High efficiency circulators for domestic central heating systems

Niels Bidstrup[1], David Seymour[2]

[1]GRUNDFOS Management A/S,
[2]Grundfos Pump, UK

Abstract

High efficiency circulators for commercial buildings have been on the market since 2001. Now high efficiency circulators are also available for domestic central heating systems. These circulators can save up to 80% electrical energy compared to conventional circulators installed today. This is achieved by using high efficiency permanent magnet motors and speed control. To increase market share of circulators with higher efficiency, a labeling scheme has been introduced. Circulators are now labeled with A-G energy label - well known from white goods and household lamps market. The labeling scheme came in force in March 2005 and is controlled by a voluntary industry commitment agreement which is managed by Europump It is estimated that 120 million domestic circulators are installed in EU25 today. These circulators are responsible for up to 15% of the electricity consumption for some European households. The average energy efficiency of installed circulators today corresponds to label “D” or “E”. If those circulators were changed to “A” labeled high efficiency circulators the electrical energy saving potential in EU25 could be 44 TWh per year, with a reduction of 17,6 million tonnes CO_2 per year. This paper describes how energy labeling in combination with national schemes can increase the market share of high efficiency circulators for domestic central heating systems.

1. Background

Energy consumption of circulators has been high on the agenda for the last 10-15 years. The reason for this is the huge energy saving potential, which could have a significant influence on CO_2 emissions. Circulators consume a lot of energy due to the high running hours in some countries and the very large installed numbers. In SAVE II [1], the installed base in EU15, was estimated at 87 million units. Based on this figure the pump industry estimate the current installed base in EU25 is 120 million. The estimated energy consumption of those circulators is 57 TWh per year, assuming a heating season of 285 days.
The typical lifetime of a circulator is 10-15 years, but circulators, which are 15-20 years old, are also operating today. These old circulators are less efficient and are responsible for up to 15% of the electricity consumption of some European households. By replacing the old circulator it is possible to save up to 10% of the electricity consumption for these households.

2. High efficiency domestic circulator

High efficiency circulators for commercial buildings have been on the market since 2001 [2]. Since 2005 high efficiency circulators are also available for domestic central heating systems. Figure 1 shows a high efficiency and a standard domestic circulator. A high efficiency domestic circulator looks similar to a standard domestic circulator from outside and is interchangeable with these. Internally the induction motor is replaced by a permanent magnet motor and the terminal box contains a full three phase frequency converter with motor control, system control and intelligent adaptive functions.

Figure 1 High efficiency and standard domestic circulator

A high efficiency circulator uses considerably less energy per year than a standard circulator. This is not only achieved by higher efficiency in the component i.e. pump and motor, but also due to speed control. Speed control enables the circulator to adapt to the changing demands in the heating systems, which would otherwise result in hydraulic loss in control actuators i.e. thermostatic radiator valves etc.
Speed controlled circulators for domestic heating systems have shown savings up to 50% compared to a standard circulator. A high efficiency circulator combines speed control with a permanent magnet motor, which has higher efficiency especially at part load. This results in energy savings up to 80% compared to the circulators installed today.

3. A-G energy labeling of circulators

Speed controlled circulators have been on the market for approximately 15 years. Despite short pay back time for the end user (typically 2-3 years in replacement situations) less than 20% of circulators sold today are speed-controlled. To increase market share of circulators with higher efficiency a labeling scheme has been introduced. Circulators are now labeled with A-G energy label well known from white goods and household lamps market. The labeling scheme came in force in March 2005 and is controlled by a voluntary industry commitment agreement [3], which is managed by Europump. Seven companies with a total market share of more than 80% have signed up to this commitment agreement so far.

3.1 Classification scheme

A-G Energy labelling of circulators is based on a classification scheme developed by Europump. The classification scheme is summarized below. A detailed description of the theory behind it is given in [4] and [5]. The A-G labeling comprises all circulators for heating systems, which fulfill all conditions below

- Stand alone (not an integral part of a boiler)
- Pump and motor integrated
- Wet runner (glandless)
- Centrifugal pumping
- P1<2500 *W*

Stand alone circulators with pump and motor integrated are circulators which are sold as a separate products and not as an integral part of, for example, a boiler. Wet runner means that the rotor is running in the pumped fluid. Only circulators with a power input P1<2500 [W] (for every head on double pumps) and based on centrifugal pumping principle are comprised.
Circulators are labeled based on an Energy Efficiency Index (EEI). the EEI is calculated as

$$EEI = \frac{P_{L,avg}}{P_{ref}} \quad [-]$$

,where

$P_{L,avg}$: is the average compensated power input
P_{ref}: Reference power input

$P_{L,avg}$ is a weighted averaged power input based on a yearly load profile and compensated for control error. Pref is the reference power input for a standard circulator at a specific size. By dividing these

two figures the EEI expresses how efficient a specific circulator is compared to the circulators on the market in 2002. The system is calibrated as shown in table 1

Table 1 Calibration of EEI to A-G energy label

Class	Energy Efficiency Index (EEI)
A	$EEI < 0.40$
B	$0.40 \le EEI < 0.60$
C	$0.60 \le EEI < 0.80$
D	$0.80 \le EEI < 1.00$
E	$1.00 \le EEI < 1.20$
F	$1.20 \le EEI < 1.40$
G	$1.40 \le EEI$

This calibration implies that circulators on the market in 2002 will get a “D” or “E” label (EEI=1.00). To get an “A” label the average power input must be reduced by at least 60% compared to that.
The label is shown in figure 2.

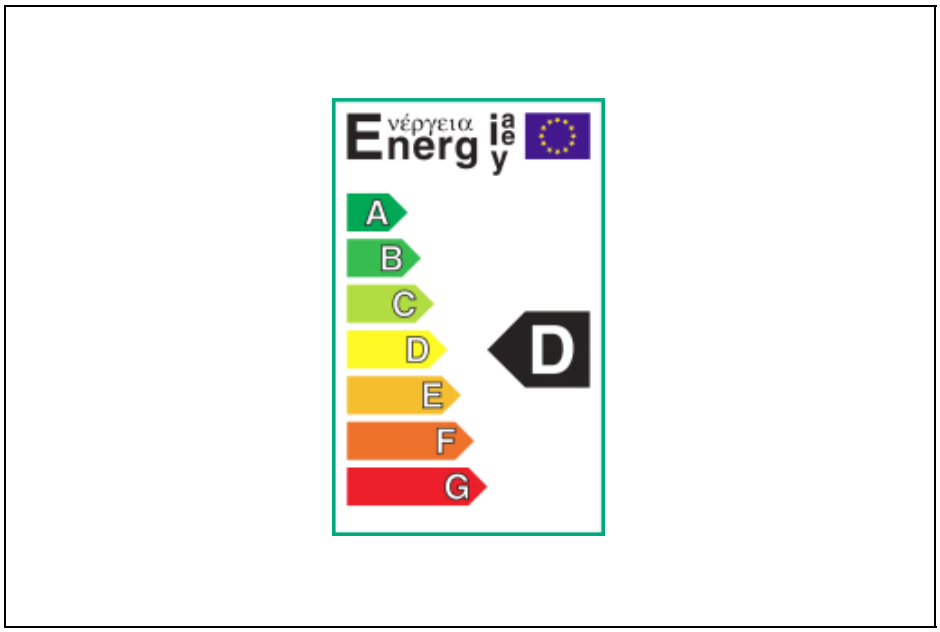

Figure 2 EU A-G energy label for circulators

Only information about average power consumption is on the proposed label, which is indicated by the letters and arrows on the label. The yearly energy consumption depends on running hours of the circulator, which depend on the heating system.
The average energy efficiency of installed circulators today corresponds to label “D” or “E”. If those circulators were changed to “A” labeled high efficiency circulators the electrical energy saving potential in EU25 could be 44 TWh per year, a reduction of 17,6 million tonnes CO_2 per year.

4. Energy consumptions and savings – an example

Energy consumption and savings vary a lot between installations and depends on circulator age, dimensioning, setting and running hours. In the following example a comparison between different circulator options in a specific heating system is made. The idea with this comparison is to show the energy consumption and savings in an ideal case where pumps are dimensioned and set correctly. Actual consumption and saving would be higher in most systems, where the pump very often is too big and/or the setting is too high.
The heating system for this example is defined as

- Dimensioned heat load: 15 kW
- Dimensioned flow temperature: 75 °C

- Dimensioned return temperature: 60 °C
- Dimensioned pump flow: 860 l/h
- Dimensioned pump head: 2 m

Calculations are based on a heating season of 285 days, which is a typical heating season in mid EU25.
Four different circulator options are chosen. A “C” labeled fixed speed circulator set on speed 2 (mid setting), which is 1-10 years old. A new “B” labeled fixed speed circulator set on speed 2 (mid setting). A high efficiency “A” rated circulator operated as fixed speed circulator in speed 2 (mid setting). This is an option if uncertainty about boiler minimum flow rate exists in relation with variable speed mode. The last option is an “A” rated high efficiency circulator operated as variable speed.
In table 2 the annual energy consumptions of the different circulator options are calculated. The load profile is the same used for EEI calculation. Notice that circulators only operate at 100 % flow 6 % of the time and are below 50 % for nearly 80 % of the time. This is due to the distribution of outdoor temperature and the nonlinear characteristics of the heating system.

Table 2 Yearly energy consumption of different circulator options in a specific system

Load Profile		**Fixed speed circulator <2005** **UPS 25-40** **Labelled: “C”**		**New Fixed speed circulator >2005** **UPS 25-40** **Labelled: “B”**		**High efficiency circulator (fixed speed)** **Alpha Pro 25-40** **Labelled: “A”**		**High efficiency circulator (variable speed)** **Alpha Pro 25-40** **Labelled: “A”**	
Flow [%]	Time [%]	P1 [W]	E [kWh]	P1 [W]	E [kWh]	P1 [W]	E [kWh]	P1 [W]	E [kWh]
100	6	44	18	34	14	25	10	19	8
75	15	44	45	33	34	25	26	15	15
50	35	42	101	32	76	25	60	11	26
25	44	41	123	31	93	25	76	9	27
		∑E	**287**	∑E	**217**	∑E	**171**	∑E	**76**

The power input shows that a high efficiency circulator only draws 9W at 25% load, where the corresponding fixed speed circulator draws 41 [W]. Most circulators installed today draw between 60 – 100 W at 25 % load.
The bottom line of the table shows the yearly energy consumption in bold letters. A high efficiency circulator in variable speed mode consumes only 76 kWh per year instead of 287 kWh per year, which is a saving of 73 %.
These results are also shown in the figure 3 below, where consumptions in percentages are also depicted.

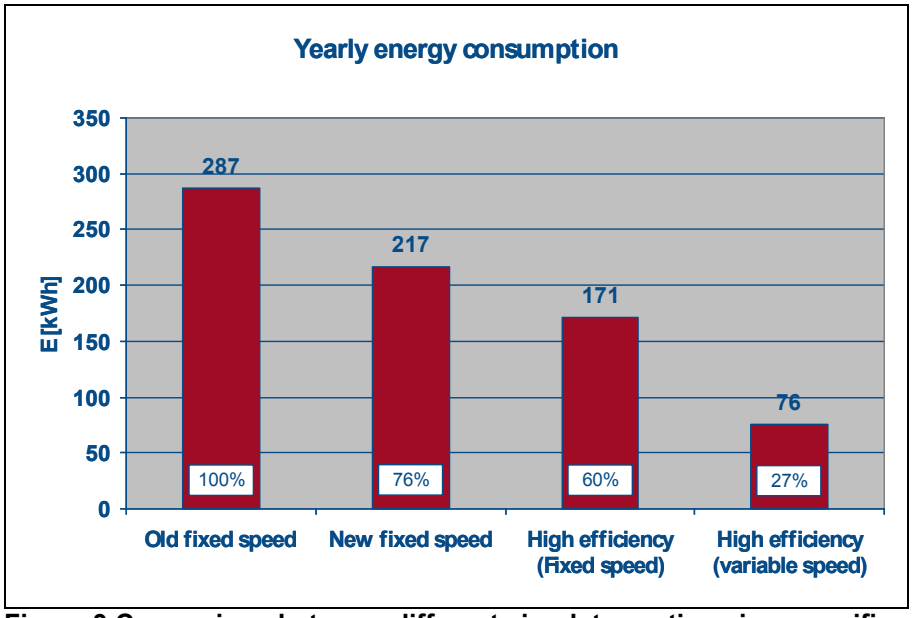

Figure 3 Comparison between different circulator options in a specific system

4. Promotion of high efficiency domestic circulators

A-G labeling is first of all a marketing tool directed towards end-users, but labeling can also be used to set minimum standards and targets, which is easier to monitor and evaluate. From that point of view labeling is a useful tool for promotional campaigns on national and EU level to accelerate market transformation towards circulators with higher efficiency. Different national schemes are already using these possibilities.

4.1 Denmark

Danish ELFOR is running a campaign to change all pumps towards better efficiency. A key element in this campaign is the "List of Energy Efficient Pumps" [6], which is a website that enables installers and consultant engineers to identify and select the right energy saving pump for a specific installation. Only circulators with rating "A", "B" and "C" are on the energy saving pump list, which means that labeling is used to set minimum standards. Furthermore the actual labels for the different circulators are also displayed, which make it easier to select the most efficient circulators for a specific job.
Another campaign is carried out by the Energy Saving Trust in Denmark. This campaign is focused on domestic circulators and directed towards the end-user. TV commercials and website [7] are used to increase awareness of old energy wasting domestic circulators and how to select an energy efficient circulator by using the A-G energy labeling.
It is difficult to measure the impact of different campaigns separately, but today 50 % of domestic circulators sold are energy saving circulators with the majority belonging to class "A" or "B" and a few in class "C". Before A-G labeling and these campaigns only 20% of the circulators was energy savings circulators belonging to class "B" and "C".

4.2 UK

In January 2006 the Energy Saving Trust approved the Grundfos "A" and "B" rated circulator as Energy Saving measures. The labeling scheme and EEI were used to classify the measures and using the UK SAP assumption of 2000 running hours, the savings were sanctioned as 78 and 52 kWh respectively. This enabled Grundfos to approach the UK Energy suppliers to secure promotional funding from the Energy Efficiency Commitment scheme operating in the period 2005 to 2008. These new measures were particularly attractive as the savings are attributed to electricity not gas and oil. Grundfos will work with Energy Suppliers to create market transformation in the new and replacement circulator market.

5. Conclusions

High efficiency “A” labeled circulators are now available for domestic central heating systems. These circulators can save up to 80% electrical energy compared to conventional circulators installed today. An example calculation showed that even in an idealized case, where standard circulators were dimensioned and set correctly, savings of 73% were achieved by using a high efficiency circulator in a certain situation

The A-G labeling scheme of circulators came in force in March 2005. The labeling is controlled by a voluntary industry commitment agreement and is managed by Europump. Seven companies with a total market share of more than 80% have signed up to this commitment agreement today

It is expected that the A-G energy labeling will have a great impact on the circulator market in EU25 in the coming year, especially if combined with other market transformation programs. In Denmark A-G labeling is combined with two different promotional programs and the sale of energy efficient circulators have increased from 20% to 50%.

The average energy efficiency of installed circulators today corresponds to label “D” or “E”. If those circulators were changed to “A” labeled high efficiency circulators the electrical energy saving potential in EU25 could be 44 TWh per year, with a reduction of 17,6 million tons CO_2 per year.

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