790 kWh/dwelling). What is slightly different are the distribution & emitter losses, which of course depend on the type of boiler and control. The table shows the distribution & emitter losses just for the reference case of a non-condensing boiler (continuous heating). Interestingly, according to the calculations of EdilClima following CEN TC89, distribution losses become a very important factor in the heat demand especially in warmer regions and especially with collective heating systems.

Table 3-9. ASSOTHERMICA, Heat load house for 3 building/heating & 3 climate zones *

Type of dwelling	Volume built	Floor area*	Heat load house (losses+ internal gain)			Distribution & emitter losses		Hot Water	Total net heat demand
	m³	m²	MJ	kWh	kWh/ m²	MJ	%	MJ	MJ
Apartments (16), coll. Heating									
MILANO, building	4422	1579	611968	169991	108	164781	26,9%	218268	995017
per avg. dwelling	276	99	38248	10624	108	10299	26,9%	13642	62189
ROMA	4422	1579	333198	92555	59	129419	38,8%	218268	680885
per avg. dwelling	276	99	20825	5785	59	8089	38,8%	13642	42555
PALERMO	4422	1579	156493	43470	28	88023	56,2%	218268	462784
per avg. dwelling	276	99	9781	2717	28	5501	56,2%	13642	28924
Apartments (16), indiv. Heating									
MILANO									
zone 1	317	113	43454	12071	107	2081	4,8%	13644	59179
zone 2	240	86	26982	7495	87	1292	4,8%	13644	41918
zone 3	244	87	27542	7651	88	1319	4,8%	13644	42505
zone 4	314	112	41866	11629	104	2005	4,8%	13644	57515
zone 5	303	108	23836	6621	61	1141	4,8%	13644	38621
zone 6	229	82	13185	3663	45	631	4,8%	13644	27460
zone 7	233	83	13494	3748	45	646	4,8%	13644	27784
zone 8	299	107	22633	6287	59	1084	4,8%	13644	37361
zone 9	302	108	23779	6605	61	1139	4,8%	13644	38562
zone 10	229	82	13156	3654	45	630	4,8%	13644	27430
zone 11	232	83	13465	3740	45	645	4,8%	13644	27754
zone 12	299	107	22598	6277	59	1082	4,8%	13644	37324
zone 13	312	111	57174	15882	143	2738	4,8%	13644	73556
zone 14	236	84	37127	10313	122	1778	4,8%	13644	52549
zone 15	240	86	37848	10513	123	1812	4,8%	13644	53304
zone 16	308	110	55391	15386	140	2652	4,8%	13644	71687
MILANO TOTAL Building	4337	1549	473530	131536	85	22675	4,8%	218304	714509
per avg. dwelling	271	97	29596	8221	85	1417	4,8%	13644	44657
ROMA TOTAL Building**	4337	1549	257823	71617	46	37708	14,6%	218304	513834
per avg. dwelling	271	97	16114	4476	46	2357	14,6%	13644	32115
PALERMO TOTAL Building**	4337	1549	121092	33637	22	35111	29,0%	218304	374506
per avg. dwelling	271	97	7568	2102	22	2194	29,0%	13644	23407
Villa (single family house)									
MILANO	949	330	204575	56826	172	3097	1,5%	27288	234960
ROMA**	949	330	111385	30940	94	12301	11,0%	27288	235070
PALERMO**	949	330	52314	14532	44	13060	25,0%	27288	92662

*= calculated from volume at floor height 2,8 m

**= calculated VHK from Milan data and known Rome/Palermo data

***= R. Stella,, Energetic and Economic Evaluations for Operations of Energy Saving, Assothermica con EdilClima Srl, Milano, Italy, 2006

The table shows

- The lowest heat load per square meter of floor area can be found in individually heated apartments , with a value of 85 kWh/m² (Milan) versus 108 kWh/m²(Milan) for collectively heated apartments (23% higher). In single family houses the value doubles (172 kWh/m²). These proportions also go for Rome and Palermo, as regards the heat load of the dwelling.

- Not surprisingly, the heat load per square meter of floor area is highest in Milan. In Rome it is only 54% and in Palermo a mere 26%. However, the differences in total heat demand is more moderate than that, because sanitary hot water demand is not depending on the climate and the fraction of the distribution losses increases substantially in warmer climates.

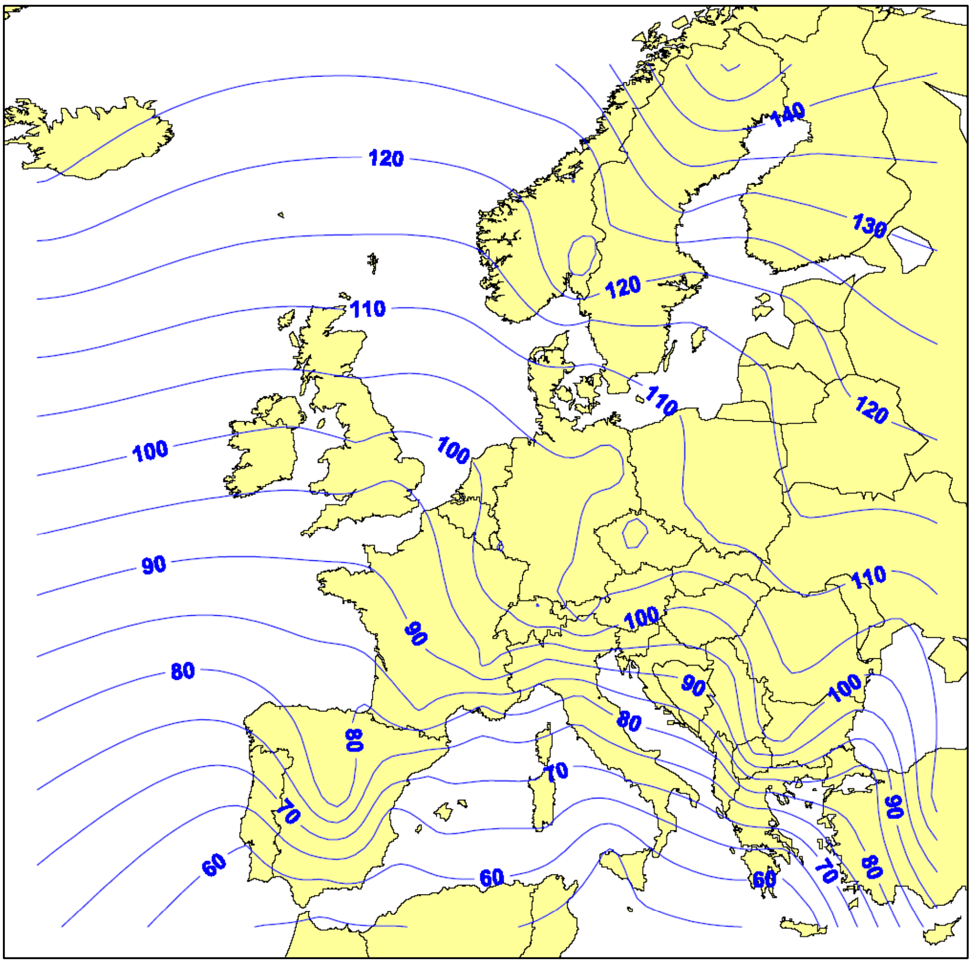
3.7.4 Ecoheatcool project

In October 2006 the Ecoheatcool Workpackages were published by Euroheat & Power, the association of district heating companies. This study project was done by Chalmers University in Sweden with the European district heating companies. As part of the scope, the study proposes a parameter that could be relevant for the underlying study, i.e. the *'European Heating Index'*.

The index aims to be an improvement over the degree-day method in estimating the real heat demand of buildings. The idea behind this is, that '*the degree-day method cannot directly be used to explain how the space heating demands vary from North to South, since the actual demands also depend on how well the buildings are insulated. …[The degree-day method used by Enerdata 2003 and IEA 2004] assumes that the same building with the same insulation exist in both Palermo in Southern Italy and Kiruna in Northern Sweden.* '

The authors take the rule of building physics that the long-term optimal insulation thickness is proportional to the square root of the degree-day number, by assuming a certain heat cost and a certain insulation cost. Also recovery of heat from ventilation would follow the same relation. From this the index can be created, whereby the index=100 is equal to the average European condition.

Figure 3-2.
European Heating Index
(Ecoheatcool project, 2006)



3.7.5 PRIMES 'Shared Analysis'

The PRIMES model covers the whole EU energy-economy, both the sides of energy supply and energy-demand. It was used for the 'Shared Analysis' in 1999 by the three DGs of the European Commission most involved in energy and climate change (DG TREN, DG ENV, DG ENTR) and later it was used during the ECCP process (see next paragraph). In 2006, the University of Athens (author of the model) has published a long-term forecast on CO_2 emissions in the context of the Energy Efficiency improvements planned in the EU.[31]

The historical data in PRIMES are based on official statistics data (e.g. Eurostat) and the researchers use simplified models to produce forecasts. We will not go into detail on the modellingbut the table below shows the main data for the households energy consumption, published in 2006.

It is important to note

- that these data for the residential sector <u>do not include the power generation losses</u> and the generation and distribution <u>losses of district heating</u>. In PRIMES these losses are partitioned to the energy sector, whereas for the ecological impact assessment these types of losses will eventually have to be partitioned to the final demand sectors (industry, tertiary, residential, transport). This is a disadvantage,

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[31] Mantzos, L. and Capros, P., European Energy and Transport, Trends to 2030- Update 2005, May 2006 (ref.'PRIMES 2006'). prepared by the Institute of Communication and Computer Systems of National Technical University of Athens (ICCS-NTUA), E3M-Lab, Greece, for the Directorate-General for Energy and Transport and represents that organisation's views on energy facts, figures and projections. These views have not been adopted or in any way approved by the Commission and should not be relied upon as a statement of the Commission's or the Directorate-General's views.

but the advantage is that it enables a comparison between the generation losses of fossil fuel fired boilers and the now '100% efficient' district heating and electric heating.

- Furthermore, PRIMES is based, for 1990-2005, on the annual statistics that Eurostat retrieves from the national statistics offices, which in turn are based on the energy deliveries of as reported by energy companies. This means that these data – though not perfect—are probably the most accurate to be found. The disadvantage is of course that they are delivered at a high aggregation level and the PRIMES-authors do not supply an insight in the exact modelling behind these figures.

Data are given for 5-year intervals. For our purpose it was useful to assess an interpolated figure of 17370 kWh per household in 2003, because this is the most recent year for which detailed housing statistics are available for all Member States (see Table 3-11). Also the figure of 191,4 mln. households in 2003 is an interpolated figure.

Comparing between Member States, already at this high aggregation level, there are some remarkable figures showing that there is a wide variation of 11300 kWh/household for Spain to 37380 kWh/household for Luxemburg (2005 data).

Climate seems only a part of the explanation of the differences in kWh/household. Compare e.g. Belgium and the Netherlands; compare new Member States (NMS) and the EU-15. This will be explored in par. 3.8. The CO_2-emission data per household are – as explained above—as yet not saying too much because they do not include the CO_2 emissions in the energy sector that are caused by the energy demand in the residential sector.

The 2006 publication on PRIMES doesn't provide a split-up of the energy consumption per fuel/energy source. For that reason we present data for 2003 compiled in the Ecoheatcool project and then use the percentages to make the split. See Table 3-11.

Table 3-10. EU Residential Energy use and CO_2-emissions PRIMES (source: PRIMES Baseline Scenario, release 2006)

	Parameter	*unit*	EU-25	AT	BE	CY	CZ	DK	EST	FI	FR	DE	GR	HU	IE	IT	LV	LT	LU	MT	NL	PL	PT	SK	SI	ES	SE	UK
	No. of households (PRIMES 2006)																											
1	households 1990	mln	167	3,0	3,9	0,1	3,6	2,2	0,6	2,0	22,5	33,8	3,3	4,0	1,0	21,5	1,0	1,3	0,1	0,1	6,0	12,3	3,3	2,1	0,6	12,3	3,9	22,5
2	households 1995	mln	176	3,1	4,1	0,2	3,8	2,3	0,6	2,2	24,0	35,3	3,5	4,1	1,2	23,0	1,0	1,3	0,2	0,1	6,4	13,1	3,5	2,3	0,6	13,2	4,0	23,9
3	households 2000	mln	186	3,2	4,2	0,2	3,9	2,4	0,6	2,3	25,5	36,7	3,7	4,2	1,3	24,4	0,9	1,3	0,2	0,1	6,8	13,8	3,6	2,5	0,6	14,0	4,1	25,3
4	households 2005	mln	195	3,4	4,4	0,2	4,1	2,5	0,6	2,4	27,1	38,3	3,9	4,3	1,4	25,6	0,9	1,4	0,2	0,2	7,3	14,4	3,8	2,7	0,7	14,6	4,3	27,0
5	households 2010	mln	205	3,5	4,6	0,2	4,2	2,6	0,6	2,5	28,7	39,8	4,1	4,3	1,5	26,8	0,9	1,4	0,2	0,2	7,8	14,9	4,0	2,8	0,7	15,2	4,5	28,6
6	households 2015	mln	211	3,6	4,8	0,2	4,2	2,7	0,6	2,6	30,1	40,7	4,2	4,3	1,6	27,8	0,9	1,5	0,2	0,2	8,2	15,0	4,2	2,9	0,7	15,6	4,7	30,1
7	households 2020	mln	218	3,6	4,9	0,2	4,2	2,8	0,6	2,7	31,5	41,5	4,3	4,3	1,7	28,7	0,9	1,5	0,2	0,2	8,6	15,1	4,3	2,9	0,7	16,0	4,9	31,6
	Residential Energy Consumption in ktoe (1 toe=41,86 GJ=11627 kWh)																											
8	Net energy total 1990	ktoe	261.006	5832	8337	120	8254	4043	1271	5319	35753	58223	3054	5992	2323	30494	2240	1662	519	55	9772	18126	2290	2416	850	9266	6838	37957
9	Net energy total 1995	ktoe	274.621	6256	9295	181	5608	4472	1118	5460	36086	62995	3327	5449	2198	31692	883	1248	559	70	11124	23284	2569	1983	1176	9986	8029	39573
10	Net energy total 2000	ktoe	273.302	6472	9465	219	5260	4141	928	4922	38425	63063	4470	5281	2475	28766	965	1345	596	82	10286	17516	2804	2186	1116	11881	7539	43099
11	Net energy total 2005	ktoe	294.611	7505	9963	254	6022	4293	1001	5260	41352	67715	5647	6563	2821	29410	1368	1425	643	94	10615	17950	3271	2930	1263	14208	7660	45378
12	Net energy total 2010	ktoe	311.966	8156	10314	290	6637	4443	1100	5635	43461	70501	6509	7333	3154	30336	1773	1582	669	109	11115	19188	3942	3440	1393	16075	7821	46990
13	Net energy total 2015	ktoe	327.949	8446	10456	322	7022	4604	1172	5901	44585	72081	7010	8044	3406	32583	2102	1796	679	121	11623	21388	4479	3903	1491	17523	8049	49163
14	Net energy total 2020	ktoe	338.740	8440	10324	340	7271	4700	1240	6009	44927	72615	7281	8463	3609	35141	2341	2026	672	130	12042	24090	4905	4280	1561	17728	8144	50461
	Energy per Household in MWh/hh																											
15	Net energy /househ. 1990	MWh/hh	18,17	22,60	24,85	13,95	26,66	21,37	24,63	30,92	18,48	20,03	10,76	17,42	27,01	16,49	26,04	14,86	60,34	6,39	18,94	17,13	8,07	13,38	16,47	8,76	20,39	19,61
16	Net energy /househ. 1995	MWh/hh	18,10	23,46	26,36	10,52	17,16	22,61	21,66	28,86	17,48	20,75	11,05	15,45	21,30	16,02	10,27	11,16	32,50	8,14	20,21	20,67	8,53	10,02	22,79	8,80	23,34	19,25
17	Net energy /househ. 2000	MWh/hh	17,10	23,52	26,20	12,73	15,68	20,06	17,98	24,88	17,52	19,98	14,05	14,62	22,14	13,71	12,47	12,03	34,65	9,53	17,59	14,76	9,06	10,17	21,63	9,87	21,38	19,81
18	Net energy /househ. 2005	MWh/hh	17,55	25,66	26,33	14,77	17,08	19,97	19,40	25,48	17,74	20,56	16,84	17,75	23,43	13,36	17,67	11,83	37,38	5,46	16,91	14,49	10,01	12,62	20,98	11,31	20,71	19,54
19	Net energy /househ. 2010	MWh/hh	17,73	27,09	26,07	16,86	18,37	19,87	21,32	26,21	17,61	20,60	18,46	19,83	24,45	13,16	22,91	13,14	38,89	6,34	16,57	14,97	11,46	14,28	23,14	12,30	20,21	19,10
20	Net energy /househ. 2015	MWh/hh	18,05	27,28	25,33	18,72	19,44	19,83	22,71	26,39	17,22	20,59	19,41	21,75	24,75	13,63	27,16	13,92	39,47	7,03	16,48	16,58	12,40	15,65	24,77	13,06	19,91	18,99
21	Net energy /househ. 2020	MWh/hh	18,07	27,26	24,50	19,77	20,13	19,52	24,03	25,88	16,58	20,34	19,69	22,88	24,68	14,24	30,24	15,70	39,07	7,56	16,28	18,55	13,26	17,16	25,93	12,88	19,32	18,57
	Residential CO_2 -emissions (excl. Transport) in Mt CO_2																											
22	Mt CO_2 total 1990	MtCO_2	506	10,1	18,7	0,2	24	4,9	1,2	6,4	55,2	129,8	4,6	13,6	7	65,4	4,4	2,5	1,3	0,1	19,2	33,1	1,6	5,8	1,7	12,9	4,8	77,8
23	Mt CO_2 total 1995	MtCO_2	486	9,8	20,1	0,2	10,4	4,9	0,5	6,1	52,2	126,4	4,8	9,9	5,7	64,5	0,5	0,8	1,3	0,1	20,6	44,4	1,9	3,3	2,1	13,6	4,5	77,3
24	Mt CO_2 total 2000	MtCO_2	452	9,6	20	0,2	7,9	3,9	0,3	3,5	54	117,3	7,4	8,8	5,7	55,7	0,3	0,5	1,4	0,1	18,9	27,9	2	3,3	1,3	16,4	3,7	82
25	Mt CO_2 total 2005	MtCO_2	467	9,9	20,4	0,2	8,7	3,5	0,2	3,1	55	121,6	10,3	10,7	6,1	55,3	0,4	0,5	1,5	0,1	19,1	25,9	2,8	4,7	1,5	19,3	2,6	84
26	Mt CO_2 total 2010	MtCO_2	483	10,7	20,8	0,2	9,1	3,3	0,3	3,4	57,6	123,7	12,4	11	6,7	55,7	0,5	0,6	1,5	0,1	19,4	26,2	3,9	5,6	1,7	21	2,4	84,7
27	Mt CO_2 total 2015	MtCO_2	494	10,9	20,7	0,2	9,1	3,3	0,3	3,6	57,5	124,2	13,4	11,3	7	57,9	0,6	0,7	1,5	0,1	19,7	27,4	4,6	6,1	1,9	22,2	2,2	87,3
28	Mt CO_2 total 2020	MtCO_2	495	10,5	19,8	0,2	9,1	3,3	0,3	3,7	56	123	13,7	11,4	7,3	59,7	0,7	0,9	1,5	0,1	19,8	28,8	5	6,5	2,1	21,8	2	87,7
	CO_2 -emissions per household																											
29	Mt CO_2 /household 1990	tCO_2	3,03	3,37	4,79	2,00	6,67	2,23	2,00	3,20	2,45	3,84	1,39	3,40	7,00	3,04	4,40	1,92	13,00	1,00	3,20	2,69	0,48	2,76	2,83	1,05	1,23	3,46
30	Mt CO_2 /household 1995	tCO_2	2,75	3,16	4,90	1,00	2,74	2,13	0,83	2,77	2,18	3,58	1,37	2,41	4,75	2,80	0,50	0,62	6,50	1,00	3,22	3,39	0,54	1,43	3,50	1,03	1,13	3,23
31	Mt CO_2 /household 2000	tCO_2	2,43	3,00	4,76	1,00	2,03	1,63	0,50	1,52	2,12	3,20	2,00	2,10	4,38	2,28	0,33	0,38	7,00	1,00	2,78	2,02	0,56	1,32	2,17	1,17	0,90	3,24
32	Mt CO_2 /household 2005	tCO_2	2,39	2,91	4,64	1,00	2,12	1,40	0,33	1,29	2,03	3,17	2,64	2,49	4,36	2,16	0,44	0,36	7,50	0,50	2,62	1,80	0,74	1,74	2,14	1,32	0,60	3,11
33	Mt CO_2 /household 2010	tCO_2	2,36	3,06	4,52	1,00	2,17	1,27	0,50	1,36	2,01	3,11	3,02	2,56	4,47	2,08	0,56	0,43	7,50	0,50	2,49	1,76	0,98	2,00	2,43	1,38	0,53	2,96
34	Mt CO_2 /household 2015	tCO_2	2,34	3,03	4,31	1,00	2,17	1,22	0,50	1,38	1,91	3,05	3,19	2,63	4,38	2,08	0,67	0,47	7,50	0,50	2,40	1,83	1,10	2,10	2,71	1,42	0,47	2,90
35	Mt CO_2 /household 2020	tCO_2	2,27	2,92	4,04	1,00	2,17	1,18	0,50	1,37	1,78	2,96	3,19	2,65	4,29	2,08	0,78	0,60	7,50	0,50	2,30	1,91	1,16	2,24	3,00	1,36	0,41	2,78

Table 3-11. EU Residential net energy use by energy source 2003 (source: VHK compilation of PRIMES 2006 and Euroheat & Power 'Ecoheatcool' 2006)

	Parameter	unit	EU-25	A	B	CY	CZ	DK	EST	FIN	F	D	GR	H	IRL	IT	LT	LIT	LUX	MT	NL	PL	P	SK	SLO	E	S	UK
	PRIMES Base data (2003= interpolation from PRIMES 2000-2005)																											
1	Energy/hh 2003	kWh/hh	**17370**	24805	26277	13952	16519	20004	18832	25242	17653	20326	15720	16495	22911	13497	15591	11913	36288	7092	17179	14599	9627	11637	21238	10736	20979	19647
2	households 2003	mln.	**191,4**	3,3	4,3	0,2	4,0	2,5	0,6	2,4	26,5	37,7	3,8	4,3	1,4	25,1	0,9	1,4	0,2	0,2	7,1	14,2	3,7	2,6	0,7	14,4	4,2	26,3
3	Floor area/dw. 2003	m²	**87**	94	86	145	76	109	60	77	90	90	83	75	104	90	55	61	125	106	98	68	83	56	75	90	92	87
	Residential net energy consumption by fuel in % (Euroheat & Power 2006)																											
4	Coal and Coal Products	%	**1,9**	1,5	1,1	0,0	6,4	0,0	0,0	0,0	0,6	0,7	0,0	3,0	12,8	0,0	2,0	2,0	0,0	0,0	0,0	18,5	0,0	1,9	0,0	0,4	0,0	1,4
5	Petroleum Products	%	**17,8**	27,0	34,5	30,0	0,9	14,4	0,0	15,5	19,7	25,0	55,8	3,4	37,2	18,1	4,0	4,1	45,5	33,3	0,5	6,3	24,3	0,0	33,3	28,0	7,7	6,6
6	Natural Gas	%	**40,0**	21,6	36,2	0,0	39,0	15,6	3,1	0,5	39,6	37,4	0,5	58,3	20,2	57,1	6,0	8,2	36,4	0,0	74,2	18,0	5,6	53,8	7,1	20,4	0,7	65,9
7	Geothermal	%	**0,1**	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
8	Solar/Wind/Other	%	**0,2**	1,2	0,0	20,0	0,0	0,0	0,0	0,0	0,1	0,3	2,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,3	0,0	0,9	0,0	0,0	0,2	0,0	0,0
9	Biomass and Waste	%	**6,6**	17,4	1,4	0,0	5,5	6,9	28,1	13,5	11,4	4,8	10,0	6,8	1,1	2,8	38,0	24,5	0,0	0,0	1,3	10,9	29,0	0,0	21,4	10,9	7,7	0,3
10	Electricity	%	**24,8**	23,2	26,6	50,0	23,9	23,1	18,8	37,8	28,3	19,6	31,1	17,0	28,7	22,0	10,0	14,3	13,6	66,7	21,9	13,1	40,2	17,0	26,2	40,1	49,8	25,8
11	Heat	%	**8,6**	8,1	0,3	0,0	24,3	40,0	50,0	32,6	0,0	12,0	0,5	11,5	0,0	0,0	40,0	46,9	4,5	0,0	1,8	33,1	0,0	27,4	11,9	0,0	34,0	0,0
12	TOTAL	%	**100,0**	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0	100,0
	Residential net energy consumption by fuel in kWh/household (calculated from above)																											
13	Coal and Coal Products	kWh/hh	**337**	383	297	0	1061	0	0	0	108	151	0	491	2925	0	312	243	0	0	0	2707	0	220	0	44	0	280
14	Petroleum Products	kWh/hh	**3092**	6704	9056	4186	152	2876	0	3924	3470	5087	8770	562	8531	2444	624	486	16494	2364	89	918	2339	0	7079	3004	1625	1290
15	Natural Gas	kWh/hh	**6944**	5363	9501	0	6441	3126	588	131	6998	7595	83	9616	4631	7711	935	972	13196	0	12750	2635	540	6258	1517	2187	141	12940
16	Geothermal	kWh/hh	**16**	0	0	0	0	0	0	0	49	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Solar/Wind/Other	kWh/hh	**33**	287	0	2790	0	0	0	0	10	63	331	0	0	0	0	0	0	0	45	0	90	0	0	22	0	0
18	Biomass and Waste	kWh/hh	**1151**	4310	371	0	909	1375	5296	3401	2021	968	1572	1123	244	380	5924	2917	0	0	224	1595	2789	0	4551	1171	1625	61
19	Electricity	kWh/hh	**4305**	5746	6978	6976	3940	4626	3531	9548	4997	3984	4881	2808	6581	2963	1559	1702	4948	4728	3758	1909	3869	1976	5562	4308	10454	5076
20	Heat	kWh/hh	**1493**	2011	74	0	4016	8002	9416	8240	0	2437	83	1895	0	0	6236	5592	1649	0	313	4834	0	3184	2528	0	7134	0
21	TOTAL	kWh/hh	**17370**	24805	26277	13952	16519	20004	18832	25242	17653	20326	15720	16495	22911	13497	15591	11913	36288	7092	17179	14599	9627	11637	21238	10736	20979	19647
	Residential net energy consumption by fuel in kWh/m² and MJ/m² (calculated from above)																											
22	Avg. kWh/m² (all)	kWh/m²	**199**	264	304	96	217	183	313	328	197	227	190	220	220	149	281	197	290	67	175	214	116	207	283	119	229	226
23	Avg. MJ/m² (all)	MJ/m²	**718**	951	1096	347	779	660	1126	1180	709	816	684	792	793	538	1013	708	1045	240	631	771	418	747	1019	429	825	814

3.7.6 European Climate Change Programme (ECCP)

The European Climate Change Programme started in 2000 as a collaboration between DG ENV, DG ENTR and DG TREN of the European Commission on one hand and the stakeholders in the relevant sectors on the other hand to identify and evaluate possible EU policy measures. Starting point for the quantitative analyses in this programme – from the side of the Commission— was the so-called Shared Analysis (1999) performed by the University of Athens for the European Commission, using the *PRIMES* model.[32] This analysis was built upon with a higher level of detail by reports of independent consultants and reports by the stakeholders. Especially in the building sector, responsible for 40% of the CO_2-related greenhouse gas emissions, the programme has tried to identify and clarify which products are responsible. EurACE put forward studies by CALEB Consulting and the Commission has tried to harmonise these results with other inputs, e.g. from the then ongoing SAVE studies in the field of space and water heating (BRE 2002, Novem 2001). The outcome of the quantitative analyses were scenarios for the 1990 and 2010 baseline, as well as a scenario for the 2010 'with measures', presented in Annex I of the second ECCP report 2003.

The Annex I of the European Commission's 2nd ECCP Report compiles data on energy demand from the stakeholders and experts in the working groups WG 3 (buildings) and WG 5 (electrical appliances). The Table 3-13 gives a selection of these data, relating to the residential sector. Reference years are 1990 and 2010.

The ECCP project presents the most comprehensive attempt at giving a split-up of EU residential energy use around, but there are some snags:

- The ECCP tables relate to EU-15 and will have to be updated to include the new Member States;
- The technical analyses stem from what was available in 2001/2002. This includes the SAVE projects on Heating Systems (BRE, 2002), which was running in parallel. But it excludes the most recent market studies by BRG Consult (see Task 2 report).

Please note that, as opposed to the PRIMES data, the ECCP-tables do include a partitioning of the losses of power generation. For the 1990 data a conversion of 0,5 kg $CO_2/kWh_{electric}$ was used. For 2010 a higher efficiency of 0,45 kg $CO_2/kWh_{electric}$ was used. With these conversion factors the electricity consumption per household that is behind the ECPP-tables can be reconstructed in $kWh_{electric}$.. A summary is shown in Table 3-12 below.

Table 3-12. Electricity consumption per household EU-15 (extraxt from Table 3-13 next page, converted to kWh electric)

Sector/function group	Reference 1990	Baseline 2010
Electric heating/cooling/ CH pump	1277	1144
Electric water heaters	511	403
Whitegoods & Cooking	1418	975
Lighting	567	650
Electronics	227	832
Misc. Electric	255	234
Total	4255	4237

Please note that the values in this table are fully compatible with the data reported by the JS-WG (Joint Sub Working Group) elsewhere in the 2nd ECCP report.

[32] Please note that the European Commission continues to use the PRIMES model as the basis for its projections and that coherence between these policy documents at a higher aggregation level and the underlying study at product level is important. The latest publication involving PRIMES is 'European energy and transport: Scenarios for energy efficiency and renewables', European Commission, Aug. 2006.

Table 3-13. ECCP Residential sector Baselines 1990-2010 (all values in Mt CO_2 eq.)

RESIDENTIAL SECTOR Sector/function group	Fuel-Related CO_2 emissions (in Mt CO_2) Reference 1990	Baseline 2010
Total	762	797
of which		
Spaceheating/cooling, *of which*	481	466
Fossil,*of which*	371	350
Transmission losses	*190*	*186*
-windows	*75*	*70*
-walls	*55*	*55*
-floors	*30*	*30*
-roofs	*30*	*30*
Ventilation losses	*70*	*73*
Heating system losses	*111*	*91*
Electric, *of which*	90	88
Heating (incl. heatpump)	*73*	*68*
Cooling (airconditioners)	*2*	*3*
CH pump	*15*	*17*
District heating	*20*	*28*
Hot water, *of which*	103	115
Fossil	67	84
Electric	36	31
Whitegoods & Cooking, *of which*	109	84
Fossil (mainly hobs)	9	9
Electric, *of which*	100	75
Refrigeration/freezers	*62*	*43*
Washing machines	*20*	*11*
Dishwashers	*7*	*8*
Laundry driers	*4*	*6*
Electric ovens	*7*	*7*
Lighting (electr.)	40	50
Electronics, *of which*	16	64
Consumer el. (TV, audio, IRD,etc.)	15	35
Stand-by	*7*	*12*
On'	*7*	*23*
IT/ office equipment	1	29
Other(electric)	18	18
Autogeneration	0	0
Total (check)	767	797
of which (by energy source)		
Fossil	447	443
Electricity	300	326
Heat	20	28

Source: Composed by VHK 2002 for the European Commission on basis of European Climate Change Programme(ECCP) working group reports & docs JSWG and WG3 ('provisional analysis'), European Commission, 2001.

Note: Conversion Electricity 1990: 1 TWh el. = 0.5 Mt CO_2; 2010 1 TWh el.= 0.45 Mt CO_2

3.7.7 SAVE Study 2002

As mentioned, the 2002 SAVE study on Heating Systems, co-ordinated by BRE was performed in parallel to the ECCP project and also here the PRIMES data and older EU energy statistics were the basis for the estimates of the heat load in the technical analysis.

Again, this means that the SAVE study has the same snags as the ECCP analysis: It relates to the EU-15 and it lacks detail on water heaters. For that reason we will only present the main outcomes and for an explanation of the methodology we refer to the next paragraph 3.8 on the VHK update.

The Table 3-14 below gives a summary of the outcome with a annual heat load of 7250 kWh/dwelling. The Table 3-15 on the next page gives a time series of the net heat load from the study.

Table 3-14. Gas- and oil-fired CH-boiler heat demand, New (sales) and Installed (stock) 2005

	NEW (SALES) 2005		INSTALLED (STOCK) 2005	
	CH gas	**CH oil**	**CH gas**	**CH oil**
	kWh/year	kWh/year	kWh/year	kWh/year
Heat load avg. dwelling 2005	7250	7250	7250	7250
Boiler efficiency losses (eff. 87/80/ 83,3/ 77,6%)*	1083	1813	1453	2093
Circuit & emitter losses (eff. 96%)	347	378	363	389
Control inefficiency losses (18/ 18/ 20/ 20%)	1563	1699	1632	1752
Effective boiler load (fuel)/dwelling	**10243**	**11139**	**10698**	**11484**
Effective heating system efficiency	70,8%	65,1%	67,8%	63,1%
	mln #	mln #	mln #	mln #
Dwellings served EU 25, in mln. #	**6,954**	**1,709**	**89,792**	**30,250**
Of which, EU-15, in mln. #	6,750	1,594	87,158	28,214
Total fuel energy use EU 25, in TWh/yr	**71**	**19**	**961**	**347**

*= efficiencies in Net Calorific Value

SOURCES:
Kemna, R.B.J., "Task 3.1, VHK Stock Model of Residential Heating Systems", report VHK for BRE, "Study on Heating Systems Labelling/Standards" (EU SAVE II programme), Delft, The Netherlands, Sept. 2001. With contributions from Consult GB (EU), BRE (2nd source UK), VHK (EU/NL), Energie (IT data), Wuppertal Instuitute (D) and AFECI (B data).

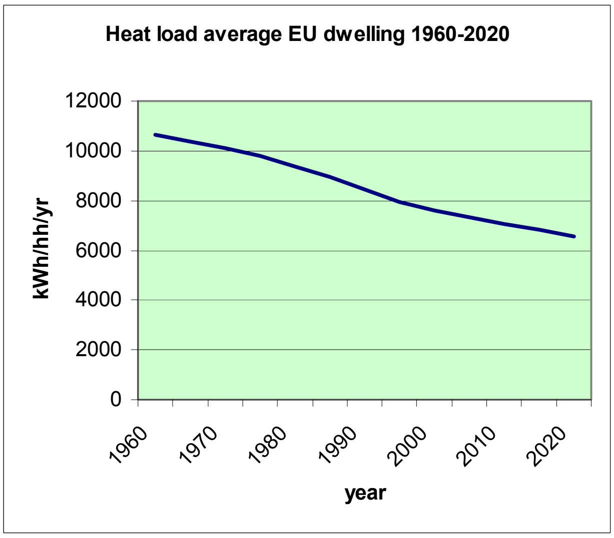
The time series 1960-2020 for the residential EU Heating System model consists of some basic parameters:

- Heat load of the house (at 100% system efficiency and optimal comfort);
- Comfort level (defined not as consumer behaviour but as restrained by the technical possibilities of the heating system);
- Heat generator efficiency;
- Emitter and distribution efficiency;
- Efficiency of temperature control;
- Efficiency of indirect energy sources (mainly conversion to electricity for electric space heating).

Table 3-15 gives the figures in Mt CO_2 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.

Table 3-15 [33]. Figures in Mt CO_2 per dwelling

[33] Conversion: in tCO2/hh;
avg. 17.8 tC/ ->65.2 tCO2/0.277GWh—> 0.235 kgCO2/kWh



	Mt CO_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 indicates 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 range from 10638 kWh/dwelling/yr in 1960 to 6564 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 2000 to 2500 kWh/dwelling/yr.[34]

Please note that the IPPC conversion figures use the lower heating values (Net Calorific Value or NGV) of the fuels. If we use the higher heating values of the fuels (or Gross Calorific Value, GCV) the 1960-2020 projections (in kWh) would be around 5% higher, based on the 2005 split-up of fuels.

3.8 Heat load: Update VHK 2006

It is outside the scope of the underlying study to evaluate the full bottom-up modelling by Ecofys, Assothermica or the Ecoheatcool project or the mainly top-down approach by PRIMES. Although certainly there are merits to all models and they provide valuable reference points, a single approach will not provide an up-to-date assessment of the heat load.

What we propose—in line with the assignment—is to continue along the lines of the ECCP and SAVE approach, i.e. to use PRIMES totals as a basis and try to make an update of the previous estimate of 7250 kWh heat load/household as accurately as possible. The ECCP/SAVE approach needs to be updated for the EU-25 and we will incorporate the latest findings of the Task 1 (building standards) and Task 2 (BRG Consult data). Also the new Energy Performance of Buildings (EPB) standards provide new inputs on hot water demand and heating.

The year for which most data are known is 2003 and we will take this as a reference year:

- Energy per household: 17370 kWh/dwelling (PRIMES, EU-25)

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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)

[34] 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).

- Households 2003: 191,4 mln. (PRIMES, EU-25)
- Average floor area/dwelling: 87 m^2/dwelling (Boverket 2005, EU-25)

These data are available for all EU-25 individual Member States. The idea is to make an estimate of the heat load for space heating by identifying in the total energy per household the following items:

- Water heater energy
- Non-heating related electricity (whitegoods, electronics, cooking, lighting, other),
- Generator, distribution/emission and control losses of the heating system.
- Indoor temperature
- Miscellaneous items (NGCV versus GCV, the role of space cooling, etc.)

The remainder is the heat load of the house, i.e. the total of

- transmission heat losses of the dwelling,
- ventilation heat losses of the dwelling
- minus internal heat gain (people, appliance, sun).

The table 3-16 shows the calculations involved, starting –after the reference data—with an assessment of water heater energy consumption. The estimate involves an iterative process, whereby all parameters must fit available sources and plausible explanations. In this context the split-up over 25 EU Member States, which is never attempted before, is not an extra burden but provides an extra possibility to test the robustness of the estimates.

3.8.1 Water Heater Energy

The water heater energy was assessed by

1. Estimating the hot water demand in litres/person.day

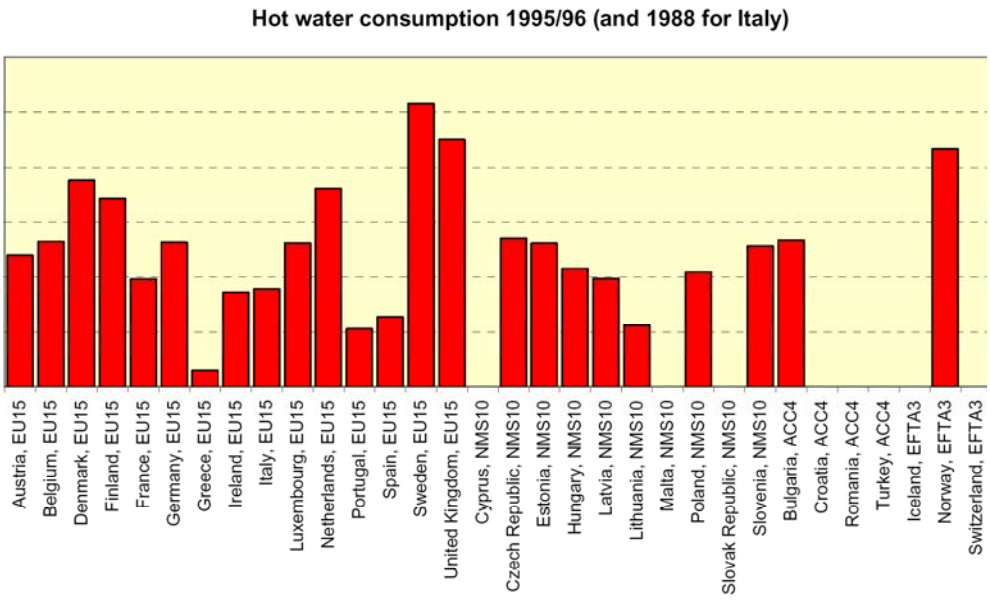
For 5 countries (NL, ES, DE, FR, UK) building standards make estimates in the range of 22-33 litres per person per day. These values are the anchor points for an estimate of hot water consumption for other countries. Inputs for this additional assessment are:

- Older data (1995-1998) where Eurostat has tried to assess the hot water demand. Because of lack of definition in the survey the absolute values of this international survey the absolute values cannot be used, but the relative values give an indication. The figure below is an elaboration of these older data by the Ecoheatcool project 2006. It shows e.g. that hot water demand in the North is significantly higher than in the South of Europe, although the Baltic States are the exception.
- A second input comes from the absolute limits of the electricity balance. For instance, if there is almost no electric heating in a country and the total electricity consumption is 1500 kWh/household, then –given that on average there is at least a refrigerator, lighting, etc. that will take a minimum of 800-1000 kWh/hh—it is impossible that average electricity consumption for water heating is more than 500-700 kWh. If all this hot water comes from an electric storage water heater at 70% efficiency, then we can calculate that this household can never use more than 17-20 litres of 60°C/hh.day on average. This is a fictituous example, but it comes close to the situation e..g in Baltic States.
- A third input comes from anecdotal data on habits, demographics and the technical limtits of the water heaters.
    - In Scandinavia it is normal for a person to take a daily long hot shower and a few baths (or a sauna) per week. Especially for the large fraction of one- and two person households this doesn't give any problems in terms of time

('bathroom-occupancy') and also the large storage vessels or district heating for water allow this.

- In Western Europe (NL, UK, IE, North of FR, etc.) it is more common to take a (short) shower every other day and rarely have a bath. For certain countries also the limited capacity of the appliance plays a role, e.g. the limited flow rate of e.g. electric showers in the UK and Ireland or the traditionally smaller storage vessels in the Netherlands.
- Germany and Belgium/Luxemburg are somewhat in the middle: There is a tradition of huge hot water storage vessels (>200-400 litres) and powerful electric instantaneous water heaters, but at the same time the latest German building standards –presumably reflecting German surveys—anticipate only a very limited hot water demand of 22 litres/person per day.
- Further down South, the frequency and temperature of showers diminishes, the bidet is used daily, electric storage vessel volumes are much smaller, baths are mainly used for small children or to wash the curtains once a year. The young tend to use more the shower, whereas the older generation is still used to 'wash in parts' ('lavarsi a pezzi'). As the housing statistics in the previous paragraphs show, not all dwellings have showers/bathtubs.
- In some new Member States, especially in the Baltic States, a significant fraction of dwellings doesn't have its own shower/bathtub/hot water. People use common or public facilities for a full bath/shower, e.g. once a week, and showers at work.
- Finally, for all countries there is anecdotal evidence that the peak in hot water demand is in the weekends, at which time the technical limitations of the water heaters will play a bigger role than during weekdays.

Figure 3-3.
Hot water consumption.
(source: Ecoheatcool 2006)



2. Converting hot water demand to ***net*** *energy demand*

Multiplying the estimates of litres/person.day with the average household size and then with 21,1 kWh/litre (=365 days * 50 degrees * 1,16 Wh/degree) gives the annual net energy demand for hot water.

3. Applying an energy efficiency ratio from default building standard data and other sources.

For electric instantaneous heaters 97% was assumed, for storage water heaters 65-70%, for combi-boilers 55%, for indirect cylinders 50%, for dedicated gas water heaters around 45%. These values refer to the installed stock, not the new appliances [35].

4. Assessing the share of each water heater type in the EU-25 park

For this we used the Task 2 stock data from BRG Consult, distinguishing between primary water heaters and –for 32% of the EU—secondary water heaters. It was assumed –roughly as indicated in standards—that the secondary water heater is mainly placed in the kitchen and –if present—takes care of one-third of the hot water drawn off.

The results are given in Table 3-16.

3.8.2 Non-heating electricity consumption

The ECCP-tables gave a subdivision of electricity consumption that is not related to space heating/cooling or hot water preparation. On a total of around 4200-4300 kWh per household per annum (kWh/hh.a) the EU-15 used 2400-2500 kWh/hh.a for non-heating purposes in 1990 and with a forecast to rise to 2600-2700 kWh/hh.a in 2010 , mainly due to an increased energy consumption of consumer electronics.

On average, the 2006 PRIMES data for the EU-25 also indicate an average annual electrticity consumption per household in the range of 4200-4300 kWh. Obviously, for the EU-15 the electricity consumption rose more than expected (e.g. due to the not anticipated rise of residential air-conditioners), because the average electricity use of the new Member States is –according to Enerdata—substantially lower varying between 1500 and 2200 kWh/hh.a. The share of electric sanitary water heating is also higher in the new Member States, mainly because they are cheaper than gas-appliances and serve as a back-up for failing district heating. All in all, this leads to an estimate of 2300-2400 kWh/hh.a of non-heating electricity consumption (incl. electrici cooking) for the EU-25. For a subdivision per country see the table.

3.8.3 Generator, distribution and control losses

1. Generator efficiency

Generator, distribution/emission land control losses can be estimated, apart from what is said in the ECCP project, from data comparing buildings with and without district heating. The result of this comparison should constitute the generator losses of gas- and oil-fired boilers. E.g. from research in Germany by Techem it is known that this comparison leads to a calculated generator efficiency of 70% for gas-fired boilers and 66% for oil-fired boilers. Also in the Netherlands, where district heating is charged on a 'not-more-than-else' basis (*'niet-meer-dan-anders'*), this type of surveys is frequent and leads to similar outcomes of around 65-70%. Of course, these are mostly modern (weather-controlled) district heating systems compared to collective boilers without proper temperature control (see below), so a part must be attributed to 'control losses'. Also district heating is mostly linked to multi-family dwellings, whereas for single-family dwellings the average boiler-efficiency will be better. But still an efficiency in the range of 70-72% (on Gross Calorific Value, around 80% on net calorific value) seems realistic.

2. Distribution and heat emission losses

To this we have to add the distribution and emission losses inside the building (around 5-10%). As is shown e.g. in the Assothermica study, these losses can be as low as 5% in colder climates and individual heating, up to 15-20% for collective heating and up to

[35] The "Solar Thermal" value (150%) assumes a 90-95% efficient boiler /WH with 50-60% solar contribution. Quantitatively this would appear as a 150% efficiency (1 kWh in à 1,5 kWh output). The value is used as a first rough check on statistics as given.

50% for collective heating in warmer climate zones. All in all, distribution and emitter losses of 10% are assumed.

3. Control losses

Control losses are difficult to assess, because they are very often not perceived as such. A very basic distinction could be whether there is a control or not. As the Assothermica study shows, many older collectively heated apartment buildings in Italy have ‘continuous heating’, which means that the boiler is switched on mid October and switched off mid April and runs continuously –mostly at fixed boiler water temperature— in between. If such a collective boiler would be allowed even a basic intermittent control, the saving would be at least 10%. If each apartment had individual control (either by having a boiler per apartment or by an individual control system) Assothermica calculates a saving of 20-25%. A similar situation, probably worse, occurs with older district heating systems for apartment-buildings in –mainly—new Member States. These data are anecdotal, but –without considering too much sophistications as electronic vs. mechanical control, modulating thermostats, radio-systems. etc.— it is not exaggerated to estimate average control losses in the range of 10-20%. The lower figure would apply to countries with a low share of apartment buildings like NL, BE, UK, IE, whereas the higher figure applies to countries with a high share of apartment buildings.

All in all, if we sum 32% generation losses, 10% distribution and emitter losses and some 13% control losses we end up with an overall figure of 55% losses for heating systems with fossil-fuel fired boilers. In the case of electric space heating, where the power generation is not included in the PRIMES residential definition, and the district heating dwellings (likewise) we have to calculate –for now— a generator efficiency of 100%. For electric (resistance) space heating the distribution, emitter and control losses will be minimal and we estimate a total of 10%[36]. In the case of district heating distribution and control losses will be high (on average) and we estimate 30% losses.[37]

3.8.4 Indoor Temperature

In calculating the average heat load of a house according to building standards, an average indoor temperature of 18°C is taken as an average, typically based on a living room of 20-21°C, kitchen 18-20°C, bedrooms 16°C and bathroom 24°C. On average for Europe we believe this to be roughly correct, although it could be closer to 17°C. than to 18°C.

However, at the level of Member States there are significant differences. The Swedish Chalmers University (Ecoheatcool project) reports average indoor temperatures of 21-22°C for Sweden. This may given over 20% more energy use than the assumed 18°C. At the same time, in the poorest parts of the European population and in the South of Europe the average indoor temperature may well be a few degrees lower than 18°C. Especially in countries with a high share of local heaters at best the living room temperature will be 20°C, but the year average for the other rooms will be closer to the EU-25 year average of 11°C. This means an average indoor temperature of around 15-16°C, which gives an (unvoluntary) energy saving of 25% or more with respect of an 18°C dwelling , depending on the climate.

It is very important to realize that when the new Member States or the ‘fuel poor’in the UK get richer and get better heating systems –which will hopefully happen—that a large part of the expected efficiency improvement from a more efficient boiler will be counterbalanced by a higher heating comfort, i.e. an actual temperature of 18°C instead of 15°C.

[36] Of course this is only due to the state of accounting. In reality the EcoReport will take into account the efficiency of power generation (40%→60% losses on primary energy).

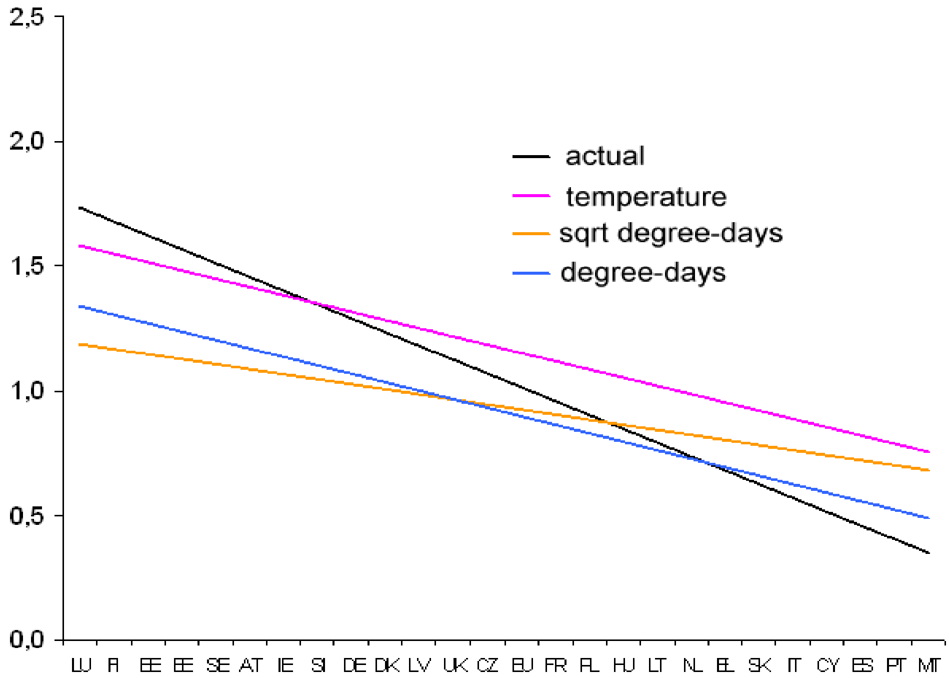
[37] Again this is only due to the PRIMES accounting. In reality the EcoReport will take into account the appropriate share of generator and transmission losses of district heating. Please note that these values will differ very much between e.g. new district heating systems in Sweden and older district heating in new Member States. But for our purpose –the assessment of a heat load per dwelling—this is accurate enough.

It is also equally important to realize that this trend is independent of the efficiency of the new central heating system that people will install. In other words, with an efficient boiler and controls one can hope to neutralize the comfort improvement. With an inefficient boiler and limited control the energy requirement will rise by 25% or more in the poorer regions and poorer fractions of the EU-25 population.

Trying to attempt to quantify this phenomenon is difficult. In the 2002 SAVE study the 'Overall Demand Factor' (ODF) was introduced, which was set at 82% for 2005 and projected to rise to 86% in 2020. This means that –all things being equal—the heating energy use should rise by 4-5% over that period for the EU-15. However, the addition of the new Member States will contribute to this effect and the rise we may expect is higher, i.e. somewhere around 8-9% of the total.

Quantifying this phenomenon is not easy. Of all the possible yardsticks –degree-days, the square root of the degree-days, annual average outside temperature—we have found that none is a good match to the actual data (see figure).

Figure 3-4.
Trendlines for sorted actual heat load data, as well as heat load data outdoor temperature-corrected, corrected with the square root of the degree-days (normalized) and a simple correction with degree-data per country (normalized)



This implies that 'climate' offers at best a partial explanation of the differences in insulation levels and ventilation heat recovery. With all 3 yardsticks countries like Belgium, Luxemburg, Austria have a higher heat load of the building shell than could be expected from the climate. And countries like Spain, Portugal, Poland, Lithuania always have a lower apparent heat load than one can expect from the climate.

Also it is visible that countries like the Netherlands (in the same climate zone as Belgium!), Sweden, Denmark, etc. have a better insulated dwelling than any EU climate-corrected average.

For climate-correction at the level of individual Member States it is clear that the square root of the degree-days or the annual average outside temperature are more appropriate than the degree-days. The latter suggest differences up to a factor 9-10, whereas the other two parameters show a more realistic difference of a factor 3,5 to 4. For instance the outdoor temperature is on average (weighted by location of dwelling stock and not surface area) 11,7°C, with a range of 5,6°C in Finland and almost 20°C in Malta and Cyprus. These values can be indexed on the EU-average (11,7°C=100) and then applied to the average EU heat load (7400 kWh/hh.a) to define a climate-correction. The result is shown in the figure below.

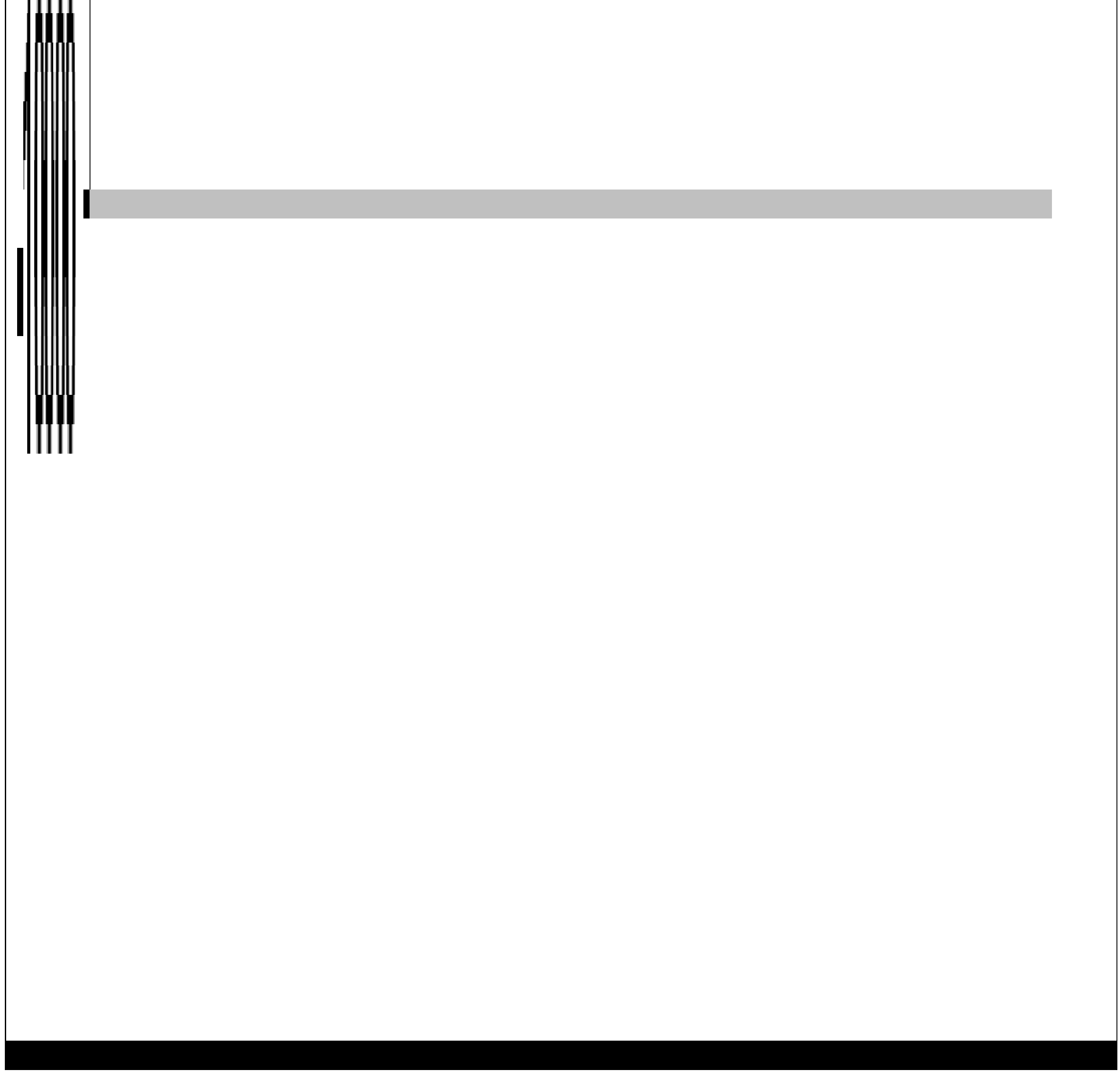


Figure 3-5. Actual heat load per dwelling in kWh/hh.a. for EU-25. Orange bars indicate how far above or below the climate corrected average each Member States'average heat load is.

But the climate certainly doesn't explain all, e.g. the highest EU heat loads per dwelling can be found in the middle of the EU, i.e. in Luxemburg (15.400 kWh/hh.a) and Belgium (12.200 kWh/hh.a). In the same climate zone we find the Netherlands with a calculated heat load of a little over 6000 kWh/hh.a, which is apparently half of the heat load in Belgium.

A part of this difference , almost half, can be explained by the fact that –in order to arrive at an EU average— we used the same average generator, distribution and control efficiencies for all countries in Europe, whereas there are huge differences even in neighbouring countries. For instance, the task 2 report shows that over 90% of the boiler stock in Belgium consists of atmospheric types, preferably floorstanding, with a simple on-off room thermostat. An average generator efficiency of 65% (on GCV) for the fossil-fuel fired boilers would probably already be very optimistic. On the other hand, the Netherlands are by far the country with the highest penetration of condensing gas-boilers in the EU. A generator efficiency of 85% is realistic, and also distribution and control losses would be much lower than in Belgium.

If –instead of using the overall fossil-fuel heating system efficiency of 54% (68%*90%*87%)—we use a value of 49% fossil-fuel heating system efficiency (63%*90%*87%) then the resulting net heat load of the Belgian dwelling becomes only 11331 kWh/hh.a (900 kWh less). On the other hand if we use for the Netherlands a value of 74% (85%*95%*92%) we see that the net heat load of the building will rise to ca. 8132 kWh/hh.a (2100 kWh more). In other words, a closer examination shows that of the original 6200 kWh difference in calculated heat load actually only 3200 kWh (11331-8132) is caused by a difference in insulation and ventilation losses and a good 3000 kWh is due to a difference in heating boiler efficiency. Fortunately, The situation in Belgium and the Netherlands is well documented and this explanation could be found. However, this certainly is not the case for all EU Member States and that is why we prefer to use an overall same value for all. In Task 7 (impact assessment) this subject will be further explored, but for now it is important to indicate that the accuracy of the given heat load figures at the level of individual Member States should not be overrated.

3.8.5 Miscellaneous items

Already the calculations in the previous paragraphs are not easy to communicate and we have tried to keep the link with the original PRIMES data as much as possible. However, there are a number of general items concerning the accuracy of the data that we at least would like to mention. They didn't lead to a correction of the heat load, but they could be subject for discussion.

The first is the current practice in the EU energy statistics in ton oil equivalent (toe) and that the EU is not –like the US or China— using the upper heating value (GCV) but the lower heating value (NGV). This means 1 toe = 41,86 GJ. Furthermore the conversion for electric energy would then be 1 kWh = 3,6 MJ. However, if we use the Gross Calorific Value, like e.g. also Eurogas is doing[38], the conversion 1 toe= 44 GJ and all values would be 5% higher, but it is not clear what this would do with e.g. the conversion of electric energy and district heat. In our study, following the findings in Task 1 report, we use the upper heating value efficiency (GCV) and this means that in the worst case the heat load of 7500 kWh could be 5% or 350 kWh higher.

At the same time there are some issues where our estimate should be lower:

For instance, the electricity consumption for space heating that we have mentioned, will –depending on the reliability of the national statistics— not just include heating, but also (at least parts of) space cooling with air-conditioners and the auxiliary electricity for circulator pumps. These two items should not be include in the space heating load, but the problem is that for the official statistics they are both difficult to grasp.

For residential air conditioners there is the problem of a rapid growth in very recent years and there is the problem that a considerable part of the split units<12 kW should not be partitioned to the residential sector but are in fact 'small commercial' with e.g. doctors, lawyers, veterinarians, etc. combining home and practice. This also goes for small shops where the shop-owners live above the air-conditioned shop. Another problem is the evaluation of single duct units, which are sold in large numbers but used only in extreme wheather conditions. Hopefully, the preparatory Ecodesign study on air conditioners will provide better data, but for now we will use the data from the MEEUP Product Case. There the JRAIA projections predict that 30 million units <12 kW are installed in 2004. Let us assume that 60% (18 mln.) are actually residential. At an average annual electricity use of 800 kWh this comes down to around 14400 mln. kWh. Per average household, for 191,4 mln. households, this means 75 kWh/year. In the worst case the 'error' in the heat load would be around 125-150 kWh/year.

Another item is the circulator pump, which according to the MEEUP Product Cases would on average consume 390 kWh per pump per year. Most people are not aware that it exists and a considerable number of the households do not actually own a CH pump

[38] Eurogas reports for the EU-15 with '*1000 m³ of natural gas = 0.9 ton oil equivalent*' which implies 39 MJ/*m³(GCV)*

but it is part of the collective provisions in a collectively heated apartment building (like elevators, lighting in the hall, etc.). At the same time, however, the electricity consumption of these CH pumps is registered with the utility companies as a delivery to the residential sector. What very often happens, is that this electricity use is registered as ‘miscellaneous’ in the category ‘non-heating electricity’. And finally, there is a group of households (around 20-30%) with electric radiators or district heating that really does not have a CH pump on the residential energy bill. All in all, we estimate that in the very worst case the ‘error’ in the calculated heat load is 200 kWh.

Table 3-16. EU Hot Water Energy Consumption 2003 (source: VHK 2006 analysis based on Task 2 Report and misc. sources)

	Parameter	*unit*	EU-25	AT	BE	CY	CZ	DK	EE	FI	FR	DE	EL	HU	IE	IT	LV	LT	LU	MT	NL	PL	PT	SK	SI	ES	SE	UK
	Base data 2003																											
1	Energy/hh 2003, of which	kWh/hha	17370	24805	26277	13952	16519	20004	18832	25242	17653	20326	15720	16495	22911	13497	15591	11913	36288	7092	17179	14599	9627	**11637**	**21238**	**10736**	**20979**	**19647**
3	Households 2003	mln.	191,4	3,3	4,3	0,2	4,0	2,5	0,6	2,4	26,5	37,7	3,8	4,3	1,4	25,1	0,9	1,4	0,2	0,2	7,1	14,2	3,7	**2,6**	**0,7**	**14,4**	**4,2**	**26,3**
4	Persons/hh 2003	#	**2,5**	2,4	2,4	3	2,4	2,2	2,4	2,2	2,4	2,1	2,8	2,6	2,9	2,6	2,5	2,6	2,5	3	2,3	2,8	2,8	2,6	2,8	2,9	1,9	2,4
5	Floor area/dw. 2003	m²	87	94	86	*145*	76	109	60	77	90	90	83	75	104	90	55	61	125	106	98	68	83	56	75	90	92	87
6	Secondary WH per hh.	%	32	34	48	8	31	8	11	3	13	45	8	22	81	22	8	12	48	8	28	34	7	19	55	23	1	48
	Sanitary Hot Water (SHW) demand (litres of 60°C per day)																											
7	Litres/person.day	ltr	24	35	30	25	15	45	10	50	25	25	25	25	25	25	10	10	50	25	31	15	25	15	20	23	50	25
8	Litres/hh.day	ltr	59	84	72	75	36	99	24	110	60	53	70	65	73	65	25	26	125	75	71	42	70	39	56	67	95	60
9	Net SHW energy/hh.yr	kWh/hha	1246	1778	1524	1588	762	2096	508	2329	1270	1111	1482	1376	1535	1376	529	550	2646	1588	1509	889	1482	826	1186	1412	2011	1270
10	of which																											
11	**Primary WH energy**	kWh/hha	**1114**	**1577**	**1281**	**1545**	**683**	**2040**	**489**	**2305**	**1215**	**945**	**1442**	**1275**	**1121**	**1275**	**515**	**528**	**2223**	**1545**	**1369**	**788**	**1447**	**773**	**968**	**1304**	**2004**	**1067**
12	**Second. WH energy**	kWh/hha	**133**	**201**	**244**	**42**	**79**	**56**	**19**	**23**	**55**	**167**	**39**	**101**	**414**	**101**	**14**	**22**	**423**	**42**	**141**	**101**	**35**	**52**	**217**	**108**	**7**	**203**
	Water Heater Park EU-25, market penetration in %																											
	PRIMARY WATER HEATERS (efficiency)																											
13	**District Heat** (100%)		**1%**	**3%**	**0%**	**0%**	**7%**	**15%**	**22%**	**8%**	**0%**	**1%**	**0%**	**2%**	**0%**	**0%**	**12%**	**14%**	**0%**	**0%**	**1%**	**8%**	**0%**	**8%**	**2%**	**0%**	**12%**	**0%**
14	**Linked to Boiler,** of which		**49%**	**47%**	**47%**	**27%**	**51%**	**44%**	**16%**	**31%**	**46%**	**46%**	**27%**	**37%**	**84%**	**55%**	**17%**	**23%**	**47%**	**27%**	**82%**	**31%**	**4%**	**24%**	**44%**	**27%**	**63%**	**83%**
15	Combi Boilers (55%)		23%	6%	21%	1%	24%	1%	4%	0%	28%	6%	1%	15%	2%	49%	5%	7%	21%	1%	71%	7%	3%	15%	5%	20%	0%	31%
16	Ind. Cylinders Int. (50%)		5%	4%	7%	3%	0%	9%	0%	20%	9%	7%	3%	0%	0%	3%	0%	0%	7%	3%	0%	3%	0%	0%	3%	3%	42%	0%
17	Ind. Cylinders Int. (50%)		21%	36%	19%	23%	27%	33%	13%	11%	9%	32%	23%	23%	81%	3%	13%	16%	19%	23%	10%	20%	1%	9%	36%	3%	20%	52%
18	Solar Thermal (150%)		0%	1%	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
19	**Dedicated,** of which		**50%**	**50%**	**53%**	**73%**	**42%**	**41%**	**62%**	**61%**	**53%**	**53%**	**73%**	**60%**	**17%**	**45%**	**71%**	**63%**	**53%**	**73%**	**17%**	**61%**	**96%**	**68%**	**54%**	**73%**	**25%**	**17%**
20	Solar Thermal (150%)		1%	5%	0%	11%	0%	2%	0%	0%	0%	2%	11%	0%	0%	0%	0%	0%	0%	11%	1%	0%	0%	0%	0%	1%	1%	0%
21	Electr. Instant.>12 kW (97%)		7%	2%	0%	1%	2%	0%	2%	1%	0%	29%	1%	0%	4%	0%	2%	4%	0%	1%	0%	7%	0%	5%	0%	0%	0%	8%
22	El. Store >30 ltr. (65%)		29%	42%	33%	61%	36%	38%	59%	61%	46%	13%	61%	43%	9%	35%	69%	59%	33%	61%	11%	50%	14%	53%	53%	29%	24%	8%
23	Gas Instant. 13+ l/m (45%)		11%	0%	17%	0%	0%	0%	0%	0%	6%	5%	0%	6%	0%	7%	0%	0%	17%	0%	3%	0%	81%	1%	0%	42%	0%	0%
24	Gas Storage (45%)		2%	0%	2%	0%	5%	0%	0%	0%	2%	3%	0%	11%	4%	2%	0%	0%	2%	0%	2%	4%	0%	9%	0%	0%	0%	1%
25	*Primary WH avg eff.**		*60%*	*66%*	*56%*	*71%*	*61%*	*67%*	*71%*	*63%*	*58%*	*69%*	*71%*	*58%*	*53%*	*57%*	*67%*	*68%*	*56%*	*71%*	*57%*	*65%*	*48%*	*65%*	*59%*	*54%*	*61%*	*57%*
	SECONDARY WATER HEATERS (efficiency)																											
26	**El. Storage,** of which		**57%**	**85%**	**75%**	**88%**	**55%**	**94%**	**44%**	**70%**	**63%**	**88%**	**88%**	**59%**	**9%**	**99%**	**65%**	**35%**	**75%**	**88%**	**73%**	**19%**	**28%**	**46%**	**98%**	**33%**	**90%**	**8%**
27	<30 Litres Press. (65%),		24%	17%	60%	9%	35%	89%	41%	70%	22%	2%	9%	14%	6%	99%	44%	19%	60%	9%	68%	19%	28%	38%	43%	33%	90%	4%
28	<30 Litres Unpress(65%)		33%	68%	15%	79%	20%	4%	3%	0%	41%	87%	79%	45%	3%	0%	19%	16%	15%	79%	5%	0%	0%	8%	55%	0%	0%	3%
29	**El. Instant<12 kW** (97%)		**24%**	**1%**	**1%**	**7%**	**26%**	**4%**	**22%**	**29%**	**0%**	**5%**	**7%**	**0%**	**90%**	**0%**	**16%**	**36%**	**1%**	**7%**	**1%**	**30%**	**6%**	**36%**	**0%**	**0%**	**10%**	**84%**
30	**Gas Instant.** of which		**18%**	**14%**	**24%**	**5%**	**20%**	**3%**	**35%**	**0%**	**37%**	**6%**	**5%**	**40%**	**1%**	**1%**	**19%**	**28%**	**24%**	**5%**	**26%**	**50%**	**65%**	**18%**	**2%**	**67%**	**0%**	**8%**
31	5 -<10 Litres/min (45%)		9%	0%	9%	1%	0%	0%	19%	0%	37%	0%	1%	20%	0%	1%	0%	0%	9%	1%	13%	0%	65%	14%	1%	67%	0%	0%
32	10 -<13 Litres/min (45%) *		9%	14%	15%	4%	20%	3%	15%	0%	0%	6%	4%	21%	1%	0%	19%	28%	15%	4%	13%	50%	0%	4%	1%	0%	0%	8%
33	*Secondary WH avg eff.**		*69%*	*63%*	*61%*	*66%*	*69%*	*66%*	*65%*	*73%*	*58%*	*65%*	*66%*	*57%*	*94%*	*65%*	*66%*	*70%*	*61%*	*66%*	*60%*	*65%*	*54%*	*73%*	*65%*	*52%*	*68%*	*90%*
	Result: Energy consumption water heaters in kWh/household.year																											
34	**Energy cons. WH**	**kWh/hha**	2048	2719	2706	2240	1240	3115	717	3670	2180	1632	2090	2392	2550	2374	788	808	4698	2240	2641	1365	3067	1266	1971	2624	3281	2112
35	of which electric WH	**kWh/hha**	725	1327	944	1526	474	1278	473	2192	911	717	1424	941	638	847	571	521	1639	1526	398	729	322	724	1125	649	750	420

Table 3-17. EU Residential Heat Load Assessment (VHK 2006)

	Parameter	*unit*	EU-25	AT	BE	CY	CZ	DK	EE	FI	FR	DE	EL	HU	IE	IT	LV	LT	LU	MT	NL	PL	PT	SK	SI	ES	SE	UK
	Base data 2003																											
1	Energy/hh 2003	kWh	17370	24805	26277	13952	16519	20004	18832	25242	17653	20326	15720	16495	22911	13497	15591	11913	36288	7092	17179	14599	9627	11637	21238	10736	20979	19647
2	Households 2003	mln.	191,4	3,3	4,3	0,2	4,0	2,5	0,6	2,4	26,5	37,7	3,8	4,3	1,4	25,1	0,9	1,4	0,2	0,2	7,1	14,2	3,7	2,6	0,7	14,4	4,2	26,3
3	Persons/hh 2003	#	2,5	2,4	2,4	3	2,4	2,2	2,4	2,2	2,4	2,1	2,8	2,6	2,9	2,6	2,5	2,6	2,5	3	2,3	2,8	2,8	2,6	2,8	2,9	1,9	2,4
4	Floor area/dw. 2003	m²	87	94	86	*145*	76	109	60	77	90	90	83	75	104	90	55	61	125	106	98	68	83	56	75	90	92	87
	Water Heater energy (from previous table)																											
5	Energy cons. WH	kWh	2048	2719	2706	2240	1240	3115	717	3670	2180	1632	2090	2392	2550	2374	788	808	4698	2240	2641	1365	3067	1266	1971	2624	3281	2112
6	of which electric	kWh	725	1327	944	1526	474	1278	473	2192	911	717	1424	941	638	847	571	521	1639	1526	398	729	322	724	1125	649	750	420
7	TOTAL Net Energy Demand per hh. (PRIMES 2006)																											
8	electric	kWh	4305	5746	6978	6976	3940	4626	3531	9548	4997	3984	4881	2808	6581	2963	1559	1702	4948	4728	3758	1909	3869	1976	5562	4308	10454	5076
9	fossil & biomass	kWh	11523	16760	19225	4186	8563	7377	5885	7455	12597	13802	10425	11792	16331	10535	7795	4619	29690	2364	13063	7856	5669	6477	13147	6406	3391	14571
10	heat	kWh	1493	2011	74	0	4016	8002	9416	8240	0	2437	83	1895	0	0	6236	5592	1649	0	313	4834	0	3184	2528	0	7134	0
11	renewable	kWh	49	287	0	2790	0	0	0	0	59	103	331	0	0	0	0	0	0	0	45	0	90	0	0	22	0	0
12	Total	kWh	17370	24805	26277	13952	16519	20004	18832	25242	17653	20326	15720	16495	22911	13497	15591	11913	36288	7092	17179	14599	9627	11637	21238	10736	20979	19647
	ELECTRICITY																											
13	Electric WH	kWh	725	1327	944	1526	474	1278	473	2192	911	717	1424	941	638	847	571	521	1639	1526	398	729	322	724	1125	649	750	420
14	Non-heat electric	kWh	2123	3000	2600	2000	2100	2900	1000	3300	2500	2500	2602	1684	2500	1700	900	919	3000	2000	3000	1100	2600	1200	3165	2200	3300	2800
15	Electric cooking	kWh	267	300	300	100	50	300	50	500	300	300	300	100	300	150	50	50	300	150	300	50	200	50	50	200	400	500
16	Total non space heat	kWh	3115	4627	3844	3626	2624	4478	1523	5992	3711	3517	4326	2725	3438	2697	1521	1490	4939	3676	3698	1879	3122	1974	4340	3049	4450	3720
	FOSSIL																											
17	Fossil WH	kWh	1323	1392	1762	714	766	1837	244	1478	1269	915	666	1451	1912	1528	217	287	3060	714	2243	636	2745	542	846	1975	2532	1692
18	Fossil cooking	kWh	260	200	200	400	450	200	450	0	200	200	200	400	200	350	450	450	200	350	200	450	300	450	450	300	100	0
19	Total non-space heat	kWh	1583	1592	1962	1114	1216	2037	694	1478	1469	1115	866	1851	2112	1878	667	737	3260	1064	2443	1086	3045	992	1296	2275	2632	1692
20	SOLAR	kWh	49	287	0	2790	0	0	0	0	59	103	331	0	0	0	0	0	0	0	45	0	90	0	0	22	0	0
	SPACE HEATING Energy demand (incl. losses)																											
21	electric	kWh	1190	1120	3134	3350	1316	148	2008	3556	1287	468	555	83	3143	266	38	211	10	1052	60	30	747	2	1222	1259	6004	1356
22	fossil & biomass	kWh	9940	15168	17263	3072	7347	5339	5191	5977	11128	12687	9559	9941	14218	8657	7128	3883	26430	1300	10620	6770	2624	5485	11851	4131	759	12879
23	heat	kWh	1493	2011	74	0	4016	8002	9416	8240	0	2437	83	1895	0	0	6236	5592	1649	0	313	4834	0	3184	2528	0	7134	0
24	Total space heating	kWh	12622	18299	20471	6422	12679	13489	16615	17772	12414	15591	10197	11919	17361	8923	13403	9686	28089	2353	10993	11634	3371	8671	15601	5390	13898	14235
	SPACE HEATING Heat load dwelling																											
25	electric (90%)	kWh	1071	1008	2820	3015	1185	133	1807	3200	1158	421	500	75	2828	240	34	190	9	947	54	27	672	2	1100	1133	5404	1221
26	fossil & biomass(54%)	kWh	5368	8191	9322	1659	3967	2883	2803	3227	6009	6851	5162	5368	7678	4675	3849	2097	14272	702	5735	3656	1417	2962	6399	2231	410	6955
27	heat (70%)	kWh	1045	1408	52	0	2811	5601	6591	5768	0	1706	58	1327	0	0	4365	3914	1155	0	219	3384	0	2229	1770	0	4994	0
28	Heat load/dwelling		7483	10606	12194	4674	7963	8618	11201	12195	7167	8977	5719	6769	10506	4915	8249	6201	15436	1649	6008	7067	2089	5193	9269	3364	10808	8175
29	Heat load kWh/m²	kWh	86	113	141	32	104	79	186	158	80	100	69	90	101	54	149	102	123	16	61	104	25	93	124	37	118	94

3.8.6 *Main findings on heat load*

In this paragrph we have presented outcomes of more recent studies on the subject of on the average heat load per dwelling and have revisited every aspect of earlier studies (PRIMES 'Shared Analysis' 1999, SAVE 2002, ECCP 2003) trying to reconcile a 'bottom-up'and 'top-down' approach in not only correcting the EU-average, but also making an estimate per Member State.

Main findings:

- The average EU-25 space heating/cooling energy demand is currently around 12600 kWh/dwelling. This is 72,5% of the total average net energy demand (excl. power generation losses) of 17370 kWh/dwelling.
- Of this, the effective heating/cooling load of the dwelling (transmission, ventilation, internal gains at current comfort level) is 7400 kWh/dwelling.
- Both of the above points combined imply that around 40% of the space heating demand is due to heating system losses (generator, distribution and control losses).
- Per unit of floor area the 7400 kWh/hh.a. heat load equals around 85 kWh/m² or a little over 300 MJ/m². In Southern Europe this is half (Italy 54, Spain 37, Greece 69 kWh/m², etc.) and in Northern Europe this is double that value (Estonia 186, Finland 158, Sweden 118, etc.). But the climate certainly doesn't explain all differences, e.g. the highest calculated heat loads per dwelling can be found in the middle of the EU, i.e. in Luxemburg (15400 kWh/hh.a) and Belgium (12200 kWh/hh.a).
- On the long run (2020-2025) the data suggest
  - The heat load will increase by 7-8% because of a bigger average floor area (from 87 m² today to 94-95 m²/dwelling in 2020)
  - The heat load will decrease because of better insulation and less ventilation heat losses. Even taking into account the continuously growing floor area per dwelling the SAVE study –building on a 1960-2005 historical data—predicted a decrease of 900 kWh (12%). Given the negative effect of the enlargement of the floor area this means that insulation and ventilation measures would yield a 20% improvement.
  - The effective heat load will increase by 8% because the comfort level (the average indoor temperatures) in Southern and Eastern EU Member States will increase.
  - Combining the three points above VHK expects a decrease in the effective space heat load of the average existing dwelling by 4-5% in 2020-2025.
- Statistical information on housing characteristics has improved, but we are still a long way from being able to monitor efficiency improvements in the housing stock.
- The figures in the table per individual Member State should be understood as an attempt to test the average EU heat load data for consistency, not as our best estimate or –indeed—the best possible estimate of the residential energy balance for each individual Member State. This would require a higher level of differentiation between e.g. generator, distribution and control losses in each country and a more extensive study than what would be inside the scope of our assignment.
- Having said that, the accuracy of the EU average heat load is estimated at within ± 10%, which is sufficient for our purpose.

4 NON-RESIDENTIAL BUILDINGS

4.1 Tertiary sector

The situation for residential buildings is still relatively transparent compared to commercial and institutional buildings and buildings that have a mixed use, e.g. residential buildings with bars, restaurants and shops at the ground floor level or doctors and lawyers with a practice at home. On these items even anecdotal information is scarce.

Another problem is the definition of the sectors. There have been several attempts to capture the floor area in m² of the 'services sector' or 'the other sector' which all have failed for that reason. Examples are the Odyssee indicators[39] project and the Ecoheatcool project[40], which are each comparing 'apples and pears' with errors of up to a factor 2. [41] But also the PRIMES model, which was following the Eurostat totals for the residential sector, now seems to be using a completely different definition for the tertiary sector. [42] This makes it very difficult to make an assessment, not only of general building characteristics but also of the average heat load that can be expected. In Table 4-1 a very first attempt by VHK is given to calculate an average heat load from the available EU-wide data. But –although we are fairly confident on the EU average—the accuracy at Member State level is certainly not very good.

To firm up the assessment of the heat load we have consulted several sources at national level.

For an overview of the many inconsistencies between Member States the 2002 European Communities publication of the efforts of some national statistics offices gives a good overview.[43] This is still a relatively good source, which we have summarized in Table 4-2.a and 4.2.b.

Other than that, the best sources are national surveys by energy agencies, utilities, national statistics offices, etc. that at least are defining in detail which sectors are covered. These surveys exist in:

- the UK (Dept. of Trade and Energy 2005) , statistics based on BRE input / Ireland, 2005 survey by the Sustainable Energy Ireland (SEI). [44]
- Norway, 2005 survey of Statistics Norway[45]
- In the Netherlands, 1999 publication by Energie Centrum Nederland (ECN)[46]. Also the efforts of EIM (Economische Instituut voor het Midden- en Kleinbedrijf) need to be mentioned.

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[39] www.odyssee-indicators.org

[40] www.ecohetacool.org (published Oct. 2006)

[41] For instance, the Ecoheatcool project— of comparing the energy consumption of a German floor area for industrial, agricultural and service sector buildings, including unheated warehouses with Dutch data for the service sectors, without unheated warehouses? Why doesn't a bell start ringing with the Odyssee authors that something might be wrong when the most energy efficient builders in the residential sector (the Netherlands and Sweden) turn out to be greatest energy users per capita and per square meter?

[42] PRIMES 2003: 168 Mtoe; Eurostat 2005 pocketbook energy and transport: 129 Mtoe for the service sector. Perhaps the difference is public lighting?

[43] Energy consumption in the services sector, Surveys of EUMember States Data 1995-1999, European Communities, Luxembourg 2002.

[44] Sustainable Energy Ireland (SEI), *Profiling Energy and CO2 Emissions in the Services Sector*, April 2005.

[45] Statistics Norway, Dept. of Energy Statistics, *Energy consumption in the services sector 2000.*

- In Sweden and Denmark the national statistics offices are giving already good insights in their regular statistics. [47] The same goes for Germany for the building side[48], but the energy side needs considerable work, especially because statistics are prepared at the level of Länder and not at federal level.
- Also Switzerland has excellent statistics on non-residential buildings, but at the level of Cantons. An example is the Canton of Zürich, which is the only source we found that actually reports on commercial activities in residential buildings (bars, shops, etc. at the bottom of apartment buildings or part of a mainly residential house).
- In the US, the Energy Information administration (EIA) is gathering periodically detailed information on the energy consumption in the commercial building sector [49].
- Natural Resources Canada has published a very recent survey on commercial buildings[50].

It would be certainly outside the scope of our contract to discuss all these individual sources (and more), but it is enough to say that we have studied them extensively to get a better grip on the sector and to confirm at least our heat load estimate.

A final check is of course the ECCP project, where the stakeholders gave their input in estimating the CO_2 balance of the tertiary sector. This is given in Table. 4.3.

[46] ECN, Energieverbruik van gebouwgebonden energiefuncties in woningen en utiliteitsgebouwen, Petten, 1999.

[47] Www.sbc.se

[48] Statistisches Budesamt, *Bautätigkeit 2004*, Fachserie 5/ Reihe 1, Sept. 2005

[49] EIA, *1999 Commercial Buildings Energy Consumption Survey.* www.eia.doe.gov

[50] Natural Resources Canada, Commercial and Institutional Consumption of Energy Survey (CICES), December 2005.

Table 4-1. EU Tertairy Sector Heat Load Assessment (VHK 2006)

Parameter	*unit*	EU-25	AT	BE	CY	CZ	DK	EE	FI	FR	DE	EL	HU	IE	IT	LV	LT	LU	MT	NL	PL	PT	SK	SI	ES	SE	UK
Base data 2003 (Ecoheatcool vs. VHK)																											
Ecoheatcool est. floor area	*mln m²*	*6310*	*119*	*151*	*7*	*100*	*114*	*14*	*101*	*861*	*1852*	*149*	*101*	*58*	*453*	*23*	*14*	*7*	*4*	*183*	*382*	*126*	*81*	*16*	*341*	*161*	*892*
VHK est.heat. floor area	***mln m²***	**4655**	**80**	**114**	**7**	**100**	**70**	**7**	**70**	**800**	**1000**	**121**	**80**	**44**	**450**	**12**	**10**	**5**	**4**	**270**	**200**	**80**	**35**	**16**	**340**	**90**	**650**
Tertiary Energy Consumption in ktoe (1 toe=41,86 GJ= 11627 kWh) PRIMES																											
PRIMES 2003 (calc.)	ktoe	167810	3228	4344	156	4179	2900	419	3542	26883	33506	2835	3847	2000	15493	674	623	140	55	12078	10553	2475	1371	681	10030	5570	20228
Eurostat 2003	**ktoe**	**129156**	**2802**	**3837**	**140**	**3483**	**1959**	**344**	**1717**	**24923**	**23994**	**1663**	**3055**	**1708**	**13483**	**569**	**527**	**95**	**55**	**7587**	**6237**	**1979**	**1146**	**236**	**6962**	**4713**	**15942**
Tertiary sector kWh/floor area (VHK/Eurostat)																											
kWh per m² tertiary	kWh/m²	323	407	392	233	405	325	571	285	362	279	160	444	455	348	551	613	224	146	327	363	288	381	171	238	609	285
compare:																											
kWh per m² residential '03	kWh/m²	*180*	*259*	*264*	*82*	*193*	*171*	*288*	*292*	*171*	*212*	*129*	*220*	*187*	*137*	*252*	*201*	*320*	*72*	*177*	*250*	*79*	*171*	*230*	*79*	*215*	*225*
Tertairy heating share of total kWh/floor area (excl. cooling)																											
kWh per m² tertiary	kWh/m²	197	248	239	70	247	198	349	350	221	170	97	271	278	213	336	374	137	60	186	221	175	232	105	145	371	174
compare:																											
kWh per m² residential	kWh/m²	*145*	*195*	*237*	*44*	*166*	*124*	*276*	*231*	*139*	*174*	*123*	*159*	*167*	*99*	*242*	*160*	*225*	*22*	*112*	*171*	*41*	*155*	*208*	*60*	*152*	*164*
Tertairy heating load kWh/floor area (excl. Cooling)																											
kWh per m² tertiary	kWh/m²	117	144	142	51	155	127	235	240	128	98	55	154	168	117	207	239	75	42	102	134	109	139	62	91	289	100
compare:																											
kWh per m² residential	kWh/m²	*86*	*113*	*141*	*32*	*104*	*79*	*186*	*158*	*80*	*100*	*69*	*90*	*101*	*54*	*149*	*102*	*123*	*16*	*61*	*104*	*25*	*93*	*124*	*37*	*118*	*94*

Table 4-2.a. EU Services sector: Energy consumption for space heating and hot water 1995-1999 (source: VHK compilation of Eurostat 2002) in TJ (Terajoules)

Parameter	*unit*	EU-25	AT	BE	CY	CZ	DK	EE	FI	FR	DE	EL	HU	IE	IT	LV	LT	LU	MT	NL	PL	PT	SK	SI	ES	SE	UK*
1. Hotels and Restaurants (NACE 55)																											
Consumption per m² (MJ/m²)			-	-	-	-	320	-	791	785	821	na	-	-	-	-	-	-	-		-	-	-	-	624	518	
Heating Oil	TJ		3557	2213	-	-	319	-	973	15324	28002	2512	-	-	16440	-	-	-	-		-	1239	-	-	1356	12	32200
Natural gas	TJ		885	6708	-	-	452	-	66	19620	24679	0	-	-	60041	-	-	-	-		-	-	-	-	639	63	79300
LPG and Manuf. gas	TJ		337	113	-	-	109	-	na	na	1965	494	-	-	16014	-	-	-	-		-	4007	-	-	168	na	-
Solid fuels	TJ		na	-	-	-	-	-	na	na	2200	6099	-	-	na	-	-	-	-		-	-	-	-	2	na	600
Electricity	TJ		2072	144	-	-	233	-	486	8114	8319	0	-	-	2758	-	-	-	-		-	442	-	-	468	540	3200
District heating	TJ		476	-	-	-	1054	-	1896	-	-	-	-	-	14524	-	-	-	-		-	-	-	-	-	1508	-
Other	TJ		1179	-	-	-	-	-	87	5101	9652	109	-	-	463	-	-	-	-		-	-	-	-	0	197	-
TOTAL	TJ		8506	9178	-	-	2167	-	3508	48159	74817	9214	-	-	110240	-	-	-	-		-	5688	-	-	2633	3508	-
2. Health & social work (NACE 85)																											
Consumption per m² (MJ/m²)			-	na	-	-	648	-	980	691	731	na	-	-		-	-	-	-		-		-	-	343	579	-
Heating Oil	TJ		958	4591	-	-	254	-	2326	31277	48772	3804	-	-	8514	-	-	-	-		-	1009	-	-	680	1963	2500
Natural gas	TJ		2064	6092	-	-	1539	-	0	33005	46418	-	-	-	32346	-	-	-	-		-		-	-	549	502	73900
LPG and Manuf. gas	TJ		4		-	-	11	-	na	na	-	100	-	-	212	-	-	-	-		-	121	-	-	60	na	-
Solid fuels	TJ		na	38	-	-	-	-	-	-	3840	1382	-	-	na	-	-	-	-		-		-	-	5	na	100
Electricity	TJ		1219	160	-	-	92	-	317	8132	4809	0	-	-	1138	-	-	-	-		-	295	-	-	127	306	2600
District heating	TJ		6072		-	-	4308	-	5465	-	-	-	-	-	23068	-	-	-	-		-		-	-	-	1137	-
Other	TJ		255	116	-	-	-	-	143	8927	16819	-	-	-	72	-	-	-	-		-		-	-	9	665	-
TOTAL	TJ		10572	10997	-	-	6204	-	8251	81341	120658	5286	-	-	65350	-	-	-	-		-	1425	-	-	1430	14806	-
3. Education (NACE 80)																											
Consumption per m² (MJ/m²)			-	-	-	-	410	-	678	490	655	na	-	-		-	-	-	-		-		-	-	251	523	-
Heating Oil	TJ		3919	7855	-	-	348	-	3045	27090	36716	na	-	-	3462	-	-	-	-		-	96	-	-	616	3785	40900
Natural gas	TJ		5560	7611	-	-	1606	-	56	33299	34956	na	-	-	10861	-	-	-	-		-		-	-	409	264	44000
LPG and Manuf. gas	TJ		43	33	-	-	25	-	na	na	-	na	-	-	5	-	-	-	-		-	293	-	-	22	na	-
Solid fuels	TJ		na	36	-	-	-	-	na	na	2897	na	-	-	na	-	-	-	-		-		-	-	1	na	13900
Electricity	TJ		575	93	-	-	131	-	198	5216	821	na	-	-	155	-	-	-	-		-	229	-	-	38	814	5900
District heating	TJ		3984	-	-	-	5647	-	5116	-	-	-	-	-	10	-	-	-	-		-		-	-		8362	-
Other	TJ		288	94	-	-	-	-	407	10466	12665	na	-	-	0	-	-	-	-		-		-	-	1	565	-
TOTAL	TJ		14369	15722	-	-	7757	-	8822	76071	88055	na	-	-	14493	-	-	-	-		-	618	-	-	1087	1379	-
4. Other community, social and personal service activities (NACE 90-93)																											
Consumption per m² (MJ/m²)					-	-	395	-	851	979	842	na	-	-		-	-	-	-		-		-	-	264	502	-
Heating Oil	TJ		3604	7451	-	-	269	-	719	10174	17512	376	-	-	3906	-	-	-	-		-	281	-	-	137	1615	31800
Natural gas	TJ		4163	14048	-	-	1097	-	3	19840	16654	66	-	-	29214	-	-	-	-		-		-	-	323	112	57600
LPG and Manuf. gas	TJ		133	53	-	-	15	-	na	na	-	-	-	-	219	-	-	-	-		-	1415	-	-	18	na	-
Solid fuels	TJ		na	6	-	-	-	-	na	na	1392	800	-	-	na	-	-	-	-		-		-	-	0	na	20500
Electricity	TJ		1156	158	-	-	148	-	281	8042	6059	0	-	-	1732	-	-	-	-		-	716	-	-	140	749	-
District heating	TJ		4326	-	-	-	3456	-	2093	-	-	-	-	-	7537	-	-	-	-		-		-	-		2451	-
Other	TJ		2998	112	-	-	-	-	489	2222	6034	4	-	-	8096	-	-	-	-		-		-	-	0	142	-
TOTAL	TJ		16380	21828	-	-	4985	-	3585	40278	47651	1246	-	-	50704	-	-	-	-		-	2412	-	-	618	5069	-

Table 4-2.b. c'td EU Services sector: Energy consumption for space heating and hot water 1995-1999 (source: VHK compilation of Eurostat 2002)

Parameter	*unit*	EU-25	AT	BE	CY	CZ	DK	EE	FI	FR	DE	EL	HU	IE	IT	LV	LT	LU	MT	NL	PL	PT	SK	SI	ES	SE	UK*
5.- Offices and Administration (NACE 60-67, 70-75, 99)																											
Consumption per m² (MJ/m²)					-	-	na	-	613	698	911	na	-	-		-	-	-	-	370	-		-	-	193	486	
Heating Oil			2953	16047	-	-	1099	-	4102	35799	83289	1598	-	-	11561	-	-	-	-	296	-	1227	-	-	1373	4555	9500
Natural gas			3268	16105	-	-	1741	-	20	48664	76700	0	-	-	71509	-	-	-	-	12375	-		-	-	1092	1439	91800
LPG and Manuf. gas			771	8	-	-	38	-	na	na	2568	46	-	-	123	-	-	-	-		-	1386	-	-	143	na	-
Solid fuels			na	24	-	-	-	-	na	na	6567	3673	-	-	na	-	-	-	-		-		-	-	27	na	3900
Electricity			2861	643	-	-	304	-	1742	23594	12042	0	-	-	2088	-	-	-	-	10409	-	1234	-	-	2391	1735	15400
District heating			5062	-	-	-	6798	-	11305	-	-	-	-	-	14041	-	-	-	-	990	-		-	-		14765	-
Other			379	60	-	-	-	-	208	15475	28721	6	-	-	376	-	-	-	-	80	-		-	-	5	312	-
TOTAL			15294	32887	-	-	9980	-	17377	123532	209887	5323	-	-	99698	-	-	-	-	24150	-	3847	-	-	5031	22806	-
6. Commerce (NACE 50-52).																											
Consumption per m² (MJ/m²)					-	-	306	-	657	446	666	na	-	-		-	-	-	-		-		-	-	226	494	-
Heating Oil			2541	6123	-	-	3140	-	4229	26127	72079	3097	-	-	1586	-	-	-	-		-	0	-	-	148	1139	10500
Natural gas			1415	6511	-	-	1137	-	499	28935	68004	0	-	-	31308	-	-	-	-		-	-	-	-	249	156	47000
LPG and Manuf. gas			212	101	-	-	95	-	na	na	605	421	-	-	51	-	-	-	-		-	163	-	-	4	na	
Solid fuels			na	-	-	-	-	-	na	na	5692	10010	-	-	na	-	-	-	-		-		-	-	0	na	17200
Electricity			732	802	-	-	499	-	774	18464	14522	1	-	-	2653	-	-	-	-		-	1214	-	-	1419	1105	-
District heating			625	-	-	-	7018	-	783	-	-	-	-	-	242	-	-	-	-		-		-	-		3724	-
Other			869	51	-	-	-	-	27	4760	24858	50	-	-	0	-	-	-	-		-		-	-	0	132	-
TOTAL			6394	13588	-	-	11889	-	13359	78286	185760	13579	-	-	35840	-	-	-	-		-	1377	-	-	1820	6256	-
Space heating & SHW TOTALS BY FUEL																											
Consumption per m² (MJ/m²)			80		-	-		-	697	616	839	na	-	-		-	-	-	-		-		-	-	255	516	-
Heating Oil			17531	4428	-	-	5429	-	15394	145791	286370	11388	-	-	45469	-	-	-	-		-	3852	-	-	4310	14258	118400
Natural gas			17356	57075	-	-	7572	-	644	183363	267411	0	-	-	235278	-	-	-	-		-		-	-	3261	2536	359500
LPG and Manuf. gas			1500	308	-	-	293	-	na	na	5138	1127	-	-	16624	-	-	-	-		-	7386	-	-	415	na	-
Solid fuels			na	104	-	-	-	-	na	na	22588	21964	-	-	na	-	-	-	-		-		-	-	35	na	18500
Electricity			8614	2	-	-	1407	-	3798	71562	46572	1	-	-	10524	-	-	-	-		-	4130	-	-	4583	5249	64800
District heating			20545		-	-	28281	-	33706	-	-	-	-	-	59423	-	-	-	-		-		-	-		4218	-
Other			5968	433	-	-	-	-	1361	46951	98749	170	-	-	9007	-	-	-	-		-		-	-	15	2013	-
TOTAL			71515	1042	-	-	42982	-	54902	447667	726828	34648	-	-	376325	-	-	-	-		-	15367	-	-	12619	66235	561200
Service Sector TOTALS BY FUEL																											
Heating Oil				44280	-	-	19288	-	15394	158656	536000	na	-	-	45469	-	-	-	-		-		-	-	5352	-	-
Natural gas				57075	-	-	9888	-	644	211457	420000	na	-	-	235278	-	-	-	-		-		-	-	5515	-	-
LPG and Manuf. gas				308	-	-	293	-	na	na	26000	na	-	-	16624	-	-	-	-		-		-	-	1424	-	-
Solid fuels				104	-	-	-	-	na	na	436000	na	-	-	0	-	-	-	-		-		-	-	135	-	-
Electricity				47844	-	-	34934	-	44176	262562	115	na	-	-	204576	-	-	-	-		-		-	-	44060	-	-
District heating					-	-	28380	-	33706	-	-	-	-	-	59423	-	-	-	-		-		-	-		-	-
Other /DH				433	-	-	-	-	1361	54587	3000	na	-	-	14680	-	-	-	-		-		-	-	25	-	-
TOTAL			144278	150044	-	-	92783	-	95281	687262	1536000	na	-	-	576050	-	-	-	-		-		-	-	56511	-	-
YEAR			1998	1996	-	-	1997	-	1998	1996	1997	1998	-	-	1999	-	-	-	-		-		-	-	1998	1997	1995
floor area referred to	mln. M²						116			726	866	24-29								65		81			49		

* = UK No breakdown by branch is available for space heating and hot water but for all uses. The figures shown by branch correspond to all uses and their addition is not equal to the figures shown under TOTAL

source: *Energy consumption in the services sector, Survey of EU Member States*, European Communities 2002.

Table 4-3. Tertiary Sector Baselines 1990-2010

TERTIARY SECTOR	Fuel-Related CO_2 emissions (in Mt CO_2)	
Sector/function group	Reference 1990	Baseline 2010
Total	**457**	**523**
of which		
Spaceheating/cooling, *of which*	305	308
Fossil,*of which*	227	214
Transmission losses	*116*	*113*
-windows	*46*	*43*
-walls	*34*	*34*
-floors	*18*	*18*
-roofs	*18*	*18*
Ventilation losses	*43*	*45*
Heating system losses	*68*	*56*
Electric, *of which*	78	94
Heating (incl. heatpump)	*33*	*31*
Cooling (airconditioners)	*32*	*48*
CH pump	*13*	*15*
District heating	?	?
Hot water, *of which*	35	39
Fossil	24	30
Electric	11	9
Whitegoods & Cooking, *of which*	26	37
Fossil (mainly hobs)		
Electric, *of which*	26	37
Refrigeration/freezers	*14*	*20*
Washing machines		
Dishwashers		
Laundry driers		
Electric ovens	*12*	*17*
Lighting (incl. Street lighting)	*65*	*89*
Electronics, *of which*	14	34
Consumer el. (TV, audio, IRD,etc.)		
Stand-by		
On'		
IT/ office equipment	14	34
Industrial Motors, *of which*		
Variable speed drives (VSDs)		
Pumps		
Compressors		
Fans		
System opt.		
Other(conveyors & misc.)	12	16
Ind. process heat		
Autogeneration	neg	neg
Total (check)	457	523
of which (by energy source)		
Fossil	251	244
Electricity	206	279
Heat	?	?

Source: Composed by VHK 2002 on basis of European Climate Change Programme(ECCP) working group reports & docs JSWG and WG3 ('provisional analysis'), European Commission, 2001.
Note: Conversion Electricity 1990: 1 TWh el. = 0.5 Mt CO_2; 2010 1 TWh el.= 0.45 Mt CO_2

4.2 Industrial Buildings

No attempts to make an EU-wide analysis of the heating requirements were found. Also PRIMES and Eurostat figures on the industry are at such an aggregated level that it is impossible to make a split-up that would lead to the identification of space heating requirements. This means that we have to rely on the stakeholder approach in the ECCP and national statistics and surveys.

The relevant extract of the ECCP is given in Table 4-4. It identifies 76 Mt CO_2 for space heating and cooling in 1990 and projects 72 Mt CO_2 in 2010, but the share of district heating is not known. Without the cooling and the CH pump these figures are 65 Mt CO_2 (1990) and 57 Mt CO_2 (2010). Compared to the teriary sector in Table 4-3 this means that the industrial space heating requirement in the industrial sector is around 23% of that in the tertiary sector.

By way of illustration, some German national statistics are given in Tables 4.5 and 4.6. These relate to the 2004 building permits by type, size (in cubic metres), fuel and heating type. For a better comparison we included all sectors, i.e. also residential and tertiary sectors.

Table 4-4. Industrial Sector Baselines 1990- 2010 (ECCP 2003)

INDUSTRIAL SECTOR	Fuel-Related CO_2 emissions (in Mt CO_2)	
Sector/function group	Reference 1990	Baseline 2010
Total	**1031**	**959**
of which		
Spaceheating/cooling, of which	76	72
Fossil,of which	57	53
Transmission losses	29	28
-windows	11	10
-walls	8	8
-floors	5	5
-roofs	5	5
Ventilation losses	11	11
Heating system losses	17	14
Electric, of which	19	19
Heating (incl. heatpump)	8	7
Cooling (airconditioners)	8	12
CH pump	3	3
District heating	na	na

Source: Composed by VHK 2002 on basis of European Climate Change Programme(ECCP) working group reports & docs JSWG and WG3 ('provisional analysis'), European Commission, 2001.

* = rough estimates based on PRIMES figures for 2010 following The Shared Analysis project "Economic Foundations for Energy Policy", European Commission, Dec. 1999. PRIMES "full flexibility scenario incl. ACEA agreement" with a price of 20 EUR/t CO_2 abated. Accuracy plus or minus 10-15%.

Note: Conversion Electricity 1990: 1 TWh el. = 0.5 Mt CO_2; 2010 1 TWh el.= 0.45 Mt CO_2

Table 4-5. Deutschland, Genehmigte Bauvorhaben im Hochbau 2004, 2.2 Errichtung neuer Gebäude, 2.2.6 Genehmigungen im Wohn- und Nichtwohnbau nach Gebäudearten und Art der vorwiegend verwendeten Heizenergie *)

Gebäudeart	Insgesamt	Vorwiegend verwendete Heizenergie							
		Koks/ Kohle	Öl	Gas	Strom	Fern- wärme	Wärme- pumpe	Solar- energie	Sonstige
Wohngebäude zusammen	160.288	331	19.058	120.788	2.305	6.868	6.038	448	4.452
darin: Wohnungen	236.352	497	25.022	177.080	2.837	17.328	7.383	542	5.663
davon:									
Wohngebäude mit 1 Wohnung	134.895	269	15.290	102.585	1.952	5.609	5.181	385	3.624
Wohngebäude mit 2 Wohnungen	16.076	46	2.971	10.912	289	395	722	52	689
Wohngebäude mit 3 o.m. Wohnungen	9.146	15	785	7.164	61	838	134	11	138
darin: Wohnungen	68.504	136	3.660	52.156	307	10.779	758	53	655
Wohnheime	171	1	12	127	3	26	1	-	1
darin: Wohnungen	801	-	130	515	-	150	-	-	6
darunter:									
Wohngeb. mit Eigentumswohnungen	6.120	13	348	4.920	34	624	78	6	97
darin: Wohnungen	39.891	117	1.375	30.938	160	6.561	404	21	315
Nichtwohngebäude zusammen	14.087	73	1.792	9.425	800	1.183	193	27	594
darin: Rauminhalt (1 000 m^3)	122.624	357	10.577	84.463	1.820	21.901	923	88	2.496
davon:									
Anstaltsgebäude	617	3	45	381	46	140	1	-	1
darin: Rauminhalt (1 000 m^3)	6.779	15	644	4.111	24	1.973	10	-	3
Büro- und Verwaltungsgebäude	1.956	2	199	1.315	113	248	35	6	38
darin: Rauminhalt (1 000 m^3)	15.693	5	674	9.773	75	4.881	193	13	80
Landwirtschaftl. Betriebsgebäude	776	13	140	388	66	20	21	3	125
darin: Rauminhalt (1 000 m^3)	4.376	29	765	2.824	257	62	122	9	308
Nichtlandwirt. Betriebsgebäude	8.342	42	1.155	5.806	424	456	89	10	360
darin: Rauminhalt (1 000 m^3)	85.000	302	7.693	61.584	1.303	11.779	396	39	1.905
darunter:									
Fabrik- und Werkstattgebäude	2.890	10	480	1.843	169	157	36	3	192
darin: Rauminhalt (1 000 m^3)	28.163	183	3.631	18.944	516	3.289	173	10	1.419
Handels- und Lagergebäude	4.014	16	455	3.062	153	202	35	5	86
darin: Rauminhalt (1 000 m^3)	48.408	111	3.603	36.891	616	6.609	181	20	378
Hotels und Gaststätten	581	5	93	381	24	48	6	-	24
darin: Rauminhalt (1 000 m^3)	2.524	2	179	1.503	14	762	27	-	37
Sonstige Nichtwohngebäude	2.396	13	253	1.535	151	319	47	8	70
darin: Rauminhalt (1 000 m^3)	10.776	6	801	6.171	162	3.207	201	27	200
darunter:									
Ausgewählte Infrastrukturgebäude	3.327	12	330	2.117	253	465	48	8	94
darin: Rauminhalt (1 000 m^3)	21.858	20	1.584	13.261	252	5.961	219	27	534

*) Einschl. Fertigteilbau.

Source: Statistisches Bundesamt, Fachserie 5, R. 1, 2004

The German statistics show 14087 permits for non-residential buildings ('Nichtwohngebäude') in 2004 with a total building volume of 122,6 million m^3. Of this, there are some 2890 factories ('Fabrik- und Werkstattgebäude') with a total building volume of 28,2 million m^3. This is exactly 23%, as mentioned in the ECCP 2003.

Furthermore, Table 4-5 also shows that the use of fuels is not very different. For all non-residential buildings the building volume share of natural gas is 68,8% whereas for industrial buildings this is 67%. Non-residential buildings as a whole use relatively more district heating (18% vs. 13%) and less oil (8 vs. 13%), but the differences are not dramatic.

Also in terms of the type of heating systems the differences are smaller than one might expect. According to Table 4-6 around 75% of all heated non-residential buildings has central heating, whereas in in industrial buildings this is 78%. The share of direct air heaters, which would fall in the category single room heaters ('Einzelraumheizung') is still relatively modest at 8% of the industrial building total.

So, although these statistics relate only to 18% of the EU and to building permits and not the installed stock, they show that at least in terms of heated building volume, fuel and heating system the ECCP figure of 23% is not unlikely.

Table 4-6. Deutschland, Genehmigte Bauvorhaben im Hochbau 2004, 2.2 Errichtung neuer Gebäude, 2.2.5 Genehmigungen im Wohn- und Nichtwohnbau nach Gebäudearten und Art der Beheizung *)

Gebäudeart	Ins-gesamt	Darunter mit					
		Fern-heizung	Block-heizung	Zentral-heizung	Etagen-heizung	Einzel raum-heizung	ohne Heizung
Wohngebäude zusammen	160.311	6.868	770	150.471	1.022	1.157	23
darin: Wohnungen	236.378	17.328	1.847	213.420	2.237	1.520	26
davon:							
Wohngebäude mit 1 Wohnung	134.915	5.609	628	127.170	540	948	20
Wohngebäude mit 2 Wohnungen	16.079	395	24	15.273	221	163	3
Wohngeb. mit 3 o. m. Wohnungen	9.146	838	116	7.888	260	44	-
darin: Wohnungen	68.504	10.779	1.162	55.062	1.255	246	-
Wohnheime	171	26	2	140	1	2	-
darin: Wohnungen	801	150	9	642	-	-	-
darunter:							
Wohngeb. mit Eigentumswohnungen	6.120	624	109	5.237	134	16	-
darin: Wohnungen	39.891	6.561	559	32.037	620	114	-
Nichtwohngebäude zusammen	28.138	1.183	233	11.261	139	1.271	14.051
darin: Rauminhalt (1 000 m³)	165.431	21.901	2.648	92.423	665	4.986	42.808
davon:							
Anstaltsgebäude	617	140	10	418	2	47	-
darin: Rauminhalt (1 000 m³)	6.779	1.973	160	4.607	17	22	-
Büro- und Verwaltungsgebäude	1.956	248	16	1.555	31	106	-
darin: Rauminhalt (1 000 m³)	15.693	4.881	155	10.420	146	91	-
Landwirtschaftl. Betriebsgebäude	7.570	20	41	485	4	226	6.794
darin: Rauminhalt (1 000 m³)	24.443	62	511	2.746	5	1.052	20.067
Nichtlandwirtsch. Betriebsgebäude	15.190	456	121	6.968	75	722	6.848
darin: Rauminhalt (1 000 m³)	106.828	11.779	1.505	67.621	456	3.640	21.828
darunter:							
Fabrik- und Werkstattgebäude	3.849	157	81	2.332	20	300	959
darin: Rauminhalt (1 000 m³)	31.682	3.289	853	22.137	96	1.788	3.518
Handels- und Lagergebäude	7.223	202	23	3.495	41	253	3.209
darin: Rauminhalt (1 000 m³)	62.509	6.609	443	39.459	325	1.572	14.101
Hotels und Gaststätten	581	48	7	477	6	43	-
darin: Rauminhalt (1 000 m³)	2.524	762	63	1.670	10	19	-
Sonstige Nichtwohngebäude	2.805	319	45	1.835	27	170	409
darin: Rauminhalt (1 000 m³)	11.687	3.207	317	7.029	41	181	912
darunter:							
Ausgewählte Infrastrukturgebäude	3.976	465	76	2.479	29	278	649
darin: Rauminhalt (1 000 m³)	23.559	5.961	521	14.955	70	350	1.701

*) Einschl. Fertigteilbau.

Statistisches Bundesamt, Fachserie 5, R. 1, 2004

The tables also give some other data that at least give an order of magnitude of certain building characteristics. Regarding the average building size, the average new German non-residential building has a building volume of 8750 m, which –at an assumed gross storey height of 3,5 m— results in around 2.500 m². Anecdotal data shows that the distribution is not equal: almost half of the total floor area is in a relatively small number of large buildings (> 10.000 m²), followed by the size class <500 m² with around 80% of buildings which represent 30-40% of the floor area. The middle classes, e.g. the volume between 1000 and 10.000 m² is relatively small, but this could be exactly the area where many smaller industrial buildings (office+factory) are to be found.

The new German average industrial building has a volume of 9744 m³, which –given a higher room height—may well translate also into 2500 m² floor area.

The question remains, whether the heat load between industrial and commercial buildings is comparable. On the one hand, one can expect that the average indoor temperature in factories is lower than in an office (e.g. 18 vs. 21°C). On the other hand, the working hours may be longer in 2/3 and full-shift factories.

For that reason we present the findings of the Statistics Norway report and more specifically the measurements that were done by ENOVAS of over 1000 buildings of various types. Norway is not a member of the EU-25 but from the analytical point of view the data are very interesting. In Norway 88% of the space heating in almost all sectors is electric, i.e. the energy consumption data are hardly 'polluted' by generation losses of boilers or distribution losses in the buildings. In other words the total consumption figures give a good impression of the actual heat load in Norway.[51] The Norwegian climate in terms of degree-days (5476 in 2003, 5312 in 2004) is similar to that in Finland. [52] The average daily temperature in Oslo is 5,9°C (compare: Helsinki 5,6°C).

For climate reasons, also confirmed by the figures for the residential sector in the previous chapter, the heat load of Norwegian buildings should then be around 70-80% above the EU-average. For the various NACE branches (the same as in Table 4-2) the split-up are given below in Table 4-7.

But more important than the absolute figures of the split-up, which clearly show how Norwegian houses are heated also through waste heat from lighting and ventilation, is the fact that the ENOVAS data show that relatively the figures of the heated manufacturing buildings are on average not very different from the tertiary sector. Also, as we have assumed in par. 4.1, it confirms that on average the energy consumption per square meter is higher in non-residential buildings than in residential buildings.

[51] In any other country there should be a 10-20% correction for control losses an all losses of non-electric heating, but it must be considered that the internal heat gain from lighting in Norway is much higher than in other countries because of the abundant availability of (hydro-based) electric energy. In fact, a few years ago some utilities promoted to 'heat your house with light'. For that reason we think that no correction is needed.

[52] Eurostat, Teeemperature correction of final energy consumption, meeting of the working group 'Energy Statistics Committee', Luxembourg, 13-14 June 2005.

Table 4-7. Summary tables Norway energy consumption in the services sector 2000 (source: Statistics Norway 2005)

Consumption for space heating and hot water. 2000. Branches 1-6. TJ

	average	Heating oil	Electricity	District heating	Paraffin	Fluid propane and butane	Other	Total
	kWh/m²	TJ	TJ	TJ	TJ	TJ	TJ	TJ
Total (1-6)	98.4	11 348	37 652	3 587	42	12	189	52 830
Branches								
1 Hotels & Restaurants	201.6	118	2 483	105	0	6	3	2 715
2 Health & Social work	79.2	1 502	3 719	27	19	-	26	5 293
3 Education	99.2	847	4 393	645	5	-	-	5 890
4 Other community services	69.9	1 219	6 868	595	8	-	141	8 831
5 Offices & Administration	69.9	6 524	11 107	1 819	6	-	19	19 476
6 Commerce	157.2	1 138	9 083	396	3	6	0	10 626

Consumption for specific uses of electricity. 2000. Branches 1-6. GWh

	Lighting		Heating/ hot water	Cooling and freezing	Ventilation and air-condition	Electrical appliances	Other	Total
	kWh/m²	GWh	GWh	GWh	GWh	GWh	GWh	GWh
Total (1-6)	62,8	6 208	10 471	2 242	2 450	1 879	1 110	24 359
Branches								
1 Hotels & Restaurants	69,3	291	690	213	254	124	146	1 718
2 Health & Social work	64,6	615	1 035	176	226	188	108	2 348
3 Education	51,1	727	1 222	208	266	223	128	2 774
4 Other community services	55,8	1 136	1 911	326	417	348	200	4 337
5 Offices & Administration	55,8	1 837	3 090	527	674	563	323	7 013
6 Commerce	79,1	1 602	2 524	792	613	433	205	6 169

Table 4-8.a. Measurements of energy consumption in Norwegian buildings in kWh/m² heated area, year 2000 (source: ENOVAS in Statistics Norway 2005)

Type of building	#	energy corrected (kWh/m²)	energy (kWh/m²)	energy-split Electricity (%)	Oil (%)	Heat (%)	Gas (%)	Other (%)
Total	1039	247.8	230.2	84.9	10.6	4.1	0.1	0.2
1 Houses	13	196.5	181.6	80.2	19.8	0.0	0.0	0.0
13 Row house	3	183.7	171.0	100.0	0.0	0.0	0.0	0.0
131 Row house with 3 and 4 flats	1	151.0	141.0	100.0	0.0	0.0	0.0	0.0
132 Row house with 5 flats or more	2	200.0	186.0	100.0	0.0	0.0	0.0	0.0
15 Block of flats	10	200.3	184.8	74.7	25.3	0.0	0.0	0.0
151 Block of flats with 2 floors	2	169.0	159.0	100.0	0.0	0.0	0.0	0.0
152 Block of flats with 3 and 4 floors	4	193.3	176.3	100.0	0.0	0.0	0.0	0.0
153 Block of flats with 5 or more floors	4	223.0	206.3	43.4	56.6	0.0	0.0	0.0
2 Manufacturing-and storehouses	**21**	**294.1**	**271.7**	**42.6**	**47.0**	**10.3**	**0.0**	**0.0**
21 Industribygning	9	346.0	321.3	46.2	33.4	20.4	0.0	0.0
212 Verkstedsbygning	8	366.5	340.5	42.9	35.5	21.6	0.0	0.0
213 Produksjonshall	1	182.0	168.0	100.0	0.0	0.0	0.0	0.0
23 Lagerbygning	12	255.3	234.5	39.0	61.0	0.0	0.0	0.0
231 Lagerhall	11	255.7	234.4	40.8	59.2	0.0	0.0	0.0
239 Annen lagerbygning	1	250.0	236.0	19.1	80.9	0.0	0.0	0.0
3 Offices and commercial buildings	**180**	**286.7**	**270.3**	**88.9**	**4.6**	**5.9**	**0.0**	**0.5**
31 Office building	143	229.1	213.7	84.5	6.8	7.7	0.0	0.8
311 Office/ administration building, city hall	101	219.9	205.6	86.8	8.5	3.9	0.0	0.6
312 Bank building, post office	6	209.2	197.5	99.7	0.4	0.0	0.0	0.0
319 Other office building	34	259.4	240.2	75.8	3.6	19.0	0.0	1.6
32 Commercial building	37	509.4	489.1	96.3	0.9	2.8	0.0	0.0
321 Shopping centre, department store	22	551.5	527.2	99.4	0.6	0.0	0.0	0.0
322 Shop building	6	590.5	576.7	97.3	2.7	0.0	0.0	0.0
329 Other commercial buildings	9	352.4	337.4	83.3	0.0	16.7	0.0	0.0
4 Communication- and transport building	**34**	**366.9**	**337.9**	**83.4**	**14.5**	**2.1**	**0.0**	**0.0**
41 General office- and terminal building	24	398.4	366.6	93.3	5.1	1.5	0.0	0.0
411 General office, flight terminal, control tower	5	509.0	483.8	99.6	0.4	0.0	0.0	0.0
412 Railways	13	405.2	366.1	90.2	7.0	2.9	0.0	0.0
415 Goods terminal	1	327.0	298.0	100.0	0.0	0.0	0.0	0.0
416 Post terminal	5	284.2	264.4	91.8	8.2	0.0	0.0	0.0
43 Garage- and hangar building	6	298.3	280.7	30.8	69.2	0.0	0.0	0.0
432 Bus garage, streetcar building, locomotive building	1	120.0	106.0	65.1	34.9	0.0	0.0	0.0
433 Aircraft hangar	5	334.0	315.6	28.5	71.5	0.0	0.0	0.0
44 Road- and car supervision building	4	280.8	251.8	84.4	4.6	11.0	0.0	0.0
441 Car supervision building	3	301.7	270.0	80.6	5.7	13.7	0.0	0.0
442 Working sentral	1	218.0	197.0	100.0	0.0	0.0	0.0	0.0
5 Hotel and restaurant building	**55**	**275.7**	**266.5**	**51.7**	**46.6**	**1.6**	**0.1**	**0.0**
51 Hotel building	12	313.8	302.2	82.2	10.8	6.6	0.3	0.0
511 Hotel building	12	313.8	302.2	82.2	10.8	6.6	0.3	0.0
52 Building for overnight stop	35	215.4	208.3	36.9	63.1	0.0	0.0	0.0
523 Barracks	19	187.4	181.4	33.4	66.6	0.0	0.0	0.0
529 Other building for overnight stop	15	251.3	242.8	36.7	63.3	0.0	0.0	0.0
53 Restaurant building	8	482.3	467.4	50.8	49.2	0.0	0.0	0.0
531 Restaurant building, café building	1	381.0	365.0	100.3	0.0	0.0	0.0	0.0
532 Sentral kitchen, canteen building	7	496.7	482.0	45.5	54.5	0.0	0.0	0.0

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Table 4-8.b. C'td Measurements of energy consumption in Norwegian buildings in kWh/m² heated area, year 2000 (source: ENOVAS in Statistics Norway 2005)

Type of building	#	energy corrected (kWh/m²)	energy (kWh/m²)	energy-split Elec-tricity (%)	Oil (%)	Heat (%)	Gas (%)	Other (%)
6 Cultural- and research building	**595**	**215.2**	**197.5**	**87.6**	**7.5**	**4.9**	**0.0**	**0.1**
61 School building	479	198.7	182.2	90.8	7.5	1.6	0.0	0.1
611 Kindergarten, playground	48	232.6	211.0	98.9	1.1	0.0	0.0	0.0
612 Primary school	292	197.5	180.7	91.6	7.4	0.9	0.0	0.0
613 College	129	187.3	173.5	86.5	9.3	4.1	0.0	0.0
619 Other school building	8	210.4	191.3	81.4	18.6	0.0	0.0	0.0
62 University and academy building	50	287.2	261.6	70.8	3.9	25.3	0.0	0.0
621 Building with integrated functions and so on	40	294.1	269.2	69.5	2.6	27.9	0.0	0.0
622 Special building	6	282.8	250.5	80.3	4.7	15.1	0.0	0.0
629 Other University and academy building	4	224.3	203.0	69.8	19.6	10.6	0.0	0.0
64 Museum- and library building	6	200.8	187.2	69.5	12.6	17.8	0.0	0.0
641 Museum, art gallery	3	217.3	203.0	62.9	4.3	32.8	0.0	0.0
642 Library	3	184.3	171.3	77.4	22.6	0.0	0.0	0.0
65 Sports building	43	317.7	295.7	82.8	12.2	5.0	0.0	0.0
651 Sports building	28	242.7	222.1	82.4	13.6	4.0	0.0	0.0
652 Ice building	1	272.0	244.0	67.6	32.4	0.0	0.0	0.0
653 Swimming hall	13	478.3	455.2	84.1	9.4	6.5	0.0	0.0
659 Other sports building	1	375.0	336.0	80.7	19.3	0.0	0.0	0.0
66 Culture house	13	226.5	210.0	90.9	3.7	5.5	0.0	0.0
661 Cinema, theatre, opera/consert hous	3	177.7	166.3	100.0	0.0	0.0	0.0	0.0
662 Community centre	6	247.5	226.8	89.1	0.0	10.9	0.0	0.0
663 Discoteque, youth club	1	398.0	389.0	100.0	0.0	0.0	0.0	0.0
669 Other cultural building	3	176.3	160.3	79.2	20.8	0.0	0.0	0.0
67 Building with religious activities	3	196.7	165.3	100.0	0.0	0.0	0.0	0.0
671 Church, chapel	3	196.7	165.3	100.0	0.0	0.0	0.0	0.0
69 Other cultural- and research building	1	94.0	87.0	96.6	3.4	0.0	0.0	0.0
7 Health buildings	**135**	**297.3**	**278.0**	**91.8**	**6.8**	**0.3**	**0.5**	**0.6**
71 Hospital	15	330.9	309.1	67.7	26.3	0.0	4.1	1.8
711 Local hospital	3	316.0	295.7	76.1	23.9	0.0	0.0	0.0
712 Central hospital	6	360.8	336.2	79.5	11.0	0.0	9.5	0.0
714 Special hospital	3	351.0	331.3	66.3	25.4	0.0	0.0	8.4
719 Other hospital	3	265.7	246.0	27.6	72.4	0.0	0.0	0.0
72 Nursing home	111	300.2	281.3	95.4	3.9	0.3	0.0	0.4
721 Nursing home	82	305.6	286.9	96.5	3.1	0.3	0.0	0.0
722 Live- and treatment centre	25	286.4	267.3	93.1	6.9	0.0	0.0	0.0
729 Other nursing home	4	276.0	254.5	84.3	1.1	2.1	0.0	12.6
73 Primary health building	9	205.9	185.6	91.5	7.7	0.8	0.0	0.0
732 Health centre, maternal and child health centre	8	213.8	192.0	91.6	8.4	0.0	0.0	0.0
739 Other primary health building	1	143.0	134.0	90.3	0.0	9.7	0.0	0.0
8 Prisons, emergency buildings etc.	**6**	**228.0**	**210.8**	**81.4**	**15.5**	**3.1**	**0.0**	**0.0**
82 Standby building	6	228.0	210.8	81.4	15.5	3.1	0.0	0.0
821 Police station	5	235.6	216.2	93.2	3.1	3.6	0.0	0.0
829 Other standby building	1	190.0	184.0	12.0	88.0	0.0	0.0	0.0

4.3 Main findings tertiary and industrial buildings

To do (see VHK slides 4^{th} expert meeting for first results)

5 ENERGY SUPPLY INFRASTRUCTURE

This Chapter describes the fuel infrastructure (including electricity) for central heating boilers in Europe. It describes what fuels are used by boilers today, what the costs are and the potential for fuel switching.

5.1 Fuel use by boiler stock

Based upon data by BRG Consult the breakdown of the individual boiler stock by fuel type (including electric boilers) looks like this: Some 72% of individual boiler stock is fuelled by gas, some 20% by oil, some 2% by electricity and 6% by solid fuels. These figures relate to individual central heating systems only.

Table 5-1. individual and collective boiler stock by fuel type (in '000 units)

	GAS gas(ind + coll)	OIL oil(jet, ind+coll.)	ELECTRIC electric(wet boiler + hp)	SOLID solid
Austria	733	347	58	420
Belgium	1326	939	0	59
Cyprus	0	0	0	0
CzechRep.	1149	3	11	511
Denmark	308	370	13	51
Estonia	16	21	3	14
Finland	0	455	46	322
France	8923	4396	86	492
Germany	11045	6552	66	128
Greece	78	1670	0	100
Hungary	1273	4	0	173
Ireland	470	472	37	197
Italy	14200	910	89	79
Latvia	37	1	0	74
Lithuania	82	8	0	145
LUX	0	0	0	0
Malta	0	0	0	0
Netherlands	5044	1	9	50
Poland	1208	155	0	1761
Portugal	190	46	0	22
Slovakia	406	0	0	241
Slovenia	62	221	0	166
Spain	4179	1624	0	345
Sweden	17	393	1 038	467
UK	19714	1114	587	385
TOTAL EU22	**70461**	**19 699**	**2 043**	**6202**
	72%	20%	2%	6%

When assessed on the basis of number of dwellings the collective boilers have to be included in the assessment. This is done by taking the total number of collective dwellings (based upon BRG Consult data) and making a split up between gas and oil boilers according the sales figures of collective gas and oil boilers (based upon calculation in paragraph 3.3.2 of Task 2, Table 3-9).

The result is that the importance of oil heating increases (oil boilers are more often used on collective basis): Some 62% of dwellings with central heating are heated by gas, some 32% by oil, 2% by electricity and 5% by solid fuels.

Table 5-2. Dwellings in EU-25 by type of fuel.

	'000 dwellings heated by ... (individual wet systems and collective systems only)					% of total dwelling heated by ... (individual wet systems and collective systems only)			
	gas	oil	electric	solid	total dwellings	gas	oil	electric	solid
Austria	958	1022	58	420	4020	24%	25%	1,4%	10%
Belgium	1400	1090		59	3724	38%	29%		2%
Cyprus									
CzechRep.	1364	63	11	511	3994	34%	2%	0,3%	13%
Denmark	342	445	13	51	2800	12%	16%	0,5%	2%
Estonia	33	70	3	14	622	5%	11%	0,5%	2%
Finland	20	512	46	322	2871	1%	18%	1,6%	11%
France	10418	7739	86	492	30218	34%	26%	0,3%	2%
Germany	14500*	15024*	66	128	38398	38%	39%	0,2%	0%
Greece	78	2630		100	5650	1%	47%		2%
Hungary	1421	4		173	4173	34%	0%		4%
Ireland	470	520	37	197	1370	34%	38%	2,7%	14%
Italy	15238	5340	89	79	27941	55%	19%	0,3%	0%
Latvia	80	125		74	965	8%	13%		8%
Lithuania	108	82		145	1304	8%	6%		11%
Luxembourg									
Malta									
Netherlands	5909	129	9	50	6810	87%	2%	0,1%	1%
Poland	1841	822		1761	12683	15%	6%		14%
Portugal	191	64		22	5271	4%	1%		0%
Slovakia	551	0		241	1899	29%	0%		13%
Slovenia	78	265		166	796	10%	33%		21%
Spain	4312	3108		345	22098	20%	14%		2%
Sweden	89	717	1038	467	5060	2%	14%	20,5%	9%
UK	19763	1189	587	385	25055	79%	5%	2,3%	2%
TOTAL EU22	**79168**	**40956**	**2043**	**6202**	**207728**	**38%**	**20%**	**1,0%**	**3%**
	62%	32%	2%	5%					

* note that boiler stock data are slightly different from data Statistisches Bundesamt: There 11,2 mln. oil, 16,75 mln. gas on a total of 35,1 mln. conventional occupied dwellings (excl. coll. Homes) for Germany 2002.

These figures do not take into account dwellings with local heating, nor dwellings with a gas connection for cooking or sanitary water only (oil for cooking is rare).

Since ecodesign options for central heating boilers are partly governed by the access to fuels, it is important to complete the assessment of the fuel infrastructure for EU households and expand beyond the figures quoted above. For this an assessment of the development of the natural gas grid, LPG supply and heating oil supply is added.

5.2 Natural gas grid

Current connections

The total number of gas boilers in individual and collective systems in stock is some 72 mln. units (70,3 individual wet system gas boilers plus some 1.7 mln. collective gas boilers) which translates to a same volume of individual gas customers. The total reported number of domestic gas grid customers (by Eurogas) is 97 mln. which in many countries is higher than the number of gas boilers serviced in that country.

Table 5-3. Stock of residential boilers in '000 units (BRGC) and '000 domestic gas customers (Eurogas)

	BRGConsult	BRGConsult	BRGConsult	Eurogas	
	gas ind. wet 2004	coll.boiler gas 2004	total gas (ind + coll)	domestic customers 2004	Difference(can be local gas heater and/or cooking appliance)
Austria	732	45	777	1273	496
Belgium	1316	17	1333	2565	1232
CzechRep.	1145	44	1189	2592,4	1404
Denmark	308	7	315	340	25
Estonia	16	3	19	63	44
Finland	0	4	4	34	30
France	8907	302	9209	10731	1522
Germany	11010	698	11708	17730	6022
Greece	78	0	78	30,8	-47
Hungary	1261	32	1293	3106	1813
Ireland	470	0	470	471,7	2
Italy	14194	209	14403	15050	647
Latvia	37	9	46	425	379
Lithuania	82	5	87	518	431
Netherlands	5038	174	5212	6351	1138
Poland	1198	129	1327	6963	5636
Portugal	189	0	189	744	555
Slovakia	401	30	431	1440	1009
Slovenia	62	3	65	105	40
Spain	4172	28	4200	5378	1178
Sweden	16	15	31	52	21
UK	19705	12	19717	21378	1661
TOTAL EU22	**70339**	**1766**	**72105**	**97411**	**25306**

The difference most likely concerns gas customers that use gas just for local heating and/or cooking. The BRGC figures do not provide details for the fuel of this park of "non central heating" costumers (e.g. "dry gas/electric" and "no central heating" = local, room-based heating or no heating at all).

The 2001 SAVE Heating Systems study does provide insight in the fuel source used for local heaters. It identified some 7.65 mln. households with local gas heaters in 1995, reduced to 3.2 mln. households in 2005 for the EU15. For the EU25 the number of local heaters is presumably higher than for the EU15. If a total of 3 to 7 million local gas heaters number is subtracted from the total remainder of gas customers this leaves some 17 to 22 mln. customers using gas for cooking, but heating their premises with a different fuel.

When assessed on basis of the total number of dwellings [53] in the EU22 some 38% of dwellings are using gas for their central heating. To this has to be added an unknown percentage of dwellings that are heated by local gas heaters and dwellings that use gas for cooking (see remark in previous paragraph).

Figure 5-1. European Natural gas transmission systems in 2002 [54]

Gas grid growth

According Eurogas the European natural gas network grows at a rate of some 2% per year (expressed as domestic costumers).

On average the number of domestic gas costumers in the EU25 in 2004 has risen with 2% from 2003 [55]. Most countries experience a steady growth of number of domestic customers between 0 - 3% annually.

Countries experiencing relatively large growth figures in 2003-2004 are Greece (94.9%, coming from a very low absolute figure to start with), Poland (15%), Spain (6.7%) and Portugal (8.9%), Ireland (5.1%) and Slovenia (5%).

Negative growth figures for the Netherlands (-2.4%) are likely to be caused by either a decline in the non-domestic sector or through statistical errors (rounding of figures etc.). The negative growth figures for Estonia (-1.6%) and Finland (-0.9%) are probably caused by the very small absolute base, so that even tiny abbreviations occur as relatively large disruptions.

[53] "All" meaning the total of dwellings as presented by BRGC, which includes second homes etc.

[54] http://www.gascentre.unece.org/minisitepub/rsng/index.htm

[55] Figures are taken from the 2000 to 2005 Annual Reports by Eurogas (www.eurogas.org).

Table 5-4. Growth in number of customers connected to natural gas grid x 1000 and in %

	Gas boilers table above	Domestic customers ('000) at 1 Jan 2005	Growth 2003-2004	2002-2003	2001-2002	2000-2001
Austria	733	1273	2,3%	-2,8%	1,5%	0,0%
Belgium	1326	2565	2,5%	0,0%	1,7%	1,7%
Cyprus	0	n.a.				
Czech Rep.	1149	2592	1,1%	1,3%	1,7%	1,3%
Denmark	308	340	2,7%	1,1%	0,2%	3,6%
Estonia	16	63	-1,6%			
Finland	0	34	-0,9%	0,3%	2,4%	1,5%
France	8923	10731	0,5%	1,3%	1,6%	2,1%
Germany	11045	17730	0,8%	0,5%	2,0%	2,9%
Greece	78	31	94,9%	68,1%	46,9%	0,0%
Hungary	1273	3106	2,2%	2,3%	3,0%	2,2%
Ireland	470	472	5,1%	9,1%	8,2%	7,9%
Italy	14200	15050	0,0%	0,3%	1,4%	0,7%
Latvia	37	425	0,6%			
Lithuania	82	518	0,0%			
Luxembourg	0	70	0,0%	-3,7%	0,0%	0,0%
Malta	0	n.a.				
Netherlands	5044	6351	-2,4%	-4,3%	1,5%	0,9%
Poland	1208	6963	15,0%			
Portugal	190	744	8,9%	4,5%	26,0%	
Slovakia	406	1440	1,1%	1,5%	2,2%	
Slovenia	62	105	5,0%			
Spain	4179	5378	6,7%	4,1%	7,2%	9,6%
Sweden	17	52	0,0%	0,0%	0,0%	0,0%
UK	19714	21378	1,1%	0,9%	0,9%	0,5%
EU15		82199	1,1%	1,4%	2,0%	2,5%
EU25 (excl. Malta, Cyprus)	70461	97846	2,0%			

values in italic are based upon totals of domestic and non-domestic customers which have been split up using a share of 0.95 for domestic and 0.05 for non-domestic costumers.

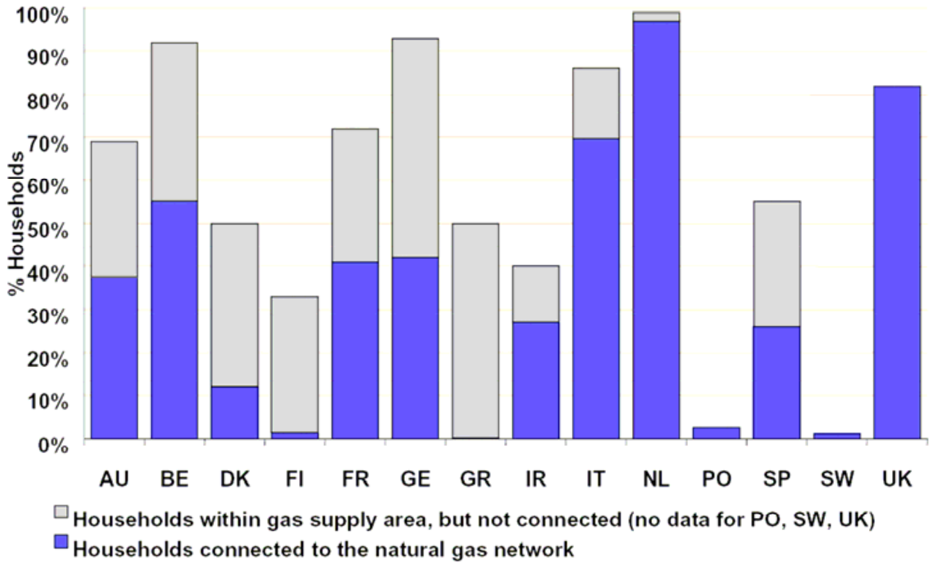
Fuel switching

Griffin (2000) [56] reports that attempts to project fuel-switching to natural gas will have to take into account infrastructural limitations and the economic feasibility of fuel switching for the individual consumer. This will depend directly on such factors as the cost of connection to the network (and the existence of schemes to deal with this), the cost of structural changes within the household, the cost of new appliances and the effects on running costs (dependent on climate as well), also in relation to the costs of other fuels.

Some data was found on the total number of households living in gas supply areas. Figure 5-2 below presents the picture based upon numbers dating from the years 1997-2000.

[56] Griffin, Harriet, Appendix R: Development of the European Gas Network, supporting document for Lower Carbon Futures, Environmental Change Institute, University of Oxford, UK, 2000.

Figure 5-2.
Households within gas supply area and connected to gas supply [57]



The figure does not take into account the obstacles for households to get connected, for instance Denmark shows a high percentage of households living within the gas supply network but (as other data shows) most of these households are connected to District Heating networks. Nor does the figure take into account the development of gas grids, as is happening in Portugal and Greece. The figure thus only presents a theoretical potential for fuel switch towards gas.

Anecdotal evidence suggests that in the new accession countries: In Slovakia the share of households connected is 85%, but only 25% use gas for heating.

Costs of realisation of a gas network connection

The costs for connecting a household to a gas network depend on several factors, the most important of course the distance from dwelling to mains gas supply. Other factors may concern the number of connections to be made (one-off or 'x' % of multiple dwellings), the capacity of the connection, local circumstances (like does the connection needs to cross a road or not) and the tariffs used.

Anecdotal evidence from the UK [58] suggest connection costs to be in the area of 700 GBP (1050 euro) to maximum 1400 GBP (2000 euro) per household (penetration 40% or less). A case study shows that the costs can however be reduced by intensive cooperation of parties involved to 85 GBP (125 euro) per household (depending on circumstances of course). Anecdotal evidence from Germany suggests 2500 euro for establishing a gas connection. Prices are perceived to be end-consumer prices (not confirmed).

5.2.1 LPG as heating fuel

Besides using natural gas from the gas network liquefied petroleum gas (LPG) can also be used as (cooking and) heating fuel. In fact in Portugal LPG is the most used form of gas (mainly for water heating: 64% of households, data relate to 1998-1999) [59] .

This section discusses trends in application of bulk LPG (in stationary containers) and does not concern the use of LPG through (portable) cylinders or cartridges.

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[57] Griffin, Harriet, Appendix R: Development of the European Gas Network, supporting document for Lower Carbon Futures, Environmental Change Institute, University of Oxford, UK, 2000.

[58] Leap-frogging the status quo, First Annual Report, Design & Demonstration Unit, Oct 2003 - Mar 2005 (accessed at http://www.dti.gov.uk/files/file16629.pdf)

[59] Lower carbon Futures, Country profile Portugal, by Environmental Change Institute, Oxford, http://www.eci.ox.ac.uk/lowercf/countrypictures/CP_portugal.pdf#search=%22portugal%20lpg%20heating%20cooking%22

In essence the use of LPG is quite similar to that of fuel oil: One needs a storage tank which is periodically filled. A large difference is that LPG tanks are usually sited outside the dwelling , above ground (although underground is also possible) whereas storage for oil is usually inside the dwelling.

The number of LPG consumers in Europe is difficult to assess, data is scattered and fuel end-use (cooking, space-heating and or water-heating) tends to get mixed.

All in all BRGC estimates the number of central heating boilers using LPG as fuel is around 4% of sales, with main areas of demand (90%) found in non-basified areas in Italy, Spain, France, UK and Portugal (p. 63 of BRGC Draft Final report).

Costs of realisation of a LPG storage tank

The installation itself normally costs between EUR 200 - 450 (GBP 150-300), after which an annual rental fee of between EUR 90-150 (GBP 60-100) [60] is paid. This fee covers for the installation, 24/7 emergency cover, testing and maintenance (including parts). Running costs vary depending on usage and appliances.

Using the example of a three bedroom property, the following costs are based on an 'A' rated boiler at retail price with flue arrangements (LPG conversion kit & Worcester Greenstar II 28 HE system boiler, Oil Grant Vortex 26kw Kitchen system oil boiler & balanced flue kit) and bunded tank.

Table 5-5. Tank costs for heating oil and LPG in the UK

Source: www.RuralFuel.co.uk	Heating Oil	LPG
Tank	1300	225
Tank installation	600	260
Boiler	3500	1780
Annual service	110 (includes parts which need regular changing due to heating oil viscosity)	80
Tank maintenance	Householders' responsibility	90
Total cost	5560	2435

Numbers have been converted from GBP to EUR with 1 GBP = 1.49 EUR and rounded.

In this example the LPG installation is around 3000 cheaper than the equivalent oil installation.

Besides the purchase price of the boiler (part of Task 2, Market Analysis) the price of the storage tank is an important element of the total price. When looking more closely at prices of oil storage tanks the price of 1300 euro may be considered relatively high, considering offers for plastic 'tank-in-tank' (no bund required) systems of 500 to 600 euro [61] (for 1500 litre).

[60] Quote from http://www.shellgas.co.uk/index.html?page=64

[61] http://www.heizungs-discount.de/Online-Katalog/Oltanks/oltanks.html

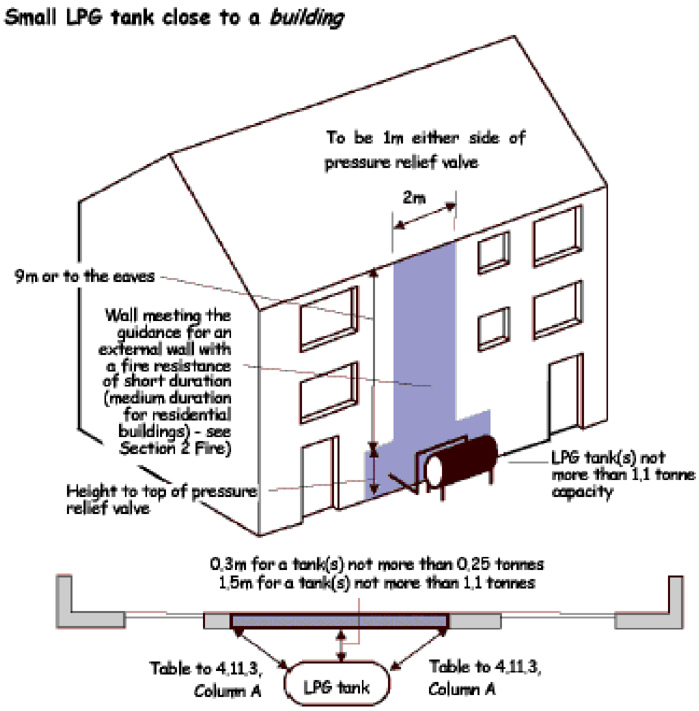
Figure 5-3.
plastic oil storage tanks[62]

LPG storage tanks are usually not owned by the customer but by the supplier who also takes care of maintenance.

Siting of LPG bulk storage tanks

Siting of LPG storage is subject to Codes and Practices, in many cases a permit from local authority is needed. Requirements relating to siting concern fire safety measures, ability to perform inspections, access and ability to fill up the tank, etc. The proximity of the tank to nearest buildings ranges from 0.3 - 7.5 m, depending on capacity of tank and existence of fire wall.

Figure 5-4.
Siting of LPG tanks according UK Code of Practice (< 4 tonne) [63]



Other requirements to siting of tank are [64]:

- good natural ventilation on site;
- adequate surface quality (hard, flat, incombustible, even with surrounding terrain);
- access for supply, inspection/maintenance or emergencies (no shrubberies);
- no danger of collision with vehicles etc. (protection may be needed);

[62] Source: www.heizungsdiscount.de

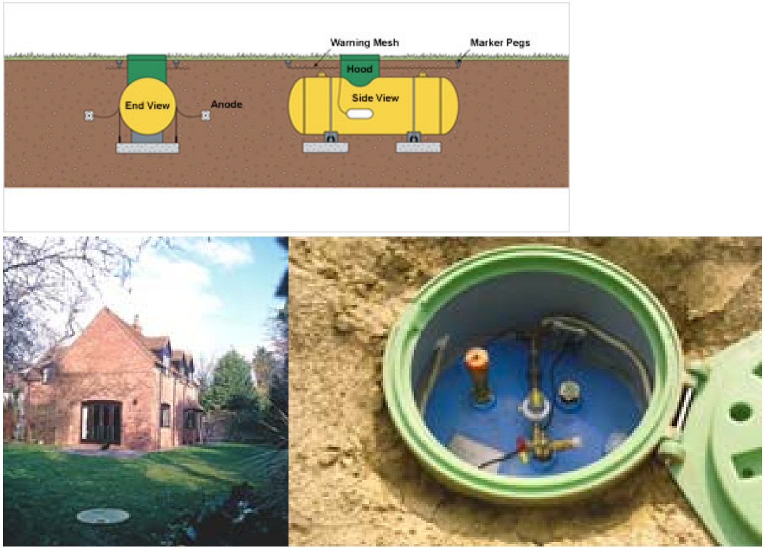
[63] http://www.sbsa.gov.uk/current_standards/th_html_2006/bsthd-81.htm#4111

[64] Source: www.shellgas.nl

- supply truck should be able to reach and leave the site. Gas supply hose may not be led through enclosed spaces (buildings). Supplier must be able to visually check storage tank as well as supply truck;
- no electrical installations within 5 metres of tank;
- no smoking or objects with surface temperature over 300°C in 5 metres range;
- in case storage tank is in terrain open for public access it should be protected with a fence in a range of 1.5 metres.

Figure 5-5.
Above ground LPG storage tank [65]

Figure 5-6.
Underground LPG storage tank [66]



Potential of LPG fuelled households

Guidelines like mentioned above limit siting of LPG bulk storage to (predominantly) rural areas. According to the OECD definition, which is based on population density, rural regions [67] represent in the EU25 92% of the territory. Furthermore, 19% of the population live in predominantly rural regions and 37% live in significantly rural regions [68].

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[65] www.calorgas.co.uk

[66] www.calorgas.co.uk

[67] The OECD definition is based on the share of population living in rural communes (i.e. with less than 150 inhabitants per km²) in a given NUTS III region. See Extended Impact Assessment - SEC(2004)931. This is the only definition of rural areas internationally recognised. However, in some cases, it doesn't fully take into account the population living in more densely populated rural areas, particularly in peri-urban zones.

[68] European Commission, Proposal for a COUNCIL DECISION on Community strategic guidelines for Rural Development , SEC (2005) 914, Brussels, July 2005.

Figure 5-7.
Fact sheet - New perspectives for EU rural development, European Commission 2004. Predominantly rural = green, significantly rural = light yellow, significantly urban = red.

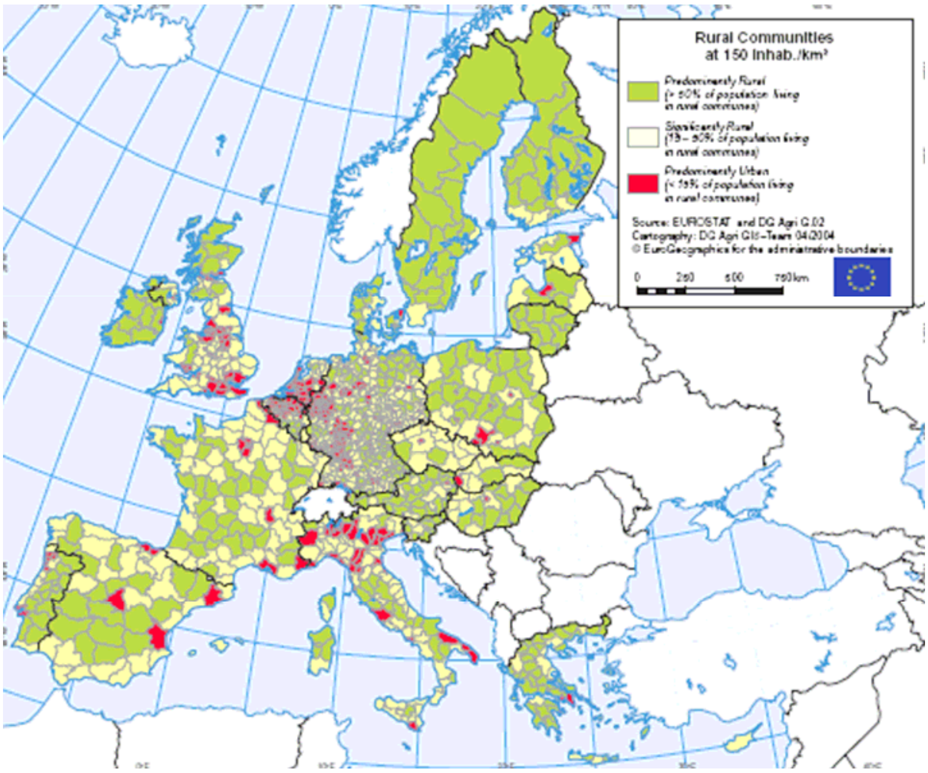
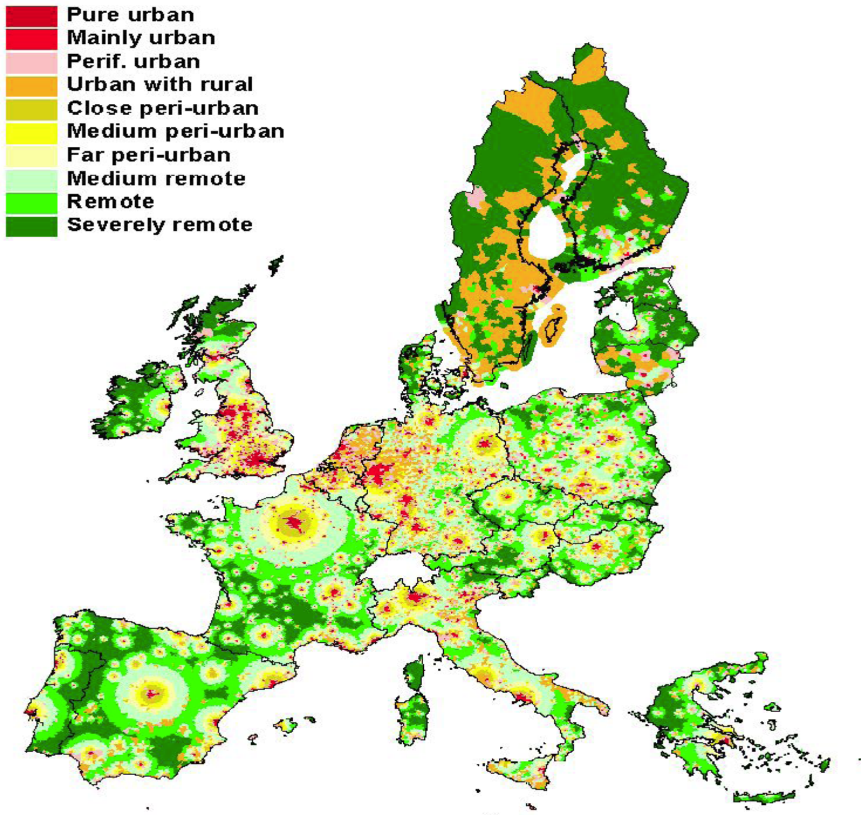


Figure 5-8.
A possible classification of communes[69]



[69] Gallego, F.J. Mapping rural/urban areas from population density grids, Institute for Environment and Sustainability, JRC, Ispra (Italy), 2004.

Table 5-6. EU-25 split of urban and rural population

	population ('000)	Urban	Rural	source	year
Austria	8032	67%	33%	1)	2001
Belgium	10287	100%	0%	1)	2001
Cyprus	789	61%	28%	1)	2001
Czech Rep.	10224	74%	26%	1)	2001
Denmark	5349	85%	15%	1)	2001
Estonia	1364	69%	31%	1)	2001
Finland	5176	61%	39%	1)	2001
France	58620	76%	24%	1)	1999
Germany	82335	88%	12%	2)	no data
Greece	10950	69%	31%	2)	no data
Hungary	10188	64%	36%	1)	2001
Ireland	3917	60%	40%	1)	2002
Italy	57157	14%	86%	1)	2001
Latvia	2355	68%	32%	1)	2001
Lithuania	3481	67%	33%	1)	2001
Luxembourg	442	81%	19%	1)	no data
Malta	383	-	-		no data
Netherlands	15864	64%	36%	1)	2000
Poland	38251	62%	38%	1)	2001
Portugal	10356	55%	45%	1)	2001
Slovakia	5380	56%	44%	1)	2001
Slovenia	1996	49%	49%	1)	2002
Spain	40721	76%	24%	2)	no data
Sweden	8896	33%	67%	2)	no data
UK	59114	91%	9%	2)	no data
EU15		85%	15%	2)	no data
EU25		19% predominantly rural 37% significantly rural 44% significantly urban			

Sources:
1) UN Human Settlements (http://w3.unece.org/stat/HumanSettlements.asp)
2) Eurostat

5.3 Heating oil

In 2004 some 41 million dwellings are heated by oil boilers (almost 20% of all dwellings [70]). The total number of oil boilers in stock is probably around 24 million of which 19.4 million are found in individual systems and some 4.3 million serve in collective housing (using an average of 5 dwellings per collectively used oil boiler). In the UK most oil boilers use Kerosene which has a slightly lower heat output per litre than light fuel oil or Gas oil). Kerosene also has poorer lubrication characteristics and is rarely used as heating fuel on the Main Land..

Siting of an oil storage tank is, similar to LPG tanks, bounded by Codes of Practice and local requirements. Unlike LPG however the vapour from oil storage tanks does not usually lead to explosive environments, making the requirements for siting somewhat more relaxed.

[70] Dwellings following the definition by BRGC which includes second homes etc.

However, in case of leaks (spills in case of oil storage) the danger for pollution of the environment is more eminent and that's why legislation and codes of practice focus on that issue.

Options for siting an oil storage tank depend on requirements regarding secondary containment and/or fire protection [71]. The requirements described below are from an English document, but similar provisions apply in most other Member States as well.

Secondary containment, eg. a bund capable of retaining 110% of the tank capacity, is required to reduce the risk of oil spills to the environment. A bund is required in case of a tank capacity over 2500 litres, when the tank is sited close to open water, an open drain, borehole or spring, and/or on hardened surfaces allowing oil to spill into the above. A bund is also required for situations where the overflow vent is not visible by the person responsible for tank filling and if the tanks supplies a building other than a single family dwelling.

The fire protection requirements specify minimum distances from walls, boundaries and eaves with a certain fire-resistance and openings and/or flue terminations. Placement in a fire resistant chamber might be required. Furthermore the tank has to be placed on a non-combustible surface which extends 300 mm outside the tank.

Figure 5-9.
Bunded tank [72]

Costs of realisation of an Heating Oil storage tank

See: Costs of realisation of a LPG storage tank, section 4.2.1.

Oil spills

Oil spills can be an extra cost for oil storage tanks owners and fines can be substantial: For UK commercial storage (capacity from 200 litres and upwards) the fine is 5000 GBP (EUR 7450) for non-compliance and 20.000 GBP (30.000 EUR) if spill occurs (www.ruralfuel.co.uk).

5.4 Electricity

There are some 2 million individual central heating systems that are fuelled by electric central heating boilers of which some 1.1 are of the electric immersion (resistance heating) type and some 0.9 million are electric heat pumps. This represents approximately 1% of the total dwelling stock.

[71] The requirements stem from www.oftec.co.uk http://www.oftec.co.uk/publications/T14_Iss2_sept_05.pdf

[72] www.oftec.co.uk/ consumers/regulations_ storage_tanks.htm

Infrastructural

For electric resistance boilers an extra fuse box with high capacity is needed. A normal fuse box usually allows some 16 Amperes at 230 Volts or 3.7 kW of power to be drawn from that fuse. In most cases this not enough to heat a house during cold winter months.

The extra fuse boxes with larger capacity need to be installed by an competent installer for electric installations. In most cases the higher capacity socket is a three-phase 380 Volt socket, dedicated for these boilers. The costs for such installations are approximately a few hundred euro (depending on location, age of existing installation, etc.).

5.5 Renewable energy

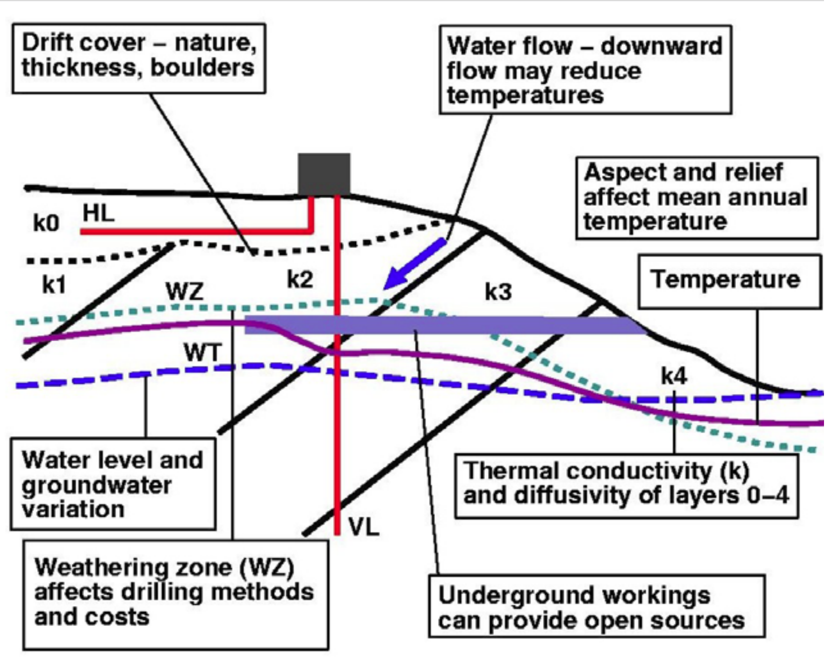
5.5.1 Heat pumps

As noted in section 4.4 the EU stock contains some 0.9 million heat pump boilers. Since virtually all heat pumps are of the electric type (gas driven heat pumps do exist but are a rarity) and can easily draw some 4-5 kW of electric power a standard fuse box normally does not suffice for powering the electric compressor and a high capacity fuse box needs to be installed (see above, section 4.4).

The main fuel source however is the ambient heat, extracted from either ground, water or air. Most heat pumps applied for central heating use heat from a ground source. Geothermal heat pumps work in much the same way as standard air heat pumps, except instead of working on the temperature difference between indoor and outdoor air temperatures, it works on the difference between indoor air temperature and the ground temperature. In winter, these systems draw on "earth heat" to warm the house, and in summer they (if reversible) can transfer heat from the house to the earth, which ranges in temperature from 10 to 21 degrees Celsius depending on latitude.

The feasibility of a site or location to function as potential geothermal source depends on a variety of aspects, to be described in a georeport. Based on such information the preferred type of heat collector can be decided and whether the system can be an open loop (no separate heat transferring circuit) or closed loop (with a heat transfer circuit filled with brine or water with anti-freeze). The figure below indicates aspects to be covered by a georeport

Figure 5-10.
Georeport aspects



In general one can say that a sandy ground, with high ground water levels has high thermal conductivity and is a good environment for a bore hole collector. Other types of collectors are the horizontal collector and the ground water/surface water heat pump. The types of heat pumps and their collectors are described in the Task 2 report, Market Analysis.

5.5.2 Solar collectors

Infrastructural aspects related to solar collectors are limited to the methods of attaching collectors to a vertical, sloped or horizontal surface (usually roof or façade) and the distance to the storage vessel.

For both main types of collectors (flat plate and vacuum tube) an extended array of aids and fasteners are available to integrate the collector with tiled roofs, flat roofs or vertical facades. For optimal performance the collector is of course positioned towards the sun. Higher inclination angles (pitch) result is higher performance during the winter season.

For certain types of solar collectors it essential that the storage vessel is positioned above the collector to allow a thermosyphonic effect for circulating the working fluid. Such collector types are however more typical for hot water function only.

The distance and height difference between storage and collector is overcome by a circulator. Although each system can be made to fit, average domestic systems employ circulators with a maximum height of 5 meters. Longer distances should also be avoided to reduce heat losses.

6 SITING OF BOILERS

The position, or siting, of a boiler in a building can both be a consequence of certain dwelling/system characteristics (dependent on existing piping, type of boiler, fuel/energy source, flue, etc.) and be a determining factor for certain system characteristics (a small kitchen may be able to suite a wall hung boiler, but not a large floorstanding one, etc.).

The selection of the boiler site will depend on costumer preferences (or in case of new build, the preference of the architect/planner/developer) and the options open to him/her regarding boiler type, flue type and placement, fuel/energy source and many other aspects. The decision process concerning siting of the boiler is at best a balancing of sometimes contradictory choices, e.g. a wish to have the boiler located close to the kitchen faucet opposed to a reality that the only room available for the boiler of choice can be found in the attic.

A planner should take into account the following aspects when determining the siting of a boiler:

- Access: Especially boilers in apartment buildings should be accessible without having to enter the private domain of building occupants. For boilers in single family houses this is often difficult to avoid (even if the boiler is placed outside).
- Position in relation to fuel/energy source: It is evident that there is a certain logic to the relation of boilers and their fuel/energy source. Solid fuel fired boilers are located close to the fuel storage (or vice versa). Oil boilers are often located next to the (existing) tank although extended supply lines are possible (with the oil tank outside the house). LPG boilers are not allowed to be placed next to the storage tank, but the gas line can more easily be routed through the house. This also goes for natural gas fired boilers. For heat pumps using ventilation air as heat source the routing of ventilation ducts influence the position of the boiler. Heat pumps with ground source collectors have somewhat more flexibility although the distance to the source should be limited, which also goes for boilers connected to solar collectors. Small electric flow-through boilers can be sited virtually everywhere.
- Position in relation to flues and chimneys: A similar logic applies to boilers and their flues so that most boilers are positioned in the vicinity of either an outside wall, roof or chimney/flue duct. The flue itself must also be positioned in accordance with local building regulations that may prohibit flues in the vicinity of awnings, windows, doors, passageways, etc. So it might be your neighbours window which prohibits installation of your flue and consequently your boiler in a certain place.
- Position in relation to mains water, drainage, existing pipework: Apart from fuel/energy and flues boilers are also connected to mains water (in case of combis and for topping up system pressure), drainage (for condensing boilers) and central heating pipework.
- Weight of the boiler (possibly including storage tanks): Boilers weighing over 50 to 60 kg 9dry weight) are often sited on the ground floor, lighter boilers can be hung from the wall in any floor. However exceptions do occur since there are wall hung boilers with a 60 litre storage horizontally placed next to the boiler with an overall dry weight of 60 kg and over 120 kg when in operation. Limits to what one person is allowed to lift apply in many countries.
- Volume of the boiler: Just like weight, the volume of the boiler (including tanks) determines its options for positioning the system. Many ground source heat pump

systems would be very flexible in siting given that electricity and the collector circuit is relatively easy to route and there are no flues to take into account. However if a storage tank is supplied with the heat pump the only option often is the basement or a large attic. This aspect is therefore also related to the average size of dwellings which varies considerably across the EU.

- Noise: Often overlooked as argument in siting of a boiler it certainly is a very important aspect. Modern fan-assisted boilers can produce sound levels that make placement in or near bedrooms or living areas unpleasant. The same goes for electric, compressor-type heat pumps (although modern heat pumps are claimed to be less noisy than their predecessors). There are examples where heat pumps had been installed under the stairs, in a cupboard which acted as a soundboard [73] .
- Ambient aspects like temperature / moisture: Most, if not all installations, need to be protected from freezing and/or excessive moisture (risk of corrosion). This could for instance prohibit placement in an un-insulated loft or basement. The house owner should therefore first take measures to prevent freezing or prolonged exposure to excessive moisture before installing a boiler in such areas. Measures could range from insulating the loft/basement to applying anti-freezing equipment (heating wires). Whether a boiler is situated in a heated or unheated area is also recognised in many building energy performance calculations. Some boiler types are designed to be placed outdoor (e.g. on balcony).
- Distance to rest of heating system: This issue is most relevant for hot water equipment, including combi-systems. A long distance from the combi to the kitchen faucet (which induces the most frequent tappings) should be avoided.
- Safety aspects: Safety is also of major influence on boiler siting. In many countries boilers operating with combustible fuels are not allowed to be placed in main living areas (like bedroom of living room) and strict regulations for the ambient conditions of the boiler apply (an example are the German FeurungsanlageVerordnung "FeuVo" for each region).
- Comfort aspects: For the small group of backboilers it is of course the local heat emission that requires siting of the boiler in the main living area [for 'noise': see above]

Many of these aspects are regulated through local building regulations and limit the options for siting a boiler. This also means that siting of boilers in buildings is very much influenced by the characteristics of the buildings in that area, which are often a result of cultural factors. Such factors may explain why it is that in two major 'gasified' countries, the UK and Italy, boilers are usually situated in the kitchen, whereas in the Netherlands (the third 'gasified' country) the boiler is often located in the loft or attic. Given the long history of heating it is often difficult to identify whether the house helped shaping the position of the boiler or the other way around. The legacy of previous heating systems installed is certainly a powerful aspect of siting.

In new builds the position of the boiler is not constrained by existing systems and installations and one can imagine that in smaller projects, where client and architect work together closely, the position is well thought through. In larger development projects (plans for tens to hundreds of houses) such eye for detail is not automatically the same and it is often noted that such projects the installation is often considered in the design stage at the very latest, meaning that the boilers and all other equipment have to be squeezed into an existing floorplan, which is of course not always optimal[73].

The following pages present some examples of boiler siting.

[73] Roelof, A.van, Belangrijke rol architect bij inpassing warmtepomp, Stedenbouw & Architectuur 16, 2000.

Figure 6-1.
Heat pump in basement (storage left)
(Source:
http://www.waermepumpentag.de)

Figure 6-2.
Heat pump in boiler room
(Source: http://www.alfredschneider.de)

Figure 6-3.
Gas storage boiler (together with central ventilation air heat recovery unit) in basement (Source: www.passiefhuis.nl)

Figure 6-4.
Removal of old oil boiler, new boiler in background
[www.renovieren-mit-energie.de/index.php?id=26]

Figure 6-5.
Boiler in conservatory
[www.geosolar.co.uk]

Figure 6-6.
Boiler in attic [www.geosolar.co.uk]

Figure 6-7.
Boiler in loft
[www.vanderschaftbv.nl/htm/home.htm]

Figure 6-8.
Boiler plus instantaneous gas water heater in loft [anonymous]

Figure 6-9.
Boiler in conservatory
[www.geosolar.co.uk]

Figure 6-10.
Electric boilers can be sited virtually everywhere [www.geosolar.co.uk]

Figure 6-11.
Boiler in kitchen with fascia [www.briscoe-smith.org.uk]

Figure 6-12.
Boiler in kitchen
[www.mkweb.co.uk/.../
DisplayArticle.asp?ID=20625]

Figure 6-13.
Boiler in kitchen
[www.blackhallplumbing.co.uk/
gas_service.htm]

Figure 6-14.
Boiler outside
[http://www.heatingworld.com/grandee1/
external.htm]

Figure 6-15.
Air-to-air heat pump outside
[www.heinzebauoffice.de/
bauprodukte/index.php?...]

Figure 6-16.
Air-to-air heat pump inside

7 DISTRIBUTION

7.1 System lay-out

The 2003 report on classification of circulators [Bidstrup 2003] presents a picture of distribution systems for central heating in Europe (EU15). Two systems prevail: the one-pipe system where radiators are connected in series, and the two-pipe systems where radiators are connected in parallel. The two systems can be combined and this is quite usual in apartment buildings / multi-family housing with a collective boiler: The vertical strands follow the one-pipe system (effectively creating a feed circuit for each floor), the horizontal strands (usually per apartment) follow the two-pipe system (less cross influence of radiators on each other).

Figure. 7.1.
the one-pipe system layout

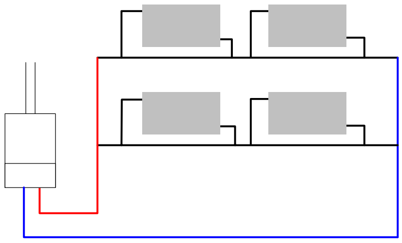
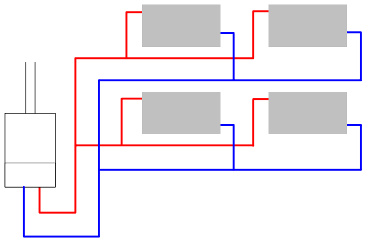
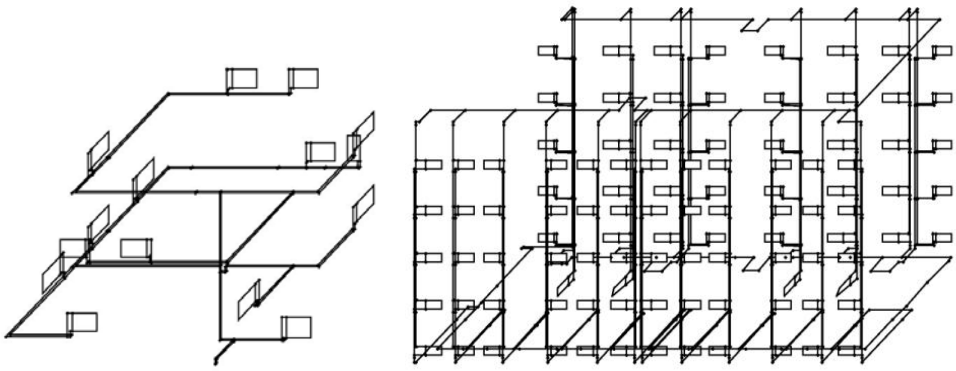


Figure.7.2.
the two-pipe system layout



The lay-out of the distribution system can become quite complicated as shown in the figure below.

Figure 7-3.
Single family housing (right), Multi-family housing [74](left)



The two-pipe system appears the prevalent distribution system: 12% of the European central heating systems are one-pipe systems and 88% are two-pipe systems. Only in The Netherlands and Austria do one-pipe systems make up more than 20% of installations.

[74] Source: mlu.mw.tu-dresden.de/.../trnsys/type_57.htm

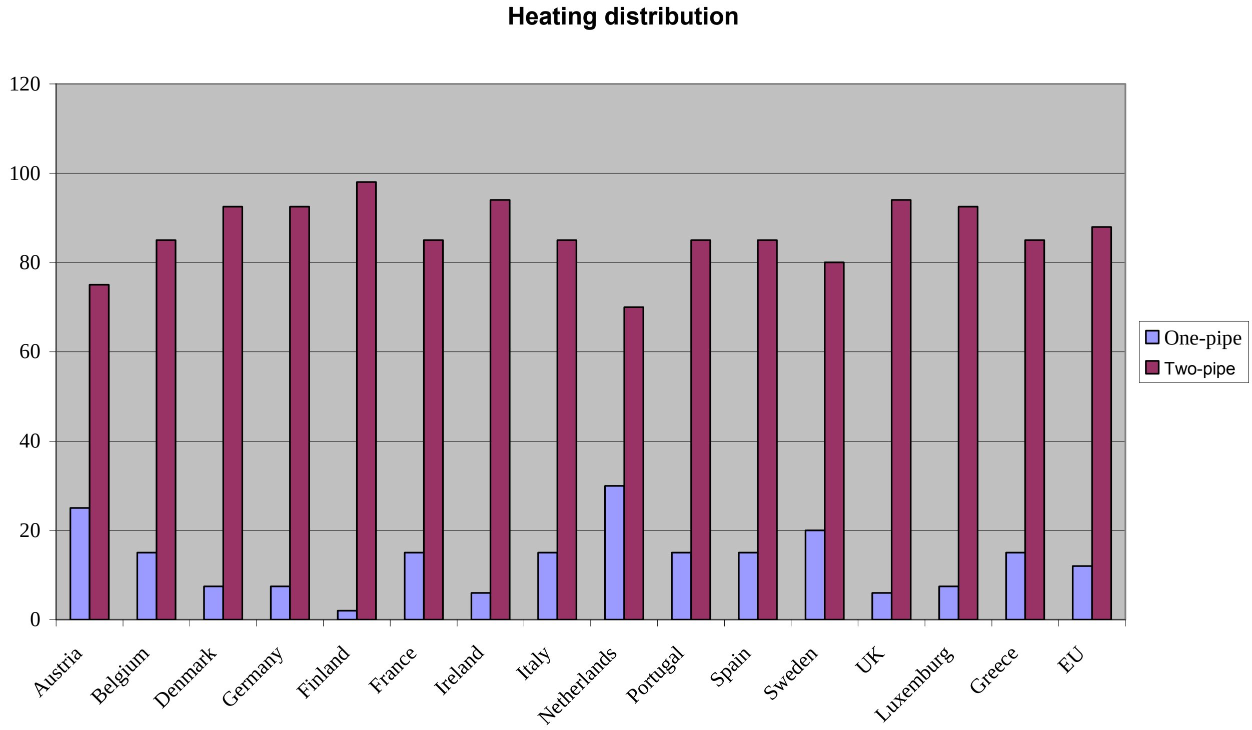


Figure 7-5.
EU-25 split between one- and two-pipe systems per country: Bidstrup 2003

Most new distribution systems are two-pipe, since dimensioning and control of flow is more simple: All radiators are fed with the same temperature. For optimal heat distribution the radiators have to be 'tuned' (NL: inregelen) to align the pressure drop in each radiator with the rest of the system. The siting of the boiler is relatively robust (can be changed).

One-pipe systems require less space to install, but are more difficult to dimension. The first radiator gets the hottest water, so the surface area can be smaller. The subsequent radiators need to be sized according the feed temperature at that point in the strand which also may change if the preceding radiator(s) is/are turned on (valve open) or off (valve closed). The siting of the boiler cannot be changed afterwards (or would require re-sizing of radiators). One-pipe systems are quite common in combination with back boilers. The back boiler itself heats the main room, the one-pipe systems feeds adjacent bedrooms, kitchen. etc.

It is easy to see that if a modern boiler is combined with an old 'inherited' distribution system (with a layout made specific for a certain system temperature and boiler siting) the result can be suboptimal - e.g. the return temperature does not reach the desired values, the heating performance in certain areas/rooms is inadequate (too hot or too cold). A boiler with high enough power output, combined with a powerful circulator is often able to deliver heat to even the most remote areas of the house, but needless to say it does this with a efficiency loss.

8 EMITTERS

8.1 Components

Radiators

According to BRGC (page 71) some 50 million radiators were sold in the EU 25 [75] , of which 3.6 million were dry electric convectors / storage heaters, leaving some 46 million wet system radiators, or the equivalent of 6.6 radiators per boiler sold. This includes radiators sold for district and collective heating.

Table 8-1. Radiator sales by country

Country	1990		2004		1990-2004
	000	%	000	%	% change
Austria	890	2,1%	844	1,7%	-5%
Belgium	859	2,0%	1100	2,2%	28%
Czech Rep.	826	2,0%	1398	2,8%	69%
Denmark	503	1,2%	391	0,8%	-22%
Estonia	29	0,1%	89	0,2%	207%
Finland	307	0,7%	298	0,6%	-3%
France	5704	13,5%	7014	14,1%	23%
Germany	10340	24,5%	7759	15,6%	-25%
Greece	863	2,0%	1178	2,4%	37%
Hungary	540	1,3%	926	1,9%	71%
Ireland	392	0,9%	1002	2,0%	156%
Italy	6295	14,9%	6399	12,9%	2%
Latvia	11	0,0%	191	0,4%	1636%
Lithuania	50	0,1%	217	0,4%	334%
Netherlands	1909	4,5%	1578	3,2%	-17%
Poland	1641	3,9%	3545	7,1%	116%
Portugal	33	0,1%	287	0,6%	770%
Slovakia	230	0,5%	445	0,9%	93%
Slovenia	140	0,3%	214	0,4%	53%
Spain	2247	5,3%	4281	8,6%	91%
Sweden	1100	2,6%	844	1,7%	-23%
UK	7365	17,4%	9726	19,6%	32%
Total EU22	42274	100,0%	49726	100,0%	18%

Most radiators sold in the EU are of the steel panel type (59%), followed by aluminium (15%) and other steel (eg. tubular designs, also 15%). Cast iron forms a small portion of sales (3%). Towel warmers (radiators designed for bathroom environments, allowing easy drying of towels) make up 8% of radiator sales (page 8 of BRGC).

[75] Excluding Cyprus, Luxemburg and Malta.

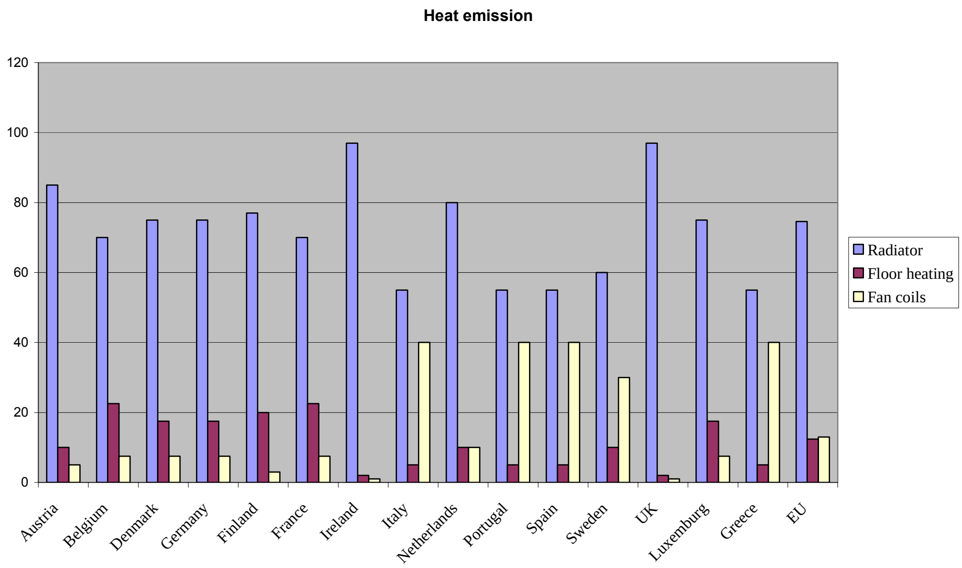
Radiator sales by type

Table 8-2. Radiator sales by type (BRGC)

Country	steel panel	other steel	cast iron	aluminium	other materials	towel warmer
Austria	82%	7%		3%		7%
Belgium	80%	3%			4%	4%
Czech Rep.	77%		6%		4%	13%
Denmark	96%					4%
Estonia	80%		3%	7%		5%
Finland	85%	15%				(oth. st.)
France	69%	5%		14%		10%
Germany	76%	12%		1%		11%
Greece	80%	15%		2%		3%
Hungary	86%			12%		5%
Ireland	92%	6%				2%
Italy	2%	25%	18%	43%		12%
Latvia	94%		1%	2%		2%
Lithuania	83%		4%	6%		7%
Netherlands	86%	7%				7%
Poland	67%			19%		14%
Portugal	6%			80%		13%
Slovakia	85%		3%	2%		10%
Slovenia	77%			14%		8%
Spain	17%	%	3%	75%	1%	4%
Sweden	94%	6%				(oth. st.)
UK	90%	1%	1%	1%		7%
Total EU22	**59%**	**15%**	**3%**	**15%**		**8%**

[Bidstrup] shows that 75% of all central heating systems in the EU have radiator systems. Floor heating systems and fan-coil systems are 12% and 13% respectively. These figures are probably including commercial systems, since fan-coil systems are very rare as domestic systems. Figures for underfloor heating remain very difficult to retrieve although the segment is growing in new housing and non-residential housing and especially in Germany.

Figure 8-1.
Emitters in Europe
(Source: Bidstrup 2003)

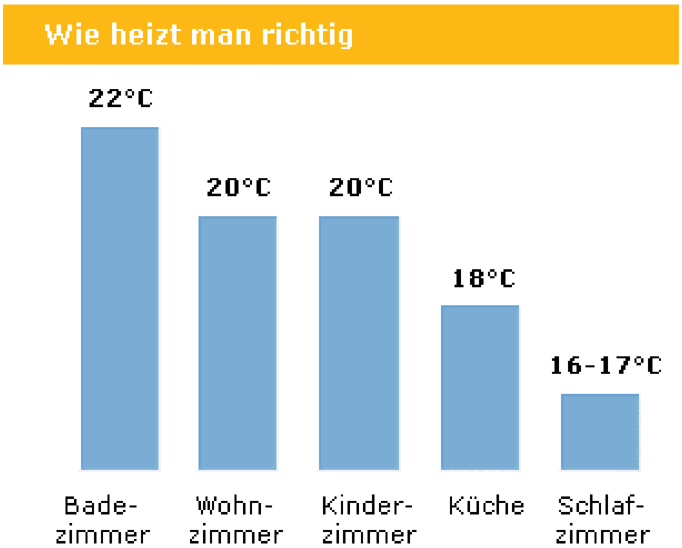


9 CONTROLS

9.1 Comfort issues

Most, if not all, building regulations prescribe the room temperatures that are to be achieved during the coldest day. For the living room this is often 20 to 22°C, for the kitchen and bedroom this is often 18°C. The figure below presents the values for the German DIN 4701.

Figure 9-1.
Wie heizt man richtig? [76]



These values are of course design values. For heat loss calculations one can use these design values or an overall average room temperature as the Dutch EPN does (with a daily average indoor temperature of 18ºC). The German PassivHause-concept calculates with 20ºC due to ventilation with heat recovery and no nighttime reduction (because of very high insulation level). This raises the question whether in modern dwellings (with ventilation with heat recovery and no nighttime reduction) one should calculate with 18ºC. [77]

Besides calculating with design temperatures one can also use the real-life values. Some sources recommend lower temperatures than the regulations mention, see the example below by www.wasserwaermeluft.de (Standard DIN4701 between brackets) [78]

- The temperature in the living room should be 20°C average (20°C);
- For the bedroom 16 - 17°C (20°C) suffices for a healthy sleeping environment;
- The children's room can be kept at average 20°C (20°C);
- The bathroom should be kept warm at 22°C (24°C);
- In the kitchen a temperature of 18°C (20°C) suffices, due to the extra heat produced by cooking.

[76] www.erdgasinfo.de

[77] http://www.passiefhuis.nl/images/Artikel-06-2006.pdf

[78] http://www.wasserwaermeluft.de/b2c/waerme/heizung/index.html

9.2 Controls at emitter level

9.2.1 *Control through Radiator Valves*

CH Tuning for optimal flow

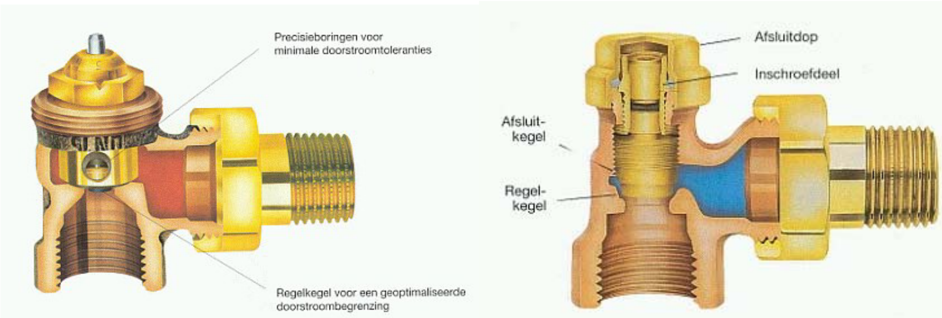
One aspect of distribution that is often overlooked is the adjustment of the radiator flow to the needs of each radiator (DE: "Ausgleichen", NL: "inregelen"). In old, gravity fed central heating systems the correct sizing and dimensioning of pipes and flows (here: "CH tuning") was necessary to achieve a satisfactory performance of the system. However with the advent of two-pipe distribution systems and powerful circulators the "art" of system tuning is neglected and in many cases even new installed systems are delivered without tuning the system for optimal flow [79] .

The relevance for the central heating boilers lies herein that with a optimalised (tuned) system the feed and return temperature reach their designed pre-set value. In practice many flow-regulating valves are left in the 'open' position and combined with a oversized circulator (reasoning: "better to be on the safe side") the resulting flow is too large, leading to too little heat exchange with the room and a too high return temperatures. The opposite is also possible (valves are closed too much, too little flow, too high temperature difference) but this is less often the case.

An optimised system may also result in less temperature overshoot and thus a more even heating up of the premises. In case the dwelling previously had some "cold spots" the tuning of the system may lead to an increase of energy consumption (but with higher comfort level).

The valves that regulate the flow (set once, not used for on/off or temperature adjustment) are often incorporated in the "foot-valve" of the radiator or in the "top-valve" (the manual or thermostatic valve). See the next paragraph for more information on the type of valves used in most central heating systems.

Figure 9-2.
Adjustable radiator valves (left: top-valve, right: foot-valve)



Sales and stock of valves

BRGC states that thermostatic radiator valves (TRVs) are very common in heating systems in the coldest climates in Europe (Scandinavia and Germany, Austria, 60% tot 95%) and making progress in UK, Ireland (close to 40%). Netherlands, Belgium and France are between 20 tot 30% and Italy, Portugal, Spain and Greece are at 15-20%. The Luxembourg score of 95% may be due to limited reliability of the survey (normally Luxembourg data resembles Belgian data closest). For new radiators the percentage equipped with TRVs is higher.

All in all it is believed that in the EU15 some 49% of all systems have thermostatic valves and 47% have manual valves [80]. The rest have either TRVs fitted in the return

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[79] http://www.senternovem.nl/kompas/utiliteitsbouw/Hulpmiddelen/wzi/index.asp

[80] MTS states that 50% of EU central heating system is fitted with TRV is a little bit overestimated. According to BRGC 2006-2007, the TRV penetration on stock is around 42%. It is confirmed that TRVs sales are increasing (year 2006: around 50%)

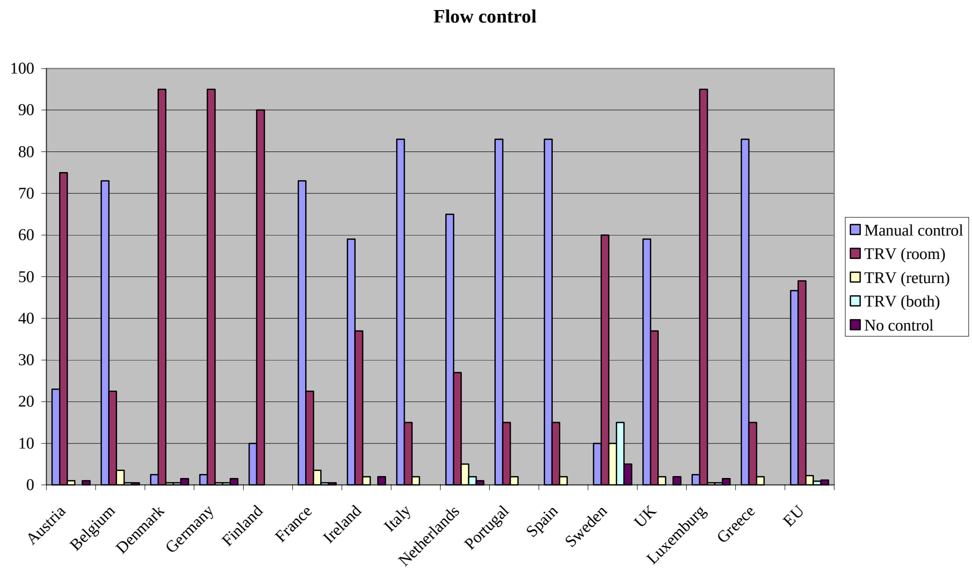
pipe (not adjusted by end-users) or on both (2% and 1% respectively). Some 1% of installations apply no flow control (in Sweden this is 5% of installations).

Table 9-1. Penetration of Thermostatic Radiator Valves in use and new sales (BRGC)

Country	% of radiators fitted with TRV's	
	in use	of new sales
Austria	75%	75%
Belgium	22%	30%
Czech Rep.	majority of systems	40%
Denmark	95%	95%
Estonia	few systems	large majority
Finland	90%	> 90%
France	22%	70%
Germany	95%	95%
Greece	15%	?
Hungary	few systems	65%
Ireland	38%	50%
Italy	15%	50%
Latvia	few systems	50%
Lithuania	few systems	50%
Luxemburg	> 90%	90%
Netherlands	< 30%	50%
Poland	unknown	large majority
Portugal	< 20%	67%
Slovakia	unknown	40%
Slovenia	unknown	70%
Spain	15%	15%
Sweden	60%	50%
UK	40%	67%
Total EU15	49%	

The report by [Bidstrup 2003] presented similar figures and estimated some 49% of EU15 installations to be equipped with TRVs.

Figure 9-3.
Classification of Circulators, (Bidstrup 2003 [81]



If we assume that almost 50% of all EU central heating systems are equipped with thermostatic radiator valves and the other half with manually controlled valves the average EU heating boiler is faced with a emitter system with variable volume.

This is an important issue for central heating circulators that more and more are integrated with the boiler. Fixed speed circulators (single speed or manually adjustable 3 speed setting) cannot respond to a lower system volume, caused by closing of TRVs (or closing of manual valves) and continue to circulate the water with too much pressure, causing flow noises and unnecessary power consumption. Automatic variable speed circulators have features that allow them to respond to diminishing system volumes by lowering their speed and thus their power consumption as well. In how much the power consumption goes down depends on the actual motor type and control algorithm used in the variable speed circulator.

9.3 Controls at system level (outdoor/room + boiler)

See Task 4 report.

9.4 Users and heating controls

In 2004 a report called "User behaviour in energy efficient homes" [82] was issued in the UK, describing a survey of over 118 people who have received energy efficiency improvements to their homes to find out what use they are making of them. It is the largest study of its kind and has produced valuable information. It is clear that more work could be done, especially comparing these people with those who have not had improvements to their homes, which would give an even greater picture of the extent to which domestic energy use could be reduced simply by recommended use of existing systems, rather than some of the more wasteful ways that individuals can devise. It is of even more concern to realise that some of the most wasteful ways do not even result in comfort levels desired by the occupant, so that the waste achieves nothing.

The hypothesis has been set up, describing the relationship between the results someone gets from their system (“Desired Results” – Yes or No), their behaviour in

[81] N. Bidstrup, G. Hunnekuhl, H. Heinrich, T. Andersen, Classification of Circulators (ver 5.0), Europump - WG 13, February 11, 2003

[82] Pett, Jacky, Guertler, Pedro, User behaviour in energy efficient homes - Phase 2 Report, UKACE, Energy Saving Trust and Housing Corporations, March 2004.

managing their heating ("Behaviour Style" – Efficient, Reasonable or Inefficient) and four key influences on that behaviour. These four influences or factors are:

- demographics such as age and employment situation
- previous experience such as heating systems and whether they lived in the house before it was improved
- their general energy awareness as shown through heating system use, use of energy saving strategies elsewhere in the home and attitudes to energy supplier switching
- the instructions and advice they were given, by whom and when

The analysis found that the most likely influences on Behaviour Style are whether or not a household has children, is full time employed, has had previous experience of gas central heating, has switched energy supplier and is aware of energy labels. The most likely influence on whether or not Desired Results are achieved appears to be the position of the thermostat.

The following findings are made in relation to the hypothesis of user behaviour in energy efficient homes:

- Most respondents (86%) get the Desired Results from their heating systems
- 23% use their heating systems in a way that corresponds to policy expectations, i.e. are Efficient;
    - 89% of these get the Desired Results
- 50% do it in a way that is efficient from their own perspective; i.e. they get results in a way that suits them and their lifestyle, i.e. is Reasonable;
    - 96% of these get the Desired Results
- The remaining 23% are Inefficient; they do not use the systems effectively and they do not get the best value for their lifestyle;
    - only 55% of these get the Desired Results

Further research is suggested to develop the relationships between Behaviour Style in using the system, obtaining Desired Results, and the likely influences on these identified in the analysis. In addition it is recommended that further analysis of energy advice provision is carried out to determine with greater certainty the 'best practice' case study examples, that best practice in setting heating controls and TRVs in relation to thermostat positions is identified and that energy advice providers review heating system documentation provided by installers.

Table 9-2. Control systems for gas/oil fired central heating systems

Type	*Time set*	*Temper-ature set*	*Location*	*No.*
Mechanical 24 hr	19	3	Kitchen	11
			Airing cupboard	5
			On boiler!	3
Mechanical 7 day	6	4	Kitchen	4
			Hall	1
Digital 7 day	49	3	Kitchen	28
			Hall/foot of stairs	2
			Living room	1
			Top of stairs	1
			Bedroom	5
			Cupboard (inc. airing)	2
			On boiler	1
Integral time/temperature controller	2	3	Hall	1
			Kitchen	1
			On boiler	1
Wall mounted room thermostats	14	74	Kitchen	4
			Hall/foot of stairs	39
			Living room	26
			Top of stairs	2
Thermostatic radiator valves (TRVs)	54		All radiators	
Bypass systems	5	1		

Table 9-3. Heating pattern description classified by type of response

Heating pattern described	*No.*
Set hours with or without manual intervention	37
All day (assumed efficiently)	14
Switch on/off at boiler or thermostat	21
Reliance on secondary heating e.g. gas fire/cooker	2
Other (storage radiators, community heating)	13

Figure 9-4.
Thermostat settings in degrees Celsius; all responses and excluding over 75s

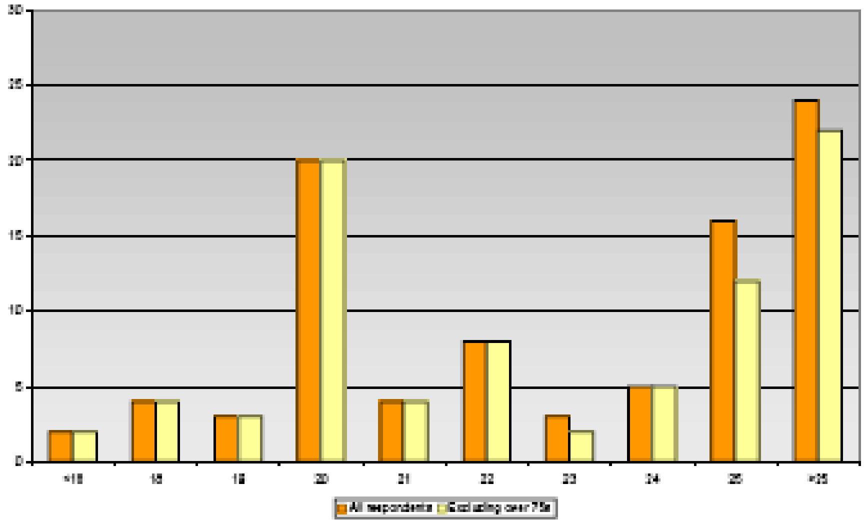


Table 9-5. Number, position and settings of thermostats for key indicators

	All	Hall		Kitchen		Living room		n/s	
	deg C	No	deg C	No	deg C	No	deg C	No	deg C
All		39	22.8	4	21.25	26	23.3	21	24.8
Yes	23.3	33	22.7	3	20.7	26	23.3	20	24.7
No	23.9	6	23.2	1	23			1	28
EB	22.1	10	22.1	2	21	9	21.4	1	25
RB	23.6	24	23	1	20	14	24.5	13	24.3
IB	24.7	5	23.6	1	23	3	24	7	25.9

10 CHIMNEYS, FLUES AND PLUMES

10.1 Introduction

This section has been presented as an separate report before. The reason why this subject was treated with priority is that it has given rise to concern and misunderstanding, especially in view of some Member States (on the verge of) making condensing boilers almost mandatory. Between the parties discussing this issue there is a clear need for more objective technical information that this first draft of the Task 3 tries to provide.

The main message of this report is that there are several good and economical solutions to realizing rooftop flue gas outlets for condensing boilers. That these solutions are not applied is a problem of lack of knowledge/training of the installers, and is typical of the first few years in which a country is confronted with the condensing boiler technology without proper training of the installers.

It is hoped that this first draft report on Task 3 will help in clarifying to the ongoing discussion. Comments and contributions are welcome.

10.2 Classification of gas appliances according to the method of evacuation of the products of combustion

In 1999 TC 109 produced the CEN Report CR 1749: European scheme for the classification of gas appliances according to the method of evacuation of the products of combustion (types)appliance categories, which identifies the various ways (or types) of evacuation of combustion products, often combined with ways to supply air for combustion.

The table on the following page gives an overview of the categories of flue gas systems. Basically, there are three main categories: A (no flue gas exhaust), B (open systems with a flue gas exhaust) and C (room-sealed or 'closed' systems, i.e. that take the combustion air from outside). For central heating boilers only type B and C are relevant.

After this letter there are two digits. In the B-type this relates to the presence of a flue damper (no=1, yes=2) or whether the flue gas is collective (=3). With the C-type this relates to several (1 to 8) configurations, e.g. vertical or horizontal pipe, air intake from the same pressure zone as the flue gas exhaust or not, chimney and boiler certified separately, etc..

The second digit relates to whether the combustion takes place without a fan (=1), after the heat exchangers (=2) or before the burner (=3). For flue gas systems of type B11 (open system with flue damper and no fan), which is normally only allowed in a well-ventilated boiler room or similar— there is an extra denomination 'B11BS' if the type B11 is equipped with a thermal security provision and could thereby sometimes be used in a living space. It shuts off the gas supply if it detects flue gases in the room; after a while it automatically checks if the situation has improved.

For Germany and Austria an extra indent "x" in the column "Airtight enclosure" stands for appliances that fulfil higher standards on airtightness of the enclosure: all parts (of the cabinet /flue gas system) under positive pressure are leakproof so no critical quantities of flue gases can escape.

Most boiler manufacturers test and certify their models with several types of flue systems and present these options in the brochures and installation manuals that go with the product. But the installer must always respect the national regulation specifying requirements for chimneys.

Table 6-1: Classification of Appliances and flue gas systems according CR1749

		Flue gas system	Supply air	type of flue gas system	Position of fan		Airtight enclosure	Remarks
A	A1	no		open exhaust (flue gas emitted in surroundings)	1	no fan		
	A2				2	after heat exchanger		
	A3				3	before burner		
B	B11	yes	from room (open system)	1 with flue damper	1	no fan		(B12/14 not admissible in DE)
	B12				2	after heat exchanger		
	B13				3	before burner		
	B14				4	behind flow direction		
	B21			2 without flue damper	1	no fan		(B21 not admissable in DE)
	B22				2	after heat exchanger		
	B23				3	before burner		
	B31			3 without flue damper, collective chimney	1	no fan		(B31 empty category)
	B32				2	after heat exchanger		
	B33				3	before burner		
C	C11		from outside (room sealed)	1 Lateral (horizontal, through wall/roof) flue exhaust and air intake - in same pressure zone	1	no fan		
	C12				2	after heat exchanger	x	
	C13				3	before burner	x	
	C21			2 Combined single shaft air intake / flue exhaust	1	no fan		(typical for UK)
	C22				2	after heat exchanger		
	C23				3	before burner		
	C31			3 Vertical (through roof) flue exhaust and air intake - in same pressure zone	1	no fan		(C31 not admissible in DE)
	C32				2	after heat exchanger	x	
	C33				3	before burner	x	
	C41			4 Dedicated separate shafts for flue exhaust and air intake (possibly collectively used)	1	no fan		(C41 not admissible in DE)
	C42				2	after heat exchanger	x	
	C43				3	before burner	x	
	C51			5 Flue exhaust and air intake in different pressure zones	1	no fan		(C51 not admissible in DE)
	C52				2	after heat exchanger	x	
	C53				3	before burner	x	
	C61			6 Gas-fired appliance to be connected with flue gas / air intake system tested and certified separately	1	no fan		(C61 not admissible in DE and C6x Belgium)
	C62				2	after heat exchanger	x	
	C63				3	before burner	x	
	C71			7 vertical flue exhaust and air-intake - air intake from loft space	1	no fan		(C7x not admissable in DE, typical for UK)
	C72				2	after heat exchanger	x	
	C73				3	before burner	x	
	C81			8 Flue exhaust connected to negative pressure chimney shaft, air intake from different pressure zone	1	no fan		
	C82				2	after heat exchanger	x	
	C83				3	before burner	x	

Although in CR 1749 a wide range of methods of evacuation of combustion products are mentioned some evacuation methods are typical for certain EU countries. The national regulations per country stipulate the possible methods.

In Sector Group Forum Gas TC 109 – TC 166 changes of CR 1749 can be discussed. The classification is introduced in the Harmonised Standards (e.g. EN 483) developed in the light of the Gas Appliances Directive 90/396/EEC.

10.3 Classification and designation of Chimneys

The type of chimney that can be applied to a certain boiler and site depends on the chimney performance. EN 1443:2003 designates chimneys in terms of a coded string for the following performance aspects: temperature class, pressure class, condensate resistance class, corrision resistance class and soot fire resistance class.

The above general designation string is further complicated depending upon the product standard in question. This means that the designation string can be different for chimneys made of metal, plastic, clay/ceramic or concrete. The examples below already show the differences between metal and plastic designations.

Table 6-2: Designation of chimneys accoridng EN1443, two examples

Example plastic	System chimney	EN14471	T120	P1	W	1/2	O (30)	I C/E L
Example metal	System chimney	EN1856-1	T250	N1	D	Vm - L11045/063	O (40)	
relates to:								
Product description	...							
European standard		ENxxx						
Temperature class			Txxx					
Pressure class				P/N/H,1/2/3				
Resistance to Condensate class					W/D			
Corrosion resistance class						(V),1/2/3		
for metals: Liner specifications						*Lxxxxx*		
Soot fire resistance class							O/G	
Distance to combustible material							(xx)	
for plastics: Location Fire behaviour Enclosure								... ...

The sections below describe the common chimney performance characteristics that are covered by most chimney designation requirements. Note that these are not exhaustive and the designation may differ from type and material of chimney.

10.3.1 Product description

Describes the product in general terms, e.g. system chimney, non-bonded flue block, single wall chimney, liner, etc.

10.3.2 European standard

Gives European standard for which the product has been tested, e.g.:

Table 6-3: Some European standards for chimneys, structured by material

EN 1856-1	for metal chimneys, e.g. stainless steel, aluminium
EN 14471	for plastic chimneys, e.g. polypropylene
EN 13063-1 -2	for clay/ceramic products
EN 1858	for concrete products

10.3.3 Temperature class

Temperature class is expressed as "T" followed by a number which is less than or equal to the nominal working temperature i.e. the average flue gas temperature in ºC obtained during the nominal/rated output (usually the maximum operating level, DE: Nenndauerbelastung), eg. T120 is max 120ºC and T450 is max. 450ºC.

Table 6-4: Temperature classes

Temperature class	design operating temperature ºC
T080	>80
T100	>100
T120	>120
T140	>140
T160	>160
T200	>200
T250	>250
T300	>300
T400	>400
T450	>450
T600	>600

The flue gas temperature is mainly determined by the type of boiler. Most conventional, atmospheric gas and oil-fired boilers operate with average flue gas temperatures of 200-250°C. The maximum temperatures may be higher (up to 300°C). Plastic flue liners (PP - polypropylene) can widthstand operating temperatures up to 120ºC and are therefore not suited for conventional and low temperature boilers. Modern condensing boilers produce flue gases at an average temperature of 60°C with a maximum of 120°C. In that case plastic flues and chimneys can be used and in fact are –for cost and technical reasons—very common.

10.3.4 Pressure class

Pressure class is expressed as either "N", "P" or "H" followed by either "1" or "2". N relates in general to natural draught chimneys i.e. operating under negative pressure where the value 1 or 2 allows for a different class of leakage rate for the product. In the UK for instance the value N2 will be assigned as a minimum for masonry chimneys. Simple slide-in aluminium tubes (no seals) are often tested as N1 and not suited for fanned boilers. P and H relate to chimneys which operate under 'normal' and 'high' positive pressure e.g. for fan assisted applications and diesel generators respectively.

Table 6-5: Pressure classes

Pressure class	Leakage rate	Test Pressure (Pa)
N1	2.0	40 for negative pressure chimneys
N2	3.0	20 for negative pressure chimneys
P1	0.006	200 for positive pressure chimneys
P2	0.120	200 for positive pressure chimneys
H1	0.006	5000 for high positive pressure chimneys
H2	0.120	5000 for high positive pressure chimneys

10.3.5 Corrosion class

This designation refers to operating conditions (wet or dry), corrosion characteristics of the fuel used and (if applicable) the properties of the liner.

Operating conditions

The indent W or D in the chimney designation indicates whether the chimney is suited for wet or dry operating conditions.

Table 6-6: Condensate resistance

W	wet operating conditions
D	dry operating conditions

Condensation in the chimney occurs if the wall temperature of the flue is below the dew point of the flue gases. LT boilers produce fluegases with low temperatures, with the result that the gases can condensate on the inner wall of the chimney.

When installing condesing boilers as retrofit, the flue gas system must be suitable for condensing application and the consistence of the old system must be checked. Normally changing a boiler means at the same time changing the flue.

Fuel types

The corrosion resistance class of the chimney is indicated by a number that relates to the type of fuel:

Table 6-7: Corrosion resistance class

V1	is for gas and light fuel oil (kerosene) with a sulphur content below 50mg/m^3.
V2	is for light oil / wood in open fires (DE: Naturbelassenes Holz)
V3	for heavy oil / wood in closed stoves / coal and peat
Vm	not tested and approved but rating declared by the manufacturer

The corrosion class for gas (natural or LPG) is "1": condensate that is produced when gas flue gases cool down is slightly acidic, much like normal rain water. Ceramic (for wet conditions), corrosion-resistant metals and plastics can be used (provided flue gases are not too hot).

Normally oil-fired boilers require chimney materials in corrosion class "2", but "low-sulphur content fuel oil" does not produce condensate with sulphuric substances and such condensate can be disposed off like normal gas fired boiler condensate. Suitable materials for low or no sulphuric substances in flue gases are: Polypropylene, PVDF, Stainless steel or Aluminium (thick wall).

Liner specifications

Important parameters for corrosion resistance of metal flues are flue material and wall thickness. At the moment there is no European standard specifying wall thickness of all possible flue pipes and many member states still have a minimum flue wall thickness specified in their national legislation. The standard EN 1856-1 (metal chimneys) therefore asks for flue liner specifications to be indicated in the product designation, enabling checks for compliance with national regulations by (local) authorities.

Two features are specified, firstly a code for the minimum material grade and secondly material thickness (used for metal liners).

Table 6-8 : Liner specifications

Material grade		Wall thickness (example)	
L11	for Aluminium 99% pure	040	means 0.4 mm thickness
L20	for stainless steel 304		etc.
L30	for stainless steel 304L		
L40	for stainless steel 316		
L50	for stainless steel 316L		

For system chimneys (sold together with gas boilers) the current EN483/A4 contains criteria for the flue section of gas appliances so that these system chimneys are in line with the requirements of the CPD. Note that these criteria have not been officially agreed by TC 166 (relevant for chimney components).

Table 6-9: Extract from EN483/A4 regarding wall thickness of metal chimneys

Material	Symbol	Minimum nominal thickness (mm) [b]	
		non-condensing	condensing
EN AW-4047A	EN AW AlSi12(A), and Cu<0,1%, Zn<0,15% (cast aluminium)	0.5	1.5
EN AW-1200A	EN AW-Al99,0	0.5	1.5
EN AW-6060	EN AW-AlMgSi	0.5	1.5
1.4401	X5CrNiMo 17-12-2	0.4	0.4
1.4404 [a]	X2CrNiMo 17-12-2	0.4	0.4
1.4432	X2CrNiMo 17-12-3	0.4	0.4
1.4539	X1NiCrMoCu 25-20-5	0.4	0.4
1.4401	X5CrNiMo 17-12-2	0.11 [c]	0.11 [c]

1.4404 [a]	X2CrNiMo 17-12-2	0.11 [c]	0.11 [c]
1.4432	X2CrNiMo 17-12-3	0.11 [c]	0.11 [c]
1.4539	X1NiCrMoCu 25-20-5	0.11 [c]	0.11 [c]

[a] Equivalent for material N° 1.4404 = 1.4571 (symbol X6CrNiMoTi 17-12-2).

[b] According to declaration of manufacturer, see defnition 3.4.19 (of EN483:1999/prA4:2006)

[c] Flexible liners only allowed when installed in an existing chimney

10.3.6 Soot fire resistance

Expressed as either G (with soot fire resistance) or O (without soot fire resistance), followed by the declared minimum distance to combustibles expressed in mm.

Table 6-10: Soot fire resistance

O	not soot fire resistant
G	soot fire resistant

To obtain the G classification means that the product has been tested at 1000°C for 30 minutes and remains intact and the temperature of combustible material at the designated distance does not exceed 100°C at T.amb. 20°C.

Minimum distance to combustible materials

The "O/Gxx" value indicates the minimum distance to combustible materials. The two digits describe the minimum distance to the chimney wall in mm. O50 indicates a minimum distance of 50 mm or 5 cm.

The distance to combustibles has to be read in conjunction with the soot fire resistance classification and is not a stand alone classification.

10.3.7 Additional designation

As said before different chimney materials may require different designations. For certain chimney products dimensions, thermal resistance, wall temperatures, flow resistance for the flue gas or freeze-thaw resistance etc. shall be included in the designation. These aspects are all described in the relevant European Standards.

Table 6-11: Example of additional designation for plastic and metal liners

Plastic liners		
Location	I/E/B	internal / external / both
Reaction to fire	F0/F1	classes F0 or F1
Enclosure class	L0/L/L1	classes L0/L/L1
Metal liners		
Heat resistance	Gxx,	where 'xx' indicates the heat resistance of the chimney wall material in m^2K/W multiplied by a factor 100. Therefore R40 indicates a heat resistance of 0.40 m^2K/W

For CE marking purposes the manufacturer must mark the product with all the information prescribed in the Annex ZA of the relevant harmonised product standard.

Sometimes this includes the product designation, sometimes it doesn't (depends on relevant standard and Annex ZA). It is also possible that other information, not included in the designation string, is part of the required marking.

Note that the CE marking does not always need to be on the product itself, in certain cases the marking can be put on a label, the packaging or the accompanying commercial documents.

10.4 Retrofitting of flue systems

The chimney material and performance is not the only relevant factor to consider when replacing boiler type and/or renovation of the flue gas system. The dimensions of the new chimney is at least as important for proper functioning, as well as the proper configuration of air inlets and exhausts.

For both single- or multi-family houses, single or collective shafts, flue-only or combined with air supply, etc. the chimney industry has come up with clever solutions to tackle many retrofit issues, such as illustrated below.

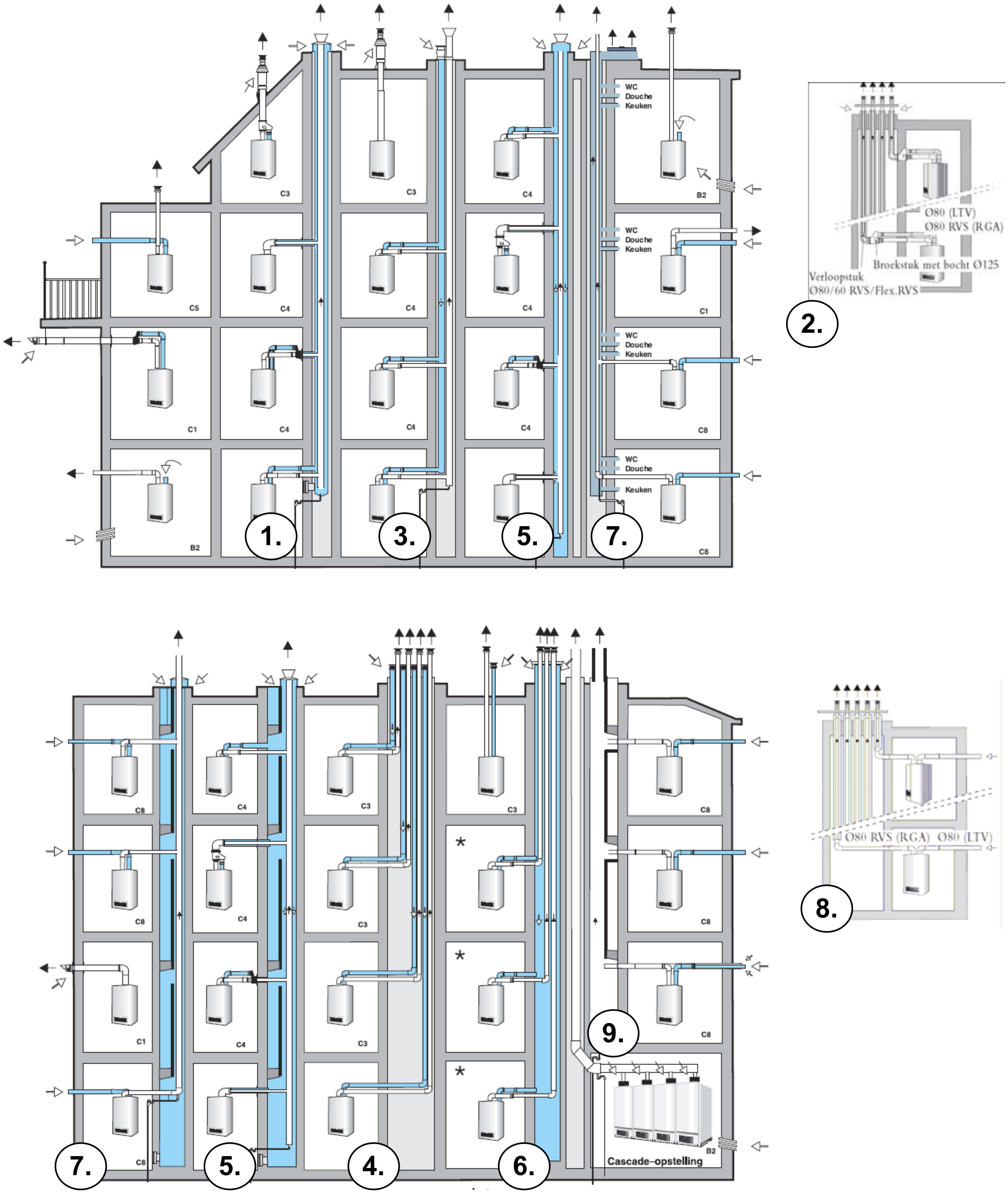


Figure 6-1. Chimney solutions (picture courtesy of Nefit-Buderus)

10.4.1 Mutli-family retrofits

A well-known retrofit problem occurs in multi-family buildings with individual appartment-owners on each floor. In such cases it can be difficult to introduce a condensing boiler on one floor whereas the other floors are still using old, atmospheric boilers, especially if all are connected to a collective flue/air shaft.

To raise the flue outlet of this individual boiler to the roof level is often not a desirable option.

To guide the flue outlet to the facade (lateral outlet) is often not an option in such buildings, either from technical point of view (too close to facade openings, in danger of not catching enough wind, too far from roof, etc.) or from easthetic/practical point of view (the lateral outlet is a nuisance for neighbours and/or easthetically undesirable because of the plumes).

A lot thus depends on how the collective chimney shaft is used and how much surplus space it provides. The table below indicates several options open to builders/house owners to connect boilers to a flue/air system in a multi-family house (the numbers refer to the numbers in figure 10-2).

Table 6-12. Flue gas exhaust options for multi-floor housing

Options		Class
1.	boilers are connected to a collective concentric flue/air system	C4
2.	boilers are connected to individual concentric flue/air pipes, the pipes are combined i a single shaft (also as flexible liner in existing individual flue pipe and remaining cavity functions as air supply)	C3
	flue gas exhaust and air intake through a parallel liner in existing shafts (flexible liners possible)	
3.	boilers are connected to a collectively used parallel air duct and flue exhaust	C4
4.	boiler are connected to individual parallel air/flue pipes (nees enough space in shaft to accomodate this)	C3
5.	flue gas exhaust through collective liner, air intake collective through shaft cavity	C4
6.	flue gas exhaust through individual liners, air intake collective through shaft cavity	C4
7.	flue gas exhaust through collective liner, air intake individual from facade	C5
8.	flue gas exhaust through individual liners, air intake individual from facade	C5
9.	flue gas through existing chimney (no liner > condensate proof surface treatment), air intake through facade	C5

Not included in this overview is the possibility for insertion of flue liners in dedicated ventilation ducts/shafts (and retrieve ventilation air from elsewhere). The extremely small diameters that stainless steel and plastic flexible liners offer (80, 60, 50 and even 45 mm - in combination with suitable boilers) are versatile enough to enable this.

Another option for combining old and new boilers in a house with a collective parallel flue/air shafts is the insertion of flue liners in the air shaft. The fan-assisted boilers can cope with the reduced air and flue pipe cross sections. The flue gas shaft remains operational for the old boilers not replaced yet (figure below). The reduced cross section of the air shaft should of course not hinder the functioning of the atmospheric boilers.

Figure 6-2. Buderus solution for combining old boilers and new condensing ones in a single chimney (with separate flue gas and air shaft).

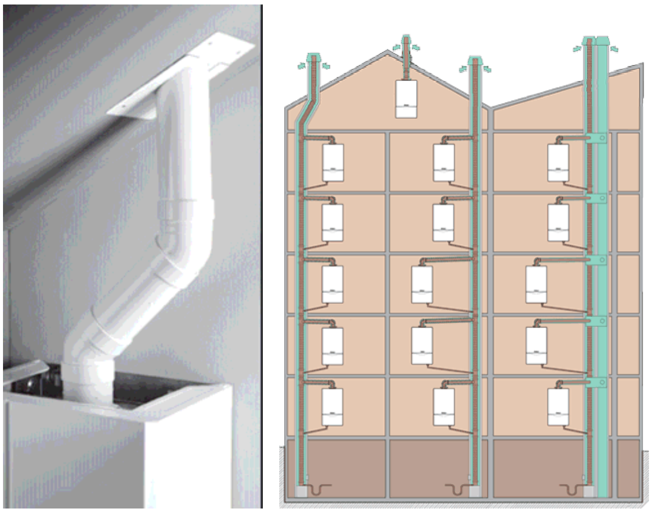
A final option, not investigated thoroughly and as such presented as merely an idea, is to insert a metal (e.g. stainless steel) flexible flue liner of small diameter in the existing collective chimney/ flue shaft, provided the shaft is large enough. The metal liner should be able to widthstand the operating temperatures of the conventional boilers that still use the same shaft. Since the cross section of the new flue pipe is smaller than what was needed before (replaces atmospheric boiler), there should be no negative effect on the functioning of the other boilers. The supply air can be drawn from the facade.

One note regarding collective flues as described in options 1, 3, 5, 7 and 9: Virtually all modern boilers are fan-assisted and thus the flue pipe is under positive pressure. In order to avoid leakage of flue gases through boilers that are not operated, a boiler with flue gas return valve can be selected, thereby preventing such reverse flue gas flow.

German manufacturer Vaillant added another function to the flue liner by proposing condensate drainage through the flue liner in case there is no possibility to connect the condensing boilers to the household wastewater system on each floor. Provided that the flue system protrudes through each floor the bottom-side of this liner collects all condensate that may occur in the flue pipe and boiler and is connected to a drain. Needless to say that this improves renovation economics by combining two functions in a single product.

Figure 6-4 (left): Example of a concentric system including concentric bends (figure: Muelink&grol)

Figure 6-4(right) Vaillant collective condensate drainage solution (with condensate drain at bottom of each chimney) [83]



Liner propertiesand pressure loss

An important factor to consider when applying flue liners in multi-floor buildings is the maximum allowable pressure drop. Most fan-assisted room-sealed boilers allow a pressure drop of 75 to 125 Pa from air inlet to flue gas outlet without performance being affected[84]. The table below gives average pipe diameters for positive and negative pressure chimneys[85].

Table 6-13. Recommended diameters (mm) collective air intake / flue exhaust systems

	Positive pressure					Negative pressure				
Floors	conc.		par		C5	conc.		par		C5
	flue	air	flue	air	flue	flue	air	flue	air	flue
2	90	125	80	80	75	135	260	135	220	135
3	100	150	100	100	90	160	300	160	260	160
4	110	165	110	110	105	170	315	170	270	170
6	130	200	135	135	125	185	350	185	300	185
8	150	230	150	150	140	205	385	205	330	205
10	165	260	170	170	160	220	420	220	360	220
12	180	275	185	185	170	240	450	240	385	240
16	200	330	210	210	195	275	520	275	445	275
20	220	360	235	235	220	310	585	310	505	310

As can be seen from the table there often is more than enough space for insertion of positive pressure liners in negative pressure flues, even creating concentric systems. Calculations by Nefit-Buderus show that 50 to 60 mm diameter flues can be applied up

[83] source: www.bauzentrale.de

[84] The capacity for hot water supply may be affected (up to 6% less capacity)

[85] Nefit-Buderus, Technisch Bulletin 19, September 2005, Deventer, The Netherlands

to respectively five (5) and seven (7) floors up in combination with certain boiler models (boilers can be boosted to increase maximum allowable pressure drop). The tables below give some examples of pressure drop calculations for two 600 mm applications and a 50 mm application [86].

Table 6-14 .Example 1: 60 mm over 5 floors, type C5

Application 7. Air from facade, flue liner in existing individual flue pipe (C5)	
5 floors (12.2 m vertical: 4*2.8m +1*1m)	
Flue exhaust	Pressure drop
12.2 m flexible liner stainless steel 60mm	42.7 Pa
Flue cap	1.3 Pa
1 adapter ø80/60	5.0 Pa
2 bends 90º ø80mm	10.4 Pa
1 m stainless ø80mm	1.0 Pa
Air intake	
1 m plastic ø80mm	0.7 Pa
1 bend 90º ø80mm	2.9 Pa
Total	64 Pa

Table 6-15 .Example 2: 60 mm over 4 floors, type C3

Application 2. Individual air and flue liner concentric in existing 100 mm pipe (C3)	
4 floors (9.4 m vertical: 3*2.8m +1*1m)	
Flue exhaust	Pressure drop
9.4 m flexible liner stainless steel ø60mm	32.9 Pa
Flue cap	1.3 Pa
1 adapter ø80/60	5.0 Pa
2 bends 90º ø80mm	10.4 Pa
1 m stainless ø80mm	1.0 Pa
Air intake	
9.4 m concentric (existing pipe)	10.0 Pa
1 m plastic ø80mm	0.7 Pa
1 bend 90º ø80mm	2.9 Pa
Total	64.2 Pa

Table 6-16. Example 3: 50 mm over 3 floors, type C5

Application 7. Air from facade, flue liner in existing individual flue pipe 100 mm (C5)	
3 floors (6.0 m vertical: 2*2.8m +1*0.4m)	
Flue exhaust	Pressure drop
6 m flexible liner stainless steel ø50mm	60.0 Pa
Flue cap	1.3 Pa
1 adapter ø80/60	5.0 Pa
2 bends 45º ø80mm	3.2 Pa
1 m stainless ø80mm	1.0 Pa
Air intake	
1 m plastic ø80mm	0.7 Pa
1 bend 90º ø80mm	2.9 Pa
Total	74.0 Pa

[86] Nefit-Buderus, Technisch Bulletin 17, March 2005, Deventer, The Netherlands

Figure 6-3.
Inserting the flexible liner
figure: Muelink&Grol)

The effect of reduced performance (capacity) is probably only noticeable in instantaneous combi-boiler configurations on the lowest floor where hot water performance is reduced by maximum 6% [87]. The efficiency of the boiler is not affected.

Note that with at a pressure reduction of 1 Pa per m pipe (ø80mm) and a maximum pressure by the boiler of 125 Pa a straight flue pipe of 125 m can theoretically be installed (neglecting air intake pressure loss). With a small 50 mm diameter liner the pressure drop is much larger (10 Pa/m) but the maximum allowable length is still 12.5 m. Flexible liners (plastic and/or stainless steel) should not be applied horizontally or at modest slopes: Check the installation instructions for the minimum slope.

10.4.2 Free-standing / terraced house retrofit

With boilers that are placed directly under the roof of the main house —e.g. an accessible attic— or the roof of an extension of the main house —e.g. utility room— chimney renewal is relatively easy and cheap. There are several boiler manufacturers and specialists that can supply a flue/air system chimney for a few hundred euros that can be mounted in a couple of hours. For truly condensing boilers (max. temperature 120°C) these sets can be completely made of plastic; for LT boilers at least a part of this chimney set has to be made of stainless steel or thick-wall aluminium (follow national building codes for miminum wall thickness).

The renovation of lateral (through-the-wall) flue gas outlets is not always self-evident and depends on local building regulations and the possibility of nuisance from plumes. In the case of terraced housing it is often not so difficult to extend the flue to roof level and "plume management-kits" (extended chimneys) are easily available. For free-standing or semi-terraced housing plumes from lateral outlets are considered less of a problem in general.

For larger dwellings where the flue spans one or more floors similar solutions as for multi-family dwellings apply, e.g. the insertion of (flexible) liners in existing flue or air shafts.

Many of these solutions have become possible because of the material properties of plastics and metals that allow the design of very compact flue/(air) solutions, like ready-made concentric pipes and bends and flexible liners (plus accompanying products like roof terminals, studs, etc.).

Glazed ceramic pipes by example are also perfectly suited for corrosive, hot and condensing flue gases, but flexible and/or and concentric solutions are either not possible or much more diffcult to apply in most retrofit applications where a standard boiler is replaced by a condensing boiler.

[87] Nefit-Buderus, Technical Bulletin 20, December 2005, Deventer, The Netherlands

10.5 Legislation

10.5.1 Harmonised Standards

Chimney products need to have CE markings, just as any other construction product covered by the "Construction Products Directive" 89/106/EEC. Below are listed the standards relevant for chimneys (and to a lesser degree combustion air pipes), sorted by material and based on the essential requirements as mentioned in the CPD. The harmonisation of standards for chimneys and flues is the responsibility of CEN Technical Body CEN/TC 166 (Chimneys) [88]. For extra clarification some standards are accompanied by explanatory text [89].

Most of the standards are relevant for type B/C boilers, whereas for type C6 boilers + air/flue systems the boiler test standards apply (see EN483/A1).

Table 6-17. EN standards related to various flue gas systems and components

General	
CEN/TR 1749:2006	European classification of gas appliances according flue systems
	This technical report has been prepared under the aegis of the Sector Forum Gas Utilisation committee to provide guidance to CEN Technical Committees who are preparing European Standards for appliances burning combustible gases. It gives details of a general scheme for the classification of such appliances according to the method of evacuating the products of combustion. It must be stressed that this scheme only concerns appliances that are intended to be installed within buildings. It does not apply to outdoor appliances. This form of appliance classification is widely used in the preparation of European Standards for gas appliances to identify the requirements and methods of test that are applicable to the various methods of evacuating the products of combustion. Appliances classified in this way are generally described as "types" and this description has been retained for the purposes of this general scheme. The main purpose of the scheme is to promote harmonization in the classification of appliance types. This should ensure that there is a clear understanding of the various appliance types and will avoid confusion arising from Technical Committees describing them in different ways. CEN Technical committees are therefore requested to use this scheme in all circumstances in which it is appropriate. They should not deviate from it unless there are sound technical reasons for so doing.
EN 1443:2003	Chimneys - General requirements
	This European Standard specifies general requirements and the basic performance criteria and specifies limit values where appropriate for chimneys (including connecting flue pipes and their fittings) used to convey the products of combustion from heating appliances to the outside atmosphere. It is intended to be used as a reference for product standards for chimneys, flues and specific products (elements, kits and terminals) used in the construction of chimneys. It also identifies minimum requirements for marking and evaluation of conformity.
EN 13216-1:2004	Chimneys - Test methods for system chimneys - Part 1: General test methods
EN 13384-1:2003 /A1:2005/C1:2007	Chimneys - Thermal and fluid dynamic calculation methods - Part 1: Chimneys serving single appliances
EN 13384-2:2003	Chimneys - Thermal and fluid dynamic calculation methods - Part 2: Chimneys for heating appliances
EN 13384-3:2005	Chimneys - Thermal and fluid dynamic calculation methods - Part 3: Methods for development of diagrams and tables for chimneys serving single appliances
EN 14297:2004	Chimneys - test methods for the icing and thaw resistance of chimney products
EN 12101-7:2004	Installations for control of smoke and heat - Part 7: Flues
EN 1998-6:2005	Eurocode 8: Design and calculation of earthquake resistant constructions - Part 6: Towers, masts and chimneys
Plastics	
EN 14471:2005	Chimneys - System chimneys with plastic flue liners - Requirements and test methods
	This European standard specifies the performance requirements and test methods for system chimneys with plastic flue liners used to convey the products of combustion from appliances to the outside atmosphere. It also specifies the requirements for marking, manufacturer's instructions and evaluation of conformity. This European standard describes chimneys components from which system chimneys can be assembled.
EN 14241-1:2005	Chimneys - Elastomeric seals and sealing products - Material requirements and test methods - Part 1: Seals in exhaust systems
Metals	
EN 1856-1:2003 /A1:2006	Chimneys - Requirements for metal chimneys - Part 1: System chimney products

[88] The list of standards under the responsibility of TC166 can be found at http://www.cenorm.be/newapproach/dirlist.asp (search Construction Products > Chimneys)

[89] Please note that many titles of standards were translated from Dutch and therefore may not correspond with official English titles.

	This standard specifies the performance requirements for single- and multi-wall system chimney products of combustion liners (chimney sections, chimney fittings and terminals, including supports) used to convey the products of combustion from appliances to the outside atmosphere. It also specifies the requirements for marking, manufacturer's instructions, product information and evaluation of conformity. Metal liners and metal connecting flue pipes not covered here, are included in prEN 1856-2:1996.
EN 1856-2:2004	Chimneys - Requirements for metal chimneys - Part 2: Metal liners and connecting flue pipes
	This document specifies the performance requirements for rigid or flexible metal liners, rigid connecting flue pipes and rigid fittings used to convey the products of combustion from appliances to the outside atmosphere (including their supports). Vitreous enamelled connecting flue pipes are also covered by this document. Rigid liners can be used as flue liners for renovation or adaptation of existing chimneys and as flue liners of custom built chimneys. Flexible metal liners described in this document are exclusively for renovation or adaptation of existing chimneys. This document also specifies the requirements for marking, manufacturer's instructions, product information and evaluation of conformity. Flexible connecting flue pipes and extensible flexible products designed to be compressed or extended along their length are excluded from the scope of this document. Single wall and multi-wall system chimney products are covered by EN 1856-1.
EN 1859:2000 /A1:2006	Chimneys - Metal chimneys and flue liners - Test methods
EN 12391-1:2004	Execution standard - Code of practice for Chimneys - Requirements for metal chimneys - Part 1: Chimneys for non-room sealed heating appliances
EN 15287-1:2005	Chimneys - Design, realisation and practice of chimneys - Part 1: Chimneys for room sealed heating appliances
EN 14989-1:2007	Chimneys - Requirements and test methods for metal chimneys and material independent air supply ducts for room sealed heating applications - Part 1: Vertical air/flue terminals for C6-type appliances
EN 14989-2:2004	Chimneys and air supply duct systems for room sealed appliances - Requirements and test methods - Part 2: Flue and air supply ducts for individual room sealed appliances
EN 13084-6:2004	Free standing chimneys - Part 6: Steel liners - Design and realisation
EN 13084-7:2005	Free standing chimneys - Part 7: Requirements for cylindrical steel components to be used in single-sided steel chimneys and chimney lining
Ceramic	
EN 1457:1999 /A1:2004/C1:2007	Chimneys - Clay/Ceramic Flue Liners - Requirements and test methods
EN 13069:2005	Chimneys - Clay/ceramic outer walls for system chimneys - Requirements and test methods
EN 1806:2006	Chimneys - Clay/ceramic flue blocks for single wall chimneys - Requirements and test methods
EN 13502:2002	Chimneys - Requirements and test methods for clay/ceramic flue terminals
EN 13063-1:2005/A1:2007	Chimneys - System chimneys with clay/ceramic flue liners - Part 1: Requirements and test methods for soot fire resistance
EN 13063-2:2005/A1:2007	Chimneys - System chimneys with clay/ceramic flue liners - Part 2: Requirements and test methods under wet conditions
EN 13063-3:2007	Chimneys - System chimneys with clay/ceramic flue liners - Part 3: Requirements and test methods for air flue system chimneys
Concrete	
EN 1857:2003 /C1:2006/prA1:2007	Chimneys - Components - Concrete flue liners
EN 1858:2003	Chimneys - Components - Concrete flue blocks
EN 12446:2003	Chimneys - Components - Concrete outer wall elements
prEN 13084-2:2005	Free standing chimneys - Part 2: Concrete chimneys
prEN 13359:1998	Chimneys - Components - Concrete in-situ insert parts
Stone	
EN 13084-4:2005	Free standing chimneys - Part 4: Stone inner cladding - Design and realisation
EN 13084-5:2005	Free standing chimneys - Part 5: Materials for stone inner cladding - Product specifications

Product-related health and safety risks should be no longer an issue. For more information on the legal background see van Rienen and Wasser [90], that give an extensive presentation of the implications of the Gas Appliances Directive and the EU product-related legislation in general.

10.5.2 Design, installation and commisioning

Besides fulfilling the product standards the design, installation and commissioning of chimneys must be in accordance with the national building regulations -if they exist.

[90] **Van Rienen, W., Wasser, U**., *EG-Recht der Gas- und Wasserversorgungstechnik*, Wirtschafts- und Verlagsgesellschaft Gas und Wasser mbH, Bonn, 1999.

These building regulations a.o. describe where flue outlets may be positioned (distance to openings, distance from roof, etc.) and despite efforts to harmonise design,installation and commissioning guidelines (e.g. EN 12391-1) there are still many differences in national legislation. Some examples:

In some countries concentric flue systems are compulsary because of safety reasons (the constructions prevents leakage of flue gases), other countries prefer parallel pipes.

Some countries (e.g. Belgium) do not allow certain solutions (C6 system chimneys) leaving it up to the person responsible for installing the chimney to use a different route to show compliance with building regulations.

Regarding lateral outlets the Feueranlagenverordnung (FeuVO) of Bayern and Baden-Wurttemberg [91] by example states that lateral chimneys are allowed, if:

- A flue exhaust over the roof is not possible;
- the appliance is of the 'closed' type;
- the appliance is max. 11 kW (for space heating) or max. 28 kW (for water heating);
- and no nuisance or other hindrance/danger is caused.

Pluming, or the formation of visible white clouds of moist air, also occurs with atmospheric boilers at cold outside temperatures and has been the inspiration for many Christmas cards, but with condensing boilers emitting flue gases with close to 100% relative humidity (due to low temperatures) the visibility near the outlet is higher and can be considered a nuisance at ground level or easthetically undesirable (in case of historic city views). In many member states [92] this has led to the situation that in practice lateral outlets at ground level for terraced houses and lateral outlets for flats are not acceptable. For semi-terraced houses and freestanding houses, lateral flue gas outlets are still an accepted solution.

TC 166 is in the process of preparing general commissioning standards of metal chimneys for normal and room sealed boilers (EN 12391-1 and 15287-1 and 2). Countries who do not have legislation can adopt these standards as a technical report.

10.5.3 Private labels

Test institutes may also carry private labels, indicating that certain product or production standards have been met or that the product complies with certain national regulations. Some examples are shown below.

Figure 6-5
Examples of labels for flue systems

[91] FeuVO's of other regions do not mention this explicitly and only require the flue exhaust to be positioned far enough from the roof or other building parts.

[92] For instance in Italy the cause of hindrance by flue gas outlets is regulated in the Codice Civile art. 844 - Immissioni: *"Il proprietario di un fondo non può impedire le immissioni di fumo o di calore, le esalazioni, i rumori, gli scuotimenti e simili propagazioni derivanti dal fondo del vicino, se non superano la normale tollerabilità, avuto anche riguardo alla condizione dei luoghi. Nell'applicare questa norma l'autorità giudiziaria deve contemperare le esigenze della produzione con le ragioni della proprietà. Può tener conto della priorità di un determinato uso."*

11 SYSTEM ANALYSIS (HEAT BALANCE)

Introduction

Modelling the heating system and specifically the CH-boiler is relevant for the future assessment of boiler efficiency for several tasks of the preparatory study:

- the definition of the basecase (Task 5),
- the evaluation of design options (Task 6) and
- the sensitivity analysis (Task 7/8)

The aim is to provide the mathematical background for an evaluation of boiler features, which –as in many EPB standards—comes on top of the outcome of the existing test standards (EN 303, etc.). The most important task will be not only to generate numerical values the efficiency effect of single design options/features, but especially to evaluate the combined effect of several options.

The ECOBOILER model builds on

- Task 1, where –amongst others- the deficiencies of current test standards are discussed, which underline the need for the modelling.
- Task 2, where amongst others the technical market segmentation gives us insights in the penetration of boiler features. And above all
- Task 3, where statistical data are retrieved on EU-building characteristics and where a mathematical model of the Heat Balance of the residential dwellings was developed that is in line with EN, prEN and national energy performance of buildings standards.

The integrated ECOBOILER model stems from two separate models: The Heat Balance of the dwelling/building (Task 3) and a Boiler Model (Task 4).

The Heat Balance relates not only to the climate and building —following EN 832, SAP, DIN V 4801-6, RT 2005 etc.—but also to the heating emitters, CH-distribution network and (self-contained) controllers, following the EN 15136 series and several national standards. The Heat Balance assumes an 'ideal boiler' (100% efficient, no inertia, etc.), a radiator network [93], controllers for radiators and sensors and distribution losses resulting from a system temperature that is 'unavoidable' with a certain control strategy.

More information on the integration of this Heat Balance with the Boiler Model into eventually the ECOBOILER model can be found in Task 4 report.

Development in stages

The development of the system analysis for central heating (combi-boilers) took several steps:

First the model of the dwelling (in Task 3) and the model of the central heating system (in Task 4) were developed as separate entities. A trace of this exercise can be found in the Annexes of the Task 3 report –for the dwelling model—and in the current Task 4 report for the boiler model (see Annex XX). This separate development took place from Nov. 2006- Jan. 2007.

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[93] Radiators are present in >80% of the dwellings where new boilers will be placed (see Task 2). Floor heating and convector systems are not included here.

Subsequently the two separate models were integrated in the ECOBOILER Integrated Model (or simply "ECOBOILER model"), enabling a system approach (not just the heat generator). The focus of the first version, presented in March 2007 to the expert meeting, was on the space heating function.

In the period May-June, the water heating function (combi) was added, consistent with the ECOHOTWATER model of the preparatory study for Lot 2 but with its own peculiarities regarding the use of wast. Multiple generators (including heat pump and solar) were accommodated.

In parallel, the ECOBOILER model was being reviewed by the experts from the boiler industry, who also called in the expertise of the iTG Dresden to review the suitability of the model for labeling purposes.[94]

Most of the above is discussed in the Task 4 Report and especially the Annexes. Here we will focus on the part related to the Heat Balance of the dwelling.

Annex A (" Heat Balance Notes") describes the separate Heat Balance, which preceded the ECOBOILER integrated approach.

Important Notice:

The Excel-file, this documentation and description of the model is appropriate for the purpose of this preparatory study, i.e. a review by boiler experts who have been involved in the development process. However, it is also clear that if and when the ECOBOILER model is used for other purposes, i.e. labelling and/or integration with harmonised EPBD standards (see Task 7 report), that a complete re-structuring and clean-up of the Excel file, the documentation and an appropriate discussion of the equations is absolutely necessary. This is most definitely outside the budgetary and time scope of the underlying preparatory study.

[94] Institute für Technische Gebäudeausrüsting Dresden (iTG), prof. Oschatz. Et al.. "Analysis of the Kemna model as a basis for the labeling of heat generators, Dresden, May 21,2007. Note that the iTG was one of the parties working on the EnEV and the latest German EPB standards DIN 18599

Annex A

Heat Balance Notes

Boiler Modelling Notes

This annex contains the documentation of the first version of the separate Heat Balance of a dwelling/building. The separate Heat Balance was later incorporated in the ECOBOILER Integrated Model, where it was then altered, debugged etc. (see also Task 4 report, Chapter 11 + Annexes). Nevertheless, although it is not a 100% compliant with that model it provides an insight into how several equations were arrived at.

It is added here as a general background information

Heat balance residential dwellings

Introduction

Modelling house and climate features is relevant for the evaluation of boiler efficiency for several tasks of the preparatory study:

- the definition of the basecase (Task 5),
- the evaluation of design options (Task 6) and
- the sensitivity analysis (Task 7/8)

The aim is <u>not</u> to tread new ground, but to accomodate the existing EPB standards on EU and national scale (EN 832, DIN V 4108-6, DIN 4701-10, SAP, RT2005, NEN 5128, etc.).

Having said that, this is not an easy task, because every country employs its own simplifications, look-up tables and shortcuts. To accomodate all these different simplifications and shortcuts means that the mathematical model of the heat balance has to incorporate more elements than each single standard that was used as a basis.

Our focus is on the most relevant parts for the heating installation, which are also the most difficult parts of the heat balance: the effects of thermal mass, internal heat transfer, indoor temperature fluctuations, stratification, etc.. For the general heat balance –transmission and ventilation losses, internal and solar gains—we have used the more extended versions to establish appropriate default values, but for the final mathematical model we have maintained only a simplified approach with very few parameters. For our purpose this is sufficient and in any case coherent with EPB-standards (i.e. easily extendable).

The modelling concerns not only the dwelling, but –with the exception of the boiler— also the heating installation elements that can be found in <u>existing</u> housing: emitters, piping, controls. The argument for using the existing housing as a basis stems from the fact (see Task 2 report) that most (>80%) of boilers end up in existing housing with typically a radiator network (also >80%). Floor heating systems (<10% of boiler market) are not taken into account. The basis for the modelling of installation components is the EN 15136 series standards for the residential sector, national standards, etc..

The time scope of the model, as in the latest EPB-standards, is <u>monthly</u>, but a month is characterised by an average month day of 24 hours in the heating season, subdivided into 5 day-periods that are most commonly used for timer action (morning, midday, evening, late evening, night). Furthermore, the dwelling is subdivided in 3 temperature zones (day-zone, night-zone and bath). This is a minimum to be able to evaluate the effects of thermal mass and internal heat transfer with a non-numerical methods. The model is accompanied by an Excel spreadsheet, parts of which will also be shown in the following paragraphs (example below)

ZONES & DAY-PERIODS		morn	mid	eve	late	night	tot
Time of day for each period	h-h	7-9h	9-16h	16-21h	21-23h	23-7h	
Hours per day	h	2	7	5	2	8	24
Hours per month (hrs)	h	61	212	152	61	243	729

Figure A-1. Relevant part of the spreadsheet showing the day-periods start/end time, number of hours per day and number of hours per month (non-editable, hard-coded in the expressions)

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General heat balance

The heating demand (QH in kWh for a period of time) follows from ventilation losses (QV), transmission losses (QT) minus solar and internal gains (QG):

$$QH = QV + QT - QG =$$

$$0{,}001 * \{hrs * V * (T - Tout) * [ah * (qv * (1 - qrec) + qinf) + (AV * U)] - F * (Qgain + qsol * sgf) * dpm\} \quad \textbf{[1]}$$

where

- 0,001 is a conversion-factor for Wh to kWh
- hrs is the number of hours of the period, in h.
- V is the (internal) volume of the dwelling, in m^3
- T is the indoor temperature, in °C
- Tout is the outdoor temperature, in °C
- ah is the specific heat of air, constant 0,33 $W/K.m^3$.
- Qv is the ventilation-rate vs. the volume of the dwelling, in m^3/m^3.
- qrec is energy recovered from outgoing ventilation air, in %.
- Qinf is the infiltration-rate vs. the volume of the dwelling, in m^3/m^3.
- AV is the ratio between dwelling volume V and exterior surface A, in m.
- U is the (equivalent) specific transmission coefficient per unit of exterior surface A, in $W/K.m^2$
- F is the heated floor area of the building, in m^2
- Qgain is the internal gain (from people, appliances, etc.) per day, in kWh/d.
- qsol is the global solar irradiance per day in $kWh/m^2.d$
- sgf is the solar gain factor
- dpm is the average number of days per month (30,5).

The geometrical properties of the dwelling - **V, AV and F** - are taken from the statistical averages found in the Task 3 report for a house ('single- or two family dwelling') and an apartment. The house has a heated floor area F of 88 m^2 and –using a floor height h=2,75 m—a heated volume of 242 m^3. For the apartment F=65 m^2 and V= 178 m^3. The AV ratio for the house is estimated at 0,6, which is comparable to a 2-storey terraced house (slightly bigger). For the apartment we used AV=0,4, which is slightly bigger than the smallest possible AV-factor. The values apply to the average EU, but –for the sake of the sensitivity analysis— the model also employs geometrical data sets per Member State.

Please note that F, AV and V relate to heated floor area, i.e. conservatories, garages, unheated cellars, attics, etc. are not included. Especially in 'houses' (single- or two-family dwellings) these unheated spaces can be a significant part of the real estate floor area (up to 50%).

Also note that the figures do include vacant, secondary or otherwise unheated houses and apartments. This means that the energy consumption figures cannot be used directly to calculate the average energy consumption per country. It has to be considered that the equivalent of around 13% of 'houses' and 16% of 'apartments' are unheated (avg. EU) and that around 5-10% of the dwellings are underheated, i. e. do not have/use heating in certain parts of the house (e.g. 'fuel poor'). Including both effects, the total energy consumption will be 15% (houses) to 25% (apartments) lower than a simple multiplication of the number of dwellings with the energy use per dwelling suggests.

The **U-value** indicated is an aggregated figure that incorporates:

- The U-value of the 'heavy' building components in the building shell (walls, floors, etc.)
- The U-value of the 'transparent' building components (windows, doors) and
- A value (per m² of building shell) that corresponds to the transmission losses through the cold bridges.

This latter value usually relates to the perimeter of the dwelling (in m), but –because for the boiler it isn't very relevant where the losses come from— we have incorporated the cold bridges in this aggregated U-value (relating to m² building shell).

As data-input for the **U-value** in the average dwelling we took Ecofys/Eurima data concerning 1975-1990 dwellings as a starting point but this U-value was then calibrated so that the net heat load would match the one found in the statistics (see Task 3, chapter 3). E.g. in the moderate climate zone, featuring an U-value of around U=3 for 'transparent' components and 0,9 for 'non-transparent' building components. For the house we assumed the 'transparent' parts to be 10% of the total exterior surface, resulting in a composite U-value of 1,14. Adding an extra 15% for the cold bridges to the ground[95] this gives a total equivalent U-value of 1,2-1,3. For an apartment, the partitioned share of the cold bridges will be much less, but the 'transparent' share in the total exterior wall will be higher (>20%), which again leads to an initial estimated equivalent U-value of 1,2-1,3. The values apply to the average EU, but –for the sake of the sensitivity analysis— the model also employs geometrical data sets per Member State that were established in a similar way. For new dwellings we used the Ecofys/Eurima data directly, again assuming a 10% 'tranparent' share and a 15% cold bridge contribution for the house. As background information the Eurima/Ecofys values are given in the "library" worksheet of the spreadsheet file.

For the infiltration rate **qinf**, the most recent standards start from the tested 50 Pa infiltration ("blower door test", e.g. in Germany) or an assumed 10 Pa infiltration (NEN 5128), which is then corrected with a series of multipliers depending on the details of the construction, the AV ratio, etc. towards realistic average infiltration rates. Both in Germany and the Netherlands this corrected infiltration rate is for a house around 0,15-0,22 m^3air/h.m^3V, with the lower value applying to new houses and the higher value for existing houses. Please note that in many existing houses the fight against infiltration losses is one of the most popular (cheapest) insulation measures. For apartments, with a smaller AV ratio, the infiltration rate is less and there we assume 0,12-0,15 m^3/m^3. We have used these values throughout the EU, as more exact infiltration rate per Member State were not available.

The prescribed **ventilation rate qv** varies according to the standards from different countries between 0,47 and 0,7 $m^3/h.m^3$. For the EU average existing house and apartment we assumed 0,6 $m^3/h.m^3$. Most countries, although the ventilation standards for new houses are rapidly updated for mechanical systems, start from the assumption of natural ventilation (opening windows) and/or mechanical extraction. A significant share of balanced ventilation with heat recovery can currently only be found in Scandinavia and the Netherlands. From market data we estimate that EU-

[95] Value as found e.g. in calculation examples of terraced houses in NEN 5128 and VDI Handbuch 2005 for DIN 4701-10.

penetration is less than 10% and a heat recovery rate of 80%. Therefore the aggregated heat recovery rate **qrec** is set at 8% for both the average EU apartment and house. In the data per Member State we assume 40% heat recovery for Finland and Sweden, 15% for the Netherlands and 5% for the existing German and French housing stock.

The internal gain **Qgain** is in most standards set at around 5 W/m² (DE, NL, UK). With a heating season of 5000 hours, this comes down to 25 kWh/m².year = 3,65 kWh/month =120 Wh/day. Of course we could construct a more accurate estimate from the statistical data in the Task 3 report, but for the moment we will adhere to what is in the standards. For the **solar gain qsol*sgf** , the older building regulations in the moderate EU-climate zone use a value that is slightly less than the internal gains, somewhere around 17-18 kWh/year per m² of floor area. This is around 11% of the global solar irradiance Qsol, which is the value we use for sgf. Please note that we have employed a single solar multiplier, because this is enough for an evaluation of the heating installation. For architectural purposes it would of course be very educational to split this single multiplier into its components (shadowing, orientation, etc.), but –as mentioned—this was not our scope.

For the global solar irradiance **(qsol)** and the outdoor temperature **(Tout)** we use the data from JRC-Ispra. Please note, that the outdoor temperature is the actual average outdoor temperature over a period as opposed to the 'daily outdoor temperature' that is used e.g. in some EN standards, which is *the lowest outdoor temperature found in the whole day (typically around sunrise) over the last 20 years.*

Note that expression **[1]** gives the heat demand QH, but the equation can also be solved to provide the indoor temperature T if QH is known. Thus in the summer months or other periods when there is no heating (QH=0) the indoor temperature can be calculated. Likewise the maximum achievable indoor temperature can be calculated at maximum radiator output (QHmax). The equation is

$$T = Tout + \{QH+F*(Qgain + qsol*sgf)*dpm\} / \{hrs*V*[ah*(qv*(1-qrec)+qinf) +(AV*U)]\} \quad \textbf{[2]}$$

The figure below shows the most relevant part of spreadsheet for the general heat balance. Note that in the "MAIN" worksheet only the yellow cells should be used (click and select from list): The "Country" cell (avg. EU-25 + every single Member State) loads the outdoor temperatures, global solar irradiance values and construction values. The "Dwelling Type" makes a distinction (per country) between 'new' or 'existing' and 'house', 'apartment' or 'average'.

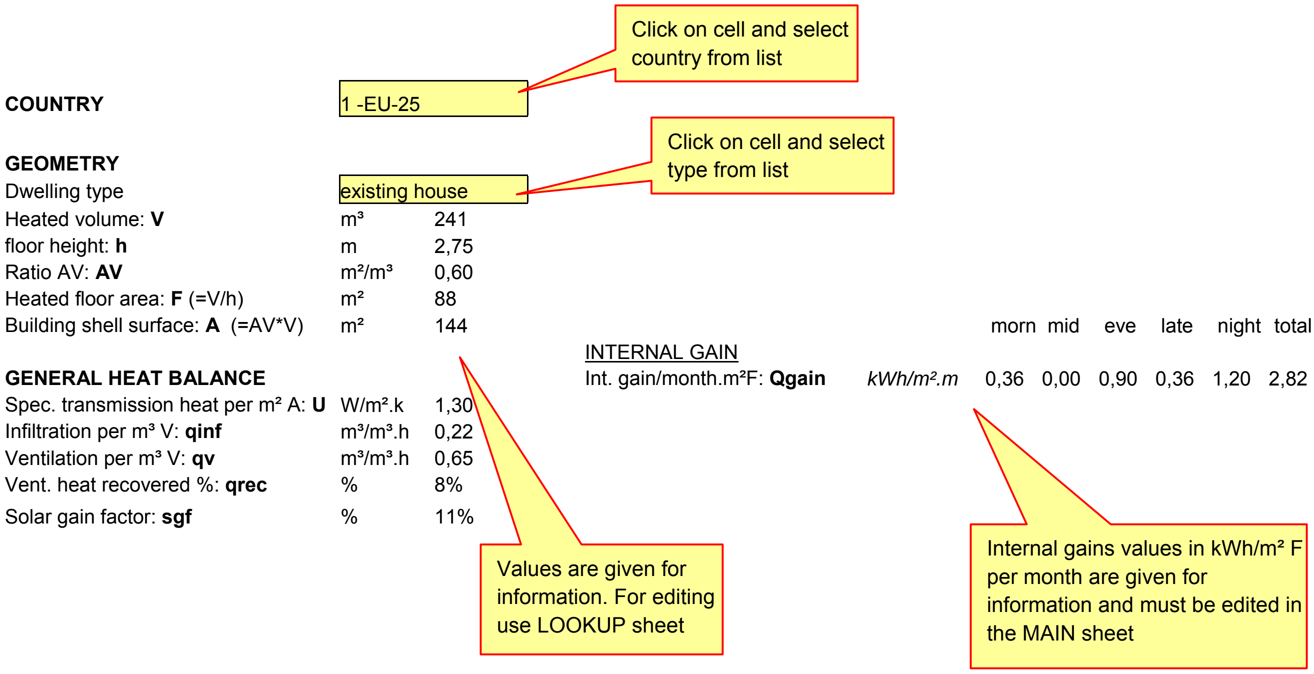


Figure A-2. Relevant part of spreadsheet for the general heat balance inputs

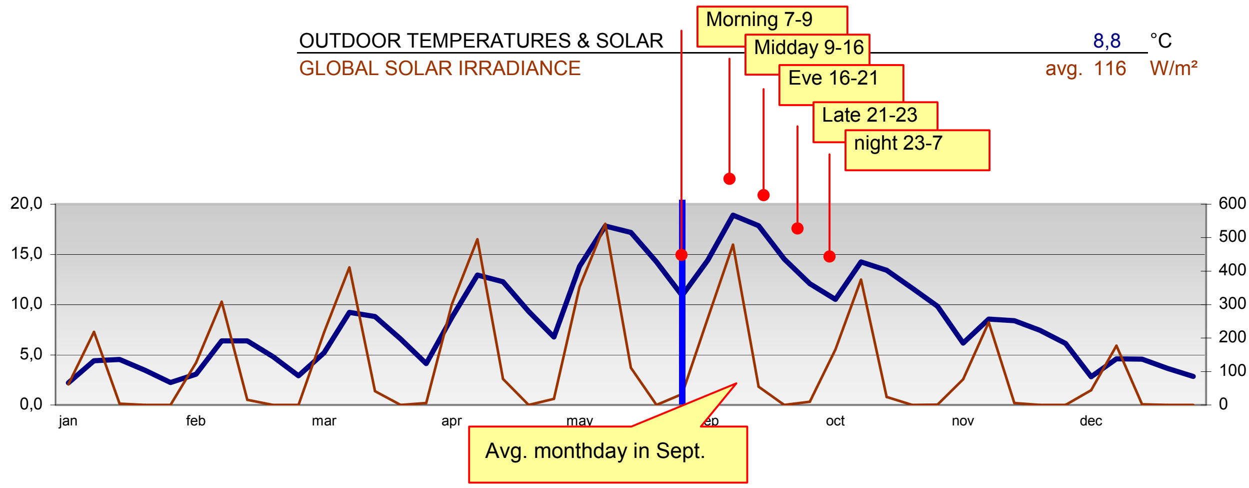


Figure A-3. Relevant part of spreadsheet showing outdoor temperatures (in °C) and global solar irradiance (in W/m²) for a 9 month period (year, excl. June-Aug.). The graph applies to 5 day-periods per average month-day. The numerical values in the top-left corner are the averages over the 9 month period (just shown for information, should not be edited here but in the LOOKUP worksheet)

Please note that for editing of single values generally the “LOOKUP” worksheet should be used. Only the ‘internal gain’ vales must be edited directly in the “MAIN” worksheet.

The general heat balance is simple and can be extended with all sorts of educational elements if needed. For our purposes of evaluating the heating installation, however, there are other issues that are more important, which we will discuss in the next paragraphs:

- Subdivision in zones, i.e. 3 temperature zones .
- Night- and day indoor temperature setbacks, accommodating several timer regimes
- Thermal mass, to calculate the actually achievable temperature setbacks
- Internal heat transfers
- Emitter modelling (beyond but in line with tables from EN 15136-2)
- Controller modelling (beyond but in line with tables from EN 15136-2)

Temperature zones

Most EPB-standards accommodate the subdivision of dwellings in temperature zones, but differ as to exactly how and when this split up should be made. The EN 832 and German standards, focusing on the transmission heat transfer between zones (and not internal infiltration), prescribes different zones only if temperature differences of more than 4 K may occur between zones. The English SAP 2005 distinguishes between the reference room (the living room where the room thermostat is placed) and the bedrooms, using look-up tables for temperature differences. The Dutch standards usually take one layer of a dwelling as a temperature zone and distinguish zones with different emitter systems (e.g. floor and radiator heating). In design standards, determining the design emitter power per room, traditionally different temperature values were defined.

To capture these differences the model defines 3 standard temperature zones: a 50% day-zone, a 40% night-zone and 10% bath-zone. These percentages apply to F and V. Also all zones have equal U and AV values. For a house the day-zone will be on the ground floor, with an extra loss through the cold bridges, in part compensated by the benefit of a warm (constant 12/13°C) cellar. The first floor shares the bedrooms (‘night-zone’) and bath, which have extra losses through the roof. So, all in all the equal partitioning of the U values makes sense.

The 3 zones represent the 3 different design temperatures that were traditionally used, i.e. for existing houses, when determining the radiator lay-out and capacities. A living room would be set at 20-21°C, the bedrooms at 17-18°C and the bathroom at 22-24°C (say 20/18/24) and then the radiator power would be determined using a heat balance comparable to the one described in the early chapter, using a ‘worst case’ (e.g. –10°C) outdoor temperature.

Night-setback

‘Night-setback’ is used here to indicate all timer operations aimed at reducing the indoor temperature when possible. Not all national standards deem the night setback important. E.g. in the French RT 2000/2005 it is seen as relevant, probably because in France electric (resistance) radiators and air heating are a significant part of the emitters. In the mid-European standards (e.g. NL, DE, UK) the energy saving through timer settings is very limited or not recognized at all. In Nordic single- or two family houses, with a light thermal mass (wood construction) and low outdoor temperatures the night set-back of the indoor temperature makes again sense.

Furthermore, it has to be considered that the EPB-standards relate to new houses with good insulation. In existing houses with moderate/bad insulation levels the saving potential of a night setback is obviously more.

In our model the whole phenomenon of indoor temperature setbacks is treated extensively, not so much because of its saving potential, but because it is a major source of differences between the various international and national standards.

The mathematical model employs

- Timer regimes based on occupancy with different time/temperature regimes for each zone, indicated as **"Week"** followed by 3 main temperatures. This is seen as the ideal –though theoretical—situation. Because of the effects of thermal mass and internal heat transfer it is unlikely situation, but a heating installation could try to come as close as possible.
- Timer regimes based on a simple 3K night setback, but different base levels per temperature zone. This is indicated as "Weekend" or **"Wknd"** followed by 3 main temperatures. It is a situation that reflects common practice with central timer/thermostats and is also assumed e.g. in the French standards.
- Identical temperature levels per zone with 3K night setback (e.g. all 19°C with a setback to 16°C between 23.00 and 7.00h). This is indicated as **"Uni + 3K sb"** with a temperature value after "Uni". The situation reflects common practice in e.g. apartments.
- Identical temperature levels without setback. This situation is proposed e.g. in some German (DIN 4701-10) and Dutch (NEN 5128) standards with temperatures of 19 resp. 18°C throughout. It reflects a situation in new housing with good insulation and typically at least partially floor heating. In those situations the use of night-setback is questioned and –also given the complexity of the calculations—not incorporated in the standards. This is indicated as **"Uni"** followed by a temperature value.

For each of these temperature regimes the model gives 3 temperature levels, bringing the total to 14 datasets:

- Week 21/20/24, Week 20/19/22, Week 19/18/20,
- Wknd 21/20/24, Wknd 20/19/22, Wknd 19/18/20,
- Uni 21+ 3K sb, Uni 20 + 3K sb, Uni 19 + 3K sb, Uni 18 + 3K sb,
- Uni 21, Uni 20, Uni 19, Uni 18

The default calculation mode is **"reduced setback"**, which means that during the low-temperature periods the indoor temperature is not allowed to drop below a given value. However, there is also the option of **"full setback"**, where the model just takes the set temperatures during the normal temperature periods (indicated in blue font, see fig.) and allows the temperatures during the low-temperature periods to drop as much as possible, taking into account that the room has to be reheated at the end of the cool-down period.

The table below shows the relevant part of the spreadsheet for set indoor temperatures

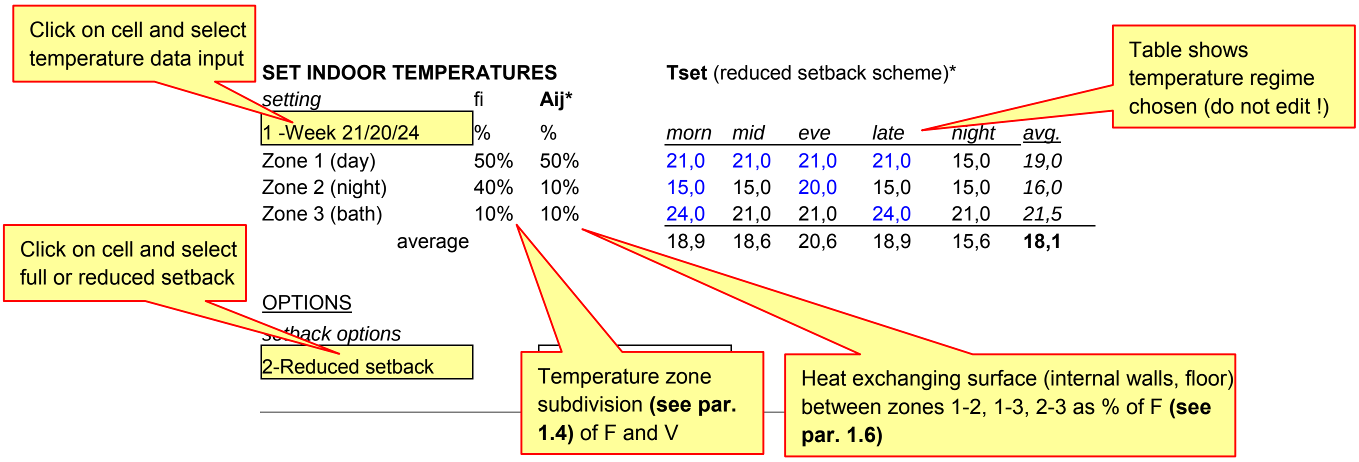


Figure A-4. Relevant part of spreadsheet for set indoor temperatures. Also including percentages of F and V for the temperature zones (see par. 1.4), as well as Heat exchanging surface (internal walls, floor) between zones 1-2, 1-3, 2-3 as % of F (see par. 1.6).

Thermal mass

11.1.1 Thermal mass per period

As mentioned, the thermal mass is an important parameter to determine what temperature drop can actually be realized through setbacks and also how fast a room can reheat to its previous level. According to the VDI manual, the calculation of the thermal mass effects is one of the most complex and error-prone items in a heat balance calculation. Currently, the EN 832 and DIN V 4108-6 give a (similar) procedure for the calculation of the thermal mass, using approximate cool-down and reheat equations that can be used in analytical (non-numerical) approach. A mere example of this calculation takes up some 10 pages (see VDI Manual), but we will present (and use) an abbreviated version.

The effective part of the thermal mass for the night-setback calculations is not the total thermal mass of all building components, but just the thermal mass of the first 3 cm of the 'heavy' construction components. The 'light' components (windows, doors) are excluded as well as ventilation and infiltration mass flows. The calculation of this effective thermal mass is a lengthy process and for this reason the standards (e.g. DIN V 4108-6) provide default values. For a heavy construction (e.g. brick) the DIN default **specific thermal mass** per unit of building volume V is given as **tm** = 18 Wh/m³.K. For light buildings (e.g. wood) the default is tm=12 Wh/m³.K. The Dutch standards (NEN 5128) give values expressed in MJ per m² floor area F, which at 2,75m floor height give similar values. At any given time, the effective thermal mass of the construction TMcon (in kWh) can thus be expressed as

$$TMcon = 0{,}001 * tm * V * (T\text{-}Tout) \qquad [3]$$

Example:
A house with 242 m³ heated volume will have an effective thermal mass in winter —with (T-Tout)=20 K—of 87 kWh.

The thermal mass of the (water in the) radiators at any time is given by

$$TMrad = 0{,}001 * 1{,}16 * (Trad - T) * 20 * Pradnom \quad [4]$$

where

- 1,16 is the specific heat of water in Wh/kg.K
- Trad is the average radiator temperature in °C (range 20-70°C)
- T is the ambient air temperature (in the room) in °C (range 15-20°C)
- 20 is water volume of a radiator per kW of nominal radiator capacity in litres/kW
- Pradnom is the nominal radiator capacity according to EN 442 in kW

Example:
In a house with 15 kW radiator capacity and all radiators running at maximum power (Trad= 70°C) to keep an indoor temperature of 20°C, the thermal mass of the radiators is 0,001*1,16*45*20*15 = 15,7 kWh. Please note that the thermal mass is similar to the nominal radiator capacity, which is a given that can be used in later equations. The specific thermal radiator mass TMrad= 0,0232*Pradnom, in kWh/K with Pradnom in kW.

Most standards ignore the thermal mass of the air and light construction parts, as will we. For comparison: the mass of 242 m³ air at (T-Tout) = 20 is approximately 1,6 kWh [96]. This is <1% of TMcon.

11.1.2 Cool down

The following equation from EN 832 gives the **indoor temperature (T)** after the heating has been switched off for X hours ('X').

$$T=Tout+tmcf*(Tprev-Tout)*EXP(-\{X / [tm*V/(1000*PH/(Tprev -Tout))]\}) \quad [5]$$

where

- T is the indoor temperature in the current period in°C
- Tout is the outdoor temperature in°C
- tmfc is a correction factor (range 0,95 – 0,99)
- Tprev is the indoor temperature in the previous period in°C
- X is the number of hours the heating is switched off in h.
- tm is the effective (3 cm) specific thermal mass of the building in Wh/m³.K (e.g. in the standards as 18 for heavy buildings and 12 for light buildings)
- V is the internal volume of the dwelling
- PH = (QH/hrs) is the heat demand QH calculated at Tprev and Tout in kWh
- hrs is the number of hours in the period in h

PH (=QH/hrs) is the average heating power demand in kW. Please note that the EN 832 uses intermediate parameters like the specific thermal mass 'C' (= tm * V) and the 'time constant' τ (=ζ C/ ξ H_s). The parameter tmfc is the equivalent of the 'ζ' or 'ξ' or 'ζ / ξ' in EN 832 or in DIN 4108-6.

We use the notation EXP(x) instead of the conventional e^x format for reasons of legibility.[97]

[96] 0,001 * 242 m³ * 20 K * 0,33 Wh/m³.K = 1,597 kWh

[97] The conventional notation: $\Theta=\Theta_{out} + \xi *(\Theta_{prev}-\Theta_{out})* e^{(-\{X / [tm*V/(1000*PH/(Tprev -Tout))]\})}$

To determine the **radiator temperature (Trad)** after the boiler has been switched off for X hours ('X') a similar, but adapted formula can be used. For the radiator the lowest temperature reference is not the outside temperature Tout, but the indoor temperature (Ta, ca. 20°C). For the time being we will dispense of the correction factor tmfc. The previous temperature is not the previous indoor temperature Tprev, but the previous radiator temperature Tradprev. The expression (tm*V) is in fact the equivalent of the specific thermal mass **tmrad= 23,2*Pradnom**, in Wh/K. Finally, for the equivalent of (1000*PH/(Tprev -Tout)) we could assume a linear expression (Pradnom/50), where 50 is the nominal temperature difference at EN 442 conditions (i.e. with ambient 20°C and avg. radiator temperature 70). But this formula is accurate only for the very first temperature drop, starting from Pradprev=70°C. As the radiator formula shows, the heat output of the radiator is not proportional to its temperature. For instance, at half the temperature difference (Tradprev= 45°C), the heat output is only 40% of the nominal output. Without going as far as to incorporate the full radiator formula we will use this average value, which leads to a formula that is most valid in the midrange and has a limited error (10-20%) at the extremes.

Thus the radiator temperature (Trad) after the boiler has been switched off for X hours ('X') becomes

$$Trad = Ta + (Tradprev - T) * EXP (-X / \{ 23,2 * Pradnom / (1000 * 0,4Pradnom / 25 \}) \rightarrow$$

$$Trad = Ta + (Tradprev - T) * EXP (-X / 1,45) \qquad \textbf{[6]}$$

Example:
After 1 hour a radiator with Tradprev=70°C and Ta=20°C will have cooled down to 45°C. Another hour later Trad becomes 33°C and after 3 hours Trad is 26°C. At this latter temperature the radiator output is negligible and it will take the radiator temperature a further 2-3 hours to crawl towards Ta.

Expressions **[5]** and **[6]** are used in case the heating is fully switched off for a known period of X hours. In case of a reduced operation with a known minimum set temperature Tmin, the equation must be solved for an unknown number of hours X it takes to cool down to that temperature level, using a natural logarithm.

$$X = tmfc * \{ tm*V / [1000 * PH /(Tmin - Tout)] \} * \ln ((Tmin - Tout) / (Tprevious - Tout)) \qquad \textbf{[7]}$$

For radiator cool down an equivalent can be constructed as above:

$$X = 1,5 * \ln ((Tradmin - T) / (Tradprev - T)) \qquad [8]$$

11.1.3 Steady state

At the end of the cool down period the radiator may start to heat up immediately or –in case of a so-called 'reduced set back', the radiator is trying to keep the indoor temperature T at a certain (minimum) level. In the steady-state situation the indoor temperature T is known and therefore the heat balance in expression [1] can be solved for a given building and known outdoor temperature and results in a heat demand QH (in kWh).

From the heat demand QH over a period of x hours we first determine the average power QH/hrs.

The relevant equation is the **'radiator formula'** mentioned in Task 4, which calculates an unknown heat output QH at a given radiator temperature:

$$QH = hrs * Pradnom * ((Trad - T)/50)^{radc} \qquad \textbf{[9]}$$

This formula can also be solved to find an unknown radiator temperature Trad if the QH is given, i.e.

$$Trad = T + 50 * ((QH/hrs)/Pradnom)^{1/radc} \qquad \textbf{[10]}$$

where

- Tb is the average required radiator temperature
- T is the ambient temperature i.e. the indoor temperature
- 50 is the temperature difference between ambient and average radiator temperature according to the standard EN 442.
- QH is the heat demand over the period
- hrs is the number of hours in the period
- Pradnom is the nominal radiator capacity according to EN 442, i.e. at 70°C average radiator temperature and Ta=20
- radc is the radiator constant, which is given by emitter manufacturers, usually radc= ca. 1,3,

Expressions [9] and [10] can be used to determine

- the boiler temperature Tb and/or
- the expected valve action (on/off times, in %) per zone

for several boiler temperature control situations:

1. **Fixed** Tb throughout a 7-month heating season (typically collective boiler)
2. **Fixed Tb** with Tb night-setback.[98] (Tb= 40°C between 23.00-7.00h)
3. **Fixed Tb** with manual seasonal Tb-correction[99]
4. **Fixed Tb** with manual seasonal Tb-correction and Tb night-setback
5. Variable Tb depending on **outdoor sensor** through heating curve[100], with Tb night setback.[101].

[98] The model uses Tb = 40 from 23.00h to 7.00h to accommodate the fixed timer regime. In reality, Tb will be lower (e.g. "heating off") and the setback-period will be shorter (5-6h) because it has to fit all inhabitants of the apartment building with collective boiler.

[99] The model uses Sept-May → 40/50/60/70/70/70/60/50/40/30 for seasonal correction.

[100] For this type of control an 'ideal' Tb is calculated based on the QH following from an indoor temperature of 25°C at a given outdoor temperature. In reality, there is a safety factor applied (see boiler model) to the heating curve.

[101] Night setback at boiler level: Tb=30°C at night.

$$Tout \rightarrow QH \text{ at } 25°C \rightarrow Trad1, Trad2, Trad3 \rightarrow Tb = MAX \{ Trad1, Trad2, Trad3 \} \quad [11]$$

Variable Tb with **modulating thermostat** in reference day-zone.

$$Tb = Trad1 \quad [12]$$

Variable Tb with **multi-zone temperature sensors and timers** ('modulating thermostats') Tb is the highest radiator temperature required. Tb = MAX { Trad1 , Trad2, Trad3 }

$$Tb = MAX \{ Trad1 , Trad2, Trad3 \} \quad [13]$$

Multiple variable Tb with **multi-zone sensors, timers and actuators**. This assumes mixing valves + circulators, either at the level of zones (compare: floor heating system) or at the level of the boiler. In the latter case, discussed in the boiler model, there may be an efficiency benefit from using different parts of the heat exchanger for each temperature level.

$$Tb1 = Trad1 \ ; \ Tb2 = Trad2 \ ; \ Tb3 = Trad\ 3 \quad [14]$$

This covers more than 90% of practical solutions.

The model accommodates two options for the **flow rate** control:

- A fixed flow rate, given as an input variable,
- A minimum flow rate as given by radiator manufacturers[102] :

$$0{,}2 * Pradnom * 1000 / 4187 \quad [15]$$

Where Pradnom is the nominal radiator capacity in kW. Actually the equation indicates that radiators should work at least at 20% of the nominal flow rate.

11.1.4 Heat up

For the reheating of a dwelling after a night setback the various standards give very diverging results. For instance the EN 832 and DIN 4806 give a reheat time of 1,85 h and 3 h for identical houses and climates. According to the VDI Manual[103] the equations are less than satisfactory. The resulting heat-up times are too long[104] and not in line with measurements of real houses, especially when the boiler uses full power after a setback to arrive at the desired indoor temperature. At this point it is highly

[102] Source: Zehnder catalogue. Please note that there is of course nothing to keep radiators from operating at lower flow rates, and still giving off useful heat, but the consistency with e.g. the radiator formula may be gone.

[103] VDI-Buch, Energieeinsparende Gebäude und Anlagentechnik,Springer Berlin Heidelberg, 2005, ISBN 978-3-540-40609-9 (Print) 978-3-540-26640-2 (Online). Chapter on: Nachweis nach der EnEV am Beispiel eines Einfamilienhauses (pp. 855-962)

[104] E.g. 2-3 hours to heat-up a well-insulated house a few degrees with a full 13 kW heating power (VDI Manual

questionable whether the exponential function reflects reality. In appendix C we give a first exploration of what really happens at heat-up.

For our mathematical model this was a reason to use simple linear reheat-equations that roughly gives the same results as EN 832, but without the error-prone exponential function.

The equation determines the reheat time $\mathbf{t_{reheat}}$ from the loss of thermal mass of the construction (**ΔTMcon**, see expression [3]) and of the radiator (**ΔTMrad**, see expression [4]) during the preceeding cool down period and determines how long –with a given power (**Pradnom*preheat**)—it takes the radiators to get to the appropriate level, also taking into account the external heat loss **PH** (=QH/hrs) during the period.

$$t_{reheat} = \{ (T_{new}-T_{cooled})*(0{,}001 * tm * V) + 0{,}0232 *P_{radnom} * (PH /P_{radnom}) * 50 + PH) \} / (P_{radnom}*p_{reheat}) \quad \textbf{[16]}$$

The first term relates to **ΔTMcon.** The second term relates to ΔTMrad and applies only in the first cooldown period.[105] The last term PH relates to the heat power loss during the reheating period.

The heat demand Q_H can be calculated from expression **[1]** and the average power now becomes PH=QH/hrs.

The temperature after cooldown ($T_{aftercooldown}$) can be calculated using expression **[5]**.

First, the T_{cooled} is calculated for the full setback-period, e.g. for a night-period of 8 hours with expression [5]. This gives the temperature "Y" from which the <u>average cooldown speed</u> during that period<u> (in °C/h)</u> can be calculated. This temperature "Y" and the set temperature that has to be reached at the beginning of the next normal period (T_{new}) is also used in a calculation of t_{reheat} using expression [16] above. This yields a reheat time and –because the temperature difference is also known—this gives an a<u>verage reheat speed (in °C/h)</u>. The ratio between cooldown and reheat speed (and the length of the setback period) then result in the acual cooldown time X. For instance if in the night-period (8 hrs.) the average cooldown speed is 1 °C/h and the average reheat speed is 3°C/h, then the cooldown period X=6 hours. With expression **[5]** we can now calculate what is the actual temperature after a cooldown of X=6 hours. This $T_{aftercooldown}$ is the <u>lowest </u>temperature that is reached during the period. The <u>average</u> temperature during <u>'full setback' </u>is

$$T_{fullsb} = \{6*0{,}5\ (T_{prev} + T_{cooled}) + 2*0{,}5(T_{cooled}+T_{new}) \} /8$$

Note that in most cases $T_{prev} = T_{new}$, so the expression can be simplified.

In case of <u>'reduced setback</u>' where the temperature should not drop below a certain known set temperature (T_{min}) expressions **[7]** and **[16]** can be used directly to determine the cooldown time, the reheat time and –if applicable— a time at steady state during the setback period. Or, as is the case in the spreadsheet, the times and temperature values are derived from the full setback calculations.

105 If there are consecutive cooldown periods, like in the case of Zone 2, the term applies only to the first cooldown period which is a minimum of 2 hours. After these 2 hours the radiator thermal mass will be close to zero.

11.1.5 Spreadsheet

The figures below show the relevant parts of the spreadsheet program, relating to thermal mass calculations: the dwelling characteristics, the installation characteristics and a multi-view output table, where one of the views shows the effect of the thermal mass on the indoor temperature that can actually be realized.

Figure A-5. Dwelling characteristics for thermal mass (loaded from LOOKUP worksheet)

THERMAL MASS		
Specific thermal mass per m³ V : tm	Wh/m³.K	18
Correction factor : ξ		0,96

INSTALLATION:

EMITTERS	Radiator-type	
Capacity & rad. constant	Pradnom	radc.
	kW	#
Zone 1 (day)	8,6	1,30
Zone 2 (night)	6,0	1,30
Zone 3 (bath)	4,0	1,30
total	*18,6*	
Reheat power (Preheat)	100%	
Minimum nom. flow (fminnom)	20%	

CONTROLLERS			
Boiler temperature controller	custom		dt boil
6 - Thermostat zone 1	70,0		6,4
Flow rate	custom		CH-flow
2 -min	1000	l/h	320

Click on cell and select 1 of 8 Tb options

Click on cell and select 1 of 2 flow options

p-band of Tb. This is an output (do not edit)

This is an input value (editablel) in case of a fixed Tb (options 1-4)

Input (editable) in case of a fixed flowrate.

Flowrate in l/hr. This is an output (do not edit)

Fig. A-6. Installation characteristics relevant for thermal mass. All 'EMITTERS' values for the nominal radiator capacity (Pradnom), the radiator constant (radc), the reheat power (Preheat) as % of nominal adiator power and the minimum flowrate (fminflow) can be edited directly in the MAIN worksheet. To edit the parameters in the 'CONTROLLER' section follow instructions as given in figure.

Figure A-7. Multi-view output table, where one of the views ('1- after Tmass) shows the effect of the thermal mass on the indoor temperature that can actually be realized. The example above corresponds to the SET INDOOR TEMPERATURE table in Fig. 4 and shows that –due to the thermal mass effects—the actual temperatures during setback periods can not reach the set temperatures for this dwelling and installation.

REALIZED INDOOR TEMPERATURES (output data)

1 -after Tmass	<—select type	Trealized					
Zone 1 (day)		21,0	21,0	21,0	21,0	19,7	*20,6*
Zone 2 (night)		15,0	15,9	20,0	19,5	17,0	*17,4*
Zone 3 (bath)		24,0	22,6	21,4	24,0	22,2	*22,5*
average		18,9	19,1	20,6	20,7	18,9	19,5

As an example the tables below show the saving effect of night-setback for Zone 1 (Living room, kitchen, etc.) in an EU-25 average existing home with a "week 21/20/24" timer regime (Table 1a) and a new home with a "week 20/19/22" timer (Table 1b). Table 1a shows a saving of on average 4-4,5% on annual energy consumption. This may vary between 2,5% (Cyprus) and 7,5-8% (Finland).

Table 1b shows that in new dwellings and a somewhat lower timer regime the average saving is 3-3,5%. Please note that –especially for Zone 2—this saving may be less due to the internal heat transfer.

Table A-1a. Example of night setback for Zone 1 (EU average existing home, week 21/20/24)

EU-25	**Zone 1 night-setback (8 h period)**						**Setback saving**
avg existing	cooldown	reheat	Tset high	Tset low	Trealized low	Treal avg	at 1°C=8% for 24h
month	time (h)	time (h)	°C	°C	°C	°C	
jan	6,8	1,2	21,0	15,0	17,2	19,1	5,0%
feb	6,8	1,2	21,0	15,0	17,4	19,2	4,8%
mar	7,0	1,0	21,0	15,0	17,7	19,3	4,5%
april	7,2	0,8	21,0	15,0	18,3	19,7	3,6%
may	7,6	0,4	21,0	15,0	19,5	20,3	2,0%
sep	7,7	0,3	21,0	15,0	19,8	20,4	1,6%
oct	7,4	0,6	21,0	15,0	19,2	20,1	2,5%
nov	7,0	1,0	21,0	15,0	18,2	19,6	3,8%
dec	6,8	1,2	21,0	15,0	17,4	19,2	4,8%
			annual saving with respect of Tset high=21				ca. 4-4,5%

Table A-1b. Example of night setback for Zone 1 (EU average new home, week 20/19/22)

EU-25	**Zone 1 night-setback (8 h period)**						**Setback saving**
avg existing	cooldown	reheat	Tset high	Tset low	Trealized low	Treal avg	at 1°C=8% for 24h
month	time (h)	time (h)	°C		°C	°C	
jan	1,1	6,9	20,0	15,0	17,0	18,5	4,0%
feb	1,0	7,0	20,0	15,0	17,1	18,6	3,9%
mar	0,9	7,1	20,0	15,0	17,3	18,7	3,6%
april	0,6	7,4	20,0	15,0	17,9	18,9	2,8%
may	0,3	7,7	20,0	15,0	18,8	19,4	1,5%
sep	0,3	7,7	20,0	15,0	19,1	19,5	1,2%
oct	0,5	7,5	20,0	15,0	18,6	19,3	1,9%
nov	0,8	7,2	20,0	15,0	17,8	18,9	3,0%
dec	1,1	6,9	20,0	15,0	17,1	18,5	3,9%
			annual saving with respect of Tset high=20				ca. 3- 3,5%

Internal heat transfer

The calculation of the heat transfer between temperature zones of a dwelling is very difficult in a monthly approach. The ideal would be a numerical method with a small time step, but numerical methods are difficult to implement in legislation and standards.

As a consequence, most standards tend to largely ignore internal heat transfer (NL, DE) or deal with it through lookup tables (UK). In fact the temperature tables for living room and bedrooms in the SAP 2005 would be difficult to explain without a significant influence of the internal heat transfer.

EN 832 provides a general formula but with very little guidance as to how this would work in practice. This general formula, e.g. for heat transfer between zone x and z, looks like

$$QHij = hrs * (Ti - Tj) * (b*qTij + qVij) \qquad [17]$$

where
QHij= heat transfer between zones i and j (in kWh)
Ti, Tj = indoor temperatures in zones i and j
b = correction factor for transmission losses
qTij = specific transmission heat transfer between i and j (in kWh/K) = Aij *Uij
with
Aij = surface (internal wall/floor) between zones i and j (in m²)
Uij =specific transmission value internal wall/floor (in W/m².K)
qVij = specific ventilation/infiltration heat transfer between i an j (in kWh/K) = Vi * qinfij
with
Vi = reference volume (either of i or j, usually the smallest)
qinfij= specific ventilation rate (in m³ /m³) relating to Vi

We have used this formula, because it is currently the best available in the standards. But it is of course a simplification and we are using specific input parameter values so the user can fine-tune these parameters to its need. The figure 4 shows heat exchanging surface area Axz (internal walls, floor) between zones 1-2, 1-3, 2-3 as % of F .

The default input values for Uxz, b and Qinfxz are given below. Please note that these values can be edited in the MAIN worksheet. As with the thermal mass, the multi-view output table also has the option to study the effect of the internal heat transfer (after the correction for thermal mass).

Figure A-8.
Input values and Multi-view output table, where one of the views ('2- plus Tintrans') shows the effect of the internal heat transfer on the indoor temperature that can actually be realized, after taking into account the effect of the thermal mass. The example above corresponds to the SET INDOOR TEMPERATURE table in Fig. 4 and the table in Figure 7- Note that especially the indoor temperature in the coldest zone (Zone 2) is influenced by the internal heat transfer.

INTERNAL HEAT TRANSFER		
Internal transmiss heat per m² Aij : Uij	W/m².K	0,60
Internal infiltration per m³ Vi : qinfi	m³/m³	0,10
Internal temp. Correction: b	b	0,50

REALIZED INDOOR TEMPERATURES (output data)

2 -plus Tintrans	<—select type	Trealized					
Zone 1 (day)		21,0	21,0	21,0	21,0	19,4	*20,5*
Zone 2 (night)		18,5	18,7	20,5	20,7	18,8	*19,2*
Zone 3 (bath)		24,0	21,1	21,0	24,0	21,1	*21,6*
	average	20,3	20,1	20,8	21,2	19,3	20,1

Please note that the spreadsheet also offers the option to calculate for a “single zone” (Zone 1) and a “multi-zone” calculation of the internal heat transfer (cell next to setback options). The “multi-zone” is the default option and should normally be used. It assumes that the controls are capable of detecting a heating deficiency in each zone and that the heating will be turned up where necessary. However, in some cases like a central thermostat control and manual valves, this may not be the case and the heating deficiency is only noticed and compensated in the reference room (Zone 1). This is what happens with the “single-zone” option which will unavoidably lead to some (small) discomfort. If and how to deal with this discomfort, is not clear yet, but in any case the model gives the option.

Control losses (ΔTfluct)

T_{fluct} is the temperature correction resulting from variations in the room temperature in time, in particular the ones caused by the heating installation.[106] In a radiator-based central heating system, which is our reference, there are basically two ways to regulate the room temperature:

- Through the boiler temperature (e.g. weather dependent, thermostats) and
- Through the flow rate of the individual radiators or radiator groups (e.g. valves, TRVs, etc.).

Both ways will result in temperature fluctuations over time. These fluctuations lead to energy loss in two ways:

- Temperature overshoot (not compensated by temperature undershoot), which means that the room will be temporarily too hot.
- The operative room temperature, i.e. the temperature to which the user reacts in terms of heating comfort, will (temporarily) drop to a too low level, prompting the consumer to raise the set temperature of the room because it is ‘too cold’. But the control of the boiler temperature is very much linked to the boiler control and will be discussed with the boiler model. Here we will limit our discussion to the flow rate control.

This subject has been introduced in the Task 4 report, which also shows the relevant table from prEN 15316-2-1, which is derived from the German DIN 4701-10. This German approach uses a fixed energy loss (in kWh per m² floor area) for each type of room control and band width.

For instance for a thermostatic radiator valve (TRV) with a p-band of 2K the energy loss is 3,3 kWh/m².a. For a low energy house with an annual heat load of 40 kWh/m².a this then results in an energy loss of 8%. For a more average (existing) house of 90 kWh/m²a this results in an energy loss of 4%. The German approach distinguishes between TRVs (with 2 band-widths: 2 K and 1K) and two types of electronic control configurations. Radiators without TRVs and also room thermostats are not considered, which could imply that this applies to systems with a weather-dependent boiler temperature control (outdoor sensor) and room temperature control exclusively through TRVs, which is the most common system in Germany for single family houses. Apart from radiator/convector systems, the Germans also evaluate floor heating systems. These are not part of our reference, but it is remarkable that the control losses are in the same order of maginitude.

The British building regulations Part L and SAP[107], which are discussed in Chapter 8 of the Task 1 report, differentiate heating system efficiency for several types of controls. No fixed energy loss is used, but instead an ***overall heating system efficiency adjustment*** is given of minus 5% in case there is no TRV (SAP-2005, Table 4c). But that is not all: Also the ***Mean Internal Temperature of the Living Area*** (usually

[106] Fluctuations in room temperature can also be caused by variations in solar gain, internal gain, infiltration and of course the outdoor temperature. But these have been taken into account explicitly or implicitly in other parts of the heat balance. Note that in the French RT 2005 the ΔtTfluct is referred to as Ttemporelle.

[107] Standard Assessment Procedure. The SAP-2005 was the basis for much of Part L.

the living room) is raised by +0,6°C in case there is no thermostatic control[108]. This is put in general terms, so it could apply to both TRVs and thermostats, but implies also an overall extra efficiency loss of around 2% for radiators without TRVs

Furthermore, the SAP considers the ***heat transfer between zones***, depending on the control type (type 1, 2 and 3[109]) as well as the Heat Loss Parameter HLP (range 1-6 W/m²K). The HLP is the heat loss (transmission + ventilation) per m² heated floor area. The table implies that in a low energy house (HLP<1) without TRVs the bedrooms will be barely (0,5°C) be colder than the living room, but in a very poor efficiency house (HLP>6) the temperature difference may be as high as 2°C. With TRVs in the bedrooms the temperature in the bedrooms can be kept some 1,4 (HLP 1) to 2°C (HLP 6) lower. So the relative benefit of TRVs diminishes if the heat load is higher. For an average existing house (HLP is 2,5 to 3) the difference between TRVs and no TRVs in the bedrooms is around +0,7°C.[110]

All in all, the British (central room thermostat) and German (weather-dependent control) approaches are complementary and set a good framework for modelling. Having said that, there are also several items missing. Especially regarding the ***quality*** of the controls, as has also been demonstrated by O'Hara[111], the approaches lack detail. Controls are characterized not only by their ***bandwidth***[112], but also their ***inertia*** (the delay before it reacts to change) and their ***logic*** (e.g. P-control like in a TRV or PID that can be realized in an electronic control). Especially the inertia can play an important role, especially at (too) high boiler temperatures: In terms of temperature overshoot it makes a considerable difference if the radiator valve closes 10 minutes too late (fast TRV), 20 minutes (average) or 30 minutes (slow TRV). 'Overshoot' means the rise of the radiator-temperature that occurs after the desired air temperature (upper band width) has been reached.

With the expression below we have tried to capture the phenomena described above:

$$\Delta T_{fluct} = (L + (pband+0{,}15)^{1{,}5})) * (t_{delay}/0{,}33) * (Tb/45) * PH/P_{radnom} \qquad \textbf{[18]}$$

where

- ΔT_{fluct} is the indoor temperature correction in K due to temperature fluctuations in K
- L is the direct controller logic (if P-control then L=0,36, if PID-control then L=0)
- pband is the bandwidth of controller in K (e.g. 2K for an unbalanced system with TRV, 1 K for a balanced system with pre-adjusted TRV, >0,5 K for electronic systems)
- t_{delay} is the reaction time of the controller in h, where the average TRV reaction time of 20 minutes= 0,33 h is used as a yardstick. [other values: 30 minutes=0,5 h for slow TRV; 10 minutes= 0,16h for fast TRV; 1 minute= 0,02 h for fast sensor]
- Tb is the average boiler temperature in °C (calculated as shown in par. 1.5), where the average boiler temperature of 45°C is used as a yardstick.
- PH=(QH/hrs) is the average heating power demand in kW in a period
- P_{radnom} is the nominal radiator power in kW

---

[108] In case of a heat pump or a community heating system the surplus is 0,3°C. Thermostatic control could relate to thermostat or TRV. Usually in the British living area it will be the thermostat; in Germany it will be TRVs (outdoor sensor control).

[109] Type 1 comprises all central control solutions for the living room, but no controls in the other rooms. Type 2 comprises also TRVs in the other rooms and more sophisticated logic. Type 3 considers multiple zone control, which means that there can be several boiler temperatures simultaneously.

[110] With TRV: around 1,7°C lower. Without TRVs: around 1°C lower.

[111] Presentation at Ecodesign Lot 1 expert meeting Nov. 2006 (see www.ecoboiler.org)

[112] To avoid misunderstanding: The bandwidth is very important and effectively the German value of 3,3 kWh/m² for a TRV with a 2K p-band presumably does not only symbolize a specific type of TRV, but relate also to the fact that the system isn't hydraulically balanced (which necessitates a large p-band).

Please note that the expression above only takes into account the direct effect of the controller. It relates to TRVs, indoor and outdoor sensors and to control logic only if it is a self-contained part of the controller, like with a TRV or a closed loop control between a sensor and a motor-valve. It does **not** take into account the interaction with the boiler CPU or other CPU-like devices[113], which we assume to be taken into account in the boiler model.

The spreadsheet gives the option to directly edit the input values in the MAIN worksheet (see fig. A-9)

Figure A-9.
Input values and Multi-view output table for ΔTfluct, where one of the views ('3- plus Ttemp') shows the effect of the temperature fluctuations on the indoor temperature, after taking into account the effect of the set temperature (fig. 4), the thermal mass (Fig. 7) and the internal heat transfer (Fig. 8).

CONTROLLER

Room temperature control type		Zone 1	other
P-band	K	2	2
Delay	h	0,33	0,33
Logic (P=0,36, PID=0)	#	0,36	0,36

REALIZED INDOOR TEMPERATURES (output data)

3 -plus Ttemp	<—select type	**Trealized**					
Zone 1 (day)		21,3	21,2	21,3	21,3	20,1	*20,9*
Zone 2 (night)		20,0	20,0	21,1	21,5	20,0	*20,3*
Zone 3 (bath)		24,2	21,2	21,2	24,2	21,2	*21,7*
average		21,1	20,7	21,2	21,7	20,1	**20,7**

Emitter efficiency (ΔTstrat)

Strictly speaking all emitters in a CH-system are 100% efficient, because the heat that isn't used to heat the room flows back in the CH-circuit. The effectiveness of the heating is another matter, keeping in mind that the function is to supply heating comfort to the inhabitants of the dwelling. In that sense it is not very effective to have a large temperature gradient in a room, because people tend to react to the coldest temperature they experience, etc..[114]

This is described in prEN 15316-2-1, which is basically a compilation of national building standards in this field (e.g. IT, DE). Non uniform temperature distribution causes energy losses because of:

1. a higher average room air temperature is needed to deliver similar comfort level at 1,15 m. from floor (sitting position);

2. increased heat transfer through surfaces that are in direct contact with these higher air/radiation temperatures (ceiling, windows, surface behind radiator);

3. increased ventilation losses (in case passive stack or traditional mechanical extraction system are used (no heat recovery)).

The vertical air temperature stratification depends on the type of emitters used (radiator / convector / floor heating). Furthermore the stratification is not constant but depends on the boiler feed temperature (in case of radiator/convector systems) or the floor temperature (in case of floor heating systems).

[113] E.g. what the SAP refers to as 'electronic optimisers'

[114] Note that in the French RT2005 this ΔTstrat is referred to as Tspatiale. In the Italian and German standards it is indicated as "emitter efficiency".

Figure A-10.

Vertical air stratification for radiator/convector systems

Tboilfeed [°C]	<25	30	40	50	60	70	80	90
Tceiling-Tfloor	1,5	2,0	2,5	3,0	3,5	4,0	4,5	5,0

Vertical air stratification for floor heating systems

Tsurface	21,5	22,0	22,5	23,0	23,5	24,0	24,5	25,0
Tceiling-Tfloor	0,50	0,75	1,00	1,25	1,50	1,75	2,00	2,25

* Tfloor and Tceiling are the air temperatures at a distance of 15mm from the surface
* Tsurface is the actual temperature of the floor

The vertical air stratification for radiators above can be described with the following equation:

$$Tceil - Tfloor = MAX\{\, 1{,}5;\quad 1{,}5+(Tbf - 20)*0{,}05 \,\} \qquad [19]$$

Formulas for calculating the correction factor for non uniform air temperature distribution

$$\Delta Tstrat' = \Delta Tstrata + \Delta Tstratt * QT/(QV+QT) + \Delta Tstratv * QV/(QV+QT) \qquad [20]$$

in which

Δtstrat'	Overall correction factor for non uniform air temperature distribution
ΔTstrata	Correction factor on average indoor air temperature to achieve air temp. set point at href meter above floor level
Δtstratt	Correction factor incorporating the additional transmission losses caused by higher air/radiation temperatures near outside surfaces
ΔTstratv	Correction factor incorporating the additional ventilation losses caused by higher extract air temperatures
QT/(QV+QT)	Share of transmission losses in total of transmission and ventilation losses
QV/(QV+QT)	Share of ventilation losses in total of transmission and ventilation losses

ΔTstrata	(h / 2 - href) * (Tceil -Tfloor) = 0,225 * (Tceil -Tfloor)
h	height of the rooms (default 2,85 m)
href	Distance from floor where reference temperature is measured (default 1,2 m)
Δtstratt	[0,5*(Tceil-Tfloor)* Astrat] - [0,5 * (Tceil-Tfloor) * (1 – Astrat)] = (Tceil-Tfloor) * (Astrat - 0,5)
Astrat	share of the outside surface that is exposed to the higher air temperatures (default 0,6)
ΔTstratv	0,5 (Tceil -Tfloor))

The figure below shows an example for h=2,75 , href=1,20, QT/(QV+QT) =0,75 , QV/(QV+QT)=0,25 and Astrat =0,60. This is typical of existing buildings.

Figure A-11.

Correction factor **Δtstrat'** for radiator/convector systems (in relation to Boiler feed temperature)

	Boiler feed temperature [°C]							
	<25	**30**	**40**	**50**	**60**	**70**	**80**	**90**
ΔTstrat;av	0,26	0,35	0,44	0,53	0,61	0,70	0,79	0,88
ΔTstrat;transm.	0,11	0,15	0,19	0,23	0,26	0,30	0,34	0,38
ΔTstrat;vent.	0,19	0,25	0,31	0,38	0,44	0,50	0,56	0,63
ΔTstrat '	**0,56**	**0,75**	**0,94**	**1,13**	**1,31**	**1,50**	**1,69**	**1,88**

Note that ΔTstrat' relates to the air temperature, but for heating comfort we use the 'operative temperature' which is according to ASHREA the average between the radiation temperature of the walls/floor/etc. –which varies very little— and the air temperature. In short, this means that a factor 0,5 has to be applied.

With this factor 0,5 and using the defaults for Astrat/Aout, h and href , as well as the empirical formula in expression [18]we can now rewrite the expression [19] as follows:

$$\Delta Tstrat =$$

$$0{,}5 * \{0{,}225 + 0{,}1 * QT/(QV+QT) + 0{,}5 * QV/(QV+QT)\} * MAX\{1{,}5;\ 1{,}5 + (T_{bf} - 20) * 0{,}05\} \quad \textbf{[21]}$$

All the parameters are determined within the model, so there is no option for editing ΔTstrat inputs. The multi-view output table shows the effect of ΔTstrat (see Fig. A-12).

Figure A-12.
Multi-view output table for ΔTstrat (Tspatial), where one of the views ('4- plus Tspatial') shows the effect of the temperature stratification on the indoor temperature, after taking into account the effect of the set temperature (fig. 4), the thermal mass (Fig. 7) , the internal heat transfer (Fig. 8), temperature fluctuations (Fig. 9).

REALIZED INDOOR TEMPERATURES (output data)

4 -plus Tspatial	<—select type	Trealized					
Zone 1 (day)		21,8	21,8	21,8	21,9	20,6	*21,4*
Zone 2 (night)		20,5	20,5	21,6	22,1	20,5	*20,9*
Zone 3 (bath)		24,7	21,7	21,7	24,7	21,7	*22,2*
	average	21,6	21,3	21,7	22,2	20,7	21,3

Distribution losses

In accordance with EN and German standards we calculate distribution losses as a function of the average boilertemperature (=**Tb**= radiator temperature), the insulation of the pipes (**Upipe** in W/mK pipe) and a multiplier (**hlf**=heat loss factor) that indicates the share of the distribution heat loss that is actually lost, i.e. not giving a useful contribution to the space heating.

For the pipe-lengths we use the DIN 4701-10 default values ('Tabellenverfahren'), relating to the heated floor area F. The DIN 4701-10 distinguishes between pipes in the circulation circuit (**L1**) and pipes from the circulation loop to the individual radiators (**L2**).

*L1 = 28 + 0,05*F (circulation circuit)* **[22]**

*L2 = 0,515*F (radiator pipes, expression incl. correction factor b)* **[23]**

The heat loss factor hlf differentiates between pipes in the unheated space (usually L1) and the ones in the heated space (usually L2). As a default temperature for the unheated space the Germans assume a cellar with a temperature of 13°C. In other countries this may be different and of course in the case of e.g. a roof the ambient temperature in the unheated space varies with the season. Therefore, we assume an ambient temperature in the unheated space of Tau= T – 7. The default values now become:

hlf1= 1 at Tau= T-7 if in unheated space **[24]**

hlf2=0,15 at Tah= 20 if in heated space **[25]**

As insulation for the piping we will assume the German default values: Upipe1=0,2 W/mK in unheated space and Upipe2=0,255 W/mK in heated space.[115]

In principle, the heat losses of circulation pipes (Qpipe1) and radiator pipes (Qpipe2) can now be written as:

*Qpipe1 = L1 * hlf1 * Upipe1 * (Tb-Tau)* **[26]**

*Qpipe2= L2 * hlf2 * Upipe2 * (Tb – Tah)* **[27]**

This would require a host of input parameters and we would like the number of inputs as small as possible, i.e. only a single hlf and Upipe as parameters. Therefore the mathematical model uses Upipe=Upipe2=0,255 W/mK as a basis and corrects for that in expression [26]. The expression of all the piping heat losses thus becomes

[115] Note that these are very (too) good insulation values to serve as an EU default, certainly in existing dwellings. On the other hand, the pipelengths given by the German standard are also rather (too) long, which may compensate for that. For now, until better data on pipe insulation are known, we will therefore keep these values for Upipe. For comparison: For large uninsulated circulation pipes (22-28 mm) the Upipe can be as high as 1 W/mK.

$$Qpipe = (28 + 0,05*F)*hlf*(Upipe-0,55*(hlf-0,15)/0,85))*(Tb-(T-7) +7*(hlf-0,15)/0,85) + (0,515*A)*0,15*Upipe*(Tb-20) \quad [28]$$

In the spreadsheet we use the input values for hlf and Upipe as indicated in the figure below

Figure A-13.
Input values for distribution losses

DISTRIBUTION

Heat loss factor: **hlf**	0,60	
Specific U value/ m pipe: **Upipe**	0,26	W/K.m pipe

For the time being we just account for the distribution losses as an extra heat demand. For now, especially if the hlf factor is in the area of 0,5-0,6 we do not assume an effect on the indoor temperature.[116] In the multi-view output table the average boiler temperatures used for the calculation of the distribution losses can be shown with table option 5.

Spreadsheet

Throughout this chapter we have shown pieces of a spreadsheet programme that accompanies this chapter. This programme is contained in an unprotected MS Excel sheet, showing

- The **user interface**: Page 1 (in print) of worksheet MAIN
- A **calculation part**: The rest of worksheet MAIN (rows hidden, but can be unhidden)
- **Look-up tables** in the worksheet LOOKUP: containing country-specific inputs and intermediary values that are loaded into the MAIN worksheet. These tables can also be found in the Appendix.
- A **library** worksheet that isn't really part of the programme, but shows all the tables in this chapter as a background information.

The user interface is shown in a figure on the next page, featuring –not announced earlier—also the OUTPUT part of all calculations in the lower right corner, showing the total energy consumption, split up by the various effects.

[116] What is actually happening is that simultaneously there is an unrecoverable heat loss (negative effect) and an extra space heat ing input (positive effect). We assume that both effects will compensate each other.

COUNTRY: 26-UK

GEOMETRY		
Dwelling type	1 -average existing	
Heated volume: V	m3	244
floor height: h	m	2,84
Ratio AV: AV	m2/m3	0,56
Heated floor area : F (=V/h)	m2	86
Building shell surface: A (=AV*V)	m2	137

GENERAL HEAT BALANCE		
Spec. transmission heat per m2 A: U	W/m2.k	1,05
Infiltration per m3 V : qinf	m3/m3.h	0,21
Ventilation per m3 V : qv	m3/m3.h	0,65
Vent. heat recovered % : qrec	%	5%
Solar gain factor: sgf	%	11%

THERMAL MASS		
Specific thermal mass per m3 V : tm	Wh/m3.K	18
Correction factor : ξ		0,96

INTERNAL HEAT TRANSFER		
Internal transmiss heat per m2 Aij : Uij	W/m2.K	0,60
Internal infiltration per m3 Vi : qinfi	m3/m3	0,10
Internal temp. Correction: b	b	0,50

CONSTANTS		
days per month: dpm	#	30,50
specific heat air: ah	W/K.m3	0,33

OUTDOOR TEMPERATURES & SOLAR		8,9	oC
GLOBAL SOLAR IRRADIANCE	avg.	95	W/m2

ZONES & DAY-PERIODS		morn	mid	eve	late	night	tot
Time of day for each period	h-h	7-9h	9-16h	16-21h	21-23h	23-7h	
Hours per day	h	2	7	5	2	8	24
Hours per month (hrs)	h	61	212	152	61	243	729

INTERNAL GAIN							
Int. gain/month.m2F: Qgain	kWh/m2.m	0,36	0,00	0,90	0,36	1,20	2,82

SET INDOOR TEMPERATURES — Tset (reduced setback scheme)*

setting	fi	Aij*	morn	mid	eve	late	night	avg.
2 -Week 20/19/22	%	%						
Zone 1 (day)	50%	50%	20,0	20,0	20,0	20,0	15,0	18,3
Zone 2 (night)	40%	10%	15,0	15,0	19,0	15,0	15,0	15,8
Zone 3 (bath)	10%	10%	22,0	19,0	19,0	22,0	19,0	19,5
average			18,2	17,9	19,5	18,2	15,4	17,5

OPTIONS

setback options	internal heat options	
2-Reduced setback	1-Multizone	0

REALIZED INDOOR TEMPERATURES (output data)

1 -after Tmass <--select type	Trealized					
Zone 1 (day)	20,0	20,0	20,0	20,0	18,5	19,5
Zone 2 (night)	15,0	15,7	19,0	18,5	16,5	16,8
Zone 3 (bath)	22,0	20,5	19,3	22,0	20,1	20,4
average	18,2	18,3	19,5	19,6	17,9	18,5

INSTALLATION:

EMITTERS	Radiator-type	
Capacity & rad. constant	Pradnom	radc.
	kW	#
Zone 1 (day)	8,6	1,30
Zone 2 (night)	6,0	1,30
Zone 3 (bath)	4,0	1,30
total	18,6	
Reheat power (Preheat)	100%	
Minimum nom. flow (fminnom)	20%	

DISTRIBUTION		
Heat loss factor: hlf	0,60	
Specific U value/ m pipe: Upipe	0,26	W/K.m pipe

CONTROLLER			
Room temperature control type		Zone 1	other
P-band	K	2	2
Delay	h	0,33	0,33
Logic (P=0,36, PID=0)	#	0,36	0,36

Boiler temperature controller	custom	dt boil
6 - Thermostat zone 1	70,0	6,6

Flow rate	custom	CH-flow
2 -min	1000 l/h	320

OUTPUT: HEAT ENERGY

	kWh	%	oC
TOTAL	15.735	100%	19,8
Tset	10.754	68%	17,5
Tmass	1.553	10%	1,1
Tintrans	525	3%	0,4
Tfluct	369	2%	0,3
Tstrat	690	4%	0,5
Distr. losses	1.844	12%	na

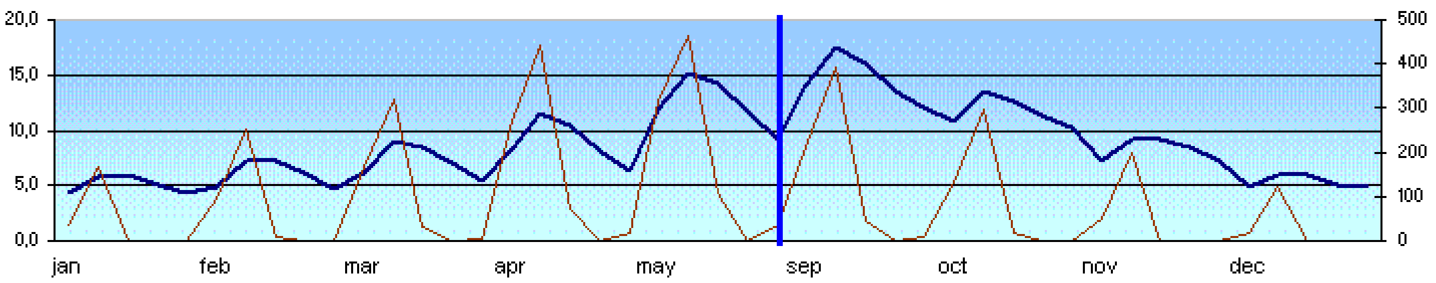


Table A-2a. Selected outputs (week 21/20/24) and comparison to statistics

EU AVERAGE EXISTING, WEEK 21/20/24,	TOTAL	(Net heat load=) Tset	Tmass	Tintrans	Tfluct	Tstrat	Distr. losses	Net heat load according to statistics	according to model (Tset-20%)
EU-25	14.849	9.968	1.722	617	314	596	1.631	7.483	7.975
AT	19.788	14.056	1.773	739	527	757	1.937	10.606	11.244
BE	22.483	15.718	2.257	673	752	940	2.144	12.194	12.574
CY	11.439	6.241	2.521	537	508	835	796	4.674	4.993
CZ	15.625	11.154	1.321	607	280	531	1.732	7.963	8.923
DK	19.772	13.808	1.794	885	463	762	2.060	8.618	11.047
EE	17.895	13.601	1.044	545	308	505	1.891	11.201	10.881
FI	18.014	13.655	948	713	303	478	1.918	12.195	10.924
FR	**14.984**	**9.873**	**1.796**	**643**	**319**	**627**	**1.726**	**7.167**	**7.898**
DE	**17.520**	**12.357**	**1.596**	**707**	**379**	**639**	**1.842**	**8.977**	**9.886**
GR	**12.604**	**7.701**	**2.084**	**514**	**344**	**650**	**1.311**	**5.719**	**6.161**
HU	**13.966**	**9.898**	**1.280**	**540**	**245**	**484**	**1.519**	**6.769**	**7.918**
EI	**22.207**	**14.999**	**2.463**	**824**	**733**	**996**	**2.193**	**10.506**	**11.999**
IT	**10.317**	**5.970**	**1.806**	**530**	**216**	**540**	**1.254**	**4.915**	**4.776**
LT	**14.242**	**10.545**	**909**	**486**	**188**	**399**	**1.715**	**8.249**	**8.436**
LI	**12.885**	**9.352**	**861**	**517**	**147**	**369**	**1.639**	**6.201**	**7.482**
LU	**29.910**	**20.939**	**2.804**	**984**	**1.325**	**1.319**	**2.539**	**15.436**	**16.752**
MT	**6.477**	**3.230**	**1.598**	**366**	**130**	**453**	**699**	**1.649**	**2.584**
NL	**14.327**	**9.361**	**1.644**	**732**	**262**	**569**	**1.760**	**6.008**	**7.488**
PL	**15.265**	**11.125**	**1.154**	**560**	**248**	**478**	**1.702**	**7.067**	**8.900**
PO	**6.608**	**3.272**	**1.585**	**378**	**108**	**409**	**856**	**2.089**	**2.617**
SK	**10.757**	**7.487**	**952**	**436**	**130**	**347**	**1.406**	**5.193**	**5.990**
SI	**17.299**	**12.380**	**1.559**	**572**	**419**	**641**	**1.728**	**9.269**	**9.904**
ES	**9.245**	**5.597**	**1.491**	**516**	**152**	**430**	**1.059**	**3.364**	**4.478**
SE	**17.403**	**12.706**	**1.158**	**800**	**311**	**523**	**1.905**	**10.808**	**10.164**
UK	**17.373**	**11.606**	**1.996**	**675**	**430**	**733**	**1.933**	**8.175**	**9.285**

Table A-2b. Selected outputs (week 2019/22) and comparison to statistics

EU-25/ AVERAGE EXISTING/ WEEK 20/19/22 /Zone1	TOTAL	(Net heat load=) Tset	Tmass	Tintrans	Tfluct	Tstrat	Distr. losses	Net heat load according to statistics	according to model (Tset-20%)
EU-25	13.550	9.296	1.365	488	272	566	1.563	7.483	7.437
AT	18.188	13.289	1.364	575	465	700	1.795	10.606	10.631
BE	20.480	14.661	1.706	527	652	890	2.045	12.194	11.729
CY	9.507	5.387	1.966	412	407	729	605	4.674	4.310
CZ	14.472	10.570	1.004	473	247	507	1.671	7.963	8.456
DK	18.224	13.052	1.374	705	407	726	1.959	8.618	10.442
EE	16.851	13.029	795	427	278	484	1.838	11.201	10.423
FI	16.941	13.098	714	554	273	458	1.845	12.195	10.478
FR	**13.535**	**9.183**	**1.413**	**508**	**275**	**580**	**1.576**	**7.167**	**7.346**
DE	**16.093**	**11.676**	**1.220**	**553**	**334**	**601**	**1.710**	**8.977**	**9.341**
GR	**11.132**	**6.934**	**1.688**	**392**	**287**	**603**	**1.228**	**5.719**	**5.548**
HU	**12.917**	**9.372**	**999**	**424**	**217**	**461**	**1.444**	**6.769**	**7.498**
EI	**20.177**	**13.928**	**1.932**	**655**	**631**	**940**	**2.090**	**10.506**	**11.142**
IT	**8.990**	**5.345**	**1.466**	**406**	**179**	**493**	**1.101**	**4.915**	**4.276**
LT	**13.350**	**10.077**	**689**	**383**	**169**	**382**	**1.651**	**8.249**	**8.061**
LI	**12.022**	**8.951**	**652**	**406**	**132**	**346**	**1.536**	**6.201**	**7.161**
LU	**27.350**	**19.670**	**2.100**	**758**	**1.158**	**1.251**	**2.414**	**15.436**	**15.736**
MT	**5.380**	**2.715**	**1.288**	**258**	**102**	**411**	**605**	**1.649**	**2.172**
NL	**12.912**	**8.741**	**1.292**	**567**	**227**	**520**	**1.565**	**6.008**	**6.992**
PL	**14.235**	**10.592**	**876**	**444**	**220**	**456**	**1.647**	**7.067**	**8.474**
PO	**5.642**	**2.774**	**1.296**	**303**	**86**	**382**	**801**	**2.089**	**2.219**
SK	**9.910**	**7.082**	**745**	**339**	**114**	**326**	**1.304**	**5.193**	**5.666**
SI	**15.913**	**11.665**	**1.214**	**444**	**369**	**605**	**1.617**	**9.269**	**9.332**
ES	**8.194**	**5.148**	**1.203**	**394**	**128**	**395**	**926**	**3.364**	**4.119**
SE	**16.231**	**12.106**	**875**	**632**	**277**	**500**	**1.840**	**10.808**	**9.685**
UK	**15.735**	**10.754**	**1.553**	**525**	**369**	**690**	**1.844**	**8.175**	**8.603**

Validation

Tables 2a and 2b show the results for the EU-25 average existing dwelling, with Zone 1 thermostat control (option 6), minimum flow rate and two timer regimes: First "Week 21/20/24" and then "Week 20/19/22". We have compared the model outcomes with the statistics outcomes from previous chapters in the last two columns. As mentioned in par. 1.2 this requires that the calculations for Tset in the model (which is the equivalent of the net heat load) should be reduced with ca. 20% to account for vacant, secondary and otherwise unheated dwellings.

The tables show, especially for "Week 20/19/22" a good match (± 5%) for most EU-15 Member States. For most new Member States (LI, PL, CZ, HU, MT, CY, etc.) the reliability must not be over-estimated, because we had to tweek the U-values to unlikely low values to find a match or we found very little reliable statistical data. There may be many causes for that: The temperature regimes in these countries may be lower than average (e.g. more use of single stove heating with unheated bedrooms), errors in the evaluation of the district heating, other statistical errors, etc.. Until more detailed statistics on the new EU-10 Member States are available, this is something we probably have to live with.

Overall, keeping in mind that the EU-15 represents over 80% of the EU-25 population, the match is deemed sufficient for its purpose.

Furthermore, the model and the spreadsheet programme are flexible and can be adapted during the rest of the decision-making process.

Outlook

The model presented here is in line with the EN and prEN standards as elaborated by TCEN/TC 89 and CEN/TC 228 and can accommodate the existing EPB-standards in the major EU Member States. Although it uses a 'bare' general heat balance, stripped of all its more educational elements for architects and builders, this part of the model is sufficient for its purpose of boiler evaluation and could be easily integrated (extended) in the ongoing EN standardisation work. As regards the specific parts which are of special interest to the heating installation, the model is more extensive than most national standards, but still at least the results are in line with the more elaborate versions (e.g. EN 832).

Perhaps just as valuable as the model itself is the host of input values for each of the EU-25 Member States that are for the first time retrieved and estimated to form a heat balance. As mentioned, there are certainly data gaps –especially for the new Member States— but there is now a basis for consensus-forming and mutual understanding of climatic, construction and installation differences in each country. It could be a very important learning experience that the high or low energy consumption in a country is not the consequence of one single factor like "climate" or "insulation". The type (e.g. apartment vs. houses) , the size of the dwelling and the compactness (AV ratio) can be equally important, showing that –in the end—the differences between heat loads in different climate zones are smaller than expected.

Finally, The model is only a part of the work. As it is, it simulates the situation of residential dwellings with the CH installation where a new boiler is likely to be installed. But the boiler itself is not part of the modelling or –in other words—an ideal boiler was assumed. This part has to be filled with the boiler model that VHK is developing as part of Task 4 and that will play an important role in Tasks 5 to 7. The 'link' between the underlying model and the Boiler Model is in the last 3 lines of the MAIN worksheet, showing the heat demand for each day-period of each of the 9 month-days.

An example of this is given in the next page for EU-25, average existing dwelling, week 20/19/21 timer regime, thermostat control and minimum flow rate.

Table A-3a. Heat demand per period (in kWh) per month day (EU-25 avg. Existing, week 20/19/22)

	JAN					FEB					MAR				
	morn	midday	evening	late	night	morn	midday	evening	late	night	morn	midday	evening	late	night
Zone 1 (day)	3,3	10,2	8,0	3,4	13,2	2,8	8,4	7,0	3,1	12,7	1,9	5,9	5,7	2,8	11,9
Zone 2 (night)	2,4	7,3	6,3	2,7	10,3	2,0	5,8	5,5	2,5	9,9	1,3	3,8	4,4	2,2	9,2
Zone 3 (bath)	0,9	2,4	1,9	0,9	3,3	0,8	2,0	1,6	0,8	3,1	0,6	1,4	1,4	0,7	2,9
total	6,6	19,9	16,1	7,0	26,7	5,6	16,2	14,1	6,5	25,8	3,8	11,2	11,4	5,8	24,0
	APR					MAY					SEP				
Zone 1 (day)	0,8	2,9	3,8	2,3	10,0	0,0	0,0	1,2	1,3	7,2	0,0	0,0	1,1	1,2	6,5
Zone 2 (night)	0,4	2,1	3,0	1,8	7,8	0,0	0,0	0,8	1,1	5,7	0,0	0,0	0,8	1,0	5,1
Zone 3 (bath)	0,3	1,0	1,0	0,6	2,5	0,0	0,0	0,4	0,4	1,9	0,0	0,0	0,4	0,4	1,8
total	1,5	5,9	7,8	4,7	20,3	0,0	0,0	2,3	2,7	14,8	0,0	0,0	2,4	2,6	13,4
	OCT					NOV					DEC				
Zone 1 (day)	1,2	2,6	3,5	1,8	8,0	2,5	7,2	6,1	2,6	10,5	3,3	10,3	8,0	3,4	12,8
Zone 2 (night)	0,7	1,9	2,7	1,5	6,2	1,7	4,9	4,7	2,1	8,2	2,4	7,4	6,3	2,7	9,9
Zone 3 (bath)	0,4	0,9	1,0	0,5	2,1	0,7	1,7	1,4	0,7	2,6	0,9	2,4	1,8	0,9	3,2
total	2,2	5,4	7,2	3,8	16,4	4,9	13,8	12,2	5,4	21,3	6,6	20,1	16,1	6,9	25,9

Table A-3b. Avg. heating power demand per period (in kW) per month day (EU-25 avg. Existing, week 20/19/22)

	JAN					FEB					MAR				
	morn	midday	evening	late	night	morn	midday	evening	late	night	morn	midday	evening	late	night
Zone 1 (day)	1,7	1,5	1,6	1,7	1,6	1,4	1,2	1,4	1,6	1,6	1,0	0,8	1,1	1,4	1,5
Zone 2 (night)	1,2	1,0	1,3	1,4	1,3	1,0	0,8	1,1	1,3	1,2	0,7	0,5	0,9	1,1	1,2
Zone 3 (bath)	0,4	0,3	0,4	0,4	0,4	0,4	0,3	0,3	0,4	0,4	0,3	0,2	0,3	0,4	0,4
total	3,3	2,8	3,2	3,5	3,3	2,8	2,3	2,8	3,2	3,2	1,9	1,6	2,3	2,9	3,0
	APR					MAY					SEP				
Zone 1 (day)	0,4	0,4	0,8	1,1	1,2	0,0	0,0	0,2	0,6	0,9	0,0	0,0	0,2	0,6	0,8
Zone 2 (night)	0,2	0,3	0,6	0,9	1,0	0,0	0,0	0,2	0,5	0,7	0,0	0,0	0,2	0,5	0,6
Zone 3 (bath)	0,2	0,1	0,2	0,3	0,3	0,0	0,0	0,1	0,2	0,2	0,0	0,0	0,1	0,2	0,2
total	0,8	0,8	1,6	2,3	2,5	0,0	0,0	0,5	1,4	1,8	0,0	0,0	0,5	1,3	1,7
	OCT					NOV					DEC				
Zone 1 (day)	0,6	0,4	0,7	0,9	1,0	1,2	1,0	1,2	1,3	1,3	1,7	1,5	1,6	1,7	1,6
Zone 2 (night)	0,3	0,3	0,5	0,7	0,8	0,9	0,7	0,9	1,1	1,0	1,2	1,1	1,3	1,4	1,2
Zone 3 (bath)	0,2	0,1	0,2	0,3	0,3	0,3	0,2	0,3	0,4	0,3	0,4	0,3	0,4	0,4	0,4
total	1,1	0,8	1,4	1,9	2,0	2,4	2,0	2,4	2,7	2,7	3,3	2,9	3,2	3,5	3,2

Parameters & Input Tables

OVERVIEW PARAMETERS USED

unit

Temperatures

T	indoor temperature	°C
Tah	ambient air temperature in a heated room (=T)	°C
Tau	ambient air temperature in unheated room	°C
Tb	Average boiler temperature	
Tbi	average boiler temperature in zone I (in case of multizone temperature control)	°C
Tbf	boiler feed temperature = Tb + ΔTb	°C
Tbr	boiler return temperature = Tb - ΔTb	°C
Tceil	indoor temperature at ceiling level	°C
Tcooled	indoor temperature after cooldown (before reheat)	°C
Tfloor	indoor temperature at floor level	°C
Tfullsb	average indoor temperature over the whole setback period	°C
Ti	indoor temperature in zone I	°C
Tmin	minimum indoor temperature limit (during reduced setback)	°C
Tnew	indoor temperature in following period	°C
Tout	outdoor temperature	°C
Tprev	indoor temperature in previous period	°C
Trad	radiator temperature (in current period)	°C
Tradi	average radiator temperature in zone I (I = 1, 2 or 3)	°C
Tradprev	radiator temperature in previous period	°C
ΔTb	temperature difference between upper/lower and average Tb	K
ΔTfluct	correction for temperature fluctuations by controls (F. *Ttemporelle*)	K
ΔTstrat	correction for temperature stratification by emitter (F. *Tspatiale*)	K
ΔTstrata	correction on avg. indoor temperature to reach air temp. setpoint at href	K
ΔTstratt	correction higher transmission losses through stratification near outside surface	K
ΔTstratv	correction higher ventilation losses through stratification near outside surface	K
50	temperature difference between ambient and average radiator temperature (EN 442)	K

Times

hrs	number of hours of a period (2, 7, 5, 2 or 8 for morn/ mid/ eve/ late/ night)	h
tcool	indoor cool-down time in a setback period	h
treheat	indoor reheat time in a setback period	h
tss	indoor steady state time in a reduced setback period (keeping T=Tmin)	h
tdelay	reaction time delay of (self-contained) controller	
d	day	d
m	month (= 30,5 d)	m

Energy and power

QH	heating demand over a period	kWh
QG	total solar and internal gains over the period	kWh
QHij	heat transfer between zones I and J in a period	kWh
Qpipe	distribution heat loss in a period	kWh
QT	transmission losses over the period	kWh

QV	ventilation losses over the period	kWh
Qgain	internal gain (from people, appliances, etc.) per day	kWh/d.
TMcon	effective thermal mass of construction (first 3 cm)	kWh
TMrad	thermal mass of radiators, incl. Water content	kWh
tm	effective specific thermal mass construction vs. V (range 12-18)	Wh/K.m³
tmrad	specific thermal mass of radiators (incl. water content , ca. 0,0232 * Pradnom)	kWh/K
PH	heating power demand = QH/hrs	kW
Pradnom	nominal radiator capacity according to EN 442	kW
qTij	specific transmission heat transfer between zones I and j	kWh/K
qVij	specific ventilation/ infiltration heat transfer between zones I and j	kWh/K
qsol	specific global solar irradiance per day	kWh/m².d
U	(equivalent) specific transmission coefficient per unit of A	W/K.m²
Uij	specific transmission heat transmission between zones I and j	W/K.m²
Upipe	specific pipe heat loss factor per m of pipe	W/m
tm	effective specific thermal mass construction vs. V (range 12-18)	Wh/K.m³
ah	specific heat of air (constant=0,33)	W/K.m³.
wh	specific heat of water (constant=1,16)	Wh/kg.K

Geometry and flow

h	ceiling height from floor	m
href	height of reference point (from floor) for indoor temperature (default 1,2m)	m
L1	pipe length circulation circuit	m
L2	pipe length from circulation circuit to radiator	m
A	exterior surface area of building shell	m²
Aij	heat exchanging surface area (wall, floor) between zones I and j	m²
F	heated floor area of the building	m²
V	(internal) volume of the dwelling	m³
Vi	reference volume internal ventilation transfer between 2 zones (usually smallest)	m³
qinf	infiltration-rate vs. the volume of the dwelling	m³/h.m³
qinfij	specific ventilation/ infiltration rate relating to Vi	m³/h.m³
qv	ventilation-rate vs. the volume V of the dwelling	m³/h.m³
20	water volume of radiator per kW of Pradnom	l/kW

Dimensionless (rates, numbers, etc.)

AV	ratio between dwelling volume V and exterior surface A	-
b	correction factor for internal transmission losses	-
radc	radiator constant (default 1,3)	-
sgf	solar gain factor	-
tmfc	thermal mass correction factor (range 0,95-0,99)	-
X	no. of hours for reheat or cool down	#
Astrat	share of exterior surface area A exposed to higher air temperatures (default 60%)	%
fi	relative size of temperature zone I as % of total V or F	%
hlf	heat loss factor of pipes (share of unrecoverable heat loss)	%
preheat	reheating power as % of nominal radiator power	%
qrec	specific energy recovered from outgoing ventilation air as % of qv	%
L	correction for controller logic (self-contained controller e.g. TRV)	-
dpm	average number of days per month (constant=30,5)	#
0,001	conversion-factor for Wh to kWh	-
3600	conversion between h and s	-

Annex B

Chimney Renovation

Selected Options and Costs NL

Introduction

One of the most obvious environmental improvements for this product is the switch from atmospheric to condensing boilers. This proven design option alone, that has been around for almost 25 years, would save approximately 15% on the emissions of this appliance.

During the MEEUP project in 2005 it was indicated by industry that the boiler industry agrees that the condensing boiler is the better option in case of new buildings. However, it was also stated, that for the replacement of existing boilers, which is 80% of the boiler-market, the condensing boiler would often not prove to be a feasible and/or better option. One of the main barriers that was mentioned was the cost of renovating the chimney. This is necessary because a conventional chimney is not suited to deal with the flue gases from a condensing boiler. Other related barriers are the general lack of know-how of installers in the field of condensing boilers and the fear that the boilers would not be optimal for the existing radiators, piping and controls.

Recognizing that these barriers, we decided to investigate the issues. For that reason the costs and savings of a number of standard solutions for chimney renovation/renewal were studied and their payback time assessed. The solutions are applicable to the Netherlands, where the condensing boiler is the standard solution also for the replacement market. Cost levels in the Netherlands are typically higher than in the UK and lower than in Germany. As such it is therefore deemed to be representative of the average situation in the EU, if condensing boilers were to become the standard practice.

Labour costs (tariffs and number of hours) were largely retrieved from standard building costs calculation programs and were verified with local installers. For the material costs we took the manufacturer's list prices, which are typically some 30% higher than street prices, and published boiler specifications. Gas rates used are typically for the Netherlands 2005, i.e. including an energy tax of 0.18 Eurocent/m³, but we also made a sensitivity analysis taking into consideration situations, e.g. in Belgium, where the energy tax is not part of the variable fuel costs. In that sense, we took great care not to depict an overly optimistic picture.

Furthermore, we did not include any credit for the fact that the heating installation and the lower energy costs increase the value of the house/building. Also we considered the worst case in terms of the type of building: a small single-family house with a modest energy use. If the house were bigger, the relative savings would be higher while the appliance cost-increase (e.g. a slightly bigger boiler) would be relatively modest and labour costs would remain unchanged. If the house were a multi-family house with a shared boiler, the costs of chimney renovation/renewal would be divided amongst the inhabitants and would be lower.

Overview

		annual gas consumption		annual gas costs*, incl. Tax		list purchase price incl. 19% VAT**	
				rate=	0.5		
		solo	combi	solo	combi	solo	combi
Appliances compared		m³/a	m³/a	EUR/a	EUR/a	EUR	EUR
VR	Atmospheric boiler, gas-fired, 22 kW, efficiency 92% on lower (net) calorific value of gas	1,200	1,700	600	850	1,139	1,304
HR	High-efficiency condensing boiler, gas-fired, 21 kW, efficiency 107% on lower(net) calorific value of gas	1,000	1,400	500	700	1,255	1,420
	Difference	200	300	100	150	-116	-116

*gas at 0.32 c/m³ gas+ 0.18 c/m³ energy tax (NL, Feb. 2005) = 0.50 c/m³ ; prices as listed on www.essent.nl for Delft. Note: 1 m³ is approx. 10 kWh

**= Nefit/Buderus, solo/combi models VR Economy 24S and HR Economy 24,;list prices as published Feb. 2005 on www.nefit.nl. Street prices are up to ca. 30% lower. Combis are a more competitive market in NL than single/solo boilers.

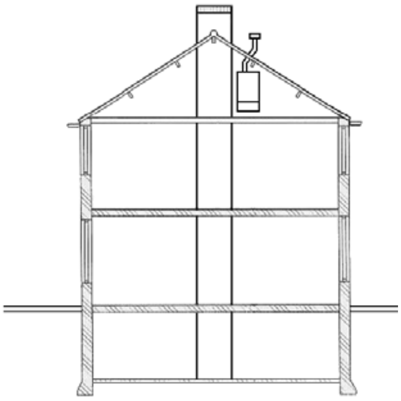
Installations (incl. Labour costs & appliance, incl. VAT) compared

		solo	combi	solo	combi	solo	combi
Reference VR atmospheric boiler							
0	Reference: standard concentric chimney (closed appliances also mandatory for new VR) with vertical roof outlet; boiler type VR; boiler position as is; frequent situation in NL (boiler in attic) and UK (boiler in utility room)	2,063	2,243				

		Total installation costs in €		Extra costs in €		Simple Payback Period*, in years	
Standard situations							
1	Reference: standard concentric chimney (concentric also mandatory for closed VR) with vertical roof outlet; boiler type VR—>HR; boiler position as is; frequent situation in NL (boiler in attic) and UK (boiler in utility room)	2,179	2,359	116	116	1	1
2	Move chimney & boiler to outer wall in garage/cellar; lateral chimney outlet; boiler type VR—>HR; frequent situation e.g. in Belgium, Germany	2,194	2,420	131	177	1	1
3	Apply concentric inner liner to existing chimney; VR—>HR; boiler position as is	2,452	2,633	389	390	4	3
Off-standard situations							
4	As situation 2, but chimney prolonged to roof level on the outside of the building	3,057	3,283	994	1,040	10	7
5	Move chimney & boiler from cellar to attic; standard chimney with vertical roof outlet; boiler type VR—>HR; price takes into account partial retubing of distribution CH pipes	3,697	3,939	1,634	1,696	16	11
6	Boiler as is, but new chimney inside the house, alongside the old one	3,838	4,010	1,775	1,767	18	12

*= simple payback period (SPP), calculated from extra costs vs. Extra savings as calculated in table above. Note: Discounted payback at 3% will yield comparable results, especially when taken into account risk factor of gas price fluctuations; At 15 years assumed Product Life only the off-standard situations 5 and 6 run the risk of not being economic. At gas prices without energy tax (i.e. at 32 c/m³) also off-standard situation no. 4 for solo/single appliances is not economic

Situation 1



Vertical Flue Terminals (Ubbink, M&G)

Tasks:
Replacing the Standard Efficiency (VR) heating system installed in the attic with a High Efficiency (HR) heating system. The single Vertical Flue Terminal has to be replaced with a new Terminal that is suitable for closed systems (mandatory both for VR and HR, for safety reasons).

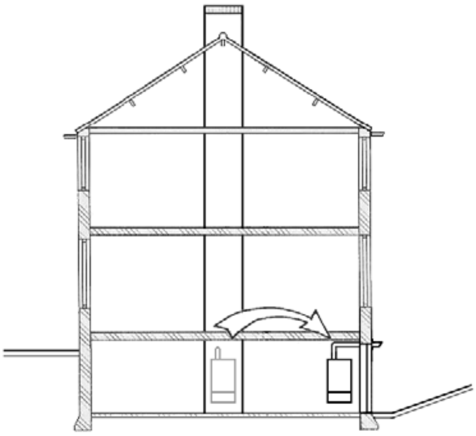
Situation 1: Heating system (Solo)

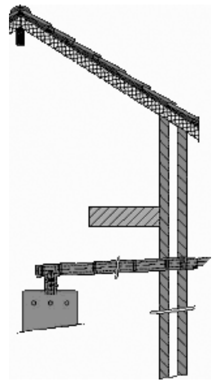
Materials*	Supplier	Price per unit/meter	Quantity	Costs	
HE Solo-system	Nefit/Vaillant/Remeha/..	€ 1,304.05	1	€ 1,054.62	
Vertical flue terminal, Twin-tube	Ubbink/M&G	€ 150.00	1	€ 150.00	
Flue tubes 80mm x 1,5mm	Ubbink/M&G	€ 15.73	1	€ 15.73	
Various Materials	var.	€ 40.00	1	€ 40.00	
Subtotal Material Costs					€ 1,260.35
Man hours**	Supplier	Price per hour/meter			
Installing Gas tubes 15mm	Installer	€ 4.44	1	€ 4.44	
Installing CH-tubes 22mm	Installer	€ 6.22	1	€ 6.22	
man hours sr.	Installer	€ 40.00	8	€ 320.00	
man hours jr.	Installer assistant	€ 30.00	8	€ 240.00	
Subtotal Work Costs					€ 570.66
Total costs					€ 1,831.01
Total costs incl VAT***					€ 2,178.90

Situation 1: Heating and warm water systems (Combi)

Materials*	Supplier	Price per unit/meter	Quantity	Costs	
HE Combi-system	Nefit/Vaillant/Remeha/..	€ 1,417.30	1	€ 1,193.28	
Vertical flue terminal, Twin-tube	Ubbink/M&G	€ 150.00	1	€ 150.00	
Flue tubes 80mm x 1,5mm	Ubbink/M&G	€ 15.73	1	€ 15.73	
Various materials	var.	€ 40.00	1	€ 40.00	
subtotal Material Costs					€ 1,399.01
Man hours**	Supplier	Price per hour/meter			
Installing gas tubes 15mm	Installer	€ 4.44	1	€ 4.44	
Installing CH-tubes 22mm	Installer	€ 6.22	1	€ 6.22	
Installing water tubes 15mm	Installer	€ 6.40	2	€ 12.80	
man hours sr.	Installer	€ 40.00	8	€ 320.00	
man hours jr.	Installer assistant	€ 30.00	8	€ 240.00	
Subtotal Work Costs					€ 583.46
Total costs					€ 1,982.47
*Total costs incl VAT****					€ 2,359.14

Situation 2





Situation-sketch M&G

Horizontal Flue Terminal (M&G)

Tasks: Move chimney & boiler to outer wall in garage/cellar; lateral chimney outlet (the distance to the ground at least 1 m.); boiler type VR—>HR; frequent situation e.g. in Belgium, Germany.

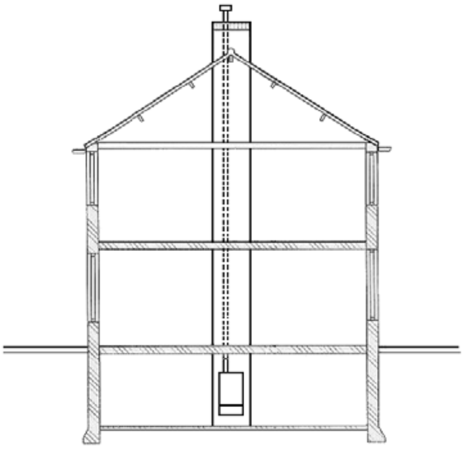
Situation 2: Heating system (Solo)

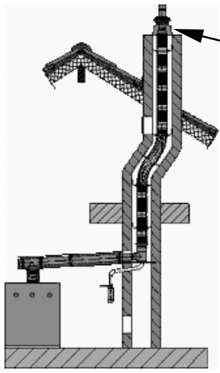
Materials*	Supplier	Price per unit/meter	Quantity	Costs	
HE Solo-system	Nefit/Vaillant/Remeha/..	€ 1,304.05	1	€ 1,054.62	
Horizontal flue terminal, Twin-tube	Ubbink/M&G	€ 115.00	1	€ 115.00	
Flue tubes 80mm x 1,5mm	Ubbink/M&G	€ 15.73	2	€ 31.46	
Various Materials	var.	€ 40.00	1	€ 40.00	
				€ 0.00	
				€ 0.00	
Subtotal Material Costs					€ 1,241.08
Man hours**		Price per hour/meter			
Installing gas tubes 15mm	Installer	€ 4.44	4	€ 17.76	
Installing CH-tubes 22mm	Installer	€ 6.22	4	€ 24.88	
man hours high	Installer	€ 40.00	8	€ 320.00	
man hours low	Installer assistant	€ 30.00	8	€ 240.00	
				€ 0.00	
Subtotal Labour Costs					€ 602.64
Total costs					€ 1,843.72
Total costs incl VAT***					€ 2,194.03

Situation 2: Heating and warm water systems (Combi)

Materials*	Supplier	Price per unit/meter	Quantity	Costs	
HE Combi-system	Nefit/Vaillant/Remeha/..	€ 1,417.30	1	€ 1,193.28	
Horizontal flue terminal, Twin-tube	Ubbink/M&G	€ 115.00	1	€ 115.00	
Flue tubes 80mm x 1,5mm	Ubbink/M&G	€ 15.73	2	€ 31.46	
Various materials	var.	€ 40.00	1	€ 40.00	
				€ 0.00	
				€ 0.00	
Subtotal Material Costs					€ 1,379.74
Man hours**		Price per hour/meter			
Installing gas tubes 15mm	Installer	€ 4.44	4	€ 17.76	
Installing CH-tubes 22mm	Installer	€ 6.22	4	€ 24.88	
Installing water tubes 15mm	Installer	€ 6.40	8	€ 51.20	
man hours high	Installer	€ 40.00	8	€ 320.00	
man hours low	Installer assistant	€ 30.00	8	€ 240.00	
				€ 0.00	
Subtotal Labour Costs					€ 653.84
Total costs					€ 2,033.58
Total costs incl VAT***					€ 2,419.96

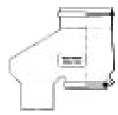
Situation 3





Situation-sketch [M&G]

Flue Terminal and Chimney-hood (Ubbink/Rolux)



Twin tube connection (Ubbink/M&G)

Tasks: Apply concentric inner liner (standard flexible product) to existing chimney; replace VR—>HR; leave boiler

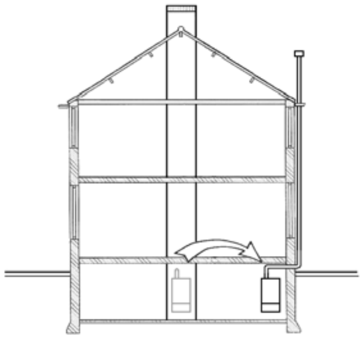
Situation 3: Heating system (Solo)

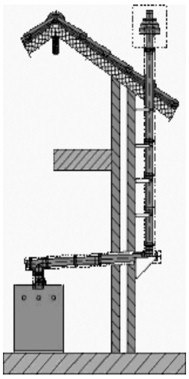
Materials*	Supplier	Price per unit/meter	Quantity	Costs	
HE Solo-system	Nefit/Vaillant/Remeha/..	€ 1,304.05	1	€ 1,054.62	
Flexible chimney renovation pipe	Ubbink/M&G	€ 15.40	10	€ 154.00	
Flue terminal flex. c.r.p.	Ubbink/M&G	€ 90.00	1	€ 90.00	
Chimney-hood	Ubbink/M&G	€ 31.20	1	€ 31.20	
Accessories flex. c.r.p.	Ubbink/M&G	€ 80.00	1	€ 80.00	
Flue tubes 80mm (2 x 0,5 m)	Ubbink/M&G	€ 15.73	1	€ 15.73	
Twin tube connection	Ubbink/M&G	€ 30.00	1	€ 30.00	
Various Materials	var.	€ 40.00	1	€ 40.00	
Subtotal Material Costs					€ 1,495.55
Man hours**		Price per hour/meter			
Installing gas tubes 15mm	Installer	€ 4.44	0.5	€ 2.22	
Installing CH-tubes 22mm	Installer	€ 6.22	0.5	€ 3.11	
man hours high	Installer	€ 40.00	8	€ 320.00	
man hours low	Installer assistant	€ 30.00	8	€ 240.00	
				€ 0.00	
Subtotal Labour Costs					€ 565.33
Total costs					€ 2,060.88
Total costs incl VAT***					€ 2,452.45

Situation 3: Heating and warm water systems (Combi)

Materials*	Supplier	Price per unit/meter	Quantity	Costs	
HE Combi-system	Nefit/Vaillant/Remeha/..	€ 1,417.30	1	€ 1,193.28	
Flexible chimney renovation pipe	Ubbink/M&G	€ 15.40	10	€ 154.00	
Flue terminal flex. c.r.p.	Ubbink/M&G	€ 90.00	1	€ 90.00	
Chimney-hood	Ubbink/M&G	€ 31.20	1	€ 31.20	
Accessories flex. c.r.p.	Ubbink/M&G	€ 80.00	1	€ 80.00	
Flue tubes 80mm (2 x 0,5 m)	Ubbink/M&G	€ 15.73	1	€ 15.73	
Twin tube connection	Ubbink/M&G	€ 30.00	1	€ 30.00	
Various Materials	var.	€ 40.00	1	€ 40.00	
Subtotal Material Costs					€ 1,634.21
Man hours**		Price per hour/meter			
Installing gas tubes 15mm	Installer	€ 4.44	0.5	€ 2.22	
Installing CH-tubes 22mm	Installer	€ 6.22	0.5	€ 3.11	
Installing water tubes 15mm	Installer	€ 6.40	2	€ 12.80	
man hours high	Installer	€ 40.00	8	€ 320.00	
man hours low	Installer assistant	€ 30.00	8	€ 240.00	
Subtotal Labour Costs					€ 578.13
Total costs					€ 2,212.34
Total costs incl VAT***					€ 2,632.68

Situation 4





Situation-sketch M&G

Concentric flue tubes (M&G). Flue Terminal (Ubbink) and Twin Tube Connection (Ubbink/M&G) as in situation no. 3

Tasks: As situation 2, but chimney prolonged to roof level on the outside of the building. Costs include building a scaffolding (half a day) to place the concentric tubes at the outside of the house. This off-standard situation may occur if the fumes/vapour of the flue gas are undesired (e.g. aesthetics) at ground-/ balcony level and the installer is unwilling/unable to apply situation 3

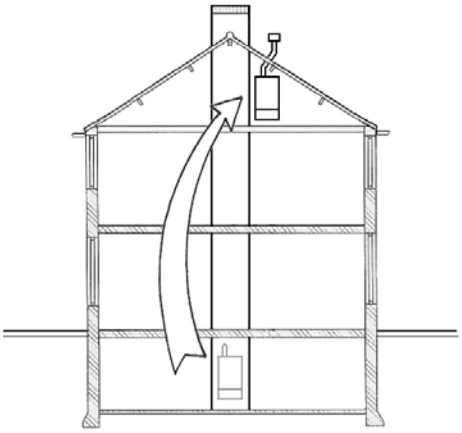
Situation 4: Heating system (Solo)

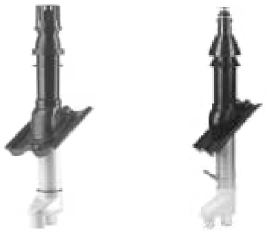
Materials*	Supplier	Price per unit/meter	Quantity	Costs	
HE Solo-system	Nefit/Vaillant/Remeha/..	€ 1,304.05	1	€ 1,054.62	
Flue tubes 80mm x 1,5mm	Ubbink/M&G	€ 15.73	2	€ 31.46	
Twin tube connection	Ubbink/M&G	€ 30.00	1	€ 30.00	
Concentric flue tubes RVS	Ubbink/M&G	€ 55.00	8	€ 440.00	
Flue terminal	Ubbink/M&G	€ 50.00	1	€ 50.00	
Various Materials	var.	€ 80.00	1	€ 80.00	
				€ 0.00	
Subtotal Material Costs					€ 1,686.08
Man hours**		Price per hour/meter			
Installing gas tubes 15mm	Installer	€ 4.44	4	€ 17.76	
Installing CH-tubes 22mm	Installer	€ 6.22	4	€ 24.88	
man hours high	Installer	€ 40.00	12	€ 480.00	
man hours low	Installer assistant	€ 30.00	12	€ 360.00	
Subtotal Labour Costs					€ 882.64
Total costs					€ 2,568.72
Total costs incl VAT***					€ 3,056.78

Situation 4: Heating and warm water systems (Combi)

Materials*	Supplier	Price per unit/meter	Quantity	Costs	
HE Combi-system	Nefit/Vaillant/Remeha/..	€ 1,417.30	1	€ 1,193.28	
Twin tube connection	Ubbink/M&G	€ 30.00	1	€ 30.00	
Flue tubes 80mm x 1,5mm	Ubbink/M&G	€ 15.73	2	€ 31.46	
Concentric flue tubes RVS	Ubbink/M&G	€ 55.00	8	€ 440.00	
Flue terminal	Ubbink/M&G	€ 50.00	1	€ 50.00	
Various materials	var.	€ 80.00	1	€ 80.00	
				€ 0.00	
Subtotal Material Costs					€ 1,824.74
Man hours**		Price per hour/meter			
Installing gas tubes 15mm	Installer	€ 4.44	4	€ 17.76	
Installing CH-tubes 22mm	Installer	€ 6.22	4	€ 24.88	
Installing water tubes 15mm	Installer	€ 6.40	8	€ 51.20	
man hours high	Installer	€ 40.00	12	€ 480.00	
man hours low	Installer assistant	€ 30.00	12	€ 360.00	
Subtotal Labour Costs					€ 933.84
Total costs					€ 2,758.58
Total costs incl VAT***					€ 3,282.71

Situation 5





Vertical Flue Terminals (Ubbink, M&G)

Tasks: Removing the SE-heting system from the cellar and placing the HE-heating system at the attic. On the roof, a Vertical Flue Terminal has to be placed. From the cellar to the attic, a gas-tube has to be installed. From the attic, the new HE heating system has to be connected to the warm and cold water circuit and the CH-circuit. Cost estimate is based on worst case, where also part of distribution CH-pipes have to be replaced (larger diam.)

Situation 5: Heating system (Solo)

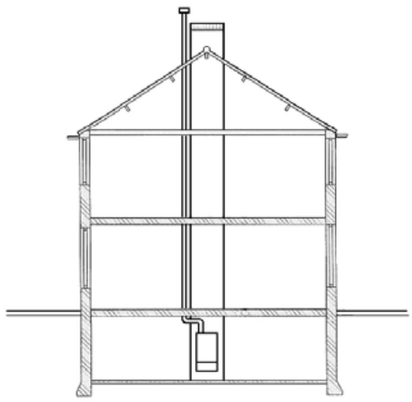
Materials*	Supplier	Price per unit/meter	Quantity	Costs	
HE Solo-system	Nefit/Vaillant/Remeha/..	€ 1,304.05	1	€ 1,054.62	
Vertical flue terminal, Twin-tube	Ubbink/M&G	€ 150.00	1	€ 150.00	
Flue tubes 80mm x 1,5mm	Ubbink/M&G	€ 15.73	2	€ 31.46	
Various Materials	var.	€ 40.00	1	€ 40.00	
				€ 0.00	
				€ 0.00	
Subtotal Material Costs					€ 1,276.08
Man hours**		Price per hour/meter			
Installing Gas tubes 15mm	Installer	€ 4.44	20	€ 88.80	
Installing CH-tubes 22mm	Installer	€ 6.22	10	€ 62.20	
man hours high	Installer	€ 40.00	24	€ 960.00	
man hours low	Installer assistant	30	24	€ 720.00	
Subtotal Labour Costs					€ 1,831.00
Total costs					€ 3,107.08
Total costs incl VAT***					€ 3,697.43

Situation 5: Heating and warm water systems (Combi)

Materials*	Supplier	Price per unit/meter	Quantity	Costs	
HE Combi-system	Nefit/Vaillant/Remeha/..	€ 1,417.30	1	€ 1,193.28	
Vertical flue terminal, Twin-tube	Ubbink/M&G	€ 150.00	1	€ 150.00	
Flue tubes 80mm x 1,5mm	Ubbink/M&G	€ 15.73	2	€ 31.46	
Various materials	var.	€ 40.00	1	€ 40.00	
				€ 0.00	
				€ 0.00	
Subtotal Material Costs					€ 1,414.74
Man hours**		Price per hour/meter			
Installing gas tubes 15mm	Installer	€ 4.44	20	€ 88.80	
Installing CH-tubes 22mm	Installer	€ 6.22	10	€ 62.20	
Installing water tubes 15mm	Installer	€ 6.40	10	€ 64.00	
man hours high	Installer	€ 40.00	24	€ 960.00	
man hours low	Installer assistant	€ 30.00	24	€ 720.00	
Subtotal Labour Costs					€ 1,895.00
Total costs					€ 3,309.74
Total costs incl VAT***					€ 3,938.59

Situation 6

Mark: the fire regulations can influence the system and thus the costs



Vertical Flue Terminal (Ubbink)

Tasks: Replacing the old system with a new HE Heating System at the same place. To get to the roof, the concentric flue tubes are installed inside the house, through the floors. To prevent that fire can spread to the next floor, the space between the hole and the tube should be closed accurately. The Exhaust tube and the intake tube come together in the twin tube connection and move on as concentric flue tubes. Plumbing material (gas-, water and CH-tubes) is needed. To drill the holes in the floors, we assume a diamond drill

Situation 6: Heating system (Solo)

Materials*	Supplier	Price per unit/meter	Quantity	Costs	
HE Solo-system	Nefit/Vaillant/Remeha/..	€ 1,304.05	1	€ 1,054.62	
Vertical Flue terminal	Ubbink/M&G	€ 150.00	1	€ 150.00	
Concentric flue tubes	Ubbink/M&G	€ 55.00	8	€ 440.00	
Twin tube connection	Ubbink/M&G	€ 30.00	1	€ 30.00	
Flue tubes 80mm (2 x 0,5 m)	Ubbink/M&G	€ 15.73	1	€ 15.73	
Various Materials	var.	€ 80.00	1	€ 80.00	
Rent vertical drill (up to 200mm)	Bo-rent	€ 80.00	1	€ 80.00	
Subtotal Material Costs					€ 1,850.35
Man hours**					
Installing gas tubes 15mm	Installer		0.5	€ 2.22	
Installing CH-tubes 22mm	Installer		0.5	€ 3.11	
Drilling holes (3x 0,18 m)	Installer		0.54	€ 56.16	
man hours high	Installer		20	€ 800.00	
man hours low	Installer assistant		20	€ 600.00	
Subtotal Labour Costs					€ 1,461.49
Total costs					€ 3,225.06
Total costs incl VAT***					€ 3,837.82

Situation 6: Heating and warm water systems (Combi)

Materials*	Supplier	Price per unit/meter	Quantity	Costs	
HE Combi-system	Nefit/Vaillant/Remeha/..	€ 1,417.30	1	€ 1,193.28	
Vertical Flue terminal	Ubbink/M&G	€ 150.00	1	€ 150.00	
Concentric flue tubes	Ubbink/M&G	€ 55.00	8	€ 440.00	
Twin tube connection	Ubbink/M&G	€ 30.00	1	€ 30.00	
Flue tubes 80mm (2 x 0,5 m)	Ubbink/M&G	€ 15.73	1	€ 15.73	
Various Materials	var.	€ 80.00	1	€ 80.00	
Rent vertical drill (up to 200mm)	Bo-rent	€ 80.00	1	€ 80.00	
Subtotal Material Costs					€ 1,989.01
Man hours**					
Installing gas tubes 15mm	Installer		0.5	€ 2.22	
Installing CH-tubes 22mm	Installer		0.5	€ 3.11	
Installing water tubes 15mm	Installer		1	€ 6.40	
Drilling holes (3x 0,18 m)	Installer		0.54	€ 56.16	
man hours high	Installer		20	€ 800.00	
man hours low	Installer assistant		20	€ 600.00	
Subtotal Labour Costs					€ 1,467.89+PM
Total costs					€ 3,370.12
Total costs incl VAT***					€ 4,010.44

PM: The total costs can be 1000-2000 euro higher if an extra shaft and interior cladding is necessary

Internet sources:

- www.technischeunie.nl; Supplier of technical installation parts.
- www.klimaatcomfort; Consumer information site for central heating systems, warm water suppliers, air conditioners etc.
- www.muelink-grol.nl; Supplier of parts for flue gas exhaust, ventilation and air supply.
- www.ubbink.nl; Supplier of parts for flue gas exhaust, ventilation and air supply
- www.bouwkostenonline.nl; Online information of building, contraction and installation costs.
- www.bo-rent.com; Rental company of tools (diamant drills etc.).

Local installers in Delft, The Netherlands