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

Appendix 5

Electrical consumption of gas & oil central heating

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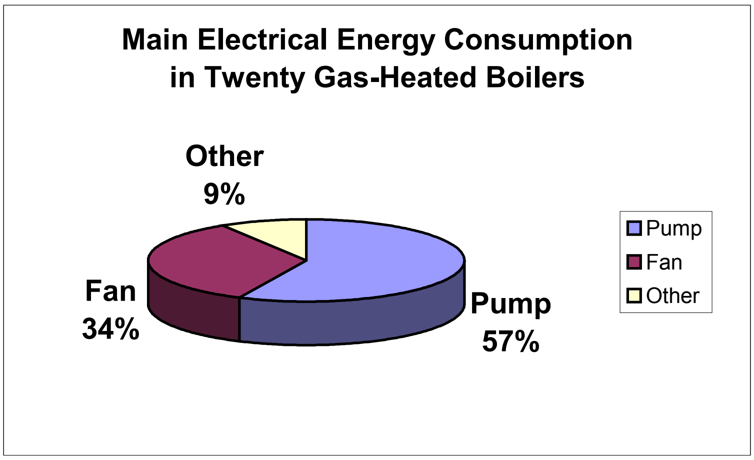
The contents of this appendix, and revisions resulting from comments by the eight project partners, are the responsibility of the task authors

Summary

Circulation pumps are responsible for 50 to 75 % of the electrical energy consumed by boiler room equipment. By introducing more efficient circulation pumps and fans it is possible to reduce the electrical energy consumption dramatically. Within the EU, the saving potential is 10-40 TWh (40 TWh assumes heat savings which require confirmation) with technology existing today or in the very near future. Due to differences in the European climate there is a wide spread in electricity consumption of gas and oil boiler equipment but the majority uses some 300-400 kWh/yr, which is comparable to widely recognised energy consumers such as washing machines. There are almost 90 million circulators within the EU in the range less than 250 W. Consequently circulation pumps are an important focus. Motorised valves, electrical trace heating, programmers and thermostats demands just a few W. Compared to pumps, fans and stand-by systems their energy consumption is negligible.

As described in the figure below fans and controls are estimated to represent 43 % of the electric energy consumption altogether and should not be neglected.



Also environmental arguments speak in favour of selecting more efficient low energy pumps and fans in heating systems for dwellings. The total electric consumption of these circulators amounts to at least 30 TWh in the whole EU. The EU SAVE II Project 2001 (Grundfos with ECI and VHK: *Promotion of Energy Efficiency in Circulation Pumps especially in Domestic Heating Systems,* Bjerringbro, Denmark June) 2001 estimates 33 TWh for pumps less than 250 W and an extra 8 TWh for pumps in collective systems and district heating, totally up to 41 TWh per year for the EU. This roughly equals to 16 million tonnes CO_2 using an emission factor of 0.4 kg CO_2 per kWh.

Automatic speed-controlled pumps are available today and seem to be one recommendable low energy solution for single houses and multifamily buildings. Energy efficient pumps can also be based on new motors (low energy permanent magnet motors). For single family homes a 20 W permanent motor speed controlled pump for single family dwellings was introduced in 2000 by the Swiss company Biral. For larger heating systems a 500 W speed controlled PM pump is available on the European market since mid 2001 with performance comparable to a 1500 W conventional pump.

For fans direct current (DC) motors seems the best way available method today to minimise the electrical energy as well as speed-controlling the fans may be one way. Power supplies for low voltage components like processors and motors should comply with international conventions discussed by EU and the IEA (International Energy Agency), as the "1-watt initiative". Hopefully stand-by equipment for boilers will follow the evolution seen in other electronic stand-by appliances as tv's and vcr's reduced to only 1 W.

If the circulation pump energy could be saved using the recommendations above we could shut down a couple of nuclear power stations in Europe or set enough energy free to heat at least 3.75 million households consuming 8000 kWh a year.

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Electrical Efficiency of Gas and Oil-fired Heating Systems

1 Introduction

A typical heating system is estimated to consume significant amounts of electrical energy to power a circulation pump, boiler fan (forced air type), electrically actuated valves and a continuously powered electronic control system. This sub-task examines the scope for improving the electrical efficiency of heating systems with the following structure.

Firstly, the electrical efficiency for components in a gas-fired and then in an oil-fired boiler room is investigated with focus on U.K. Secondly, a Swedish study of circulation pumps is presented, then experiences from some representative European countries - Germany, Netherlands, France and Sweden – are described, the total number of circulation pumps is estimated as well as the total boiler room electrical consumption. Finally, some conclusions are presented, recommendations of low energy equipment are given and measures are pointed out.

2 The electrical equipment in a gas-fired heating system

An example (G. Henderson, Oral Communication 2001, Consultant, formerly Building Research Establishment, UK) for gas-fired boilers electrical equipment frequently used in different European countries like the U. K., Ireland, France and Denmark is showed below.

- Boiler gas valve - solenoid operated, with a consumption of a few W only during the period the boiler is firing

- Boiler fan - (not present in some boilers with a balanced or conventional open flue); typical consumption 60-150 W, on only when the boiler is firing

- Circulator pump - typical consumption 65 W. (A typical circulator has three speed settings with power inputs of 40, 65 and 105 W; most are set on medium although the low setting would suffice in many cases - the high setting should be avoided because of noise and pressure related problems as quoted in the EU SAVE II Project 2001 (Grundfos with ECI and VHK: *Promotion of Energy Efficiency in Circulation Pumps especially in Domestic Heating Systems, Bjerringbro, Denmark June*) 2001 suggests that many installers set the pump at its maximum speed in order to avoid complaints of cold spots in the house - if noise problems occur they can always turn the speed down. Most UK systems run the pump only when there is a call for heat from either the hot water storage cylinder or the room thermostat (a typical run time is something like 2000 hours although more than 6000 hours is not rare in other colder countries); combi boilers may have second pump internal to the boiler or even an auxiliary electric heating element to maintain temperature

- Motorised valves - fitted to most systems that do not have combi boilers - typical consumption 6 W for the spring return type but no steady state consumption for the micro-switch operated (Satchwell) type; operate when system is on and at least one thermostat is calling for heat

- Programmers - typical consumption a few W, all the time and probably more when relays are energised to bring on the heating; programmable thermostats use similar amounts of energy

- Thermostats **-** some bi-metal thermostats have 'accelerators', which consist of a small heating element consuming about 1W, only on when the heating system is operating and the thermostat is not calling for heat

- Electrical trace heating (to prevent freezing or used to maintain temperature in pipes to prevent a delay in hot water reaching taps). Rare in the UK but could cause significant consumption if operated on a high thermostat setting. The aggregate consumption from this source should anyhow be negligible

- Secondary circulation on hot water systems (to maintain a ready source of hot water at taps) is usually only found in large houses and is not common, although it can be a significant consumer of electrical energy in those cases where it is installed. Circulator power is of the order of 50W and run times are typically all day but off overnight.

3 The electrical equipment in a oil-fired heating systems

Generally, oil-fired heating systems have the same electrical requirements as gas-fired systems but with one significant addition. The "extra" pump required to force the oil through the pressure jet of the burner. Typical motor power is about 200 W, which drives both the pressure pump and the fan that supplies air for combustion. Some older boilers used a "wall-flame" principle (which was quieter in operation than a pressure jet), but these have not been supplied in the UK (and probably elsewhere) since about 1970. Because of the "extra" pump oil-fired boilers can have larger electrical consumption than gas-fired boilers.

4 Focus on circulation pumps – Anonymous energy wasters

The electrical energy consumption of the circulator pumps is believed to be responsible for the majority of the total electrical energy consumption in boiler rooms. Still circulation pumps are one of the least known electrical energy consuming apparatus in households.

4.1 The potential of energy saving - Circulation pumps with speed-control for dwellings
It is a scarely known fact that the circulation pump are one of the largest electrical energy consumers in European households, especially in the mid and northern European climate zones where heating system circulation pumps may consume approximately 500-600 kWh/yr. This is comparable to the electric consumption of a refrigerator or a household lighting system there has been a growing interest in evaluating the options to improve the energy efficiency of these appliances. Below some Swedish experiences are presented (D. Kristiansson, P. Isaksson, B. Kjellén).

4.2 Speed-controlled circulation pumps for heating single-family dwellings
In recent years, the use of speed-controlled pumps has "gained ground" among professionals in the heating, water and sanitary trade, especially applied to large systems in multi-family dwellings. Large savings on energy have been achieved. When it comes to smaller water-borne heating systems in single-family dwellings, the interest for speed-controlled pumps has so far been slight. The additional cost of speed-control has previously been high in comparison to the energy that could be saved. In the following, one Swedish investigation explains why speed-controlled pumps are going to replace previous pumps that operate at one speed.

4.3 Pressure variations in systems

In practice it has become evident that pressure variations occur in all heating and cooling systems, even in a piping system. The reasons are that the heating demand in various rooms of the building differs depending on climatic conditions. Further, there is a huge difference in heat demand throughout the heating season, how heat is utilized and the degree of surplus heat. Pipes and valves are neither always balanced or operating perfectly.

4.4 Oversized pumps and heat losses

When the required theoretical capacity of a circulation pump is to be calculated, a marginal capacity figure is commonly added to this figure so that the pump selected, in consideration of all conceivable conditions that may arise, will not be too small. Pump suppliers plot the pump duty point in the performance curve of the nearest larger pump size so that pump performance won't fall short of the given data specified by the designer. Experience has shown that just about all the existing pumps have been sized for too high a capacity. An oversized pump causes excessive flow-generated and water-throttle noise in the system, and energy is lost as well.

Previously, fitters have tried to remedy this by introducing so-called by-pass control or by fitting multi-speed pumps controlled by a manual selector switch to lower the capacity of the pumps. The capacity of the pumps was then permanently set according to the estimated theoretical efficiency of the heating system. This capacity is only required during a few days of the heating season. During the rest of the season, the capacity of each pump is much too high, which causes the pumps to generate noise and waste energy.

Heating systems are sized according to the static maximum heating demand of the building at its geographical location. During the heating season, the current heating demand is often substantially lower than the theoretical heating demand estimate. The design capacity of the system is utilised during a few days only. This means that the flow in the system has to be throttled by a valve to reduce heating capacity during the greater part of the season.

Circulation pumps with steep performance curves are commonly used. This means substantially higher pressure in the pump if the flow rate is low and the pump motor operates at constant rpm. This occurs, for example, in the daytime, especially during spring and autumn, when many valves are closed. When the pumps run at constant speed, this produces high pressures, which easily causes leakage in control valves and, in the long run, leakage increases due to an abrasive effect caused by the particles in the fluid and unnecessary energy use.

This problem is especially apparent in older buildings, where existing pumps are usually extremely oversized and where the piping system has relatively large dimensions. This leakage gives rise to an unneeded surplus heat in a heating system, which is then ventilated away. The aforementioned leakage thus leads to higher energy cost. An other not negligible factors are improvements in insulation of houses as double glazing, cavity wall insulation, roof insulation without adapting the heating system leads to oversized heating systems

4.5 Modern circulation pumps have variable speed-control

Today, pump manufacturers offer pumps with integrated speed-control. Market competition and the development of better indoor climate techniques have now forced manufacturers to make variable-speed pumps available at roughly the same price as the old three-speed pumps. Speed-controlled pumps can also reduce or eliminate the problems associated with oversizing. Finally speed-controlled pumps are easier to install because these pumps automatically adapt to the heating system.

4.6 Saving energy and the strong influence of the pump speed

The energy consumed by one centrifugal pump decreases by the change in rpm to the third power which means a very strong, almost exponentially, correlation. This signifies that if the pump speed is halved, the energy consumed will only be one eighth of the original figure, i.e. theoretical savings will be 7/8 of the energy. However, some of the energy lost can be used for heating in a heating system.

This is why the specialists D. Kristiansson, P. Isaksson and B. Kjellén previously assumes, in this case, that about 50% of the reduction in energy is a pure economic savings, employing so-called wet pumps used in single-family dwellings. (When we refer to wet pumps for single-family dwellings, we mean pumps with slotted-tube motor. These are the most common pumps used for heating single-family dwellings in Sweden.) During the most of the heating season, pumps are required to operate at only half speed or at less than maximum rpm.

As mentioned, some field studies (which need to be confirmed) suggest that there is money to be saved on the heating side. As a rule, these savings are substantially larger than those realised through more economical pump operation. The power required by the heating system are as a rule at least 100 – 200 times greater than the power consumed by the pump.
A circulation pump, in a single-family dwelling, with a flow of 1.5 m^3/h manages heating outputs in the region of 10 – 20 kW, whereas the power required to operate the pump is only 0.06 kW.

Experiences based on field studies of 2000 families under 1-3 years at the Swedish building company 'Riksbyggen', (D. Kristiansson, P. Isaksson and B. Kjellén) has shown that savings of at least 20 – 30% can be obtained on the heating side after changing to speed-controlled pumps in a central heating system due to less heat ventilated away fewer leakage of heat, more easy to regulate and less wear and tear at valves etc. If the same savings were to apply to heating systems in single-family dwellings, an annual savings of 2400 – 3600 kWh would be obtained on an annual consumption of 12,000 kWh for heating. However our contacts seem to agree about this saving potential on the heating side we recommend some further practical studies.

If on the other hand, we cautiously assume that the heating losses in our current system can be reduced by 3% (D. Kristiansson, P. Isaksson and B. Kjellén) the annual savings of energy for heating a single-family dwelling will be 360 kWh. Already in consideration of these modest assumptions, it is obvious that it will be profitable to select speed-controlled pumps instead of traditional pumps.

A heating season can include all 7860 in-operation hours per year in the especially in the colder Nordic parts of Europe but 6000 h in operation is more realistic for the a typical Swedish circulation pump. The power supplied to the pump motor is assumed to be 0.06 kW and controlling the motor speed down to half the max. speed theoretical provides a reduction of 7/8. Typical theoretical savings estimate = 0.06 x 6000 x 7/8 provides a reduction of 315 kWh/yr.

If we, as in the previous case, assume that a true savings of 50% can be realised, it will be possible to save 157 kWh/yr on the pump operation. If we assume a savings on the heating side at a mean value of 360 kWh according to our example above, we will obtain an estimated total heating and power savings of 157 + 360 = 517 kWh/yr. If electric power costs 0.06 EUR/kWh, the cost savings will be = 31 EUR/yr. The economic useful life of the heating system is normally estimated at 15 years. We then obtain a straightforward total savings 465 EUR during this period. Measurements in progress indicate that the savings should be substantially larger than those calculated in this example. Besides engineering improvements in the system, economic arguments also speak in favour of selecting speed-controlled circulation pumps (~ 130 EUR)

In addition the EU SAVE II Project 2001 (Grundfos with ECI and VHK: *Promotion of Energy Efficiency in Circulation Pumps especially in Domestic Heating Systems,* Bjerringbro, Denmark June) 2001 suggest average potential savings in annual electricity consumption of 35% when applying self-controlled pumps with conventional asynchronous motors and 70% when applying pumps with PM motors. These savings are without the effect on heating system performance as described in the paragraphs above.

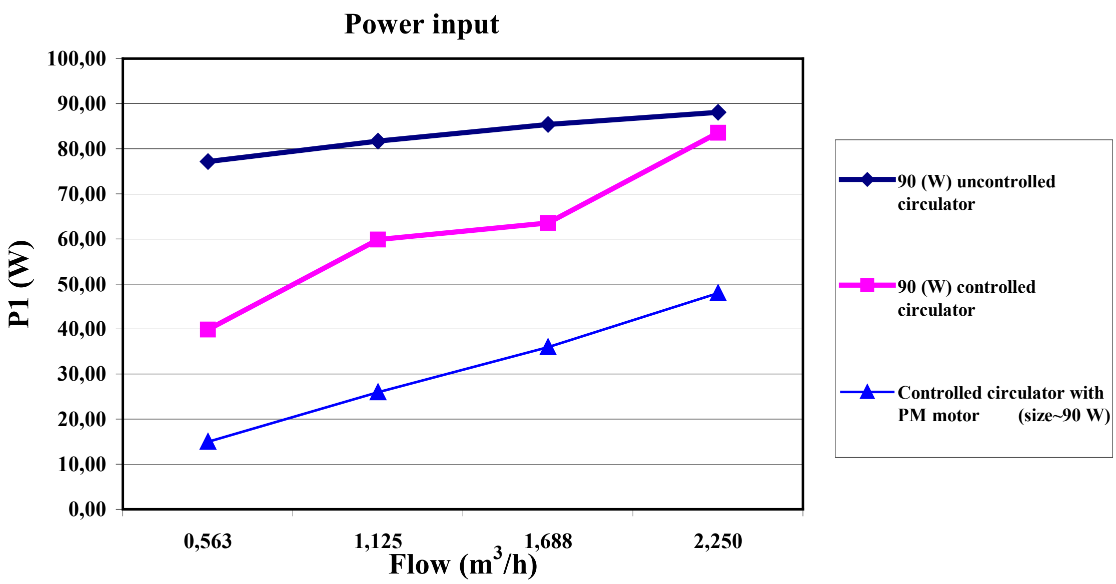

Figure 1. The figure shows the influence with a permanent magnet (PM) motor on different flows and power.

It should be mentioned that these estimated savings are different for pumps that are boiler controlled and pumps that are not boiler controlled. The boiler-controlled pumps are turned off during the summer and therefore their profile shows less time running on the lowest flow rate.

4.7 Energy and environment aspects

These savings in electric power may seem modest, however if we view it in relation to Europe, it involves a great amount of energy. There are about 1.7 million small circulation pumps in use in Sweden. The potential energy savings of all these pumps in operation would then be = 1,700,000 x 157 kWh, i.e. 267 million kWh or 0.27 TWh, only in Sweden. If we assume that the electricity we are saving is produced by coal- or oil heating power plants, which today are used to produce marginal quantities of electricity on an annual basis, this will mean 100,000 tonnes less carbon dioxide impact on the environment . Even when it comes to heating, corresponding environment benefits can also be realised.

In conclusion, heating-system engineering, economic, and environmental arguments are in favour of selecting speed-controlled circulation pumps in heating systems for single-family dwellings.

4.8 All control integrated into the pump

If the greatest possible control range is to be obtained and this technology is to be utilized to the utmost, it will be advisable to locate the pressure transducer at a spot in the piping system where the pressure differential is low. As a rule, this spot is upstream of the first branch, or farthest away between the supply and return piping.

However, in the case of smaller buildings and single-family dwellings, it is more practical and also economically more suitable to have all the equipment integrated into the pump, especially if you are replacing a pump in existing heating systems. This will limit the control range and the amount by with the pressure can be decreased. The savings that nevertheless are made possible by speed-controlled pumps with integrated control and all the noise that they eliminate in the heating system make them preferable to pumps that aren’t controlled according to the Swedish study.

The EU saving potential

5 10-40 TWh only for circulators in the EU!

The stock of circulators in EU (installed base) is estimated to be almost 90 millions in the range of less than 250 W. The 0.29 million pumps more than 250 W consumes 8 TWh are found in multi family houses or district heating systems, meaning that the circulator is shared in multiple households.

The total electrical energy consumption of these circulators, for central heating only, amounts to 30-40 TWh in the whole EU. This roughly equals to 16 million tonnes CO_2 emission (using an emission factor of 0.4 kg CO_2 per kWh). Although these figures do not include circulators for floor and wall heating, see appendix A. The potential for energy saving is for that reason in the range of 10-40 TWh due to savings also on the heating side, see scenario 1-3 below.

The EU SAVE II Project 2001 (Grundfos with ECI and VHK: *Promotion of Energy Efficiency in Circulation Pumps especially in Domestic Heating Systems,* Bjerringbro, Denmark June) 2001 identifies potential savings of 31 TWh: Business-as-usual scenario predicts electricity use of 45 TWh in 2020, ETP scenario predicts electricity use of 14 TWh in 2020 (achieved by converting all pumps to self-controlled PM pumps). A reduction of 31 TWh equals 70% reduction.

The annual electrical energy consumption of central-heating systems varies widely between about 150 and 500 kWh/yr. For the Netherlands it is reported that electrical energy consumption by auxiliary components of heating systems are calculated to consume 283 kWh/yr (in 64% of homes). For France it is reported that circulation pumps usually consumes 300 kWh/yr.

For Germany it is reported that the average household electric heating system consumes 10 145 kWh/yr, while electric pumps and other equipment associated with central heating systems consume 300 kWh per year on average. Electrical energy for heating is expected to level out after the year 2000; there is unlikely to be an increase in the proportion of owning households, though system efficiency will improve. The estimate of the electrical consumption of circulation pumps in German household heating systems is 9.8 TWh for the 22 million German circulators less than 250 W.

Although differences in the annual electrical energy consumption of circulators the average electrical energy consumption per boiler room is in the range of 300-400 kWh/yr the circulators are responsible for some 2/3. An annual electrical consumption like this puts circulators in the same order of magnitude as well known energy consuming equipment like washing machines (~ 300 kWh/yr)

Given the fact that the price and the emissions of electricity are about three to four times higher than for gas (or oil) this means that a good boiler with high electrical energy consumption does in fact use the equivalent of up to 1000 kWh per year than one with low electric consumption. According to the heat demand of modern dwellings this can come up to a maximum of about 10 % of the thermal overall efficiency.

Referring to a study by R. Aptroot and T. Helmerhorst 2001, the relative contribution by equipment for standby position can be 211 kWh/yr as an average on 27 *central* heating boilers. The standby equipment was in operation for 2000 hours at 80 W (160 kWh) and standby 6760 hours at 7.5 W (51 kWh) giving 211 kWh yearly, not at all a negligible amount.

6 Conclusion and Discussion

The investigation shows results as follows.

Table 1: Overview electrical boiler room equipment

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

We see the main saving potentials with the circulators (50 to 75 % of the total electric consumption). Assuming that circulator stand for some 2/3 (figure 1) of the electrical boiler room equipment the following table can be arranged.

Table 2: Estimated energy used by circulator pumps

Country	Estimated annual energy consumption for the circulators (kWh/year)
France	300
Scandinavia	400
The Netherlands	200
Germany	300
United Kingdom	150
Italy	Not available

Now we make some simple calculations and assume 300 kWh/year and 90 million circulators EU-wide less than 250 W giving 27 TWh of energy used for circulators. The EU-saving potential for circulators less than 250 W for small houses can than be divided in three scenarios remembering the cubic relationship between pump effect (energy) and pump speed:

- Scenario one (savings due to 50 % decrease in pump speed, no saving at the heating side) theoretical savings 87.5 % (7/8) of 27 TWh giving 23.6 TWh in saving potential.
- Scenario two (savings due to 50 % decreases in pump speed, no saving at the heating side) a perhaps more realistic assumption of 50% of 27 TWh giving 13.5 TWh in saving potential.
- Scenario three (savings due to 50 % decrease in pump speed and saving at the heating side according to the experiences at the Swedish building company ‘Riksbyggen’) of 50 % of 27 TWh and savings at 23 TWh at the heating side giving 36.5 TWh in saving potential.

In addition we have the 0.29 million pumps more than 250 W consumes 8 TWh found in multi family houses or district heating systems, meaning that the circulator is shared in multiple households.

Consequently we estimate the total saving potential of all circulation pumps in the residential sector of the EU to 10-40[1] TWh/yr with technology available now or in the year 2002 and compared the EU SAVE II Project 2001 (Grundfos with ECI and VHK: *Promotion of Energy Efficiency in Circulation Pumps especially in Domestic Heating Systems,*Bjerringbro, Denmark June) 2001 estimates estimates a growth in consumption to 46 TWh in 2020 in the Reference Case, and 14 TWh in the 'Economic Potential Case', a future saving of 32 TWh.

[1] 40 TWh assumes heat savings which not all agree with.
Further investigations are recommended on savings on the heating side.

This roughly equals to 10 million tonnes CO_2 using a emission factor of 0.4 kg CO_2 per kWh based on IEA data.

The small circulation pump used in central heating systems is usually seen as a low-cost and low maintenance product but all too often end users are unaware of the advantages of buying an energy efficient circulation pump. For instance the pay-back period for the new efficient regulator circulation pumps is in the order of three years and the EU-wide electrical energy-saving potential for this one particular product is estimated at 30 TWh/yr with technology available today, i. e. the model for dwellings, Grundfos alpha. However, further work would be needed to determine the presence of these additional savings on the heating side.

The Grundfos alpha or comparable self-controlled pumps can be recommended for energy savings in dwellings although it can be mentioned that these types of pumps do not measure the pressure, which can be recommended. The pressure is measured indirectly with an electrical method although the buyer has a possibility to have a pressure regulation as an option.

Also environmental arguments speak in favour of also selecting low energy pumps and fans in heating systems for single-family and multi family dwellings.

As described in an investigation of twenty Danish gas-fired heaters, figure 1, fans and controls are estimated to represent 43 % of the electric energy consumption together and should not be neglected.

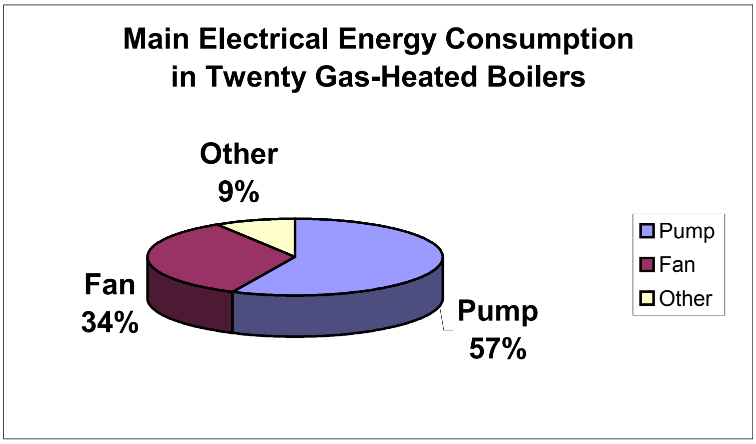

Figure 2: Nominal electrical energy consumption according to the Danish Gas Technology Centre

The observation about circulation pumps is significant but not necessarily one that applies equally in all countries. In the UK, heating systems are typically shut down overnight and often also for a period in the middle of the day. In addition, the pump is usually wired to come one with the boiler, so that it only operates when either the room thermostat or the hot-water thermostat is calling for heat. Typical pump run times are about 2000 hours per year (range 1000-8760 hours) but a typical pump run time in the colder Swedish climate are about 6000 h. With a typical pump power of 65W (on mid setting) and 2000 h yearly this results in an annual consumption of 130 kWh/yr.

Due to differences in the European climate zones and huge differences between boiler runtime regimes depending on the number of start-stops per hour and the pre- and, most decisive, after-run time there are large differences in the annual electrical energy consumption of circulators.

Appendix A also estimates a tiny electrical energy saving potential of floor heaters due to a rating on four hours per day at 100 W and as the number of floor heaters is almost negligible compared to the numbers of boilers EU-wide.

For fans DC (Direct Current) motors seems the best way available method today to minimise the electrical energy as well as speed-controlling the fans may be one way.

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

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

Power supplies for low voltage components like processors and motors should comply with international conventions discussed by EU and the IEA (International Energy Agency), as the "1-watt initiative". Hopefully stand-by equipment for boilers will follow the evolution seen in other electronic stand-by appliances as tv's and vcr's reduced to only 1 W.

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

7 Measures and policy instrument

7.1 Measures

Proposed measures for reducing (consumption of the pumps are new pump designs based upon:

- Automatic speed-control for circulation pumps. Minimise the speed since the speed strongly affects (simplified picture) the effect pump effect = constant x v^3). Available today for single and multi-family dwellings. Automatic speed control would avoid the need for the pump to be drawing full power all the time that the pump is on.
- Permanent magnet motors for circulation pumps for single and multi family dwellings (central heating) could be used. Single family dwelling can suffice with a pump of only 10 W whereas before they used an (oversized) 65 W pump according to German manufacturers. 500 W and larger motors are ready for the EU market in the autumn of 2001.
- The current housing could be improved by optimising its design for individual.
- Lastly, a seasonal switch could be introduced in systems that run the pump all year, so that it is turned off in summer.

General measures:

- Low energy equipment (i. e. equipment only driven by temperature difference or by new types of low energy motors). Warm air fans for stoves only driven by the temperature difference are already available in the American market.
- The final consumer is usually unaware of its electrical energy consumption, and even less aware of the potential improvements in efficiency, there is little or no demand for higher efficiency equipment: Show the energy costs. Display the energy used and also optional savings preferable there the user are, not only in the boiler-room.

7.2 Policy instruments

Referring to the EU SAVE II Project 2001 (Grundfos with ECI and VHK: *Promotion of Energy Efficiency in Circulation Pumps especially in Domestic Heating Systems,* Bjerringbro, Denmark June) 2001 there already exists sufficient economic reason for installing higher efficiency circulation pumps. However, they have not been produced or installed. The primary reason is that the consumer ultimately pays for the final running electricity costs. The producers of the pumps, the boiler manufacturers, and the installers do not pay for the running costs and so have no financial incentive for supplying a higher cost product. Since the final consumer is usually unaware of its electrical energy consumption, and even less aware of the potential improvements in efficiency, there is little or no demand for higher efficiency pumps. To overcome the perceived 'barrier' to higher efficiency government bodies (national or EU-level) can implement policies which would encourage the uptake of higher efficiency products and discourage the uptake of inefficient products.

Generally, the end use energy policy options can be summarised into the following categories:

- information
- ranking by efficiency (eg. labelling)
- incentives
- standards

The first step in any market transformation process is to be able to rank the products on an efficiency basis. This will require a reproducible and fair testing procedure. Once this has been satisfied, the products are usually ranked using a labelling scheme (though this need not necessarily be the case). The act of ranking the products by efficiency (the seven-scale EU A-G scheme, A being high efficiency through to G being low efficiency) is usually sufficient to 'move' the market. A commonly approved and used test standard for self-controlled circulators does not exist at the moment, but preparatory talks have begun.

The lack of energy efficiency knowledge and skills by installers contribute to the installation of energy inefficient heating systems. This actor in the installation process has been identified as one of the 'weakest links'. In French households, as a result of routine installation error, it became clear that central heating circulation pumps were wasting ca 1.2 TWh each year .

Increasing the energy efficiency awareness of this actor is seen as essential if efficient heating systems are to become common place. One of the obvious solutions includes making knowledge of efficiency part of installer's initial training and qualification. This efficiency emphasis should be continued after qualification, and should be viewed as part of continued professional development. Financial incentives can take various forms like procurement of technology, government rebates or fiscal (taxation) measures.

A strategic mix of the above can produce a coherent effective strategy. The main priorities at the EU-level to increase efficiency of circulation pumps are to introduce a mandatory A-G labelling scheme for stand-alone pumps and subsequently set minimum efficiency standards. Recommendations of EU policy measures for circulation pumps integral to boilers should be taken from the current SAVE study on space heating (the EU SAVE II Project 2001 (Grundfos with ECI and VHK: *Promotion of Energy Efficiency in Circulation Pumps especially in Domestic Heating Systems,*Bjerringbro, Denmark June) 2001). At the Member State level, the most important policy action is to improve the efficiency awareness of installers. Incentives, such as rebates, would also smooth the transition to higher efficiency products.

Other policy options may also be considered. The most obvious is to increase electricity/energy prices, which would make increased efficiency options more cost-effective to the consumer. Increasing energy costs can be achieved by introducing general energy taxes or (more environmentally targeted by introducing carbon/nuclear taxes. For further information on measures and scenarios see the EU

SAVE II Project 2001 (Grundfos with ECI and VHK: *Promotion of Energy Efficiency in Circulation Pumps especially in Domestic Heating Systems,*Bjerringbro, Denmark June) 2001.

- Include electric consumption within building regulation (this also means there's a need to include electric consumption in assessment of energy use of heating systems)
- Make hydraulic optimisation obligatory (for Germany this is theoretically fact for new systems by state of the art, but not always done correctly
- Duty to exchange uncontrolled by electronically speed-controlled pumps (minimum efficiency standards for either pumps sold separately or boilers)
- Co-operation with OEMs to get speed-controlled pumps and permanent magnet pumps into the heating (boiler labels - including electric consumption - or minimum efficiency standards might help)
- Controls e.g. by chimney sweeps
- Tax for unnecessary energy consumption or CO_2 production

Building services installations, which require electrical energy, shall be designed so that the power requirement is limited and energy is used efficiently. The general recommendation is that the requirements of the mandatory provision are complied with if ventilation, fixed lighting, electrical heaters and motors can be shown to be designed for a low power and energy requirement.

Appropriately designed heat pumps should cover the needs of the households for hot water or produce at least the same reduction in the heat energy requirement. Pump manufactures are believed to be willing to bring energy-efficient products on to the market – both the new and the replacement market – but allegedly find it difficult to re-educate or by-pass the installers in their effort to make the end-user more aware of the energy saving potential.

In the future we also may see fans driven only by the temperature difference between a cold and a hot surface, or more exactly, driven by excess heat from a boiler.

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Appendix A - Integrated electrical systems

In Finland, France, Sweden and the UK, integrated electrical systems are popular. In the UK, storage heaters are most common (80% of stock). In France permanent convectors presently account for 76% of the market, with storage heaters taking 20%. The remaining 4% is accountable to radiant panels. Currently about 0.3% of Dutch homes use electrical radiant panels as secondary heating extra comfort reasons (e.g. warm floor in the bathroom and/or in the kitchen). About 150 000 – 200 000 m^2 of electric floor heating systems are being sold annually, more than 90% is installed in existing houses.

The average power per m^2 is 50 – 150 W and an estimate is 4 m^2 of surface electric floor per house and an operating time of four hours per day. The electrical floor heating can be expensive to install and use, although the manufacturers recounts for energy savings due to possibilities to lower the indoor temperature a few degrees. In the present situation electrical floor heating can be regarded as a quite rare luxury phenomena.

Appendix B - Summary of EU SAVE II Project

Promotion of Energy Efficiency in Circulation Pumps, especially in Domestic Heating Systems

Main contractor: Grundfos A/S, Denmark (contact: Niels Bidstrup)
Subcontractors: Van Holsteijn en Kemna BV, Netherlands (contact: Martijn van Elburg)
Environmental Change Institute, Oxford University, UK (contact: Kevin Lane)

Final Report (7 June 2001)

Main activities and results per Task

Task 1: Market analysis
Product group definition: circulation pumps in domestic heating systems (max 250 W), excluding pumps for floor and wall heating. Also excluding pumps for domestic hot water systems, solar boilers and tertiary sector.
Stock: 87 million circulators with power < 250W (mostly based upon 1995 figures). Shared circulators (in collective housing and district heating) not directly assessed.
Market: 8 - 9 million circulators sold annually. Remark: sales figures of two major producers suggest larger market. Discrepancy maybe due to larger product group definition and higher estimates by producers regarding households with ‘wet’ central heating and average lifetime of circulators.
Electricity consumption of stock: small to medium circulators (max. 250 W): 33 TWh, collective systems: 8 TWh

Task 2: Technical/economical analysis
Definition of two base cases: 1 - on/off switching through boiler control, 2 - on/off switching through external device or not at all (major difference lies in number of annual operating hours).
Presentation of four design options:
Improved current housing;
Speed control;
Permanent magnet motors;
Seasonal switch.
Calculation of LCC (life cycle costs) of (combinations of) design options in comparison with base cases
Main conclusion from LCC-tables: for boiler controlled circulators lowest LCC is reached by circulators with PM and speed control. for externally controlled circulators ETP is reached by circulators with “summer switch”, PM motor and speed control.
A draft proposal for a A-G energy labeling scheme is provided, which explains the need to estimate an annual consumption figure rather than focus on efficiency alone (which would favour larger pumps

Task 3: Scenario analysis
Electricity consumption of circulators expected to rise due to increase in household and expected increase in share of ‘wet’ central heating.
Theoretical ETP scenario (ETP = economically justified and technically feasible potential) presents possible reduction of electricity use of 70% by 2020 (14 TWh compared to 45 TWh in 2020 in BAU scenario).
Major policy tools are labels and minimum efficiency standards.
Recommendations labels: boiler controlled circulators should have their label or energy consumption figure incorporated in a label for central heating boilers. Circulators sold separately should carry their own label.
Recommendations minimum efficiency standards: can be either mandatory or voluntary. Easiest to imply for separately sold circulators (also larger potential for reduced energy use)

Task 4: Dissemination
see proceedings Joint SAVE-GERG workshop at DGC Denmark on 4 April 2001.
see final report EU SAVE II Project - Promotion of Energy Efficiency in Circulation Pumps, especially in Domestic Heating Systems (by Grundfos, VHK and ECI).