

Replacement and maintenance of domestic heating systems in the European Union

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1 Introduction: the importance of the on-site efficiency

In the European Union several policy measures have been introduced to assure the development of modern domestic boilers with a high useful efficiency (1). In practice however this high quality level may deteriorate when the working conditions of the boiler are unfavourable. Therefore a consistent energy policy program also needs to guarantee that the advantages of a high development and production quality are preserved on-site. The “on-site efficiency” has to be optimized as well. Effects of user behaviour and activities of heating installers are quite important from this point of view. In the Council Directive 93/76/EEC (2) one can notice that the European Commission sustains this point of view.

It is clear that many Member States of the European Union are organising research projects and are taking incentives to improve the “on-site efficiency” of domestic heating systems. Several countries already dispose of legislative measures concerning maintenance and inspection of boilers. Computer tools are being developed to stimulate the replacement of heating systems, education programs are organised to motivate heating technicians. Despite all these initiatives and experiences, one can notice that, depending on the type and number of incentives, large differences between the Member States still occur.

More specifically in Belgium several research projects have been set up to analyse the “on-site efficiency” of domestic heating. The research projects focussed on 3 "on-site" aspects:

- *Maintenance of domestic boilers* (3): The objective of this measurement campaign was to examine the efficiency of the existing legislation concerning boiler maintenance and to compare the on-site emissions (CO, NO_x,...) with existing standards and quality labels.
- *Annual load of domestic boilers* (4, 5): On-site measurements were used to determine the average annual load and the oversizing of domestic boilers.
- *Annual efficiency of domestic boilers* (4, 5): On the basis of dynamic on-site measurements the useful efficiency of boilers was evaluated with respect to the real working conditions. At the same time effects of user behaviour were quantified.

On the basis of the “on-site” research projects two points of interest were defined:

- replacement of old boilers and choice of efficient modern heating technologies
- maintenance of boilers by heating installers.

The importance of these topics are confirmed by research on international level (6, 7, 8).

2 SAVE-project “Replacement, maintenance and use of domestic boilers”

As already mentioned, it is clear that the attitude, the knowledge and expectations of the end-users and heating technicians have a major influence on the “on-site” efficiency. To analyse these aspects in more detail a SAVE-project (9) was organized in cooperation with the European Commission (DGXVII). This SAVE-project started in January 1995 and was finished by the end of September 1996.

The project consisted of 2 phases: a detailed research in Flanders (Belgium) and a general research in the European Union.

Research in Flanders (Belgium)

The main objective of this first phase was to propose policy guidelines in order to optimize the existing situation concerning boiler maintenance and replacement in Flanders (Belgium). To define the appropriate measures a detailed analysis was performed of the barriers on end-user and technician level. The results are based on:

- 800 oral interviews of users with gas or oil fired central heating
- 35 oral and written interviews of heating technicians
- about 10 meetings with the main actors: government (energy and environment), associations of heating installers, education centres for heating technicians, oil and gas business.

Research in the European Union

In this phase an information-exchange was set up between heating experts of different European countries. About 35 experts from 16 countries (all Member States + Switzerland) participated to the information-exchange.

Both professional organisations of boiler manufacturers, installers and chimney sweeps, consumer organisations, research institutes, energy companies and governmental institutions contributed to this phase. Both gas and oil experts were represented.

The plurality of the expert group made it possible to gather complementary data and to analyse different points of view with respect to the market of heating systems.

The information exchange resulted in a general overview of the European situation:

- a comparison of the existing legislations and guidelines in the Member States with respect to boiler maintenance. Several aspects were analysed: official control of the application, education of heating technicians, technical maintenance requirements, the application area of the legislation,...
- an estimation of the number of old boilers in the European Union and the corresponding energy saving potential.
- trends in attitudes of end-users and heating technicians.

3 Boiler replacement and maintenance in Flanders (Belgium)

3.1 The present situation

In order to estimate the efficiency of replacement of residential boilers an analysis of the boiler age was performed. Figure 1 shows the frequency distribution of the boiler age for gas and oil fired heating in Flanders (Belgium). These results are based on a representative sample of 800 end-user oriented surveys.

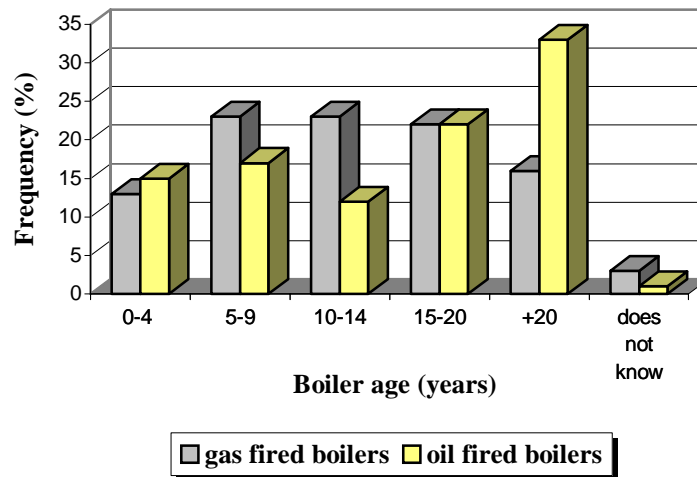


Figure 1: Frequency distribution of boiler age for gas and oil fired central heating

It can be noticed that quite a large number of boilers are older than 20 years. Especially for oil fired boilers the share of old boilers is high: over 30%. The burners of the oil fired boilers are often as old as the boiler itself: about 1 out of 4 of the burners is at least 20 years old. For gas about 15% of the boilers are older than 20 years. These figures are merely indicative. Nevertheless it is clear that the replacement rate especially of old oil fired boilers is low. Indeed, it can be concluded that for about 320.000 Flemish dwellings (= 15% of all dwellings) it would be useful to check whether it is necessary to replace the boiler and/or burner.

Moreover additional research (4,5) showed that the average annual load for a sample of 100 gas and oil fired boilers in Flanders (Belgium) amounts to 10%. This means that during 90% of the year the burner is not working and the boiler is in stand-by. This average load is low compared with the European standards for laboratory measurements on boiler efficiency which prescribe tests under 30% part load conditions.

The main cause of this situation is the oversizing of the boiler capacity. Especially for older boilers working on a constant water temperature the oversizing can have serious consequences on the useful efficiency. No specific statistics are available to estimate the share of boilers with constant water temperature. Nevertheless, depending on the load and stand-by losses of the boiler, the annual efficiency may decrease to about 50%.

Concerning maintenance of boilers the interviews with the end-users and heating technicians showed that less than 50% of the oil fired boilers comply with the existing legislation concerning boiler maintenance. The maintenance of gas fired boilers appears to be executed regularly by an expert in less than 40% of all cases.

3.2 Possible effects of boiler replacement and maintenance

The public benefits (energy use, environment, employment) of replacement and maintenance in Flanders are considerable. Possible energy savings amount to 5.354.000 GJ/year and 1.347.000 GJ/year for replacement and maintenance respectively. These savings correspond to the yearly heat consumption of more than 60.000 dwellings. Table 1 shows the corresponding environmental effects on the level of emission reduction.

	Replacement of old boilers	Maintenance of oil fired boilers
Energy savings (GJ/year)	5.354.000	1.347.000
CO ₂ reduction (ton/year)	375.000	98.000
NO _x reduction (ton/year)	268	67
SO ₂ reduction (ton/year)	401	122

Table 1: Emission reduction by replacement and maintenance of boilers in Flanders

The final emission reduction is probably higher than shown in table 1. Indeed, new boilers often have lower specific emissions (mg/kWh) in comparison to older boilers. For gas fired boilers for instance, on-site measurements indicated that the specific emissions of recent gas fired boilers are at least 30% less than of boilers older than 15 years (3).

Furthermore, increasing the efficiency of the existing legislation on boiler maintenance would create at least 800 extra full jobs in the Flemish heating sector. Replacement and maintenance should therefore be key elements in the planned energy and environmental policy plans.

However the conducted surveys showed that on end-user side the motivation is not obvious. In the first place it is difficult to justify maintenance of boilers only by the short term energy cost reduction. Security and comfort however are important arguments for the end-user. Therefore end-users have to be confronted with clear relations between replacement and maintenance of boilers on one side and the effect on chimney burn, CO-intoxication and defects on the other side.

Finally there are several financial arguments to motivate the replacement of an old boiler. Each replacement however has to be evaluated individually. Financially justified measures have to be proposed to the end-user on the basis of a generally accepted and objective calculation tool.

3.3 Proposals for a replacement and maintenance policy

Since replacement and boiler maintenance are closely linked, a general strategy is necessary to stimulate the replacement and maintenance of domestic boilers in Flanders. This strategy has to take into account the existing situation and the current barriers on end-user and technician level.

Figure 2 shows the actions that may lead to a solid energy policy. The proposed strategy consists of 4 phases:

1. apply the existing legislation on boiler maintenance effectively
2. apply the existing legislation on boiler maintenance efficiently
3. encourage the positive effect of boiler maintenance on boiler replacement
4. develop a general methodology for the maintenance of domestic heating systems and determine the specific technical maintenance requirements for every installation type.

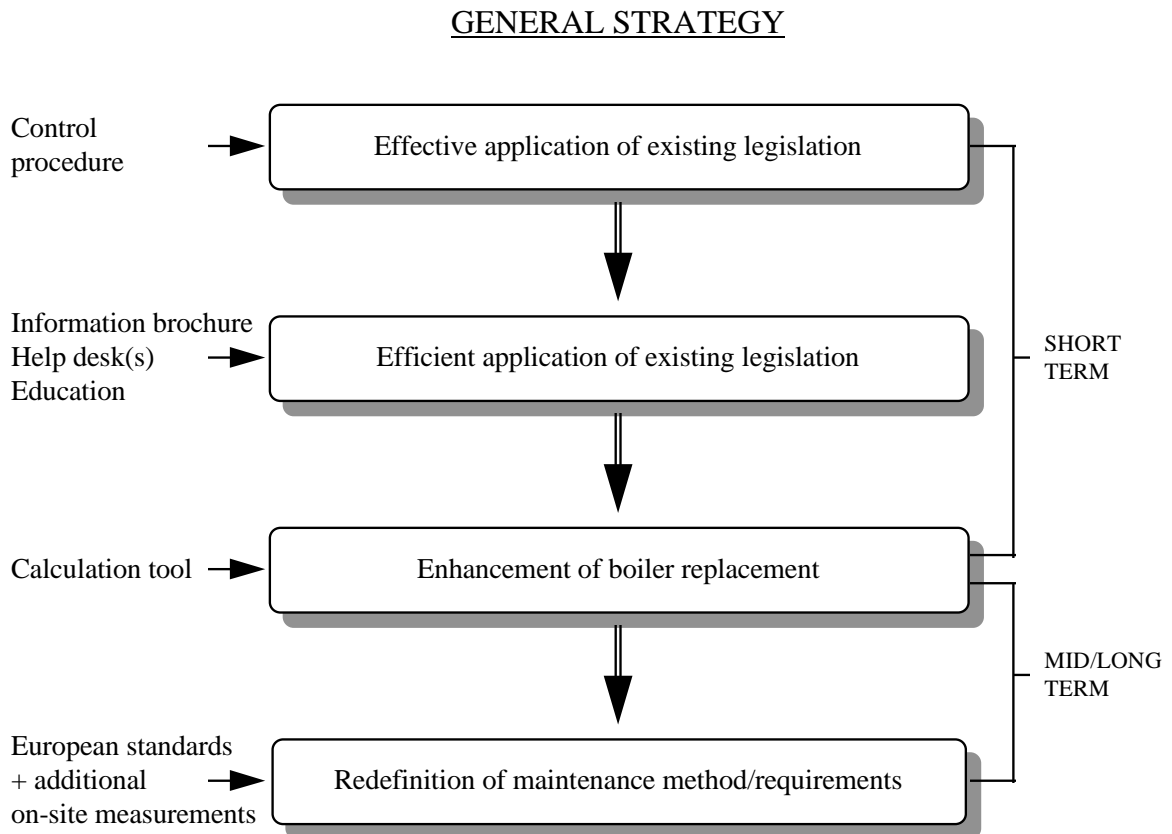


Figure 2: Strategy to stimulate the replacement and maintenance of boilers in Flanders

4 Boiler replacement in the European Union

In spite of the existing incentives it is clear that the motivation to replace old boilers is low in almost all countries. The average age of the oil fired boilers when being replaced sometimes amounts to 30 years and the percentage of boilers older than 20 years exceeds 35%. For gas fired boilers the average replacement age is slightly lower: 15-25 years. Also the amount of old boilers is relatively smaller: 5-20%.

Therefore it can be concluded that there is a significant replacement potential for oil and gas fired boilers in the European Union. The total number of boilers older than 20 years would amount to about 11.600.000 for the European Union. Experts participating to the information exchange estimated the average energy efficiency to increase respectively by 15 and 20% due to the replacement of old gas and oil fired boilers. Taking these estimations into account replacement of these boilers can result in energy savings of 2.800.000 toe/year, corresponding to a CO₂-reduction of 7.800.000 ton/year. The largest part of the potential (65% for energy and 72% for CO₂) concerns the oil fired boilers.

At the same time, a serious problem of oversizing of the boiler capacity seems to exist. According to the experts, the sizing of the boiler capacity appears to be a problem not only for the old boilers but also for the new ones. Therefore it can be concluded that not only the quantity of boiler replacement (large number of old boilers) can be increased but also the quality (new oversized boilers).

With respect to the situation described above, it is clear that end-users need to be “triggered” or “motivated” by an external source. Their own motivation (merely avoiding discomfort, defects and unsafe situations) is not sufficient. There are several reasons to assume that the heating technician can fulfill this motivating role.

Therefore to improve the motivation of the end-user following actions are necessary:

- Heating technicians have to become regular contact persons in as many dwellings as possible. An efficient maintenance procedure offers a possibility to achieve this goal.
- The task of the heating technician has to be reconsidered. Up till now in many cases the activities of heating technicians have been limited to the technical job. Real motivation of the end-user by the heating technician is not common. The role of the heating technician as an “adviser” needs to be promoted.

Once a “motivator” (the heating technician) is found, several actions may be necessary in order to support the “motivator” in his advising task. Possible actions can be:

- guidelines for acceptable values of annual efficiency and specific emissions of existing boilers
- the development and promotion of objective, generally accepted and userfriendly tools to evaluate the energy, environmental and economical (pay back) impact of a boiler replacement for a specific dwelling.

In addition, the major part of the experts believes it is necessary to introduce financial measures (subventions,...) in order to stimulate the replacement of old boilers or the introduction of new techniques.

Concerning the sizing of the boiler capacity, several actions are necessary: specific training of heating technicians, promotion of a well-defined calculation method and information of the end-users about normal load factors for their boilers.

5 Boiler maintenance in the European Union

5.1 Existing legislation or guidelines

Most of the Member States already have a legislation or guidelines to stimulate maintenance or inspection of central heating boilers. The maintenance is generally carried out by qualified technicians with an education certificate. The specific contents of these legislations however differ significantly from one country to another.

The state of the art concerning legislations and guidelines on boiler maintenance in the European Union is summarised in the table 2.

Legal status

Most of the countries have an obligatory maintenance and/or inspection for oil fired boilers. For gas fired boilers on the contrary maintenance and inspection is obligatory in only 7 countries. A legislation on maintenance of coal fired boilers and stoves is even less frequent.

General requirements

The maintenance procedure of a boiler may consist of several activities:

- cleaning: boiler, chimney,...
- flue gas measurements:
 - energy aspects: flue gas losses,...
 - environmental aspects: emissions of soot, NO_x,...
 - safety aspects: CO-emission,...
- adjustments of the burner settings
- safety checkings: tightness of fittings,...
- setting of the control system,...

Considerable differences can be noticed between the Member States. In some countries the maintenance job is limited to the cleaning part (chimney and/or boiler). In France for instance no specific legislation exists and maintenance generally consists of the sweeping of the chimney. In Sweden the legislation does not prescribe a flue gas measurement (only cleaning of boiler and chimney). In these countries the flue gas measurements (or the inspection) are considered to have only limited financial and/or energetic benefits.

In other countries the legislation prescribes a maintenance service with several aspects: cleaning of chimney, of the boiler, adjustment of the burner, flue gas measurements and safety checks (eg. Germany).

Technical requirements

There are large differences concerning the technical requirements in the different countries.

For oil fired boilers:

- Maintenance interval: The maintenance interval for oil fired boilers is mostly 1 year.
- CO₂: The CO₂ content in the flue gases is not always an obligatory requirement. Some countries only have a requirement for the flue gas losses which is the combination of a requirement for the CO₂ content and for the flue gas temperature. The CO₂ requirement varies between 8,5 and 12 volume%. A minimum value of 10% seems an acceptable value for most of the countries.
- Flue gas temperature: Similar to CO₂, the flue gas temperature is not always an obligatory requirement. Maximum values in the existing legislations vary between 210 and 320°C. 250°C seems an acceptable value for most of the countries.
- Flue gas losses: Flue gas losses for oil fired boilers vary between 8 and 22%. Sometimes different values are used depending on the heating capacity or on the age of the boiler. An acceptable value for most of the countries amounts respectively to 12 and 15% for new and old oil fired boilers.
- Soot number: A maximum soot number is mostly required for oil fired boilers. Values vary between 1 and 3 Bacharach. Exceptionally a difference is made on the basis of the boiler age (eg. Germany). A generally acceptable value amounts to 2 Bacharach.
- NO_x and CO: In the existing legislations requirements concerning NO_x and CO generally do not occur. Boilers with higher capacities (>100 kW) on the contrary mostly have to comply with minimum requirements for these types of emissions. Denmark forms an exception with CO requirements (<500 ppm 0% O₂ for installations with blue flame burners). Belgium and Italy require a maximum CO-emission of 1000 ppm (0% O₂). Also Switzerland has NO_x and CO requirements for newly installed boilers.
- Others: In some countries it is required that no oil residu may be found on the filter paper used for testing the soot number.

For gas fired boilers:

Time intervals for maintenance vary between 1 and 3 years. Requirements for CO₂, flue gas temperature and flue gas losses are not common. Typical flue gas losses vary between 10 and 15% depending on the boiler age and capacity. Not many countries require maximum values for other emissions. In some cases (eg. Denmark, Luxembourg) measurement of the chimney pressure is regarded as useful.

For coal fired boilers:

Generally the maintenance service does not consist of flue gas measurements. Therefore few information is available on the technical requirements for coal fired boilers.

Heating technicians and education

In most of the countries maintenance and inspection is carried out by “qualified” heating technicians. A qualified heating technician generally needs to have an education certificate and has to prove experience. Only in a limited number of countries the qualification of the technician is limited in time (3 to 5 years).

The type of education for the qualified technicians may differ from one country to another:

- The time of the training courses is or is not specified. When specified it may vary between 60 hours and elaborated courses of 3x280 hours.
- Some countries provide refresher courses (eg. Austria, Belgium, Denmark).

- Germany has a very specific structure concerning heating inspection and education which is based on the “Bezirksschornsteinfegermeister”.

Maintenance certificate

In several countries a maintenance certificate is obligatory. The certificate mostly contains information on the checkings made by the technicians and on the results of the flue gas measurements. Advice is rarely added. The type of this certificate may be different from one country to another: booklet, leaflet, label,...

Control on the application of boiler maintenance

Control actions can be taken on different levels:

- education level: control on the activities of the education centres
- technician level: control on the qualification of the technicians (updated lists)
control on the quality of the maintenance job (competence)
- end-user level: control of the presence/completeness of a maintenance certificate
control of the flue gas parameters (measurement check).

In most of the countries the control actions are limited to the education level and the control of the qualification of the heating technicians. Some legislations foresee control procedures and penalties on end-user level. The control procedures however are often not applied effectively.

Country	Obligatory maintenance for oil fired boilers	Obligatory maintenance for gas fired boilers	Obligatory maintenance for coal fired boilers	Obligatory maintenance for stoves
Austria	√	√	√	O
Belgium	√	O	√	O
Denmark	√	O	O	O
Finland	O	O	O	O
France	O	O	O	O
Germany	√	√	O	√
Greece	√	O	O	O
Ireland	O	O	O	no specifications
Italy	√	√	O	O
Luxembourg	√	√	O	O
Netherlands	O	O	O	O
Portugal	limited application	limited application	limited application	limited application
Spain	√	√	√	O
Sweden	√	√	O	O
Switzerland	√	√	O	O
United Kingdom	O	O	O	O

Table 2: Overview of legislations on boiler maintenance in the European Union

√: periodic inspection obligatory
O: periodic inspection voluntary

5.2 *Efficiency of the maintenance activities*

The efficiency of the incentives mentioned above is estimated to be low in about half of the Member States. A low efficiency means that about 50% or less of all gas and/or oil fired boilers is maintained regularly by a qualified technician. The presence of control procedures on end-user and technician level however appears to have clearly a positive effect. Countries with a high application efficiency generally have extended control procedures on all levels.

An effective legislation should therefore at least contain following elements:

- requirements for qualified heating technicians
- guidelines for a basic education for qualified heating technicians
- guidelines for a renewal course for qualified heating technicians
- guidelines for an official maintenance manual
- description of an obligatory maintenance certificate
- requirements for the flue gas measurements (efficiency and or emission requirements)
- a maximum time interval between two inspections
- a control procedure on several levels (preferably on end-user level).

Furthermore there is a need for common guidelines and technical maintenance requirements for all installation types on an international level.

6 Conclusions

The final efficiency of the installed boilers in the European Union is not only determined by efforts made on development of new boiler techniques and labelling. An extensive research project on European level shows that especially “on-site” factors dominate the energy use and the emissions of domestic heating installations.

It is quite obvious and commonly known that regular maintenance, a correct sizing, a motivated replacement and an efficient use of the boiler are important. Nevertheless an analysis of the existing situation reveals that many of these aspects are seriously neglected.

In Flanders technical on-site research and interviews with end-users showed that for about 320.000 Flemish dwellings (= 15% of all dwellings) it would be useful to check whether it is necessary to replace the boiler and/or burner. Moreover the existing legislation on boiler maintenance is not applied efficiently in more than 50% of the dwellings.

Corresponding energy savings amount to 5.354.000 GJ/year and 1.347.000 GJ/year for replacement and maintenance respectively.

A general strategy and specific proposals with respect to boiler replacement and maintenance have been proposed to the responsible governmental administrations.

The situation as analysed for Flanders however is not exceptional. An information exchange with 35 experts from 16 different European countries reveals the same problems in many other Member States.

The total number of boilers older than 20 years in the European Union amounts to about 12.000.000. The corresponding energy saving potential for the replacement of these old boilers amounts to 2.800.000 toe/year.

Not only replacement but also maintenance can be improved considerably on an international level. An overview of the existing legislations and guidelines on boiler maintenance resulted in significant differences (application area, general and technical requirements, education of heating technicians, control of the application,...) between the countries.

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