Appendix 6:
Lot 11 - 'Circulators in buildings'

Report to the European Commission

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Title	EUP Lot 11: Circulators in buildings
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Executive Summary

Aims of this study

The Energy Using Product (EuP) Directive (2005/32/EC) allows the European Commission to develop measures to reduce the eco-impact of energy using products within the EC. Products that do comply with these measures may have the CE mark attached, those which do not could ultimately be prohibited from being traded within the EC.

This Directive provides for the setting of requirements that the energy using products covered by implementing measures must fulfil in order for them to be placed on the market and/or put into service. It contributes to sustainable development by increasing energy efficiency and the level of protection of the environment, while at the same time increasing the security of the energy supply. Furthermore, it goes beyond just energy efficiency considerations, as it also considers whole life cycle costs, including production and disposal costs. It can therefore be thought of as “energy efficiency, but not at any price”.

In order to evaluate whether and to which extent a product fulfils certain criteria that make it eligible for implementing measures under the Directive, the MEEUP methodology (Methodology for the Eco-design of Energy Using Products) will be applied in this study. In order to facilitate the environmental impact analysis, the MEEUP methodology provides an Excel form (EuP EcoReport). In the preparatory phase of the study data was collected for inputting to this model, and comprises economic, material and energy use data for different stages of the product’s life. This model translates these inputs into quantifiable environmental impacts.

Circulators

Circulators in buildings are used primarily for pumping water in central heating systems, with <4% used for other applications such as domestic hot water circulation, solar water heating or chilling systems. The results of this study are only relevant for circulators used in central heating system.

They range in size from 25W – 2500W, and are always sold as an integrated pump:motor assembly. The circulator market is somewhat unusual in that circulators are almost exclusively manufactured and sold within the EU. There are an estimated 140M circulators in the EU-25, with few used outside of Europe. The total energy use of circulators in EU-25 is 53.2 TWhpa. In this study we distinguish between two types:

- The “Standalone” circulator is separate from the boiler and is purchased as a separate product. The typical size of a circulator used in a single house is 65W, and that of commercial or residential buildings is 450W, of which there are 6.5M sold pa.
- The “Boiler Integrated” circulator is supplied to the user already integrated into the boiler. It has a typical power consumption of 90W, of which there are 7.5M sold pa.

The Environmental Impact analysis performed by the use of the EC MEEUP model shows that in all cases it is the In use phase that dominates, and so improving the energy performance of the products is key to reducing the lifetime environmental impact.

There are three different improved technologies identified; improved (standard) circulator, variable speed (induction motor) and variable speed (permanent magnet motor). For each product the energy saving under different real life operating conditions was assessed, and then the total life cycle costs calculated.

Energy savings of 13.0TWh pa could be achieved by 2020 if the minimum energy performance of standalone circulators that can be sold is class A*, and this is found to be economic to consumers under all typical duties. Energy savings of 1.8TWh pa can be achieved by 2020 by making class B the minimum standard of circulator that can be sold.

There is an existing technical standard EN 1151-1:2006 on circulator performance measurement, which is currently under revision. The revised standard will allow measurement of circulator performance to a tolerance that is adequate for defining a CE minimum standard. There is also an existing voluntary labelling scheme for standalone circulators up to 2,500W, which is found to be adequate for the current mix of products on the market.

The actual energy saved will vary from system to system, but under all common operating profiles the use of improved standard circulators and those with Permanent Magnet variable speed control is economically attractive. Possible changes in the wider system to which they are connected could have a much larger impact on EU circulator energy consumption than any further improvements in circulator technology itself, but detailed consideration of this is outside the scope of this report.

Circulators are excluded from WEEE and RoHS legislation, but even so, all existing designs appear from our research to be compliant.

Policy recommendations

1.) The minimum allowable energy performance for all standalone circulators should be that defined as Class A* in the proposed revision to the Europump voluntary labelling scheme. At least five years notice should be given of this in order to allow all manufacturers adequate time to design and manufacture compliant products, (2012). This will lead to ultimate energy savings of 15.6TWhpa by 2022, with savings of 13.0TWh pa by 2020.

2.) Because Class B circulators use a different technology to Class A* or above circulators, they do not represent an incremental developmental step on the way to designing a Class A* circulator. It is therefore concluded that it would cause manufacturers considerable additional work for little gain if Class B was stipulated as being the interim minimum standard of circulator. Hence a direct move to Class A* is seen as being the best option for manufacturers (and consumers).

3.) Circulators should be subject to the maximum standby power targets in the EUP Lot 6 on Standby power consumption.

4.) Because the class "A" category in the existing voluntary labelling scheme is very wide, it is recommended that it is further split into three categories so as to encourage the development of products past the minimum level for class A. The revised efficiency levels (represented by Energy Efficiency Index or EEI values) are as follows:

Class	Energy Efficiency Index (EEI)
A**	EEI < 0.20
A*	0.20 ≤ EEI < 0.30
A	0.30 ≤ EEI < 0.40
B	0.40 ≤ EEI < 0.60
C	0.60 ≤ EEI < 0.80
D	0.80 ≤ EEI < 1.00
E	1.00 ≤ EEI < 1.20
F	1.20 ≤ EEI < 1.40
G	EEI ≥ 1.40

To help differentiate the performance of different circulators in advance of the split of class A circulators into new classes, the actual calculated energy consumption based on operation for 5,000 hours pa should be shown alongside the class label.

Once class A* has become the minimum standard that can be sold, the existing A-G voluntary labelling scheme will become redundant. This should be seen very positively as an example of how labelling can contribute to transforming a market. It could then be replaced by a new labelling scheme that spans up to classes A and A**, with decisions on the nomenclature to be used being defined at the same time.

5.) Class A** circulators could attract the "Top Ten" label or other mark to distinguish them as being the best available products on the market.

6.) The existing voluntary Europump labelling scheme should be made mandatory, with control therefore being taken over by the European Commission.

7.) The existing voluntary labelling scheme does not apply to boiler integrated circulators. Because of the complexities of analysing this product it is considered that for now it is adequate to allow improved circulators to be chosen as part of the total electrical consumption of the boiler. This proposal is elaborated in the Lot 1 final report. Unfortunately the phasing of the reports meant that the total electrical energy criteria detailed in the Lot 1 calculations were unable to take account of the final results of this Lot 11 study. Accordingly, sales of class A* equivalent boiler integrated circulators should be periodically reviewed to check that sales are proportionately similar to those of standalone circulators. If they are not, then this policy should be reviewed.

8.) EN 1151-1:2006 '*Pumps – Rotodynamic pumps – Circulation pumps having a rated power not exceeding 200W for heating installations and domestic hot water installations* has several weaknesses that need to be addressed for it to be used as the basis of an implementing measure

- **The permissible tolerance on the operating head (at the zero flow point) is large (+/-10%).**
- **The standard does not specify <u>any</u> tolerances for the equipment used to measure the flow.**
- **The standard does not provide any specific guidance as to how efficiency should be determined.**
- **A methodology needs to be defined for an improved way for assessing the performance of variable speed circulators.**

Table of contents

List of Figures

List of Tables

1 DEFINITION

This chapter provides an overview of circulator categories that fall within the Lot 11 study definition 'Circulators in Buildings'; it also explains EU and other relevant product standards such that policy makers and other stakeholders may understand the diversity and features of circulators within the EU.

Circulators are a type of pump and their definition is worked out below. The chapter starts by describing the range of circulators on the market, and then by consideration of primary functional parameters applied to circulators as described in the terms of reference, it reduces the scope to the two basic types that are the subject of the study. These are:

- Small circulator – used mainly in domestic applications.
  This product is further split into two types:
  - Standalone circulators that are separate from the boiler and are installed by the plumber.
  - Boiler integrated circulators that are designed for specific boilers and fitted in them at the factory.
- Large standalone circulator – used mainly in commercial and residential buildings.

There is a short section describing the construction and operation of circulators, and the implications of key primary and secondary functional parameters for pump selection and design are discussed. Current EC technical and environmental standards that impact on circulators are also discussed.

1.1 Product category and performance assessment

1.1.1 Where circulators are used

The product group included within the scope of this report are those that fall within the Lot 11 study definition of 'Circulators in Buildings':

Circulators are inline pumps that are typically used to re-circulate heating or cooling media within a closed circuit, (i.e. loop).

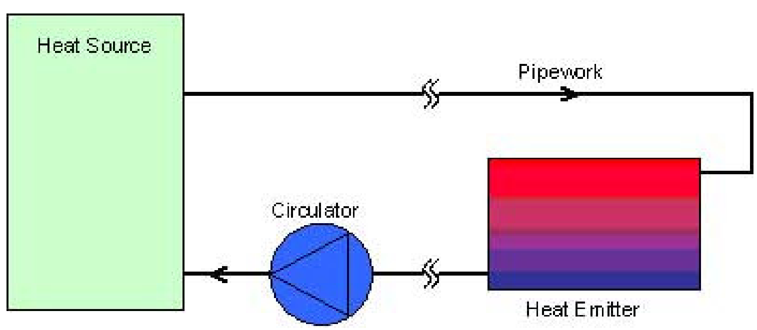


Figure 1-1 Simplified diagram of a typical heating system with circulator

Applications include:

- Heating circulators in household and small commercial central heating systems including:
  - Central heating systems
  - Domestic hot water systems
  - Under floor or wall heating systems
  - Thermal solar heating systems
  - Heat pump systems

- Heating circulators in large commercial central heating systems or community heating systems.
- Circulators in air conditioning and cooling applications

The types of circulator design used in the above applications range from small electronically controlled glandless circulators that are controlled down to an electrical input of around 5 watts, through to large glanded circulators with external 3 phase induction motors up to 37kW.

The majority of circulators are rated for operation in both heating and cooling applications, e.g. +110℃ to -10℃. There are some circulator models designed specifically for cooling applications with additional features such as those to minimise condensation, their market size however is small and there is little sales data for this sub category of circulator; Europump estimate that sales of all types of circulators into cooling applications represents considerably less than 1% of total circulator sales, i.e. <140,000pa, consequently annual sales of circulators designed specifically for cooling applications is even smaller. In keeping with Article 15 of the directive 2005/33/EC which states that certain categories can be excluded from the scope of measures on the basis of their commercial significance, their environmental impact or their improvement potential, circulators designed exclusively for cooling applications are therefore excluded from the scope of the study.

The design of circulators supplied into other applications such as **domestic hot water, under floor and wall heating systems, thermal solar heating systems, and heat pump systems** varies little from circulators supplied into heating applications, the main differences being the types of plastic the impellers are made from, or possibly the use of protective coatings inside the pump housing; the motor design is unchanged. Therefore, despite not being considered separately in this study, it is likely that in order to minimise design variation manufacturers would alter the basic design of these types to follow those of the core boiler circulator market. This market segment is anticipated to grow in the future, but not sufficiently fast to justify considering these as a new category within this study.

The range of design variation is no more than that associated with circulators designed for heating applications and hence circulators for these applications are included within the base case model.

Sales data for circulators supplied into these various other applications are not available, and consultations with circulator suppliers and Europump have indicated that sales are small (<600,000pa). Although this is greater than the indicative 200,000 units pa threshold stated in the EUP Directive, in total they use <4% of the energy used by the circulators for hot water central heating systems, and so it was not thought useful to treat them as a separate category at this time. It was stated during a stakeholder meeting that for heat pumps the main brine pump is 100-200W, and slowly getting larger over time. For solar pumps, over 95% are just for water heating rather than space heating.

Circulators supplied for drinking water applications are designed to meet hygiene standards, and are manufactured with bronze or stainless steel housings. The market for these products is small, and they are excluded from the scope of the study on the grounds of their subsequent limited environmental impact.

1.1.2 PRODCOM Definition of circulators

PRODCOM (Products of the European Community) is the international product classification scheme as used by EU customs and Eurostat, has the following definition applicable to circulators:

29.12.24.17 '*Glandless impeller pumps for heating systems and warm water supply'.*

There is no further breakdown by capacity, power consumption or similar measure.

1.1.3 Glanded and Glandless circulators

Circulators are a type of pump and there is an area of overlap with the Lot 11 study considering pumps namely, 'Water Pumps (commercial buildings, drinking water, food, agriculture)', It is therefore important to consider the boundaries of definition and application; i.e. What constitutes a 'circulator' and what constitutes a 'pump'?

For the purposes of this study, the PRODCOM definition is useful in that it helps to define the boundary between products that may be classified as circulators and those that may be classified as 'pumps'. We have used the PRODCOM definition of circulators as being 'glandless impeller circulators'.

Glanded circulators are by construction similar to the End Suction Close Coupled in line water pumps being considered by the 'Water Pumps' study, with the key distinguishing feature being that they have an external drive shaft sealed by a gland and to which a motor may be attached. Typical sizes range from 1.1kW to 7kW[1], and such circulators are used in commercial and residential buildings.

Glandless circulators have the shaft of the motor directly coupled to the impeller and the rotor is immersed in the pumped medium; hence they are sometimes referred to as 'wet running'. These glandless circulators are typically sized between 25W to 2500W. The smaller sizes are mainly used in houses with just one family, and the larger sizes used in houses of multiple occupation, tertiary or industrial buildings.

Consequently only Glandless circulators are included in this study, with Glanded circulators being considered in the parallel Pumps study. For the remainder of the report the term circulator refers to "glandless" circulators".

1.1.4 Standalone and boiler integrated circulators

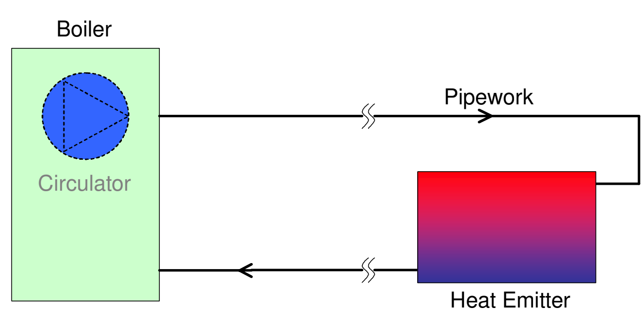
Of the circulators described above, some are designed for standalone use whilst others are designed to be integrated into the boiler.

Key features of boiler integrated circulators compared to standalone circulators:

- The boiler integrated circulator will be designed for a specific boiler, and so will be fitted with a unique manifold.
- They are frequently rated at higher heads to enable the use of a (cheaper) higher resistance heat exchanger. (Typically 5-7m head compared to 4-6m head for a standalone circulator).
- It is quicker for the installer to fit a heating system where the circulator is already connected. - the specific operation strategy of the circulator is controlled by the boiler
- The circulator control is used as well as a security functions inside the boiler to avoid boiler overheating (e.g. by pump overrun)

In order to ensure a fair comparison between standalone and boiler integrated circulators, the manifold and any other attached components of a boiler integrated circulator not directly related to the circulator function are excluded from the MEEUP analysis.

The SAVE II study of 2001 indicated that stand alone circulators comprise some 20% – 30% of the total stock of heating systems employing boilers.



[1] Where power is electrical input power to the motor and is designated 'P1'

Figure 1-2 Simplified diagram of a typical heating system showing the circulator built into the boiler

It was questioned whether boiler integrated circulators should actually be analysed as part of the EUP boiler study instead of this EUP circulator study. This point was resolved by reference to Article 22 of the Directive 2005/32/EC that defines what may be a component or sub-assembly, whilst Article 11[3] describes requirements for suppliers of components or sub assemblies to supply relevant information about these parts where they are included within a product subject to implementing measures. 'Boilers and combi-boilers (gas/oil/electric)' are products subject to the EuP Directive (see Lot 1), consequently boiler integrated circulators are subject to examination. In order to develop a fair comparison of all circulators in the market (i.e. stand alone and boiler integrated) they are included within the scope of this study, and the results are shared with the 'Boilers' study team (Lot 1).

The proposal from Lot 1 is that the boiler designer should select the circulator, fan and controls to meet a minimum total electrical requirement. Selecting a lower power circulator would then be beneficial to the boiler rating. A key energy trade off is that of minimising circulator rated head and the resistance of the heat exchanger.

1.1.5 Sizing considerations

Theoretically there are no maximum size limits to circulators, there are however significant design changes around the 2,500W size threshold where their design moves from the 'glandless' style to the 'glanded' style. Given that 'glanded' circulators are to be included in the scope of the 'Water Pumps' study, circulators rated above 2,500W are excluded from the scope of this study.

Boilers that integrate purpose designed circulators tend to be employed within domestic applications and the circulators are sized to suit these requirements, whereas boilers employed within commercial and residential buildings applications will be coupled to larger circulators of standalone design, regardless of whether they are incorporated within a boiler or not.

Table 1-1 shows the size range and typical duties of the three types of circulators considered in this study; the column 'Selected Basecase size' shows the representative size of circulator within these groups that has been selected for the Basecase analysis, and these are discussed later in the report.

Typical Application	Min delivery (l/s)	Max delivery (l/s)	Typical Head (m)	Typical rated electrical power (W)	Selected Basecase size
Domestic - Standalone	0.27	1.0	4-6	40-250	65W
Domestic - Boiler Integrated	0.27	1.0	5-7	90-120	90W
Commercial	0.5	20	2-14	<2,500	450W

Table 1-1 Typical duties of circulators

[2] Article 2 - Definitions
Components and sub-assemblies" means parts intended to be incorporated into EuPs, and which are not placed on the market and/or put into service as individual parts for end-users or the environmental performance of which cannot be assessed independently

[3] Article 11, Requirements for components and sub-assemblies
Implementing measures may require manufacturers or their authorised representatives placing components and sub-assemblies on the market and/or putting them into service to provide the manufacturer of an EuP covered by implementing measures with relevant information on the material composition and the consumption of energy, materials and/or resources of the components or sub-assemblies.

1.1.6 Typical Circulator Designs

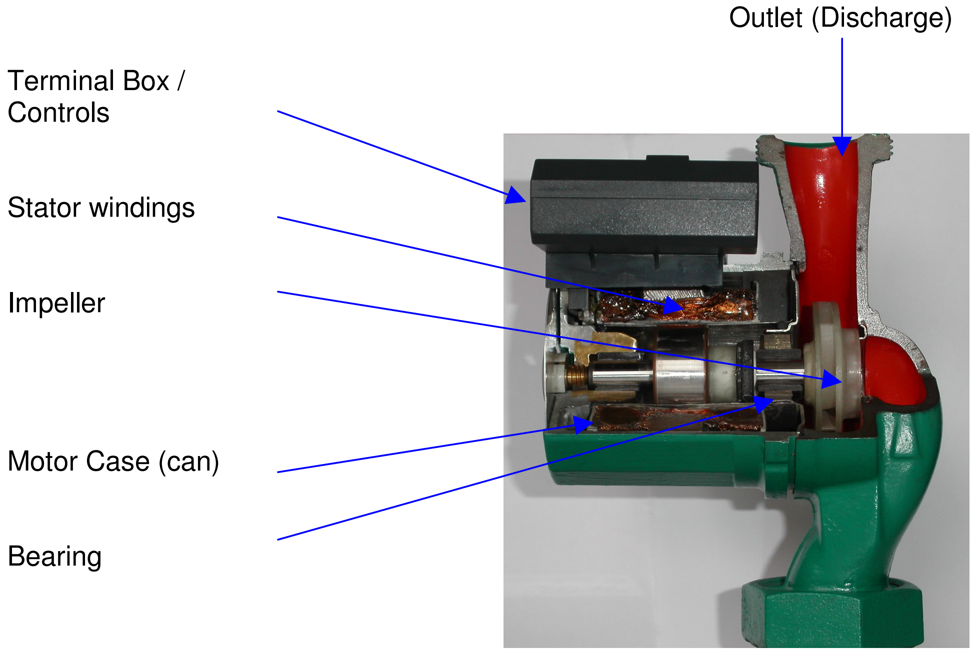


Figure 1-3 Cut away view of a typical glandless circulator

Figure 1-4 Two glanded circulators – (left) "ESOB " design, (right) "in line" design, (motors not connected).

The glandless circulator is an electrically powered centrifugal pump of sealed design; the pump impeller is mounted on the same shaft as the motor rotor, and together with the support bearings are sealed within the pumping medium (typically hot water). This avoids one of the main design challenges faced by larger, two-part pumps, that of maintaining a water-tight seal at the point where the pump drive shaft enters the pump body. The motor stator (carries the electric current and creates the magnetic field) is separated from the pumping medium by a can. The pumping medium also serves to lubricate and cool the motor.

Whilst there are benefits to this type of pump design a compromise is made in terms of motor efficiency; the can serves to add magnetic resistance and interferes with the magnetic field (flux) between the motor stator and rotor and the increased gap also reduces the magnetic flux between the motor stator and rotor.

The pump is mounted directly in line with the pipe work and is supported by the pipe work.

1.1.7 Circulator Motors

The motors used may be one of three types:

- **Fixed speed AC**. Fixed speed units are fitted with ac motors and typically run at about 2,800rpm.
- **Multiple speed AC**. Multiple speed units are by far the most common and in addition to an AC motor include a speed selector switch with 3 to 5 speed settings typically (800 – 2,800rpm). Speed selection is used to reduce the flow rate through the pump in order to limit excessive flow velocities and/or head within heating circuits and consequently reduce noise; an added benefit is reduced power consumption due to a better match between the pump and the hydraulic performance of the heating circuit.
- **Variable (modulating) speed.** Of more recent design are variable speed circulators, which use either conventional induction motors or electrically commutated (EC) motors. The advantage of variable speed is the ability of the control electronics to continually adjust the speed of the pump to match the hydraulic performance of the system at any given time. These products also tend to demonstrate improved hydraulic performance due to improvements in hydraulic design. EC motors use permanent magnet rotors, and are able to achieve higher efficiencies. (See Lot 11 Motor study for further information on the performance of these other types of motor).

Circulators integrated into boilers are in the main fixed speed (selectable) ac induction units with a customised pump component (volute) to suit the specific boiler model. The volute may be cast as part of a larger manifold into which other components such as directional valves or transducers may be fitted. Boiler designers tend to size pumps in line with the maximum performance of the boiler and possible system operating head, typically 6 metres.

Figure 1-5 Variable speed circulators *(Grundfos Alpha and Wilo Stratos series)*

Figure 1-6 Conventional 3-speed circulator (Grundfos)

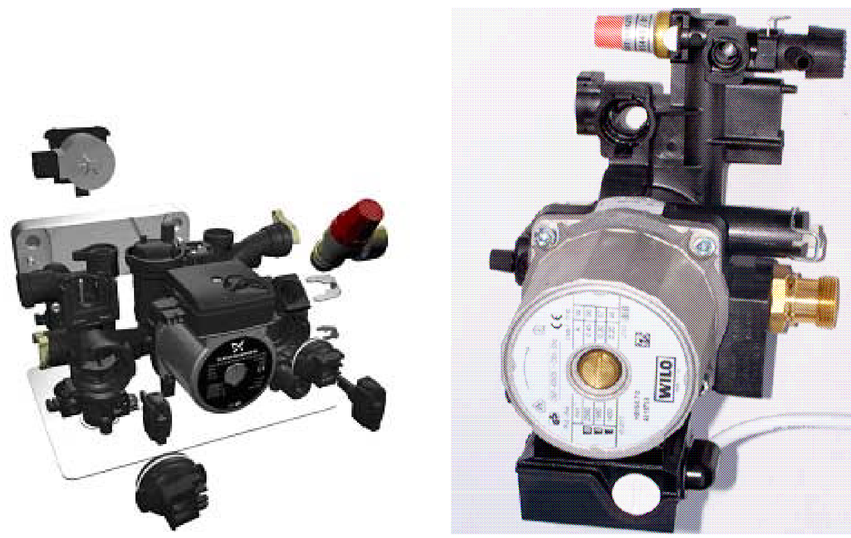


Figure 1-7 Boiler integrated circulator with associated components *(Grundfos, Wilo)*

1.1.8 Categories according to EN- or ISO-standard(s)

The relevant standard for performance testing of circulators is EN 1151-1:2006 '*Pumps – Rotodynamic pumps – Circulation pumps having a rated power not exceeding 200W for heating installations and domestic hot water installations. Part 1: Non automatic circulation pumps, requirements, testing, marking'.*

This standard is applicable to circulators rated 200W and less, it states that circulators rated 200W and less as being generally for domestic use whilst those larger than 200W are generally for use in commercial or residential buildings. The classification methodology for the Europump Circulators Classification Scheme[4] uses this test standard, despite the range of circulators covered by the scheme being rated up to 2500W.

[4] Industry Commitment: To improve the energy performance of Stand Alone Circulators through the setting up of a classification scheme in relation to energy labelling, Europump, January 2005 (www.europump.org)

1.1.9 Labelling categories (EU Energy Label, Eco-label

The European Association of Pump Manufacturers (EUROPUMP) launched a Voluntary **EU Energy Label** scheme for comprised circulators in January 2005. Circulators included in the scheme are only those used in residential and commercial heating systems within the European Union. In addition the circulators must meet the following technical criteria:

- be stand alone circulators with integrated pumps and motors
- be wet running (I.e. the rotor operates in the pumped fluid)
- be centrifugal pumping
- have a P1<2500W[5] (for each pump head on twin pumps)

In practice this scheme applies to all standalone circulators sold within the EU, but it excludes boiler integrated circulators.

In Germany there is the **'Blue Angel' ecolabelling scheme**; in the case of circulators it identifies domestic central heating circulators as 'self controlled circulators' with a maximum size of 250W. The classification methodology for the Europump Circulators Classification Scheme has adopted the load profile applied to circulators in the 'Blue Angel' scheme.

1.1.10 Circulator criteria for inclusion within the study

The definition of products to be included in the scheme is all circulating pumps "circulators" that are:

- Primarily designed for space heating applications. (Some circulator types may also be suitable for other applications such as cooling, heat pumps and solar heating.)
- Electrical power consumption not exceeding 2500W. In the case of twin pumps, this the rating per pump head.
- Wet running (glandless). This means that the motor is running in the fluid that is being pumped.
- Of centrifugal design. (Other designs would be allowable if the same quality level is reached with respect to comfort, reliabilty, noise).

and life time.

Only standalone types are included. These are circulators sold for installation outside of the boiler. (Circulators supplied to the consumer fitted within the boiler "boiler integrated circulators" are not included).

In order to encourage innovation, no limitations on the physical design of circulators are stipulated.

1.1.11 Definition of Primary Functional Parameters

The primary functional parameters are: Rated flow (denoted "Q", m^3/hour or litres/second) and the outlet pressure or head (denoted "H", in metres).

The functional unit is the reference value for any pump considered, and is independent of type. It also helps to set the boundaries for comparison of different products. For the pumps in this study, this may be assessed by considering "the rate of water pumped at the specified head, (m3/h, m)".[6]

[5] In the case of 'wet running' or 'integrated pump and motor' it is common practice for efficiency to be defined as the overall efficiency of both the pump and the motor. Input power is designated 'P1'.

[6] There is no formal naming and classification system, some manufacturers classify their products by inlet diameter and maximum operating head (against a closed valve), and some by inlet diameter and the full range of operating head. With regard to energy performance ratings they are also classified by power consumption. The majority of circulators are of the centrifugal type, their hydraulic power consumption will vary with impeller (shaft) speed, and hence operating speed is an important parameter. Power consumption will also depend on where the circulator characteristics intersect with the system characteristics, and the density of the fluid.

1.1.12 Secondary Functional Parameters

Other technical factors influencing selection include;

- Circulator volume
- Circulator weight
- Fitting dimensions (usually the dimension between the inlet and the outlet, and the associated pipe sizes)
- Bearing arrangements
- Noise (circulators must not be noisy so as to disturb the building occupants)
- Expected lifetime of the circulator
- System pressure (the overall pressure within the system, not the outlet pressure of the circulator)
- Minimum clearances required (Within the motor component this represents the gap between the rotor and stator where there is a trade off between smaller gaps realising improved motor efficiency, and the space allowed for the heating medium to circulate both for cooling purposes and to prevent any foreign debris, possibly corrosion from the heating system, from jamming the rotor. Within the pumping part reducing the gap between the impeller and the volute is more limited by manufacturing capabilities and the increased cost of manufacturing to tighter tolerances).
- Efficiency (efficiency of the circulator is the product of the motor efficiency and the pump efficiency)
- Material type (usually associated with the application type, E.g. bronze or stainless steel for hygiene requirements)
- Motor type
- Control type (fixed speed, selectable multiple speed – usually 3 or 5 settings, or continuously variable speed controlled).

1.2 Test Standards

This chapter briefly describes a) the harmonised test standards and b) the additional sector specific directions for product testing, regarding the test procedures for:

- the primary and secondary functional performance parameters mentioned above;
- resources use and emissions during product-life;
- safety;
- noise and vibrations (if applicable);
- other product specific test procedures.

Apart from mentioning these standards, other international standards that could be relevant are identified along with new standards in development. Problems with existing standards are noted and some possible corrective measures are suggested.

1.1.13 Harmonised standards - performance testing

EN 1151-1:2006: This is the most common standard for performance testing of circulators and is formally titled:
EN 1151-1:2006 '*Pumps – Rotodynamic pumps – Circulation pumps having a rated power not*

exceeding 200W for heating installations and domestic hot water installations. Part 1: Non automatic circulation pumps, requirements, testing, marking'.

This test is regarded as a type test, as it should be applied to several samples of the same type of pump. There are some weaknesses in this standard:

- **The permissible tolerance on the operating head (at the zero flow point) is large (+/- 10%).**
- **The standard does not specify <u>any</u> tolerances for the equipment used to measure the flow.**
- **The standard does not provide any specific guidance as to how efficiency should be determined.**

To calculate pump efficiency, the ratio of hydraulic power to the mechanical shaft power must be determined. Hydraulic power cannot be measured directly and is calculated by measuring the operating head and flow. The wide tolerance in operating head as permitted by the test standard will result in a wide spread of the final calculated efficiency value. This error will be carried through to calculations of energy consumption: for small circulators with typical input powers under 100W and operating heads under 5 metres the wide head tolerance may not impact the absolute energy consumption figures significantly, however as circulator sizes increase so their corresponding power consumption increases and the absolute error in energy consumption becomes large.

One explanation given for the wide head[7] tolerance is that it is difficult to manufacture small circulators to tight tolerances. In addition the relative losses in the motor element due to bearings and friction, and a wide stator to rotor gap – to allow fluid passage – are relatively high.

With increasing circulator size, the relative losses due to these factors is reduced.

Europump specify EN1151-1 as the test standard for all circulators in their labelling scheme (including circulators up to 2500W). However *when calculating efficiency (and energy consumption) of the larger circulators consideration must be given to the wide tolerance in the standard.*

EN9906:1999 Rotodynamic pumps - Hydraulic performance acceptance tests - Grades 1 and 2
The standard EN9906 is currently undergoing redrafting and will have a section relating to pumps rated down to 200W.

EN1151-3: A new annex to standard EN1151-3 is currently being drafted for application on variable speed controlled circulators.

The study group is unaware of any standards relating to circulators larger than 200W.

Due to the deficiencies associated with the EN1151-1:2006 test standard the following recommendations are made:

1) The tolerance on head measurement should be reviewed[8] and a tolerance published for the first time on flow measurement.
2) A new or revised test standard for fixed speed integrated (combined motor pump) circulators in the size range 200W to 2500W is developed.

However, it should be noted that because of the way the EU circulator labelling scheme calculates the energy performance (EEI), the final error in calculation of the EEI value will be less than these wide tolerances might imply.

It was not possible within the study to define precisely how tight it is practical to make the tolerances, but any proposals from CEN should be carefully reviewed to check that the new requirements will be adequately tight to underpin the recommended policy options. These tolerances will impact the minimum bandwidth for the revision of the labelling scheme.

[7] Output pressure

[8] For circulators up to 200W, the current tolerance is thought by some manufacturers to accurately represent the total tolerance on manufacturing spread plus measurement uncertainty. For larger circulators the tolerance does need altering, as it is not possible to simply "scale up" from that applying to small circulators.

Verification of efficiency values

It is important that the actual efficiencies of products placed on the market comply with any claimed energy performance class. Manufacturers currently use a scheme that "guarantees" that all circulators (except for a small statistical proportion) will exceed the stated class (EEI)[9] minimum level, (fig 1.8).

Manufacturers will compare where their production spread lies in comparison with the class minimum. This represents a statistical risk, based on the chances of the average of three (as used in standard verification) passing. Manufacturers who control production to give a tighter spread may chose to produce circulators with a lower mean efficiency, and can reap any cost savings from this.

It should be noted that in contrast to other products, manufacturers do not publish the actual EEI value, rather just the class that it meets. There is therefore no concept of a "declared" EEI value.

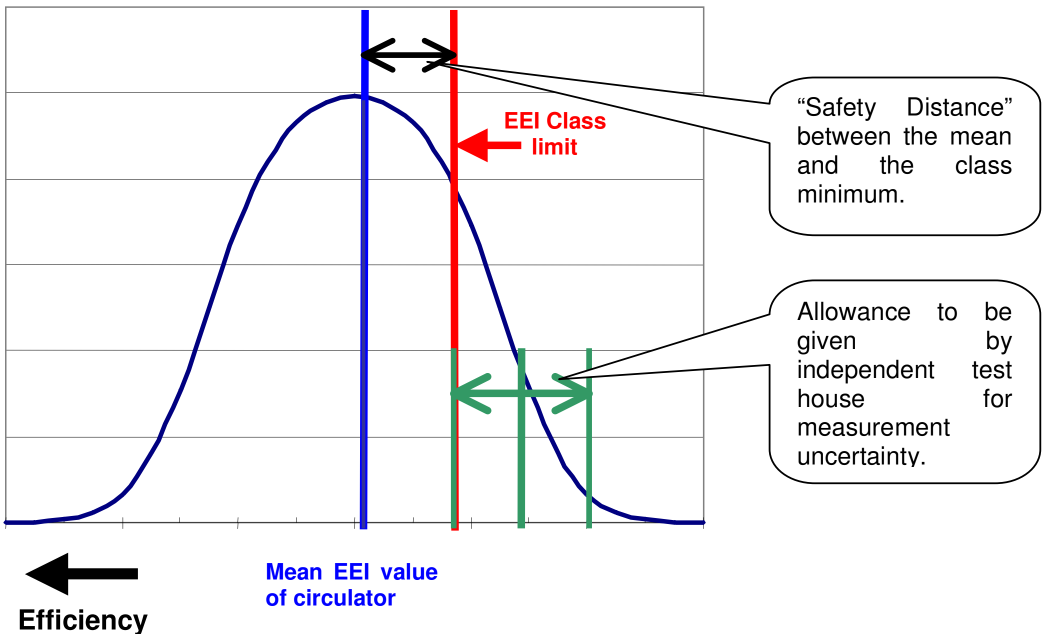


Figure 1-8 Verification of circulator efficiency

Manufacturers include an allowance for **measurement uncertainty** in their production spread and consequent decision on the declared value of efficiency. They therefore have an interest in making their measurements as accurately as possible.

There is though no agreed value on the typical tolerance on measurement that can be expected, although it is noted that manufacturers regard measurement uncertainties as being considerably less than the value of production spread.

The revision of EN1151 currently being undertaken by CEN will take account of the need to publish realistic values for measurement uncertainty.

Similarly, there will be a tolerance on the measurement of efficiency undertaken by any independent test body. It is again in the interest of the commissioning authority to use a test house that has tight tolerances.

[9] Section 1.3.1.1 defines the Energy Efficiency Index (EEI).

1.1.14 Harmonised standards – resources use

In studies such as the '*EU SAVE II Project – Promotion of energy efficiency in circulation pumps, especially in domestic heating systems',* circulators were identified as being responsible for significant amounts of energy consumption. Europump responded to this by launching a voluntary classification and energy labelling scheme for circulators in January 2005.

The scheme defines a test methodology which in turn uses a load profile developed for the German 'Blue Angel' energy labelling scheme for circulators, the methodology is described in Appendix 1.

1.1.15 Harmonised standards – health and safety

The following are the key harmonised standards applying to circulators, none of which are considered to impose difficult design constraints on standard or improved products:

EN ISO 12100-2:2003, Safety of machinery – Basic concepts, general principles for design – Part 2: Technical principles (ISO 12100-2:2003)

EN 60335-1:2002/A2:2006 Safety of household and similar electrical appliances: General requirements.

EN 60 335-2-51: 2003 Specification for safety of household and similar electrical appliances. Particular requirements for stationary circulation pumps for heating and service water installations.

1.1.16 Harmonised standards – Noise and Vibrations

EN 1151-2:2006 ***'****Pumps – Rotodynamic pumps – Circulation pumps having a rated power not exceeding 200W for heating installations and domestic hot water installations. Part 2: Noise test code (vibro acoustics) for measuring structure – and fluid borne noise'.*

1.3 Existing legislation

This chapter identifies existing relevant legislation for circulators and presents it in three parts:

- Legislation and agreements at European Community level
- Legislation at Member State level
- Third country legislation (legislation outside of the EU)

1.1.17 Legislation and Agreements at European Community Level

Energy Performance of Buildings Directive 2002/91/EC
The Directive is set to promote the improvement of energy performance of buildings with four requirements to be implemented by the Member States:

- General framework for a methodology of calculation of the integrated performance of buildings
- Setting of minimum standards in new and existing buildings
- Energy Certification of Buildings
- Inspection and assessment of heating and cooling installations.

One requirement of the EC Energy Performance of buildings Directive is that air conditioning systems with a capacity of greater than 12kW must be inspected regularly. This may have implications for some circulator systems.

http://ec.europa.eu/energy/demand/legislation/buildings_en.htm

The German standard DIN 18599 quotes electrical consumption per square meter per year, which has an impact on the selection of circulator.

There is a draft European standard (15362), which is the equivalent of the above German standard.

General EC safety and environmental legislation applicable to circulators includes the following:

Low Voltage Directive (LVD) 73/23/EEC

For the purposes of this Directive "electrical equipment" means any equipment designed for use with a voltage rating of between 50 and 1 000 V for alternating current and between 75 and 1 500 V for direct current.

http://ec.europa.eu/enterprise/electr_equipment/lv/direct/73-23.htm

General Product Safety Directive (GPSD) (2001/95/EC)

The Directive applies to products intended for or likely to be used by consumers. It obliges producers to place only "safe" products on the market.

http://ec.europa.eu/consumers/cons_safe/prod_safe/gpsd/currentGPSD_en.htm

Machinery Directive 98/37/EC

This directive provides the regulatory basis for the harmonisation of the essential health and safety requirements for machinery at a European Union level. Essentially performing a dual function, the Directive not only promotes the free movement of machinery within the Single Market, but also guarantees a high level of protection to EU workers and citizens.

Machinery is described in the Directive as "an assembly of linked parts or components, at least one of which moves, with the appropriate actuators, control and power circuits, etc., joined together for a specific application, in particular for the processing, treatment, moving or packaging of a material". The manufacturer is responsible for verifying whether a particular product falls within the scope of the Machinery Directive.

http://ec.europa.eu/enterprise/mechan_equipment/machinery/index.htm

Electromagnetic Compatibility (EMC) Directive 89/336/EEC as amended by 91/31/EEC and 93/68/EEC.

Since January 1 1996, most electrical and electronic products to be sold in the EC must be constructed so that they do not cause excessive electromagnetic interference and are not unduly affected by electromagnetic interference.

http://ec.europa.eu/enterprise/electr_equipment/emc/directiv/text2004_108.htm

WEEE (Waste Electrical and Electronic Equipment) Directive 2002/96/EC

Circulators are considered to be outside the scope of both the WEEE and RoHS Directives, with the following explanation included in support of this view:

The WEEE Directive is one of a small number of European Directives that implement the principle of "extended producer responsibility". Under this principle, producers are expected to take responsibility for the environmental impact of their products, especially when they become waste. The WEEE Directive applies this in relation to electrical and electronic equipment (EEE).

The broad aims of the WEEE Directive are to address the environmental impacts of electrical and electronic equipment and to encourage its separate collection, and subsequent treatment, reuse, recovery, recycling and environmentally sound disposal.

The WEEE Directive seeks to improve the environmental performance of all operators involved in the lifecycle of electrical and electronic equipment, especially those dealing with the disposal of old products. Accordingly it sets certain requirements relating to the separate collection of products, standards for its treatment at permitted facilities, and requires its recycling and recovery to target levels. It makes producers responsible for financing the majority of these activities. Distributors have responsibilities in terms of the provision of facilities to enable the free take-back of products from consumers and also the provision of certain information to consumers of products.

Options for EuP measures might include those that contribute to the WEEE implementation in contributing to waste prevention in reducing materials use, when possible, and in introducing e.g. easier disassembly, which will make reuse and recycling of energy using products easier

The product must meet the following criteria to be covered under the WEEE legislation:
- Main power source is electricity (including batteries)
- Less than 1,000v AC or 1,500v DC
- Electricity is needed for primary function

It must be one of the following categories of WEEE specified in Annex 1A of the WEEE Directive
1) Large household appliances
2) Small household appliances
3) IT & telecommunications equipment
4) Consumer equipment
5) Lighting equipment
6) Electrical and electronic tools
7) Toys leisure and sports equipment
8) Medical devices
9) Monitoring and control instruments
10) Automatic dispensers

The circulator cannot though be considered to fall within any of the categories specified in Annex 1A of the Directive. We therefore consider that the circulators of the type considered in this study are not covered by the WEEE Directive. This argument was proposed at the second stakeholder meeting and there were no objections to this viewpoint.

In addition, the MEEUP modelling and analysis will show if any products do contain any of the above substances, in which case a discussion to justify the continued use or phasing out of these substances will be developed.

RoHS (Restriction of Hazardous Substance Directive) 2002/95/EC

The Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment Regulations 2006 ("the RoHS Regulations") implement the provisions of the European Parliament and Council Directive on the Restrictions of the use of certain Hazardous Substances in electrical and electronic equipment ("the RoHS Directive"), as amended.

The RoHS Regulations ban the placing on the EU market of new Electrical and Electronic Equipment (EEE) containing more than the permitted levels of the following:

- lead
- mercury;
- cadmium;
- hexavalent chromium;
- polybrominated biphenyls (PBBs); or
- polybrominated diphenyl ethers (PBDEs).

In order to place products on the market in the EU, manufacturers need to ensure that their products and product components comply with the requirements of the Regulations.

Given that the scope of the RoHS Directive is drawn from that of the WEEE Directive it is assumed that certain provisions in the WEEE Directive may apply to EEE within the RoHS Directive so as to limit its scope. There is, however, no express provision in the RoHS Directive to this effect.

Circulators are excluded from the RoHS Directive on the same grounds that they are excluded from the WEEE Directive.

Existing EU Voluntary initiatives

1.1.17.1 Circulator Labelling Commitment[10]

The leading European circulator manufacturers, represented by Europump, in January 2005 launched a classification and voluntary labelling scheme applied to comprised circulators up to 2500W in heating applications. Information on the impact of the scheme to date is shown in Figure 1-9.

The Energy Efficiency Index (or EEI) on which this scheme is based is calculated as follows (detailed example in Appendix 1):

1.) A reference power consumption for the particular mechanical power consumption is found from a defined reference curve (Appendix 1).

Flow (%)	Time (%)
100	6
75	15
50	35
25	44

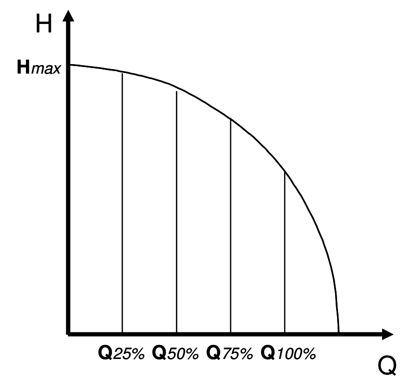


Figure 1-9 Standalone Circulator load profile as described by the German *Blauer Engel* energy labelling scheme

2.) The (electrical) energy consumption of the particular circulator is calculated using the "energy weighted" method that takes account of the energy consumption of the circulator at the 25%, 50%, 75% and 100% flow points, as determined by a standard time-flow profile curve, (figure 1.8).

3.) The ratio of the calculated mean electrical power to the reference power is known as the Energy Efficiency Index, or EEI.

The existing EU circulator labelling scheme is based on this method, and uses the thresholds shown in figure 1-10.

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

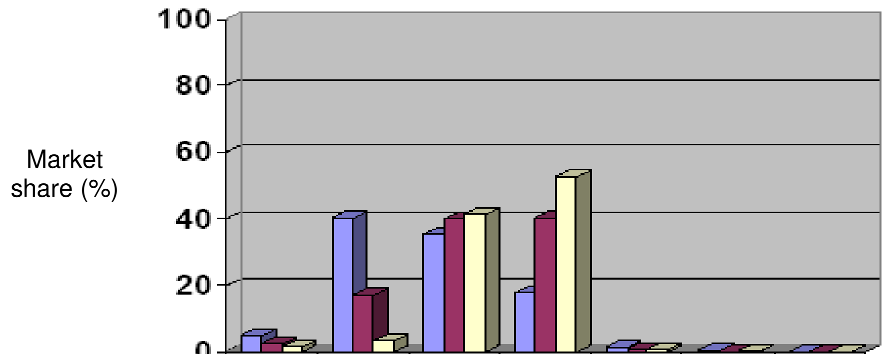
Figure 1-10 The Energy Efficiency Index

These levels are set such that only Permanent Magnet Variable Speed circulators are currently capable of reaching the A classification. Figure 1-10 presents the most recent data on circulator

[10] also 'Ecopump - Circulators Labelling Commitment', www.europump.org

sales, by class.

This shows that there has been a big shift from class D to class B circulators, with class A also increasing slightly. A basic interpretation would be that the introduction of the labelling scheme has led to this positive shift in the market, but in reality this coincided with manufacturers launching new ranges of products. While the recent very significant increase in the sales of class A and B products has been driven by this combination of a voluntary labelling scheme and manufacturers launching new products, it is thought that this growth in improved products will be limited without further market stimulation.



	A	B	C	D	E	F	G
2006	5	40.2	35.4	17.7	1.3	0.3	0.1
2005	2.6	17	39.8	40.2	0.8	0.1	0
2004	1.6	3.3	41.3	52.8	0.8	0.2	0

Efficiency Class

Figure 1-11 Breakdown of sales, by efficiency class, for standalone circulators <2.5kW. [11]

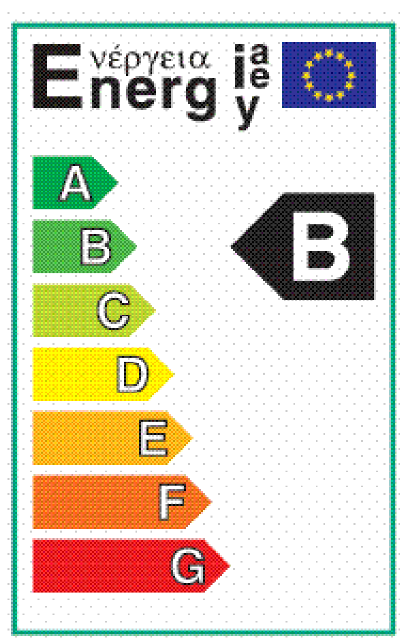


Figure 1-12 Label for the Europump voluntary labelling scheme

[11] Report from Europump published July 2007.

1.1.17.2 Energy Plus Pumps

The Energy Plus Pumps scheme is a marketing initiative to promote higher efficiency circulators, and is supported by the Intelligent Energy programme of the European Commission. See www.energypluspumps.eu.

The short-term objective of the project is to bring even more products to the market, to support their rapid break-through and thereby to reduce their prices through mass production. It aims to do this by presenting comprehensive and transparent information which will influence buyers and ultimately lead to procurement initiatives.
The ultimate long-term objective is to transform the market so that the new technology will become the standard technology, at prices close to those of today's pumps. Figure 1-11 is an extract from the Energy Pumps Plus web-site that shows the scope of the work.

The Energy+ goal will be achieved through the methods of technology procurement that have been successfully tested in the European Energy+ project for energy-efficient refrigerators and freezers.
The overall idea of this process is to get confidence between the participating parties and create awareness of the benefits of energy-saving technologies.

Procurement Declaration
Particularly large institutional buyers will be invited to sign the procurement declaration to express their serious intention to invest in energy-saving and ecological technology of Energy+ products.

Supporter Declaration
National, regional and local energy agencies, environmental and consumer NGO, energy companies, and other organizations interested in the subject are asked to sign the supporter declaration for help Energy+ with dissemination of information and campaigning activities.

Development and Lists of Energy+ products
Energy+ invites manufacturers of circulators or condensing boilers to induce the development or integration of high-efficiency circulation pumps, to list these products and to present them for the Energy+ Award.

Awards
Energy+ grants three different awards: first, for the best energy-efficient circulator, second, for the best energy-saving condensing boiler, and third, for the best supporting campaign.

Dissemination of information
Having an especially important role dissemination will be achieved through presenting the project at the ISH fair in Frankfurt, by information folders and posters about the project, listing of the product, partners and supporters on the Energy+ pumps website (www.energypluspumps.eu).

Training of installation contractors
Finally, installation contractors will be involved receiving easy-to-us materials about the new technology and being trained how to sell the high-efficient pumps based on life-cycle costs.

Figure 1-13 Scope of the Energy Pumps Plus scheme

A key aspect is a listing of superior pumps, which are those <300W which meet Class A efficiency, an example of which is given in figure 1-13, (for clarity only three of the circulators on this particular listing are shown). This type of product is classified as Permanent Magnet (Fixed or variable speed) in the later analysis in this study.

Brand	T.Smedegaard A/S	Grundfos Managemnet A/S	Wilo AG
Model	ISOBAR 2-50	GRUNDFOS ALPHA Pro 25-50	Stratos ECO 25/1-3
EEI [2]	<0.4	<0.25	<0.20
Flow rate [m/h] [3]	1.60 m3/h	1.71m3/h	1.80 m3/h
Head [m and kPa] [3]	12.75 kPa	2.36 m	1.84 m
Max. power input P1 [W] [3]	32 W	35 W	32 W
Type of speed control [4]	Variable head	Variable head	delta p-v, Autopilot
Electricity consumption [5]	130 kWh	94 kWh	70 kWh
Savings [6]	195 kWh	301 kWh	318 kWh
Mounting sizes, thread sizes, lengths available [mm]	1^n and 5/4^n 180/130mm	25/32; 130/180	Rp 1 / G1 1/2
Countries where the model is available	DK, CH, SE, NO, IT, ES, UK	EU-25	Europe
Pump diagram head versus flow including control curve	see figure	see figure	see figure
Table with input power and flow data [7]	see figure	see figure	see figure
Picture			

1 European Article Number
2 Energy efficiency index according to the Europump Labelling
3 at operating point of maximum hydraulic power
4 variable head/ constant head/ other
5 for 8 months heating period, 5000 hrs operation, to be calculated from input data for EEI calculation
6 compared to a reference (reference: EEI = 1,0) pump for 8 months heating period (5000 hrs operation, to be calculated from input 11.data for EEI calculation)
7 at 25 %, 50 % , 75 % and 100 % of the flow at the point of max. hyd. power[12]

Figure 1-14 Listing of "Energy +" Pumps, 0 - 1.85 m3/h

The Energy Efficient Pump initiative has recently launched a competition to identify outstanding circulators, with the criteria shown in figure 1-13 below. In addition to the energy performance, it also takes account of the cost effectiveness, and hence takes account of the same fundamental criteria as the Life Cycle Costing analysis used in the MEEUP model.

[12] Note that these results are not directly comparable with the results of the MEEUP analysis presented in this report due to the different assumptions made of operating patterns.

Energy efficiency
The energy efficiency index EEI (expressed as a percentage) as defined according to measurement standards and formulas described in the document "Europump Industry commitment to improve the energy performance of Stand-Alone Circulators, 2005".[4]

Price
The highly energy-efficient circulator should have a fair consumer price to allow for a large diffusion. Therefore the net end-user price compared to the net end-user price of an uncontrolled circulator with the same pump performance curve of the same manufacturer will be taken into account.
As insulation of the circulator is also an important feature for the overall energy efficiency of the heating system, the price of the insulation will be taken into account.

Installation and adjustment
The circulator should be easy to install.
In terms of installation and adjustment, among others, the jury will consider positively:

- Clear and appropriate installation instructions,
- Easy to connect to the electrical grid.
- Providing of a replacement guide,
- Brochures and other material that help installers to convince their customers of the advantages of the highly efficient pumps
- Training courses for installers and planners offered by manufacturer.

Utility
The circulator should be easy and practical to use with.
In terms of utility, among others, the jury will consider positively:

- Clear and appropriate user instructions
- Existence of a display which is user friendly (for example with easy to understand instructions

for settings, with display of technical faults etc.), but should have a low stand-by consumption.

Figure 1-15 Judging criteria for the Energy Plus award competition

1.1.18 Legislation at member state level

In **Denmark**, Heating systems must be designed with lowest possible pressure loss, taking into account the functionality and economics of the heating system. Selection and control of pumps must ensure the lowest possible electricity consumption of the pump.

Pumps must be automatically controlled according to the flow and pressure demand at the actual duty point. Excluded are pumps which operate in constant flow systems, for example those with heating coils in air conditioning systems. The pump control must not limit the ability to achieve the desired comfort level or minimum flow rate requirements.

In **Germany** legislation requires the installation of speed controlled circulators in heating systems larger than 25kW (heating power)

1.1.19 Third Country Legislation

In **Switzerland**, there is a recommendation to use Variable speed circulators.

We were unable to find any other relevant legislation in third countries. This reflects the fact that wet heating systems are largely restricted to European Countries. There is a small but growing market in these systems in the USA.

1.1.20 Summary

This chapter presents an overview of circulators and the relevant standards and legislation that apply to them in the EU.

In this study we are considering the more common glandless circulator, which means that the motor is “wet” running, ie the system fluid is in contact with the motor. The bulk of the market is for small circulators, of which the more familiar “standalone” type will have an average power of about 65W. A rapidly growing part of the market is for custom designed “boiler integrated” circulators that are included in the boiler, and these have an average power consumption of about 90W. The balance comprises larger standalone circulators for use in commercial and residential buildings in the range 200-2500W. Boiler Integrated circulators are also considered to be components of a boiler and hence policy recommendations on them are included in the Lot 1 Boilers study, and not in this report. It should be noted that the results of this study are only relevant for circulators used in central heating system.

The relevant test standard is EN 1151-1:2006 Pumps – Rotodynamic pumps – Circulation pumps having a rated power not exceeding 200W for heating installations and domestic hot water installations. Part 1: Non automatic circulation pumps, requirements, testing, marking’. This currently only applies to circulators up to 200W, but Europump are planning to extend this to circulators up to 2500W. It does not though specifiy how efficiency should be determined.
The standard, EN9906:1999 Rotodynamic pumps – ‘Hydraulic performance acceptance tests - Grades 1 and 2’ will be extended to apply to pumps down to 200W.
A new annex to EN1151-3 is being drafted that will specify procedures for testing variable speed circulators. It is therefore recommended that the wide tolerances in EN1151-1:2006 are reviewed, and that a new performance standard is written to cover circulators in the 200W – 2500W power range.

Neither WEEE or RoHS legislation applies to these products. Despite this, the materials content in all designs means that they are in any case compliant. In section 7.2 the MEEUP analysis is applied to the newer PM variable speed circulator that includes a Permanent magnet motor and electronic control PCB, but even the materials of this newer product are still RoHS compliant.

The Energy Plus Pumps scheme is a marketing initiative to promote higher efficiency circulators, and is supported by the Intelligent Energy programme of the European Commission

There is an existing (A-G) voluntary EU Labelling scheme that classifies standalone circulators up to 2500W by energy performance.

2 ECONOMIC AND MARKET ANALYSIS

The objectives of this chapter are to present the following information:

- Generic economic data - places circulators (the product group) within the total of EU industry and trade policy
- Market and stock data - provides market and cost inputs for the EU wide environmental impact of circulators
- Market trends - identifies the latest market trends so as to indicate the market structures and ongoing trends in product design
- Consumer expenditure base data - provides a practical dataset of prices and rates to be used in a Life Cycle Cost (LCC) calculation

The primary data source is Eurostats. This is selected so that all policies at an EC level (both EuP and other initiatives) are from the same data source.

2.1 Generic economic data

Circulators are considered within the context of all pumps in the Pumps report *(Section 2.1-2-2)*, and are primarily classified within Prodcom 29122417.

From the detailed discussion in section 2.2, it is estimated that the total value of the circulator market (in terms of consumer price) is split as follows:

Style of Circulator	Estimated sales (units pa, 2005)	Price/unit (euros)	Total value of the market (Meuros) pa
Small Standalone	5,500,000	120	660
Boiler Integrated	7,500,000	120	900
Large Standalone	1,000,000	400	400
Total	14,000,000		1,960

Table 2-1 Value of the EU Circulator market

2.2 Market and stock data

2.2.1 Eurostats

The Eurostat data (2006) presents EU trade for “Glandless impeller pumps for heating systems and warm water supply.”

	Production Quantity	Value (Euros)		
Country	Units pa	Production	Export	Import
France	10,262,534	270,146,000	238,885,040	59,901,510
Netherlands			2,073,900	20,607,740
Germany	1,516,504	313,831,916	245,329,390	165,604,050
Italy	694,556	30,246,000	27,160,290	97,894,800
United Kingdom	2,584,894	917,434	41,590,270	37,404,050
Ireland			11,546,270	7,438,830
Denmark	3,898,139	150,414,125	149,440,880	10,445,180
Greece			10,544,210	15,673,440
Portugal			110,480	4,617,170
Spain	5,438	1,628,808	697,130	12,216,000
Belgium			1,351,780	13,031,820
Luxemburg			143,060	3,428,780
Sweden	173,258	83,832,309	9,640,720	20,373,550
Finland			332,280	1,767,380
Austria			1,373,340	15,369,130
Estonia			165,950	1,067,920
Latvia			870,110	2,003,580
Lituania			372,010	2,417,950
Poland			938,450	27,547,100
Czech Republic			1,791,320	12,799,260
Slovakia			735,060	15,022,120
Hungary			15,460,260	13,320,860
Romania			1,778,110	11,058,420
Bulgaria	189	85,898	41,480	2,690,880
Slovenia			7,106,380	4,227,820
EU-27 Total	19,135,512	861,478,642	135,219,460	16,334,830

Table 2-2 Eurostats data on EC circulator production (Jan – Dec 2006)

The Eurostat data indicates total EU-27 production at 19.1M units pa, this is higher than the figures presented by Europump below, even after allowing for a small amount of net exports.
There are likely to be discrepancies in categorisation within the Eurostat data including the following:

- Age of data: It can take several years for information to be collected and presented in the database.
- Missing countries: Only some countries have reported, with new member states in particular not having filed returns for these early years.
- Definitions and categories:
    - Abrupt changes can result from the re-definition of product categories.
    - Categories may be interpreted differently by different countries, reflecting their individual methods of collecting data.
    - Financial values in particular can be greatly distorted by the inclusion of auxiliary components or spares.

Taking account of these factors, the 5.1Mpa discrepancy in the data provided by Europump and that of Eurostats is not unreasonable. In this study we have opted to use the data provided by Europump, as we have more confidence that the data was collected in a way most appropriate to the needs of our study.

However, the average prices implied by the data in Table 2-2 show a huge variation, which we are unable to explain. We are therefore using assumed average prices agreed in conjunction with Europump.

2.2.2 Europump data

Country	Net exports of circulators (units pa)
France	+4.0M
Belgium	-0.35M
Netherlands	-0.6M
Italy	-1.7M
Great Britain	+0.35M
Denmark	+1.5M
South	-0.62M
Scandinavia	-0.25M
Austria	-0.25M
Germany	-2.7M
Total Market	10.62M
Production	10.0M

Table 2-3 Europump data on net exports of circulators (ie Production – Consumption) by member state (2002, selected EU-15 countries only).

Style of Circulator	Estimated sales (units, 2005)
Standalone	5,500,000
Boiler Integrated	7,500,000
Large	1,000,000
Total	14,000,000

Table 2-4 Europump data on annual sales (Heating circulators), published April 2005

Europump data (table 2-3) shows estimated EU production (and consumption) of heating circulators at 10.6 million units. However, projecting this to 2006 with EU-25, it is considered that the total EU-25 market is 14.0Mpa.[13] It has not been possible to analyse the overlap between these different data sources, however it is safe to conclude that the majority of circulator sales will be in the size range <250W.

2.2.3 SAVE II Study

The SAVE II study[14] concluded the 1995 (EU-15) market for circulators (<250W) was in the region 8 to 8.5 million units whilst stock levels were 87 million units.

The SAVE II study also indicated that in most EU countries over 90% of circulators supplied are in the size range <90W, of which those having a power input 'P1' of 60W – 65W are the most typical.

2.2.4 EUP Boiler Study

The EUP Lot 1 Boiler study is the most recent and authoritative study, which yields the following information on boiler sales and stock:

[13] The September 2007 edition of Stiftung Warentest magazine, p76-79 quotes a 20 year life for circulators, but this is regarded by the study group and stakeholders as being extreme and certainly not typical. Other differences between the data in this study and the article include the power consumption of circulators, where the article picks specific models whereas the study uses averages. Also the "switch off during night" is a mistranslation for a "night setback" which is a system mostly used in Germany to slow down the circulator at night.

14 Bidstrup N. Promotion of Energy Efficiency in Circulation Pumps, especially in domestic Heating Systems. EU SAVE II Project, 2001

Destination	Proportion (%)
Replacement	60
New building	22
New (replacing alternative heating system)	14.3
Non-residential sector	3.8

Table 2-5 Breakdown of boiler sales, by destination (table 2.6 in Boiler study)

Sector	Total Stock (units)
Residential (single dwelling)	97M
Residential (multiple dwellings)	5-6M

Table 2-6 Total EU 25 stock of boilers (section 2.2.1 in boiler study)

Based on the above, the total installed stock of circulators is calculated in the following way:

Application	Stock (units)
97M + a 10% allowance for some having more than 1 circulator	107M
5.5M in mulitple dwellings with an average 4 circulators each	22M
Non-residential sector with typically 2 circulators each	8M
Non-heating uses	3M
TOTAL	140M

Table 2-7 Estimated stock of circulators

Annual Sales Growth

The boiler study has forecast future boiler sales as shown in table 2-8 below, which is approximately an additional 100,000 pa, or 1.4%pa. On this basis, a similar percentage growth in circulators is assumed, (ie an additional 200,000 pa).

Year	Sales (units)
2004/05	7.0M
2010	7.4M
2025	8.9M

Table 2-8 Sales projections of boilers (from EUP Boiler study, table 2.13)

Average Product Life

There is no definitive information on average circulator life available, there is consensus within industry that it is at least 12 years. However, this is complicated by many factors, including many being scrapped prematurely when the boiler they are connected to is replaced.

From the estimated stock (140Mpa) and annual sales (14Mpa), the average lifetime of the circulator is taken as being 10 years for the purposes of this study.

New / Replacement sales

The actual split between circulators going into new systems and those replacing failed circulators is not known. The key question is whether the uptake of improved products could be accelerated by targeting the replacement market. For boiler integrated circulators the boiler repairer would be constrained to fit the original part, and so it would not be possible to change the behaviour of this part of the market. But for the standalone circulator market, the plumber already tends to use whatever circulator they are personally familiar with, and so they could be in theory be influenced to change to a different type.

2.3 Market trends

2.3.1 Market and production structure

Product routes to end user

There are two distinct routes to market depending on the product type:

- Integrated circulators
  These are produced by a manufacturer to a unique specification and sold only to the manufacturer of the boiler to which it is fitted.
- Standalone circulators
  These are sold direct to installers. In addition some may go to manufacturers of lower volume or specialist boiler equipment, and a very small proportion will be sold direct to the public.

Major manufacturers in the market and countries of manufacture

The two major players in the heating market are:

- Grundfos: Germany, France, UK, Denmark.
- Wilo: Germany, France , UK through their Circulating Pumps subsidiary.

Collectively these companies service about 80% of the market.
The volumes that these companies produce is reflected in the net circulator consumption figures shown in table 2.3. Other players include Smedegard (Denmark), KSB (Germany), Biral (Switzerland) and Calpeda (Italy).

2.3.2 Trends in product design & features

Several positive trends are noted.

- The latest generation of circulator products have been developed to attain the ‘A’ rating in the labelling scheme; most examples combine better hydraulic design (tighter manufacturing tolerances), permanent magnet motors and variable speed control.
- The uptake of variable speed controlled units is increasing. This is mainly in commercial applications where the higher costs of variable speed circulators is less significant in relation to the whole heating system and is therefore less of a barrier.
- Circulators with higher efficiency motors (permanent magnet motors) are becoming more widespread.
- There is an increased proportion in the numbers of circulators being incorporated in boilers as this both simplifies and reduces the cost of installation of a heating system.
- In Denmark it is understood that variable speed circulators have become the norm, (see 1.3.2).

2.4 Consumer expenditure base data

2.4.1 Average consumer prices (for actual products)

- Small stand alone circulator 65W (120 Euros per unit retail).
- Large stand alone circulator 450W (400 Euros per unit).
- Boiler integrated circulator 90W (120 Euros per unit). This is based on a high volume part, and for a fair comparison is based on the circulator alone – ie without the additional manifold or similar components.

In all cases there is a large variation in prices, with cheap (fixed speed) OEM standalone circulators available at around half the price of a premium brand. In addition, for the DIY market, OEM standalone circulators are available for less than 50 euros. However, Europump reports that this accounts for less than 1% of sales, and so this is not significant in terms of the total market.

2.4.2 Electricity rates

The following data is the most recent information published by Eurostats, split by domestic and commercial users. *(Note that only domestic prices are used in the analysis, other prices are included for reference only).*

Domestic:
The electricity prices presented are charged to final domestic consumers, which are defined as follows: annual consumption of 3 500 kWh of which 1 300 kWh is overnight (standard dwelling of 90m²). Prices are given in Euro (without taxes) per kWh corresponding to prices applicable on 1 January 2006. For the purposes of the Life Cycle Costing calculations, the EU25 prices of 0.11 euro/kWh are considered as the base price.

Industrial
The electricity prices presented are charged to final industrial consumers, which are defined as follows: annual consumption of 2 000 MWh, maximum demand of 500 kW and annual load of 4 000 hours. Prices are given in Euro (without taxes) per kWh corresponding to prices applicable on 1 January 2006. For the purposes of the Life Cycle Costing calculations, the EU25 prices of 0.075 euro/kWh are considered as the base price.

Taxation and tiered pricing strategies mean that in practice the actual prices paid by end users will vary from the base price. **Therefore, 0.135 Euros is taken as being more typical for domestic users and 0.075 Euros/kWH being more typical for industrial users.[15] No prices are given for tertiary users, so a third category has been estimated, (see table 2-9).**

User	Low Price of electricity (euros)	Typical price of electricity (euros)	High price of electricity (euros)
Domestic	0.07	0.135	0.23
Industrial	0.035	0.075	0.11
Tertiary	0.05	0.075	0.15

Table 2-9 Electricity prices used in this study

There is though a large variation of prices across the EU, ranging from 0.07 Euros/kWh (including taxes) in Estonia to 0.24 Euros/kWh in Denmark for domestic users, (Eurostats , July 2006). Accordingly, the key results from the study will be re-calculated at these two extremes of rates.

Country	Industry (euros/kWh)	Domestic (euros/kWh)
EU25	7.37	13.45
EU15	7.54	13.74
BE	7.73	13.78
CZ	5.71	7.87
DK		22.31
DE	8.97	16.96
EE	3.78	6.97
EL	5.60	8.11
ES	6.39	10.52
FR	5.00	11.62
IE	9.14	13.46
IT	10.90	20.00

[15] In order to ensure consistency between these two linked reports, we have used the same figures as in the ecoboiler study.

CY	10.74	14.17
LV	3.28	6.68
LT	4.82	7.34
LU	-	14.61
HU	5.84	11.12
MT	5.72	12.01
NL	6.31	20.54
AT	7.20	12.78
PL	5.33	11.64
PT	7.30	12.60
SI	5.60	9.40
SK	7.20	11.04
FI	5.31	9.10
SE	5.17	13.23
UK	7.15	10.31

Table 2-10 EU Electricity Prices, 2006[16] [17]

A **discount rate of 2%** is taken as being typical of EU-25 and is used in the LCC analysis.

2.4.3 Repair & maintenance costs

Repair

Small domestic circulators are not considered viable too repair in Western European countries. However, there is some repair market for these types in Eastern Europe.

Larger (750W) circulators may be repaired, with typically motor needing replacing. In cases where the bearings fail, while theoretically possible to replace them, it is the norm to replace rather than repair. There is though a variation with country, where countries with lower wage rates see increased amounts of repair work.

Replacement costs

Small circulators

If done as part of the installation of more substantial work on the heating system, it should take no more than an hour to make the two connections to the pipework and to connect the wires to the electrical control box.

If installing a replacement circulator, it should take less time, as the plumbing and electrical connections are already in place. However, if the circulator is a different size, or there are other difficulties due to the age or condition of the installation, then it could take considerably longer. In addition, time must be allowed for draining down and refilling the heating system. Excluding travel time, 3 hours should be allowed.

Large circulators

Where isolating valves are not fitted for maintenance purposes the cost of replacing a large circulator can be dominated by the time to drain down and refill the system. Some dual-pump assemblies allow one pump to be removed while the other is still operating.

Excluding travel time, 3 hours should be allowed for just the replacement of the circulator.

An average labour rate of 30 euros/hour is used (based on stakeholder estimates), although it is appreciated that this will vary throughout the EC.

[16] http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1334,49092079,1334_49092794&_dad=portal&_schema=PORTAL

[17] Eurostat press release 93/2006, July 2006.

2.4.4 Disposal tariffs / taxes

The study team are not aware of any tariffs/taxes specifically applied to circulators. Given the value of the products as scrap, there is sufficient incentive to recycle old circulators without the need for additional financial measures.
Almost all circulators will be replaced by plumbers who are used to selling plumbing scrap for money, and so it is unlikely that circulators would not be recovered.

(By comparison, disposal of products that do fall within the scope of the WEEE Directive 2002/96/EC would be charged at the rate of around 0.30 euros/kg, although this figure will vary between different countries.)

2.4.5 Interest & Inflation rates

The following table shows national inflation and interest rates for the EU-25 as published by Eurostat and the European Central Bank (ECB).

Member State	Inflation rate [(a)] (%)	Interest rate [(b)] (%)
Austria (AT)	1.6	3.4
Belgium (BE)	2.8	3.4
Cyprus (CY)	1.4	5.2
Czech Republic (CZ)	1.9	
Denmark (DK)	2.2	3.4
Estonia (EE)	3.6	
Finland (FI)	1.1	3.4
France (FR)	1.8	3.4
Germany (DE)	2.1	3.4
Greece (EL)	3.5	3.6
Hungary (HU)	3.3	6.6
Ireland (IE)	2.2	3.3
Italy (IT)	2.1	3.6
Latvia (LV)	7.1	3.5
Lithuania (LT)	3	3.7
Luxembourg (LU)	3.4	
Malta (MT)	3.4	4.6
Poland (PL)	0.8	5.2
Portugal (PT)	2.5	3.4
Slovak Republic (SK)	3.9	3.5
Slovenia (SI)	2.4	3.8
Spain (ES)	3.7	3.4
Sweden (SE)	1.3	3.4
The Netherlands (NL)	2.1	3.4
United Kingdom (UK)	2	4.5
EU-15 Average	2.2	3.4 [(c)]
EU-25 Average	2.1	3.9

Table 2-11 Interest & inflation rates for EU-25

(a) Annual inflation (%) in December 2005 Eurostat "Euro-indictors", 7/2006 – 19 January 2006.
(b) ECB long-term interest rates; 10-year government bond yields, secondary market. Annual average (%), 2005.
(c) Euro zone.

2.5 Summary

This section has reviewed many different sources of data in order to present best estimates on aspects of the circulator market.

The annual market for circulators is considered to be 14M pa, comprising:

- Standalone (small) circulators 5.5M
- Boiler integrated circulators 7.5M
- Standalone (Large) circulators 1.0M

It is estimated that the circulator market will increase at the rate of 1.4%pa to 2020.

From the estimated stock (140Mpa) and annual sales (14Mpa), the average lifetime of the circulator is taken as being 10 years for the purposes of this study. These final figures represent a 'best fit' compromise such that the approximate relationship of "stock = annual sales x lifetime" remains true. Higher levels of certainty are apportioned to the annual sales and stock figures and consequently the initial lifetime estimate of 12 years was reduced in order to satisfy the relationship. The technical justification for this is that many will be scrapped prematurely when the boiler to which they are fitted is replaced. The impact of this is that stock and hence energy savings due to design options will take longer to impact the market, but also that the LCC advantages of improved circulators will be under-stated.

Circulators are little used outside of Europe, with all the major manufacturers based in Europe. Wilo (Germany) and Grundfos (Denmark) dominate, with over 80% of the market between them.

Because of the relatively low cost of circulators, when they fail they are replaced rather than repaired.

Circulators with higher efficiency motors (permanent magnet motors) are becoming more widespread.

There is an increased proportion in the numbers of circulators being incorporated in boilers as this both simplifies and reduces the cost of installation of a heating system.

A 2% Discounted Cash Factor (DCF) has been used in all calculations. Electricity prices based on Eurostats have been used, with 3 scenarios (typical, low and high) used for each customer category (residential and commercial).

3 CONSUMER BEHAVIOUR AND LOCAL INFRASTRUCTURE

This chapter aims to identify barriers and restrictions to possible eco-design measures due to social, cultural or infra-structural factors. It also quantifies user parameters that influence the environmental impact during product life that are different from the standard test conditions described earlier.

3.1 System Topology

Figures 4.1 shows the most common application of circulators, where they are being used to circulate hot water from a boiler to heating radiators and / or hot water tank and return. Also shown is a solar thermal and underfloor heating system, both of which require additional circulators.

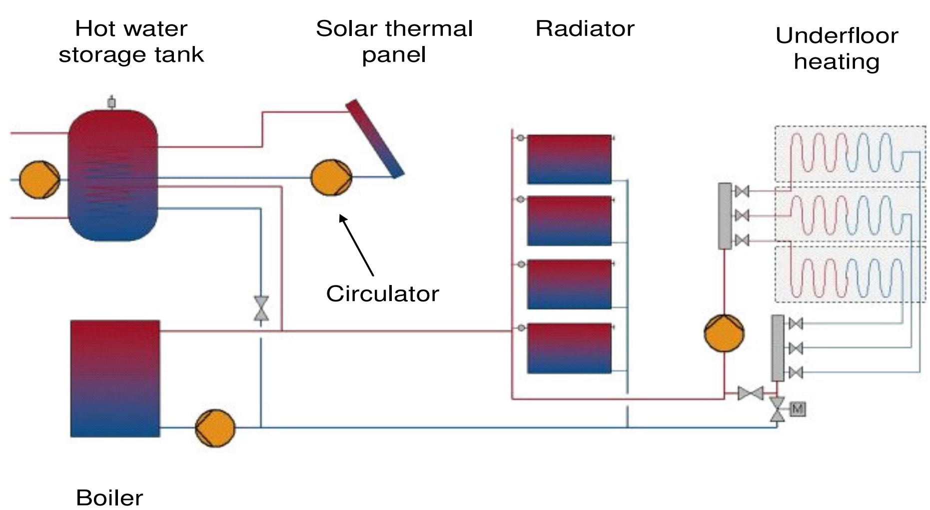


Figure 3-1 Simplified sketch showing circulator applications in a domestic environment.

Note that in figure 3-1 only the circulator adjacent to the boiler is normal, as few homes currently have solar collectors or under floor heating.

3.1.1 System Hydraulics

Figure 3-2 illustrates typical fixed speed circulator performance characteristics as the flow varies due to regulation in the heating circuit. As the flow is reduced so the duty point moves to the left of the pump curve increasing the operating pressure and reducing the efficiency of the pump.

The best efficiency point (BEP), and ideal operating point, is defined as the duty point at which the pump efficiency curve reaches a maximum. It is rare for a circulator to be constantly operating at it's BEP and the varying hydraulic load placed on the circulator will result in a spread of both efficiency and energy consumption.

In addition to flow regulation devices, the operating head may also be influenced by factors such as:

- narrow pipe diameters – increased friction resistance due to greater flow velocities
- sharp bends and T's, - increased friction resistance due to turbulence.

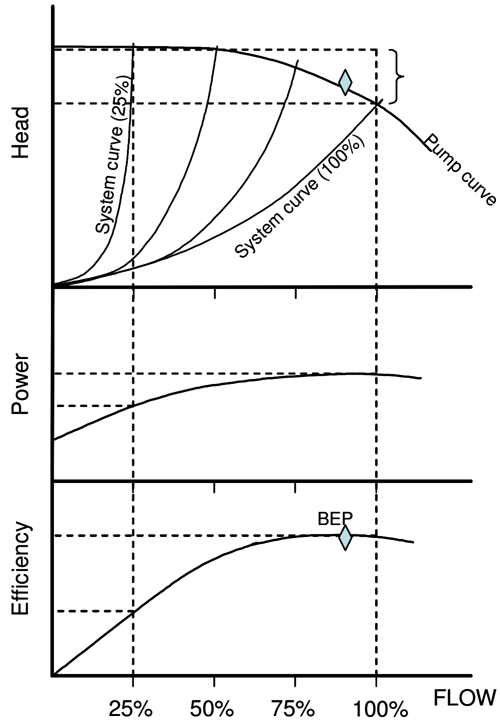


Figure 3-2 Circulator performance characteristics with varying load

3.1.2 Circulator Sizing

On selecting a circulator the system designer must ensure that the performance of the circulator is such that it will be able to provide adequate flow under worst case conditions (coldest day) when all heat emitters demand maximum flow. In practice these conditions rarely occur and flow rates under typical operating conditions are considerably reduced. Having estimated the typical conditions together with the associated flow rates the designer must select a pump whose BEP falls as near to the typical conditions as possible whilst ensuring it's maximum duty capability still meets worst case conditions, (fig 3-3).

In practice it is difficult to estimate 'typical' conditions and designers tend to select pumps against worst case requirements; this results in the selection of larger pumps whose BEP is nearer to the maximum flow conditions; consequently when operating at typical conditions this pump will be more heavily throttled. **However, in terms of energy consumption it is better to select a slightly under-sized circulator, as this will have negligible impact on the actual performance of the heating system.**

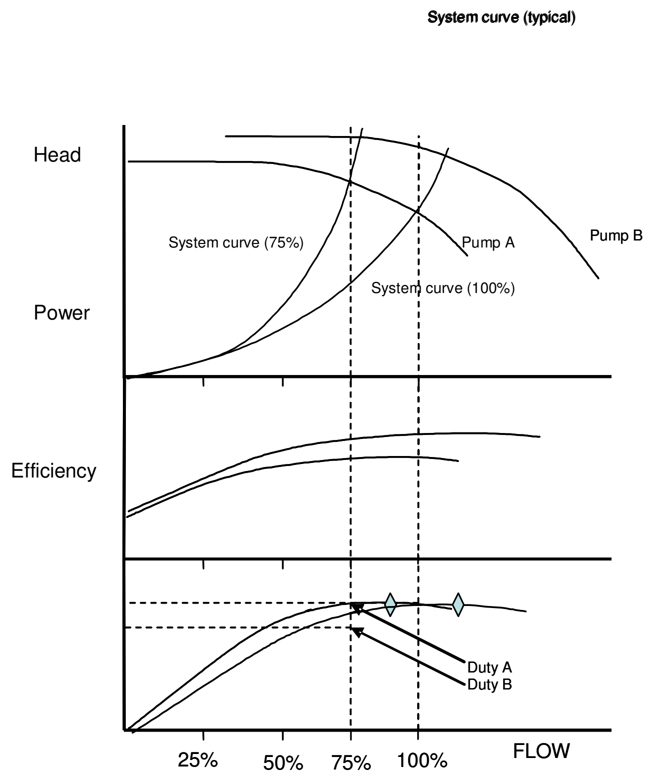


Figure 3-3 Affect of circulator sizing

Double volute pumps enable energy savings of 25 - 50% by allowing the use of just one pump for the typical 85% of the time that the demand is around the seasonal average. The second pump only needs to be turned on to meet the occasional times when higher demand is required.

Figure 3-4 Double volute circulator (Wilo)

3.1.3 Circulator Load Profile

Given the variable loads placed on circulators and in order to determine circulator energy consumption it is therefore necessary to develop a representative average load profile for circulators across Europe.

The Europump study 'Classification of Circulators[18]' examined circulator load profiles and concluded the profile as used in the German energy labelling scheme, 'Blauer Engel[19]' (see figure 1-9) for **standalone** circulators to be appropriate for the Europump circulator classification scheme (Appendix 1); in addition this profile was deemed valid for all EU member states[20]. This time-flow distribution profile is assumed to remain the same, irrespective of total running hours (ie climate) or boiler size.

This is the flow profile that has been used as the basis of the Circulator labelling scheme. There are though two known weaknesses in this:

- It does not take account of the demand for domestic hot water (DHW) in systems where the circulator pump is needed for this additional duty. This is typically considered to be about 150 hrs pa.
- It has subsequently been suggested that the profile should be more "level", ie slightly increased time at low and high flow, balanced by reduced time at mid flows.

Both of these factors would lead to a small increase in annual energy consumption. To minimise the obstacles to any EUP design options being introduced, it is desirable to use the existing reference scheme as the basis for any EUP design options, and so the subsequent analysis will be based on this existing scheme, but noting the following points;

- For systems where the circulator is also needed for DHW, the running hours will be <10% longer, and so the payback on energy saving measures would be improved.
- The impact of "levelling" the curve, is the proportion of time at high flow will increase at the expense of time at low flow. This would slightly reduce the savings from the use of speed control.

However, in order for the analysis to be representative of all types of system, it is necessary to define the flow regimes that apply to each of the different control regimes, shown in figure 3-5. These are the scenarios modelled in sections 4 and 5.

Small standalon	Boiler integrated	Large standalon	Control mode	25 % flow	50 % flow	75 % flow	100% flow	Split, by type of control (%)	Operating Hours pa
X	X	X	Continuous (Blauer Engel Distribution)	44	35	15	6	70	5000
X	X		On/Off control - room thermostat controlled	0	0	0	100	15	2300
X	X		On/Off, TRV controlled	44	35	15	6	15	2300

Figure 3-5 Flow pattern data used in the model and relative energy consumption

Continuous

The boiler runs continuously through the heating season, with flow regulated by TRVs and/or manual valves, and/or boiler modulation. This will have the standard "Blauer Engel" distribution.

On/Off – Thermostatic Radiator Valve (TRV) controlled

The flow is regulated by thermostatic radiator valves, and so for a given system it will vary over time in a complex way. There is no "agreed" flow profile for this scenario, and so the Blauer Engel distribution has been assumed. The impact of this assumption is that the time at mid flow is slightly over-estimated.

[18] Classification of Circulators, Europump, February 2003
[19] http://www.blauer-engel.de Heating Circulation Pumps RAL-UZ 10
[20] Hirschberg, R., Bestimmung der Belastungsprofile von Heizungsumwälzpum-pen in der Gebäudetechnik – Vergleichende Betrachtung für Süd- und Nord-europa, VDMA report, March 2002

On/Off control - room thermostat controlled

The thermostat is placed in a reference room and the heating system is switched on and off according to the set points of the thermostat. The flow is therefore 100% on or 100% off. Temperature control in rooms other than the reference room is poor.

It is not considered that the differences between standalone and boiler integrated circulator duties are significant, and so the same profiles are being assumed.

The percentage split of systems across the EU is a best estimate based on experience of manufacturers.

3.2 Real Life Efficiency

Circulator energy consumption, and efficiency, is governed by several factors; in heating applications there is a hierarchy of factors starting with the climatic influences where for example in colder regions there is a greater heating requirement and for longer periods, this is followed by factors such as building size and insulation, the type and size of heating system, the boiler and heating system efficiency, the heating controls, the system hydraulics and finally the performance of the circulator.

3.2.1 Climate and regional affects

Regional climatic variations within the EU will affect heating demand. In addition to supplying heat for space heating boilers are increasingly used for generation of hot water, this is especially true for dwellings with combination boilers or those fitted with hot water cylinders. The hot water requirement is throughout the year.

The Lot 1 boiler study has assumed three climate profiles, from which the operating profiles shown in 3.2.11 are derived.

3.2.2 Types of Heating System

Stand alone wet systems

These systems are most commonly associated with single dwellings and typically consist of a wall or floor mounted boiler supplying heating water directly to the heating circuit/s in the dwelling. The popularity of these systems is growing, making up almost half of the market (table 2-4) and are most commonplace in the UK, Ireland Denmark and growing in France.

The boiler may also be required as a heat source for domestic hot water, in the case of standard boilers this is achieved indirectly via a hot water storage cylinder fitted with a heat exchange coil connected to the boiler circuit; control valves are used to switch the duty between the heating circuit and the hot water circuit. In the case of combination boilers the water is heated directly and is either pressure fed from the mains supply, gravity fed, or pumped by a dedicated circulator through the boiler heat exchanger.

Some larger systems may be fitted with more than one circulator to supply more than one heating circuit.

Historically circulators were fitted outside the boiler however there is an increasing trend to incorporate circulators within the boiler and this is now the most popular option.

Collective Heating

Typically apartment blocks or flats, the central heating boiler is located in the basement and one or more, mainly larger circulators pump heating water to the individual heating circuits in each apartment.

District Heating

These systems are comprised of a large heating plant supplying heating water to many houses, apartments or other buildings in a single locality. Heating circuits in individual houses may either be directly fed or indirectly fed. In directly fed systems the heating water is pumped from the plant with a large circulator (glanded) and fed to the heating circuits within each house. In indirect fed systems the heating water from the plant supplies a heat exchanger within each house and this in turn supplies the household heating circuit; here a local circulator will be required.

3.2.3 Hydraulics and control devices

In a pumped fluid system the resistance to flow changes approximately with the square of the change in velocity of the fluid; this characteristic is referred to as the 'System Curve' and is shown in Fig 3.5. The intersection of the pump curve and the system curve is the point at which the system actually operates and is known as the 'Duty Point'.

The operation of flow regulation devices such as manual or thermostatic radiator valves (TRVs) will increase the system resistance, moving the system curve and consequently the duty point to the left. This reduced flow condition will result in the pump moving away from it's BEP, resulting in a drop in efficiency.

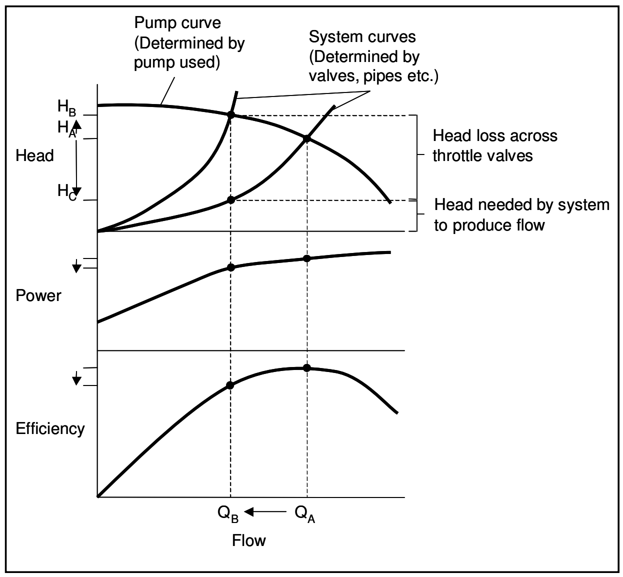


Figure 3-6 Affects of increased system resistance through valve throttling

At the design stage it is important to size and select a pump to match the system curve such that the pump operates close to it's BEP. It is common place for installers to oversize the pump out of concern that they need to ensure extra capacity in case of extreme conditions.

Other design considerations will also affect the system resistance, these include pipe sizing where smaller diameters will result in higher flow rates, and obstructions or sources of turbulence such as sharp bends and Tees, all of which contribute to increased system resistance.

The Boiler SAVELEC Study[21] suggested that a heating circuit in a typical family dwelling (15kW heating requirement, and 20K differential between flow and return temperatures) requires a differential pressure of around 25kPa to achieve a flow of 0.18 litres per second, corresponding to a hydraulic power input of 4.5 Watts. Typical circulation pumps are however capable of producing a maximum differential pressure of 50kPa at zero flow and a maximum flow of 1.1 litres per second at minimum pressure, the maximum hydraulic power output achievable is around 16W in the middle of the flow range which corresponds to an electrical power input of about 95W and an overall circulator efficiency of 18%.

Most circulators of this type are fitted with a selector switch to select three or more speed settings to enable a better match between the pump and the system requirement; in practice installers tend to leave the circulator on the maximum setting to ensure extra capacity for worst case conditions.

[21] Boiler Savelec, Characterisation and reduction of electrical consumption of central heating systems and components, Work package 3, Nick Davies, May 2005

3.2.4 Detailed configurations of heating systems

The type of heat emitters employed, their configuration and the way the heating water flow is regulated will significantly affect the heating water flow rates in the system, and the water return temperatures; these in turn will influence boiler efficiency, the overall heating system efficiency and run times. The Europump study 'Classification of Circulators' [22] examined the distribution of these systems in 15 EU countries and this is summarised in the following:

Emitter types

The principle types of heat emitters fall into the following categories:

- Radiators and Convectors (75%)
- Under floor Heating (12%)
- Fan Coil Units (13%)

System Layout

There are principally two designs of heating system pipework layout for the distribution of heating water, namely one pipe systems (fig 3-7) where radiators are connected in series and two pipe systems (fig 3-8) where radiators are connected in parallel. Two pipe systems are the most common making up 88% of systems whilst one pipe systems make up 12% of systems.

In one pipe systems the output of the first radiator feeds the second, thus influencing the water supply temperature to the second radiator and hence it's performance; these systems require careful sizing of radiators and balancing of flow rates in order to achieve optimum performance. In two pipe systems all radiators receive feed water at roughly the same temperature and require less balancing.

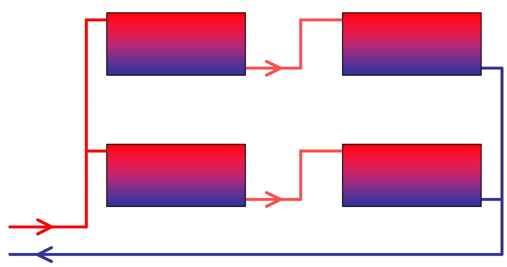


Figure 3-7 One Pipe System[23]

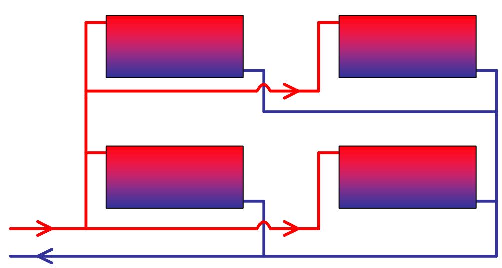


Figure 3-8 Two Pipe SystemControls (Emitters)

Heating systems are sized and configured on installation to achieve the heating requirements at the design conditions which are usually representative of the worst case scenario (the coldest

[22] Classification of Circulators, N. Bidstrup, G Hunnekuhl, H.Heinrich, T.Andersen, Feb 2003

[23] For clarity the radiator byapass, needed in case a radiator is turned off, is omitted.

day). In practice these conditions rarely occur and controls such as thermostatic radiator valves (TRV's) are employed to regulate the flow through the heat emitters and reduce the heat output to maintain a comfortable condition in the heated space. As set point temperatures are reached the flow demand is reduced and the circulator will be operating at part load. Boiler firing time and hence running hours may also be reduced.

There is a continuously varying range of flow conditions resulting from the interaction of ambient temperature conditions and valve temperature set points. Circulator performance is also critically influenced by how well it is matched in size to the system in which it is used

3.2.5 Heating System Capacity and Boiler Efficiency

The fuel type, the boiler size, and it's efficiency will affect the amount of heat delivered to the heating circuit. The capacity of the heating circuit such as the size of the radiators will influence the rate of heat delivery to the heated space; all of these combine to influence both the flow demand and the running hours. These issues are examined in detail in the parallel EuP preparatory study, 'Eco-design of Central Heating Boilers'

- Boiler efficiency is also affected by the return temperature of the heating water; as the return temperature increases so the boiler efficiency reduces. There are many permutations as to how the return temperature is affected; however the following scenarios are worth describing:
- In systems fitted with TRVs and fixed speed circulators, the system resistance increases as the TRVs start reducing flow, the heating water then finds the remaining paths of least resistance and flows at a higher velocity through the emitter circuits which are still open and returns to the boiler at a higher temperature than desired. In addition acoustic noise levels due to the higher velocities increases and this can be problematic for the building occupants. (Ideally velocities should be maintained below the following: 1.2m/sec for pipes sized 32mm in diameter and smaller, 1.5m/sec in pipes 40-50mm and 1.8m/sec in pipes 65-85mm).
- The same is true with older non modulating boilers that require a minimum flow rate through the heat exchanger in order to maintain safe operation; these systems utilise a bypass circuit to circumvent the heating circuit as the TRVs shut down and maintain the flow rate through the boiler heat exchanger; the return temperature is consequently higher resulting in a reduction in boiler efficiency.
- Systems fitted with TRVs, variable speed circulators and modulating boilers are better suited to maintaining efficiency; as the TRVs shut down the flow, resulting in increased system resistance, so the pump speed is reduced and the flow rates through the remaining parts of the heating circuit are maintained at a steady rate resulting in a more consistent return temperature to the boiler. To maximise boiler efficiency the best form of control is pump speed regulation linked to the return water temperature, some boilers with integrated pumps use this methodology.

3.2.6 Other Controls

Circulator run time is also affected by the way in which it is controlled, common methods include:

- Summer / winter switch[24] - the circulator is switched on and runs continuously throughout the heating season regardless of whether the boiler is on or off.
- Timer switch – the circulator is switched on by a timer which also controls the heating system, the circulator runs continuously during the heating period.
- Boiler controlled – the circulator is interlocked with and controlled by the boiler. As pert of the safety interlock it is switched on several seconds before the boiler ignites and then continues running for a few minutes after the boiler switches off. Practically all boiler

[2424] Boiler Savelec – characterisation and reduction of electrical consumption of central heating systems and components, Work package 3, Ch5.3.2., Nick Davies, May 2005 integrated circulators are operated under this form of control.

3.2.7 Affects of fuel mix on energy consumption by circulators

Losses in a circulator are translated into heat; in the case of glandless circulators in a heating system between 20% and 70% of the heat loss is transferred to the heating medium[25] (pumped liquid). When replacing a low efficiency circulator with an equivalent higher efficiency fixed speed circulator there will be a heat replacement effect in that the heat imparted by the low efficiency circulator will have to be made up by the boiler. In countries where the electricity that powers the circulator is generated by a non fossil fuel source the more efficient circulator will actually result in more CO_2 emissions due to the boiler burning more fossil fuel.

Replacing the circulator with a variable speed circulator is less likely to have the same result as the heat replacement effect will be mitigated by reduced friction losses in the system as the heating medium is being pumped at a reduced velocity.

3.2.8 Scope for consumer influence on circulator energy consumption

The control programme and set point temperatures will have a significant effect on the heating system energy consumption. Excluding those systems where circulators are left running continuously, setting the control program to only run the heating system when absolutely necessary, and by reducing the set point temperatures (thermostats, TRVs) will significantly reduce heating demand on the boiler and consequently reduce circulator run time.

In the case of fixed speed circulators with a speed selector switch, it is important to ensure that the circulator is set to the minimum speed that will ensure adequate heat distribution.

Stand alone circulators that are not controlled by the boiler are likely to be left running continuously; they should be switched off when out of the heating season. However, this problem is reducing due to the increasing number of boilers fitted with controls such that a separate “Summer switch” is not required.

3.2.9 Cost of Ownership

Circulators are a part of the heating system which is fitted as part of the building infrastructure. The responsibility for the heating system will depend on the respective responsibilities of the owner and the occupier, sometimes with split incentives; for the owner the incentive is to keep the overall system cost as low as possible, and in the case of the occupier who pays for the services, the incentive is to ensure lowest running costs. Where the owner is responsible for both the infrastructure and the services costs there is greater opportunity to balance the cost of the infrastructure with the long term running costs and invest in the most efficient technologies.

3.2.10 Temperature/timer settings and duty patterns

Circulator run time is calculated in terms of the heating system operating hours or where not available, the length of the heating system for each country. This is a similar approach to that taken by Bidstrup[26] and by Jardine and Lane[27].

The Lot 1 (Boilers) study has a detailed model from which the following figures are derived[28], broken down into three climate zones:

Climate zone	On/Off control (hrs pa)	Weather compensated (hrs pa)
Warm Climate (Italy)	1,700	4,750
Sea Climate (UK)	1,300	3,830
Cold climate (Finland)	1,825	5,000

[25] Full and Part Load Efficiency Measurements for Boilers, Heat Contribution of the Pump, J Schweitzer, DGC Nov 1994
[26] Promotion of Energy Efficiency in Circulation Pumps, Especially Domestic Heating Systems, SAVE, 2001
[27] Characterisation and reduction of the electrical consumption of central heating systems and components, Boiler SAVELEC, July 2005
[28] Private communication from Martn van Elburg, 10 July 2000.

Table 3-1 Running hours by climate zone and control type

Notes on the above table
1.) Hours based on boiler size class M (50% of sales).
2.) Includes 150 hrs pa for hot water heating (assuming a combi boiler)
3.) These figures assume 'boiler off' during summer months (hence heating period is 9 months).

There was agreement on the “Weather compensated” or “continuous” running hours, but other stakeholders felt that the On/Off control hours were a bit low.

For the purposes of this study, we are assuming average running hours of 2,300/5,000 hrs pa, according to type of control. For large standalone circulators, the duty patterns are more complex due to the variety of ways in which they are installed, but 5,000 hrs pa is regarded as being a reasonable average figure for the running hours. However, in the sensitivity analysis the results are re-calculated on the basis of 1,300, 2,300 and 5,000 hours pa, which takes account of the entire span of normal annual operating hour profiles.

Further comments:

- The differences between type of control are bigger than those between the different climate zones.
- Weather Compensation is rarely used in “Sea Climate” areas, and so the mean is close to the assumed 5,000 hrs pa.

3.2.11 Dosage of aux. inputs during use

Glandless circulators are designed to be maintenance free during their life; consequently their use is not associated with any consumable parts or materials.

3.3 End-of-Life Behaviour

3.3.1 Economical Product Life

As discussed in section 2.2.3, the average life of a circulator is assumed to be 10 years.

3.3.2 Circulator Maintenance

Glandless circulators are designed to be maintenance free during their life time, and little repair activity is carried out on them. Their relative low cost is such that it is more cost effective to replace a failed unit in the course of one service visit than to attempt to repair.

In the case of larger circulators (>750W) for larger installations manufacturers can supply replacement ‘heads’ (motor plus impeller) however this rarely occurs.

In cases of replacement installers are more likely to replace like for like as this removes the risk of fitting a circulator that may not meet the performance requirements of the system.

For boiler integrated circulators the replacement circulator part is likely to be unique to the model / family of boiler and there is limited opportunity to substitute an alternative.

3.3.3 End-of-Life actual behaviour (present fractions to recycling, re-use, disposal, etc)

The replacement, repair and disposal or recycling of circulators is managed by the installer. Due to their relative low cost and limited opportunity to repair, there is little re-use or second hand market for circulators.

Circulators contain cast iron, steel and copper and so have both a positive scrap value. It is to the professional installer’s advantage to send old circulators to scrap and avoid a disposal cost, this is the norm. It is assumed that all of the metallic and none of the non-metallic components are recycled.

Components of circulators are not extracted for reuse in repair or remanufacturing.

Circulator	Total weight of metal components (g)	Total weight of non-metallic components (g)	Percentage of non-metalic components (%)
Standalone 65W	2 328	615	21
Standalone 750W	17 950	2 030	10
Boiler integrated	1 509	504	25

Table 3-2 Metallic and non metallic content of circulators

Unlike products that are used by domestic consumers where most goods end up as landfill, the professional market that is responsible for disposing of old circulators is used to sending metal products for scrap. The 8% landfill figure set in the MEEUP model is therefore thought to be too high. However, as the MEEUP model showed that materials are not responsible for much of the total eco-impact, this does not represent a significant error, and so is not investigated any further.

3.3.4 Best Practice in Sustainable product use

The design of the heating system is by far the most important consideration. Initially the installer should size the heating system to match the heat demand of the building taking into account the climatic variations and the building insulation. The selection of boiler, pipe work, circulator, heat emitters and controls should be such that efficient hydraulic performance and control are achieved. The circulator should be appropriately sized to match the system duty requirements. Consideration of overall heating system efficiency must be made.

The selection and configuration of controls should be such that the circulator is run for the least number of hours possible; for systems where the circulator is left running continuously it may be possible to reconfigure and connect it to the heating controls or a time switch.

- Circulators controlled by the boiler (CPU) are likely to run for the least number of hours.
- Circulators with multiple speed settings go some way to ensuring a closer match between circulator and system whilst variable speed circulators attempt to achieve the best match possible.

3.4 Local infrastructure (energy, water, telecom, physical distribution, etc)

3.4.1 Installers

Training and ensuring competence of designers and installers is vital to ensuring proper selection and configuration of heating systems is made. Anecdotal evidence suggests installers tend to preset circulators with multiple speed settings to the highest speed setting, ‘to allow a safety margin’.

Purchasers tend to buy on lowest initial cost; a sound knowledge of life cycle cost analysis is therefore important to enable the installer to educate the purchaser to buy against these principles.

3.5 Summary

This chapter has given an overview of the typical usage patterns of different types of circulator under different control regimes. Because of the large variety of system types and running hours, the true picture is actually very complex, and so a reasonable trade-off between detail and ability to interpret the results has been made.

In the MEEUP analysis, we have analysed circulator duty based on the following operating conditions:

- **Control types:** Continuous, On/Off room thermostat controlled, On/Off Thermostatic Radiator valve controlled.
- **Flow profiles:** Because of the varying demand, the circulator in most control systems spends most of its time operating at low flows, and so the flow:time distribution is important. The standard Blauer Engel flow distribution has been used for the continuous flow case.

The impact of different heating seasons is taken account of by using sensitivity analysis that considers annual circulator running hours of 1,300, 2,300 and 5,000 hours pa.

Correct sizing of circulators is an important way to reduce energy consumption, but because there is little incentive to spend time on optimising selection, it is always the safe option to "over-size" circulators. Standard circulators usually have a 3-speed selection switch that does allow for closer matching of the circulator to the actual duty, but again it is safer to leave it set on "maximum" in order to minimise the risk of future problems. Educating specifiers and installers to correctly size and commission circulators is therefore important if greater energy savings are to be achieved.

4 TECHNICAL ANALYSIS EXISTING PRODUCTS

This chapter provides a general technical analysis of current products on the EU Market and provides general inputs for the definition of the base cases and identification of part of the improvement potential.

Important Note. The MEEUP methodology requires that this chapter considers the basecase model only. However, because of the close inter-relationships between the different technology options, stock and detailed operating scenarios, it was decided to undertake the detailed analysis of all products / operating scenarios in this chapter. This reduces the number of analytical tables and hopefully makes comparisons of the performance of the different types under different operating scenarios much simpler to follow. In addition, using a similar format of tables in chapters 7 and 8 makes the subsequent analysis much clearer.

The four technical options considered are[29]:

Option 1 – Standard (basecase)

This is the most popular type of circulator that uses a fixed speed induction motor.

Option 2 – Improved

This is the same as the basecase circulator, but will have lower losses due to improvements in the hydraulics and/or motor.

Option 3 - Variable speed (induction motor)

This uses thyristor control to alter the speed of the induction motor.

Option 4 – Permanent Magnet circulator (considered to be the currently Best Available Technology)

This uses a much more efficient type of motor that is always driven by control electronics that allow the speed to be varied. Even in on/off room thermostat control systems which have to work in fixed speed mode, this still gives energy savings over standard induction motor driven circulators.

The analysis in this section is undertaken separately for fixed and variable speed operation.

Further discussion of these technical options is given in section 7.1 *Identifying design options*.

The choice of basecase was based on data available at the start of the study. Subsequent information provided July 2007 (Table 1-10) shows that there has been a very recent decrease in sales of the type considered as the basecase, (class C/D borderline). The analysis is not though impacted by this change, as the energy saving potential of the different options is calculated relative to the assumed *business as usual* scenario that takes full account of market changes. Use of the lower efficiency values for the MEEUP basecse model also gives a much more realistic idea of the performance of existing stock, and hence of the existing eco impact and the potential for reducing the eco impact of circulators through the use of more efficient types.

[29] Fixed speed circulators are sometimes known as *uncontrolled*, and variable speed circulators as *controlled*.

Figure 4-1 Real-world products similar to the standalone basecase models (left – 65W, right 450W)

4.1 Production phase

This section presents the breakdown of the product in the form of Bill of Materials (BOMs). Each part is classified as the closest available material from the list of available materials within the MEEUP model.

4.1.1 Small Standalone Circulator, 65W

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Impeller	7.0	1-BlkPlastics	4-PP
2	Volute	912.0	3-Ferro	23-Cast iron
3	Stator Windings & Rotor Cage	302.0	4-Non-ferro	28-Cu winding wire
4	Stator (rest)	388.0	3-Ferro	23-Cast iron
5	Rotor (rest)	146.0	3-Ferro	23-Cast iron
6	Shaft	21.0	3-Ferro	23-Cast iron
7	Motor housing	180.0	4-Non-ferro	27-Al diecast
8	Paint	24.0	5-Coating	39-powder coating
9	Operating instructions	250.0	7-Misc.	57-Office paper
10	Terminal box	35.0	1-BlkPlastics	1-LDPE
11	Can	106.0	3-Ferro	23-Cast iron
12	Bearing bracket + End Shield	98.0	3-Ferro	23-Cast iron
13	Packaging (recycled paper)	174.0	7-Misc.	56-Cardboard
14	Screws Etc.	50.0	3-Ferro	23-Cast iron
15	Misc material	125.0	3-Ferro	23-Cast iron
16	Misc material	125.0	1-BlkPlastics	4-PP

Table 4-1 Bill of Materials - 65W circulator

4.1.2 Large Standalone Circulator, 450W

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Impeller	80.0	1-BlkPlastics	4-PP
2	Volute	10000.0	3-Ferro	23-Cast iron
3	Stator Windings & Rotor Cage	1400.0	4-Non-ferro	28-Cu winding wire
4	Stator (rest)	2800.0	3-Ferro	23-Cast iron
5	Rotor (rest)	700.0	3-Ferro	23-Cast iron
6	Shaft	400.0	3-Ferro	23-Cast iron
7	Motor housing	1450.0	4-Non-ferro	27-Al diecast
8	Paint	100.0	5-Coating	39-powder coating
9	Operating instructions	250.0	7-Misc.	57-Office paper
10	Terminal box	350.0	1-BlkPlastics	1-LDPE
11	Can	350.0	3-Ferro	23-Cast iron
12	Bearing bracket + End Shield	100.0	3-Ferro	23-Cast iron
13	Packaging (recycled paper)	750.0	7-Misc.	56-Cardboard
14	Screws Etc.	250.0	3-Ferro	23-Cast iron
15	Misc material	500.0	3-Ferro	23-Cast iron
16	Misc material	500.0	1-BlkPlastics	4-PP

Table 4-2 Bill of Materials - 450W circulator

4.1.3 Boiler Integrated Circulator, 90W

Pos nr	MATERIALS Extraction & Production Description of component	Weight in g	Category Click &select	Material or Process select Category first !
1	Impeller	22.0	1-BlkPlastics	4-PP
2	Pump/valve housing	357.0	1-BlkPlastics	23-Cast iron
3	Stator Windings & Rotor Cage	292.0	4-Non-ferro	28-Cu winding wire
4	Stator (rest)	488.0	3-Ferro	23-Cast iron
5	Rotor (rest)	146.0	3-Ferro	23-Cast iron
6	Shaft	21.0	3-Ferro	23-Cast iron
7	Motor housing	183.0	4-Non-ferro	27-Al diecast
8	Paint	0.0	5-Coating	39-powder coating
9	Operating instructions	0.0	7-Misc.	57-Office paper
10	Terminal box	35.0	1-BlkPlastics	1-LDPE
11	Can	106.0	3-Ferro	23-Cast iron
12	Bearing bracket + End Shield	98.0	3-Ferro	23-Cast iron
13	Packaging (recycled paper)	0.0	7-Misc.	56-Cardboard
14	Screws Etc.	50.0	3-Ferro	23-Cast iron
15	Misc material	125.0	3-Ferro	23-Cast iron
16	Misc material	125.0	1-BlkPlastics	4-PP

Table 4-3 Bill of Materials – Boiler Integrated Circulator, 90W

4.2 Distribution phase

The typical packaged circulator sizes and weights are shown in table 4-4.

Circulator Type	Packaged Size (m^3)	Weight (kg)
Small 65W	0.008	2.9
Large 450W	0.3	20
Boiler integrated	0.008	2.0

Table 4-4 Typical circulator volumes and weights

The data for the boiler integrated circulator is only approximate, as it is fitted at the factory rather than on site. This means that it will not need the same amount of packaging, and may be supplied in bulk in a box with minimal individual packaging. It will probably be supplied with some type of manifold, and so the total product volume will be larger, but it is assumed that the packed volume is the same.

The reason that the weight of the boiler integrated circulator is less than that of a standalone circulator is that in the assumed model it is of glass fibre construction.

4.3 Use phase (product)

It is difficult to meaningfully separate the performance of the product from that of the system it is attached to, and so accordingly all the analysis is contained within section 4.4.

4.4 Use phase (system)

4.4.1 Calculation of energy consumption

Because the flow (and hence power consumption) of a circulator changes with system requirements, it is not valid to simply consider circulator performance at rated flow to characterise overall energy use. Therefore three different flow-time scenarios have been developed, as shown in table 4-7. The methodology is explained for the small standalone circulator, with just the results presented for the other types.

Standby power consumption is considered in 4.4.7.

4.4.2 Small (65W) Standalone circulator

The rated power consumption at the 4 selected flow points is derived from a variety of "typical" products. *For example, in table 4-5 below, at 75% flow this is 63W.*

- For each flow point, the power is multiplied by the number of hours pa. This is calculated as a percentage of time spent operating pa. This gives the total energy consumption for each flow point.
  Eg 0.063kW x 15% x 5,000hpa = 47.25kWh pa
- This is repeated for each of the four flow points, and totalled to give total annual energy consumption for the pump under assumed operating conditions.
  19.2 + 47.25 + 108.5 + 132 = 307 kWh pa
- The calculation of P_{mean} (total energy use divided by annual operating hours) means that this data can be easily extended to any annual running hours, which is particularly useful in the later sensitivity analysis that considers the economics of various circulator types with different running hours.
  307 kWh pa / 5,000 hrs pa = 61.3W.

Flow (%)	Power (W)	Time (%)	Energy (kWh pa)
100	64	6	19.2
75	63	15	47.25
50	62	35	108.5
25	60	44	132
		Total	**307**

Table 4-5 Standard (baseline) 65W circulator performance – continuous control (5,000hpa)

This analysis is repeated for each of the different design options, (figure 4-6) and different control options (figure 4-7).

Option	Technology
1	Standard (basecase)
2	Improved
3	Variable speed (induction motor)
4	Permanent Magnet Motor (fixed speed)
5	Permanent Magnet Motor (variable speed)

Table 4-6 Circulator technology options

Control option	Annual running hours	Flow profile
Continuous	5,000	Blauer Engel
On/Off Thermostatic Radiator Valve (TRV) control	2,300	Blauer Engel
On/Off control	2,300	100% or OFF

Table 4-7 Circulator control options

The part load performance of each circulator type is shown in Table 4-8 below:

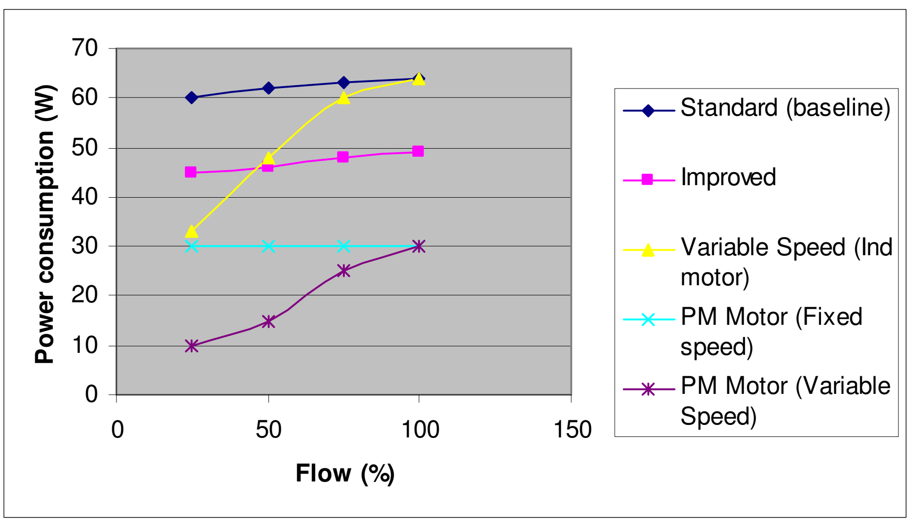


Table 4-8 Power consumption (Watts) for all types of 65W Standalone circulators with different controls

Table 4-9 shows the analysis of Pmean and total energy consumption for each of the improved circulator options. Of particular note is the large savings possible with the use of Permanent Magnet circulators when used in the variable speed mode.

65W - Improved

Flow (%)	Power (W)	Time (%)	Energy (kWh pa)
100	49	6	14.7
75	48	15	36
50	46	35	80.5
25	45	44	99

65W PM - Fixed Speed

Flow (%)	Power (W)	Time (%)	Energy (kWh pa)
100	30	6	9.0
75	30	15	22.5
50	30	35	52.5
25	30	44	66.0

Pmean	*46.0*	*Total*	230.2

Pmean	*30.0*	*Total*	150.0

65W - VS Induction Motor

Flow (%)	Power (W)	Time (%)	Energy (kWh pa)
100	64	6	19.2
75	60	15	45.0
50	48	35	84.0
25	33	44	72.6
Pmean	*44.2*	*Total*	220.8

65W PM - Variable Speed

Flow (%)	Power (W)	Time (%)	Energy (kWh pa)
100	30	6	9.0
75	25	15	18.8
50	15	35	26.3
25	10	44	22.0
Pmean	*15.2*	*Total*	76.0

Table 4-9 Calculation of Pmean and total annual energy consumption for different types of circulators under continuous (Blauer Engel) operating profile, all calculated at 5,000 hrs pa.

Based on the different assumed flow-time profiles, a single Pmean figure was calculated for each of the different circulator / control options, (table 4-10).

Circulator type & control	Continuous (P mean, Watts)	Continuous (P mean, Watts)	On/Off Room temp (P mean, Watts)
65W Standard (Baseline)	61.4	61.4	64
65W Improved	46	46	49
65W Variable speed (Induction motor)	44.2	44.2	
65W PM Motor (Fixed speed)	31	31	31
65W PM Motor (Variable speed)	15.2	15.2	

Table 4-10 Pmean (Watts) for all types of 65W Standalone circulators with different controls

To calculate annual power consumption, Pmean is multiplied by the annual running hours, giving the energy consumption shown in table 4-11. Table 4-12 shows the estimated distribution of circulator/control types, from which the total annual EU energy consumption shown in table 4-13 is calculated as 11,632 GW hpa. From this table, the EU average Pmean of this 65W basecase circulator is calculated, which is the value used as the input to the MEEUP model.

Circulator type & control	Continuous (5000 hpa), kWh pa	Continuous (2300 hpa), kWh pa	On/Off Room Temp (2300 hpa) kWh pa
65W Standard (Baseline)	307	141.22	147.2
65W Improved	230	105.8	112.7
65W Variable speed (Induction motor)	221	101.66	
65W PM Motor (Fixed speed)	155	71.3	71.3
65W PM Motor (Variable speed)	76	34.96	

Table 4-11 Annual energy consumption of circulators (kWh pa)

Circulator type & control	Continuous (5000hrs pa)	Continuous (2300 hrs pa)	On/Off (2300 hrs pa)
65W Standard (Baseline)	30	5	10
65W Improved	5	5	5
65W Variable speed (Induction motor)	30	5	
65W PM Motor (Fixed speed)			
65W PM Motor (Variable speed)	5		

Table 4-12 Estimated distribution of circulators by type and operating regime (%)

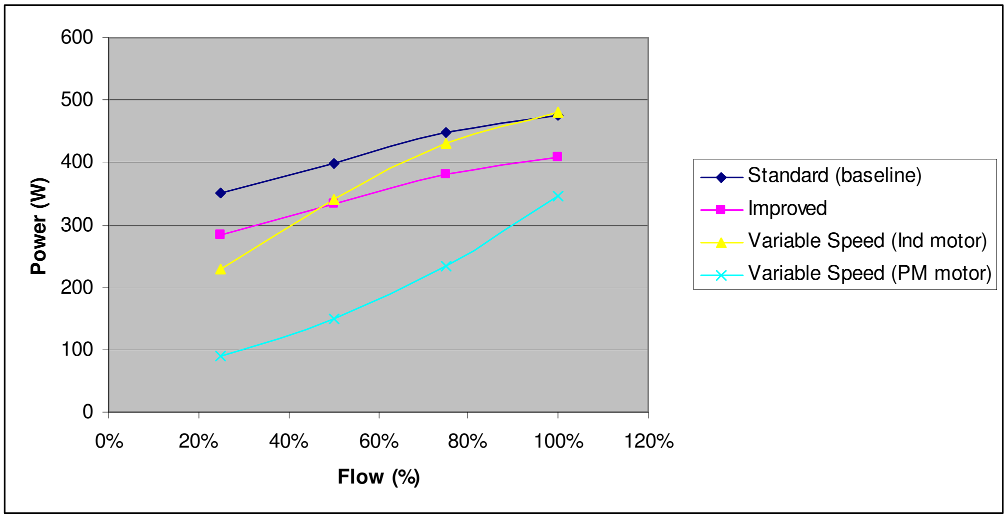
Note that in the above table it is the total of ALL cells in the table that add up to 100%, as this table shows the distribution of all products across all operating scenarios.

Circulator type & control	Continuous (5000 hpa), kWh pa	Continuous (2300 hpa), kWh pa	On/Off Room Temp (2300 hpa) kWh pa
65W Standard (Baseline)	5066	388	810
65W Improved	633	291	310
65W Variable speed (Induction motor)	3647	280	0
65W PM Motor (Fixed speed)	0	0	0
65W PM Motor (Variable speed)	209	0	0
Total Energy Use	**11,632**	**GWh pa**	

Table 4-13 Annual energy consumption of circulator stock, by type and controls (GWh pa)

4.4.3 Large (450W) circulator performance

This analysis is very similar to that of the standalone 65W circulators, but because of the large variety of possible control and hence duty profile options, it was decided to just assume the Blauer Engel distribution in all cases. Further, it was decided to assume an average operating time of 5,000 hrs pa.



Flow	Standard (baseline) (W)	Improved (W)	Variable Speed (Ind motor) (W)	Variable Speed (PM motor) (W)
100%	475	408.5	480	345
75%	447	380	430	235
50%	398	332.5	340	150
25%	350	285	230	90
Pmean	389	324	314	148

Figure 4-2 Part flow power consumption of different large standalone circulators

450W - Improved

Flow (%)	Power (W)	Time (%)	Energy (kWh pa)
100	408.5	6	122.6
75	380	15	285.0
50	332.5	35	581.9
25	285	44	627.0
Pmean	*323.3*	*Total*	1616.4

450W - VS Induction Motor

Flow (%)	Power (W)	Time (%)	Energy (kWh pa)
100	480	6	144.0
75	430	15	322.5
50	340	35	595.0
25	230	44	506.0
Pmean	*313.5*	*Total*	1567.5

450W - PM – Variable Speed

Flow (%)	Power (W)	Time (%)	Energy (kWh pa)
100	345	6	103.5
75	235	15	176.3
50	150	35	262.5
25	90	44	198.0
Pmean	*151.1*	*Total*	740.3

Table 4-14 Calculation of Pmean and total annual energy consumption for different types of circulators under continuous (Blauer Engel) operating profile.

The average power consumption of the baseline large circulator is 1,945 kWhpa.

For large standalone circulators, it is considered that they all run for 5,000 hpa with continuous flow, hence there is only the one operating regime.

Circulator type & control	%
450W Standard (Baseline)	50
450W Improved	30
450W Variable speed (Induction motor)	15
450W PM Motor (Variable speed)	5

Table 4-15 Estimated stock of circulators (%), by type.

Circulator type & control	Pmean (W)
450W Standard (Baseline)	388
450W Improved	323
450W Variable speed (Induction motor)	313
450W PM Motor (Variable speed)	148

Table 4-16 Average power consumption of different circulators

Circulator type & control	Annual Energy Consumption (kWh pa)
450W Standard (Baseline)	1,940
450W Improved	1,615
450W Variable speed (Induction motor)	1,565
450W PM Motor (Variable speed)	740

Table 4-17 Annual energy consumption for each type of circulator

Circulator type & control	Annual Energy Consumption (GWh pa)
450W Standard (Baseline)	9,700
450W Improved	4,845
450W Variable speed (Induction motor)	2,348
450W PM Motor (Variable speed)	370
TOTAL	**17,263 GWh pa**

Table 4-18 Annual energy consumption of circulators

The total EU energy consumption of large circulators is therefore estimated to be 17.263 TWh pa. Hence, (based on 10M installed large circulators) the **average energy consumption of each large circulator is 1,730 kWh pa.**

4.4.4 Boiler integrated circulators

While these are strictly outside the scope of this study, a simplified analysis of this class of circulator is undertaken so that at least a good estimate of the total energy consumption of these devices can be calculated. Because the circulators are boiler specific, it was thought that to develop a single representative basecase would be mis-leading, and so instead we have just assumed the same power:flow profile as with the 65W standalone circulators, scaled to give the same 100% (rated) flow power consumption.

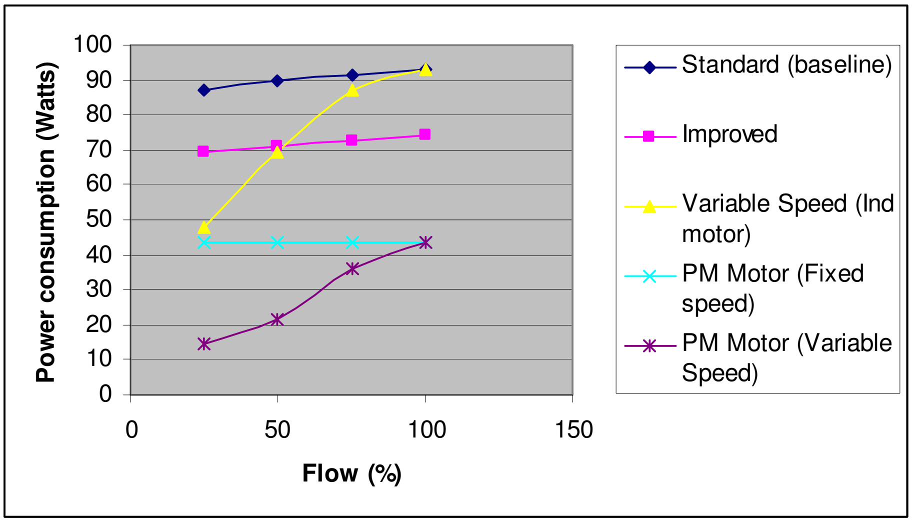


Figure 4-3 Power consumption of different 90W Boiler Integrated Circulators

Circulator type & control	Continuous (5000hrs pa)	Continuous (2300 hrs pa)	On/Off (2300 hrs pa)
90W Standard (Baseline)	445	205	213
90W Improved	354	163	170
90W Variable speed (Induction motor)	320	147	0
90W PM Motor (Fixed speed)	218	100	100
90W PM Motor (Variable speed)	110	51	0

Table 4-19 Estimated annual energy consumption of all types of 90W Boiler Integrated circulators with different controls

Circulator type & control	Continuous (5000hrs pa)	Continuous (2300 hrs pa)	On/Off (2300 hrs pa)
90W Standard (Baseline)	35	5	10
90W Improved	5	5	5
90W Variable speed (Induction motor)	30	5	
90W PM Motor (Fixed speed)			
90W PM Motor (Variable speed)			

Table 4-20 Assumed split of stock, by type and control (%)

Circulator type & control	Continuous (5000hrs pa)	Continuous (2300hrs pa)	On/Off (2300 hrs pa)
90W Standard (Baseline)	11685	768	1601
90W Improved	1327	610	638
90W Variable speed (Induction motor)	7210	553	0
90W PM Motor (Fixed speed)	0	0	0
90W PM Motor (Variable speed)	0	0	0

Table 4-21 Total energy consumption of Boiler Integrated Circulators, by type and controls

4.4.5 Summary – Average energy consumption of each basecase circulator

The following table shows the average annual energy consumption of each of the basecase circulators, which is used as the input to the MEEUP model:

Basecase type	Average Annual energy consumption (kWh pa)	Total energy consumption of the stock (GWh pa) 2010
Small (65W) standalone circulator	212	11,658
Large (450W) standalone circulator	1,730	17,263
Boiler integrated (90W) circulator	323	24,255
TOTAL		**53,176**

Table 4-22 Annual energy consumption of different types of circulator

4.4.6 Sales by efficiency

As shown in Figure 1.10 (Chapter 1), the move towards more efficient circulators is only very recent, and so it is reasonable to consider class C(C/D borderline) as the basecase for calculating energy consumption of the total stock for both sizes of standalone circulator. The basecase model is in fact of this type.

Future sales are anticipated to grow by 1.4%pa, with (small) standalone circulator sales thought to remain static, and hence all the growth will be in the boiler integrated circulator market.

This data is used later in the study to construct a simple stock model of EU-25 circulator stock and hence predicted energy consumption over time.

4.4.7 Standby Power consumption

Small (domestic) circulators are either On or Off, and so the concept of the standby mode is not relevant. An estimated (by AEAT) 20% of large PM circulators have a standby consumption when they are run in the remote "stop/start" mode. This is unusual and only applies to PM circulators used in buildings that have an integrated Facilities Management system connected to the circulator.

Based on 5,000 hrs pa operation, there is 3,760 hours potential standby time, with an estimated 3W standby power consumption. Even if ALL such circulators were of the PM type, (ie stock of 10M units), then the total energy used would be 22 GWhpa. This is small compared to the total operating energy consumption of the stock, and so is ignored in further calculations. However this power consumption would be subject to the policy options in the Lot 6 report on Standby Power consumption.

4.5 End-of-life phase

Old circulators are sent to scrap where metal components are extracted for recycling. This is discussed in Chapter 3 of this study.

The default values adopted are those shown in section 3.

4.6 Summary

This section provides the technical inputs needed for the MEEUP model. Because of the large amount of subsequent analysis that each basecase entails, three basecases were selected and these are representative of the market:

- Small standalone Circulator, 65W.
- Large Standalone Circulator, 450W.
- Boiler Integrated Circulator, 90W.

Each basecase represents the “typical” product sold today, and is characterised in terms of lifetime environmental and financial impacts. (In fact when the project started the class D was considered as the basecase, but the July 2007 sales data (Figure 1-10, Chapter 1) showed that class C is now more typical. However, the use of class C/D as the baseline makes the benefits of improved models much clearer, and is also much more representative of existing stock.)

The Bill of materials data have been compiled and supplied by manufacturers, they were examined and verified by the study team, and can be regarded as being representative average of the products on the market that meet the detailed performance specifications outlined above.

The variety of operating scenarios for each type of circulator that are described in chapter 3 means that the actual energy consumption of the same basecase circulator will vary significantly. A weighted average annual energy consumption of each basecase under each control regime has therefore been calculated and used in this analysis. This has resulted in an average power consumption for each type of circulator and control regime, which shows in a simple way the actual energy consumption of each circulator under different “real life” operating conditions.

The total energy consumption of all circulators in the EU is calculated to be 53.2 TWh pa (2006)

5 DEFINITION OF BASE CASE

This chapter presents the results of the Environmental Impact Assessment performed on the three basecase models using the MEEUP model. The environmental impact is split into the following catagories:

- Materials
- Other resources and waste
- Emissions to air
- Emissions to water

The results show the total environmental impact in the following phases of product life:

- Production phase
- Distribution phase
- In Use phase
- End of life phase

In addition, economic information is provided to enable detailed LCC analysis to be undertaken as the basis of devising policy options.

5.1 Product specific inputs

The following tables relating to Disposal and Recycling are derived from the BOM and are used as inputs for the Environmental Impact Assessment, the Life Cycle Cost calculation and the EU Totals calculations. Note that the values for annual energy consumption assumed in this MEEUP model use the weighted average energy consumption of all operating scenarios that are developed in chapter 4 and summarised in table 4-22.

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	235	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	150	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	17	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	2	1%	4
235	Plastics: Materials Recycling (please edit% only)	15	9%	4
236	Plastics: Thermal Recycling (please edit% only)	150	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	2637		fixed

Table 5-1- 65W circulator Disposal and Recycling

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	1598	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	837	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	93	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	9	1%	4
235	Plastics: Materials Recycling (please edit% only)	84	9%	4
236	Plastics: Thermal Recycling (please edit% only)	837	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	18098		fixed

Table 5-2- 450W circulator Disposal and recycling

Pos nr	DISPOSAL & RECYCLING Description		unit	Subtotals
	Substances released during Product Life and Landfill			
227	Refrigerant in the product (Click & select)	0	g	1-none
228	Percentage of fugitive & dumped refrigerant	0%		
229	Mercury (Hg) in the product	0	g Hg	
230	Percentage of fugitive & dumped mercury	0%		
	Disposal: Environmental Costs perkg final product			
231	Landfill (fraction products not recovered) in g en %	164	8%	88-fixed
232	Incineration (plastics & PWB not re-used/recycled)	485	g	91-fixed
233	Plastics: Re-use & Recycling ("cost"-side)	54	g	92-fixed
	Re-use, Recycling Benefit	in g	% of plastics fraction	
234	Plastics: Re-use, Closed Loop Recycling (please edit%)	5	1%	4
235	Plastics: Materials Recycling (please edit% only)	49	9%	4
236	Plastics: Thermal Recycling (please edit% only)	485	90%	72
237	Electronics: PWB Easy to Disassemble ? (Click&select)	0	YES	98
238	Metals & TV Glass & Misc. (95% Recycling)	1434		fixed

Table 5-3 90W Boiler Integrated circulator Disposal and recycling

5.2 Base Case Environmental Impact

This section presents the outputs from the MEEUP model to show the total environmental impact of each of the products, split by the phase of lifecycle.

Nr	Life cycle Impact per product:	Date	Author
0	65 Watt Circulator, Standalone, Europump average	38987	CG

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			167			150	17	167	0
2	TecPlastics	g			0			0	0	0	0
3	Ferro	g			1846			148	1698	1846	0
4	Non-ferro	g			482			39	443	482	0
5	Coating	g			24			2	22	24	0
6	Electronics	g			0			0	0	0	0
7	Misc.	g			424			34	390	424	0
	Total weight	g			2943			372	2571	2943	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	107	12	119	60	22366	26	18	8	22554
9	of which, electricity (in primary MJ)	MJ	5	7	12	0	22365	0	0	0	22377
10	Water (process)	ltr	24	0	24	0	1491	0	0	0	1515
11	Water (cooling)	ltr	23	3	26	0	59640	0	0	0	59666
12	Waste, non-haz./ landfill	g	6812	38	6850	55	25999	289	0	288	33193
13	Waste, hazardous/ incinerated	g	2	0	2	1	515	150	0	150	668
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	6	1	6	5	976	2	1	1	988
15	Ozone Depletion, emissions	mg R-11 eq.					negligible				
16	Acidification, emissions	g SO2 eq.	104	3	107	14	5760	4	2	2	5883
17	Volatile Organic Compounds (VOC)	g	0	0	0	0	8	0	0	0	9
18	Persistent Organic Pollutants (POP)	ng i-Teq	18	0	18	0	147	2	0	2	167
19	Heavy Metals	mg Ni eq.	21	0	21	3	384	7	0	7	415
	PAHs	mg Ni eq.	5	0	5	3	44	0	0	0	52
20	Particulate Matter (PM, dust)	g	28	0	29	28	123	34	0	34	214
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	5	0	5	0	144	2	0	2	151
22	Eutrophication	g PO4	2	0	2	0	1	0	0	0	3
23	Persistent Organic Pollutants (POP)	ng i-Teq					negligible				

Table 5-4 EIA Impact of a single 65W circulator

0	65 Watt Circulator, Standalone, Europump average								38987 CG		
	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			1			1	0	1	0
2	TecPlastics	kt			0			0	0	0	0
3	Ferro	kt			10			1	9	10	0
4	Non-ferro	kt			3			0	2	3	0
5	Coating	kt			0			0	0	0	0
6	Electronics	kt			0			0	0	0	0
7	Misc.	kt			2			0	2	2	0
	Total weight	kt			16			2	14	16	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	1	0	1	0	123	0	0	0	124
9	of which, electricity (in primary PJ)	PJ	0	0	0	0	123	0	0	0	123
10	Water (process)	mln. m3	0	0	0	0	8	0	0	0	8
11	Water (cooling)	mln. m3	0	0	0	0	328	0	0	0	328
12	Waste, non-haz./ landfill	kt	37	0	38	0	143	2	0	2	183
13	Waste, hazardous/ incinerated	kt	0	0	0	0	3	1	0	1	4
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	0	0	5	0	0	0	5
15	Ozone Depletion, emissions	t R-11eq.	negligible								
16	Acidification, emissions	kt SO2 eq.	1	0	1	0	32	0	0	0	32
17	Volatile Organic Compounds (VOC)	kt	0	0	0	0	0	0	0	0	0
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	0	0	1	0	0	0	1
19	Heavy Metals	ton Ni eq.	0	0	0	0	2	0	0	0	2
	PAHs	ton Ni eq.	0	0	0	0	0	0	0	0	0
20	Particulate Matter (PM, dust)	kt	0	0	0	0	1	0	0	0	1
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	0	0	1	0	0	0	1
22	Eutrophication	kt PO4	0	0	0	0	0	0	0	0	0
23	Persistent Organic Pollutants (POP)	g i-Teq	negligible								

Table 5-5 EIA Impact of 2006 production of 65W circulators

Nr	Life cycle Impact per product:	Date	Author
0	450 Watt Circulator, Standalone, Europump average	39309	HF

	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**930**			837	93	**930**	**0**
2	TecPlastics	g			**0**			0	0	**0**	**0**
3	Ferro	g			**15100**			1208	13892	**15100**	**0**
4	Non-ferro	g			**2850**			228	2622	**2850**	**0**
5	Coating	g			**100**			8	92	**100**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**1000**			80	920	**1000**	**0**
	Total weight	g			**19980**			2361	17619	**19980**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	567	81	**647**	**385**	**178506**	166	68	**98**	**179636**
9	of which, electricity (in primary MJ)	MJ	20	49	**69**	**1**	**178501**	0	0	**0**	**178570**
10	Water (process)	ltr	50	1	**50**	**0**	**11901**	0	0	**0**	**11951**
11	Water (cooling)	ltr	133	23	**155**	**0**	**476002**	0	2	**-2**	**476155**
12	Waste, non-haz./ landfill	g	34042	252	**34295**	**187**	**207304**	1960	1	**1958**	**243744**
13	Waste, hazardous/ incinerated	g	7	0	**7**	**4**	**4113**	837	0	**837**	**4961**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	36	4	**40**	**24**	**7790**	12	5	**8**	**7862**
15	Ozone Depletion, emissions	mg R-11 eq.				negligible					
16	Acidification, emissions	g SO2 eq.	511	19	**530**	**72**	**45969**	25	6	**18**	**46590**
17	Volatile Organic Compounds (VOC)	g	2	0	**2**	**6**	**67**	1	0	**0**	**76**
18	Persistent Organic Pollutants (POP)	ng i-Teq	145	0	**145**	**1**	**1171**	14	0	**14**	**1331**
19	Heavy Metals	mg Ni eq.	110	0	**110**	**10**	**3063**	47	0	**47**	**3231**
	PAHs	mg Ni eq.	34	0	**34**	**16**	**352**	0	0	**0**	**402**
20	Particulate Matter (PM, dust)	g	224	3	**227**	**1026**	**984**	216	0	**216**	**2453**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	32	0	**32**	**0**	**1151**	14	0	**14**	**1198**
22	Eutrophication	g PO4	3	0	**3**	**0**	**6**	1	0	**1**	**9**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Table 5-6 EIA Impact of a single 450W circulator

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	450 Watt Circulator, Standalone, Europump average	39309	HF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			1			1	0	1	0
2	TecPlastics	kt			0			0	0	0	0
3	Ferro	kt			15			1	14	15	0
4	Non-ferro	kt			3			0	3	3	0
5	Coating	kt			0			0	0	0	0
6	Electronics	kt			0			0	0	0	0
7	Misc.	kt			1			0	1	1	0
	Total weight	kt			20			2	18	20	0
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	1	0	1	0	179	0	0	0	180
9	of which, electricity (in primary PJ)	PJ	0	0	0	0	179	0	0	0	179
10	Water (process)	mln. m3	0	0	0	0	12	0	0	0	12
11	Water (cooling)	mln. m3	0	0	0	0	476	0	0	0	476
12	Waste, non-haz./ landfill	kt	34	0	34	0	207	2	0	2	244
13	Waste, hazardous/ incinerated	kt	0	0	0	0	4	1	0	1	5
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	0	0	8	0	0	0	8
15	Ozone Depletion, emissions	t R-11 eq.				negligible					
16	Acidification, emissions	kt SO2 eq.	1	0	1	0	46	0	0	0	47
17	Volatile Organic Compounds (VOC)	kt	0	0	0	0	0	0	0	0	0
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	0	0	1	0	0	0	1
19	Heavy Metals	ton Ni eq.	0	0	0	0	3	0	0	0	3
	PAHs	ton Ni eq.	0	0	0	0	0	0	0	0	0
20	Particulate Matter (PM, dust)	kt	0	0	0	1	1	0	0	0	2
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	0	0	1	0	0	0	1
22	Eutrophication	kt PO4	0	0	0	0	0	0	0	0	0
23	Persistent Organic Pollutants (POP)	g i-Teq				negligible					

Table 5-7 EIA Impact of 2006 production of 450W circulators

Nr	Life cycle Impact per product:	Date	Author
0	BI Circulator	39273	HF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	g			**539**			485	54	**539**	**0**
2	TecPlastics	g			**0**			0	0	**0**	**0**
3	Ferro	g			**1034**			83	951	**1034**	**0**
4	Non-ferro	g			**475**			38	437	**475**	**0**
5	Coating	g			**0**			0	0	**0**	**0**
6	Electronics	g			**0**			0	0	**0**	**0**
7	Misc.	g			**0**			0	0	**0**	**0**
	Total weight	g			**2048**			606	1442	**2048**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	MJ	79	26	**105**	**60**	**34126**	44	11	**33**	**34325**
9	of which, electricity (in primary MJ)	MJ	2	16	**18**	**0**	**34125**	0	0	**0**	**34143**
10	Water (process)	ltr	3	0	**3**	**0**	**2275**	0	0	**0**	**2278**
11	Water (cooling)	ltr	13	7	**20**	**0**	**91000**	0	1	**-1**	**91019**
12	Waste, non-haz./ landfill	g	6433	82	**6516**	**55**	**39631**	201	1	**200**	**46402**
13	Waste, hazardous/ incinerated	g	1	0	**1**	**1**	**786**	485	0	**485**	**1273**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	kg CO2 eq.	5	1	**6**	**5**	**1489**	3	1	**3**	**1503**
15	Ozone Depletion, emissions	mg R-11 eq				negligible					
16	Acidification, emissions	g SO2 eq.	97	6	**103**	**14**	**8788**	7	1	**6**	**8911**
17	Volatile Organic Compounds (VOC)	g	0	0	**0**	**0**	**13**	0	0	**0**	**13**
18	Persistent Organic Pollutants (POP)	ng i-Teq	16	0	**16**	**0**	**224**	1	0	**1**	**241**
19	Heavy Metals	mg Ni eq.	19	0	**19**	**3**	**586**	12	0	**12**	**620**
	PAHs	mg Ni eq.	5	0	**5**	**3**	**67**	0	0	**0**	**75**
20	Particulate Matter (PM, dust)	g	21	1	**22**	**28**	**188**	57	0	**57**	**295**
	Emissions (Water)										
21	Heavy Metals	mg Hg/20	4	0	**4**	**0**	**220**	4	0	**4**	**228**
22	Eutrophication	g PO4	0	0	**0**	**0**	**1**	0	0	**0**	**1**
23	Persistent Organic Pollutants (POP)	ng i-Teq				negligible					

Table 5-8 EIA Impact of a single 90W Boiler Integrated circulator

Nr	EU Impact of New Models sold 2005 over their lifetime:	Date	Author
0	BI Circulator	39273	HF

Nr	Life Cycle phases -->		PRODUCTION			DISTRI-	USE	END-OF-LIFE*			TOTAL
	Resources Use and Emissions		Material	Manuf.	Total	BUTION		Disposal	Recycl.	Total	
	Materials	**unit**									
1	Bulk Plastics	kt			**4**			4	0	**4**	**0**
2	TecPlastics	kt			**0**			0	0	**0**	**0**
3	Ferro	kt			**8**			1	7	**8**	**0**
4	Non-ferro	kt			**4**			0	3	**4**	**0**
5	Coating	kt			**0**			0	0	**0**	**0**
6	Electronics	kt			**0**			0	0	**0**	**0**
7	Misc.	kt			**0**			0	0	**0**	**0**
	Total weight	kt			**15**			5	11	**15**	**0**
									see note!		
	Other Resources & Waste							debet	credit		
8	Total Energy (GER)	PJ	1	0	**1**	**0**	**256**	0	0	**0**	**257**
9	of which, electricity (in primary PJ)	PJ	0	0	**0**	**0**	**256**	0	0	**0**	**256**
10	Water (process)	mln. m3	0	0	**0**	**0**	**17**	0	0	**0**	**17**
11	Water (cooling)	mln. m3	0	0	0	0	**683**	0	0	0	683
12	Waste, non-haz./ landfill	kt	48	1	**49**	**0**	**297**	2	0	**2**	**348**
13	Waste, hazardous/ incinerated	kt	0	0	**0**	**0**	**6**	4	0	**4**	**10**
	Emissions (Air)										
14	Greenhouse Gases in GWP100	mt CO2 eq.	0	0	**0**	**0**	**11**	0	0	**0**	**11**
15	Ozone Depletion, emissions	t R-11eq.				negligible					
16	Acidification, emissions	kt SO2 eq.	1	0	**1**	**0**	**66**	0	0	**0**	**67**
17	Volatile Organic Compounds (VOC)	kt	0	0	**0**	**0**	**0**	0	0	**0**	**0**
18	Persistent Organic Pollutants (POP)	g i-Teq	0	0	**0**	**0**	**2**	0	0	**0**	**2**
19	Heavy Metals	ton Ni eq.	0	0	**0**	**0**	**4**	0	0	**0**	**5**
	PAHs	ton Ni eq.	0	0	**0**	**0**	**1**	0	0	**0**	**1**
20	Particulate Matter (PM, dust)	kt	0	0	**0**	**0**	**1**	0	0	**0**	**2**
	Emissions (Water)										
21	Heavy Metals	ton Hg/20	0	0	**0**	**0**	**2**	0	0	**0**	**2**
22	Eutrophication	kt PO4	0	0	**0**	**0**	**0**	0	0	**0**	**0**
23	Persistent Organic Pollutants (POP)	g i-Teq				negligible					

Table 5-9 EIA Impact of 2006 production of 90W Boiler Integrated circulators

5.3 Base Case Life Cycle Costs

Life cycle costs per product and total annual expenditure are calculated for each product:

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	10	years
B	Annual sales	5.5	mln. Units/year
C	EU Stock	55	mln. Units
D	Product price	120	Euro/unit
E	Installation/acquisition costs (if any)	60	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	0.135	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	0	Euro/ unit
M	Discount rate (interest minus inflation)	2.0%	%
N	Present Worth Factor (PWF) (calculated automatically)	8.98	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	1.00	

	65 Watt Circulator, Standalone, Europump average *Item*	LCC new product	total annual consumer expenditure in EU25
D	Product price	120 €	660 mln.€
E	Installation/ acquisition costs (if any)	60 €	330 mln.€
F	Fuel (gas, oil, wood)	0 €	0 mln.€
F	Electricity	258 €	1661 mln.€
G	Water	0 €	0 mln.€
H	Aux. 1: None	0 €	0 mln.€
I	Aux. 2 :None	0 €	0 mln.€
J	Aux. 3: None	0 €	0 mln.€
K	Repair & maintenance costs	0 €	0 mln.€
	Total	438 €	2651 mln.€

Table 5-10- 65W circulator Life cycle costs

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	**10**	years
B	Annual sales	**1**	mln. Units/year
C	EU Stock	**10**	mln. Units
D	Product price	**400**	Euro/unit
E	Installation/acquisition costs (if any)	**60**	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	**0.135**	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	**0**	Euro/ unit
M	Discount rate (interest minus inflation)	**2.0%**	%
N	Present Worth Factor (PWF) (calculated automatically)	**8.98**	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	**1.00**	

	450 Watt Circulator, Standalone, Europump average *Item*	LCC new product		total annual consumer expenditure in EU25	
D	Product price	400	€	400	mln.€
E	Installation/ acquisition costs (if any)	60	€	60	mln.€
F	Fuel (gas, oil, wood)	0	€	0	mln.€
F	Electricity	2062	€	2410	mln.€
G	Water	0	€	0	mln.€
H	Aux. 1: None	0	€	0	mln.€
I	Aux. 2 :None	0	€	0	mln.€
J	Aux. 3: None	0	€	0	mln.€
K	Repair & maintenance costs	0	€	0	mln.€
	Total	**2522**	€	**2870**	mln.€

Table 5-11: 450W circulator Life cycle costs

nr	INPUTS FOR EU-Totals & economic Life Cycle Costs Description		unit
A	Product Life	**10**	years
B	Annual sales	**7.5**	mln. Units/year
C	EU Stock	**75**	mln. Units
D	Product price	**120**	Euro/unit
E	Installation/acquisition costs (if any)	**10**	Euro/ unit
F	Fuel rate (gas, oil, wood)		Euro/GJ
G	Electricity rate	**0.135**	Euro/kWh
H	Water rate		Euro/m3
I	Aux. 1: None		Euro/kg
J	Aux. 2 :None		Euro/kg
K	Aux. 3: None		Euro/kg
L	Repair & maintenance costs	**0**	Euro/ unit
M	Discount rate (interest minus inflation)	**2.0%**	%
N	Present Worth Factor (PWF) (calculated automatically)	**8.98**	(years)
O	Overall Improvement Ratio STOCK vs. NEW, Use Phase	**1.00**	

BI Circulator *Item*	**LCC new product**	**total annual consumer expenditure in EU25**
Product price	120 €	900 mln.€
Installation/ acquisition costs (if any)	10 €	75 mln.€
Fuel (gas, oil, wood)	0 €	0 mln.€
Electricity	394 €	3291 mln.€
Water	0 €	0 mln.€
Aux. 1: None	0 €	0 mln.€
Aux. 2 :None	0 €	0 mln.€
Aux. 3: None	0 €	0 mln.€
Repair & maintenance costs	0 €	0 mln.€
Total	**524** €	**4266** mln.€

Table 5-12 90W Boiler Integrated Circulator Life cycle costs

5.4 EU Totals

The final output from the MEEUP model shown in this chapter is the total environmental impact of the stock of each type of basecase circulator.

main life cycle indicators	value	unit
Total Energy (GER)	**130**	PJ
of which, electricity	12.3	TWh
Water (process)*	9	mln.m3
Waste, non-haz./ landfill*	190	kton
Waste, hazardous/ incinerated*	4	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**6**	mt CO2eq.
Acidifying agents (AP)	**34**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**2**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**1**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-13 Environmental Impact assessment of total stock - 65W circulator

main life cycle indicators	value	unit
Total Energy (GER)	**189**	PJ
of which, electricity	17.9	TWh
Water (process)*	13	mln.m3
Waste, non-haz./ landfill*	254	kton
Waste, hazardous/ incinerated*	5	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**8**	mt CO2eq.
Acidifying agents (AP)	**49**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**1**	g i-Teq.
Heavy Metals (HM)	**3**	ton Ni eq.
PAHs	**0**	ton Ni eq.
Particulate Matter (PM, dust)	**3**	kt
Emissions (Water)		
Heavy Metals (HM)	1	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-14 Environmental impact assessment of total stock - 450W circulator

main life cycle indicators	value	unit
Total Energy (GER)	**270**	PJ
of which, electricity	25.6	TWh
Water (process)*	18	mln.m3
Waste, non-haz./ landfill*	363	kton
Waste, hazardous/ incinerated*	10	kton
Emissions (Air)		
Greenhouse Gases in GWP100	**12**	mt CO2eq.
Acidifying agents (AP)	**70**	kt SO2eq.
Volatile Org. Compounds (VOC)	**0**	kt
Persistent Org. Pollutants (POP)	**2**	g i-Teq.
Heavy Metals (HM)	**5**	ton Ni eq.
PAHs	**1**	ton Ni eq.
Particulate Matter (PM, dust)	**2**	kt
Emissions (Water)		
Heavy Metals (HM)	2	ton Hg/20
Eutrophication (EP)	0	kt PO4

Table 5-15 Environmental impact assessment of total stock – 90W Boiler integrated circulator

5.4.1 Comparison of Environmental Impact by Phase of Lifecycle

The MEEUP model is only able to calculate the environmental impact of each category separately – it does not attempt to calculate a single “weighted environmental impact” figure derived from the values from each category. However, to proceed in the analysis of the products it is necessary to understand which phase of the lifecycle of greatest importance in terms of the total impact of each of the above quantities. Figures 5-1 to 5-3 achieve this by comparing the environmental impact of each phase for each of the impacts listed.

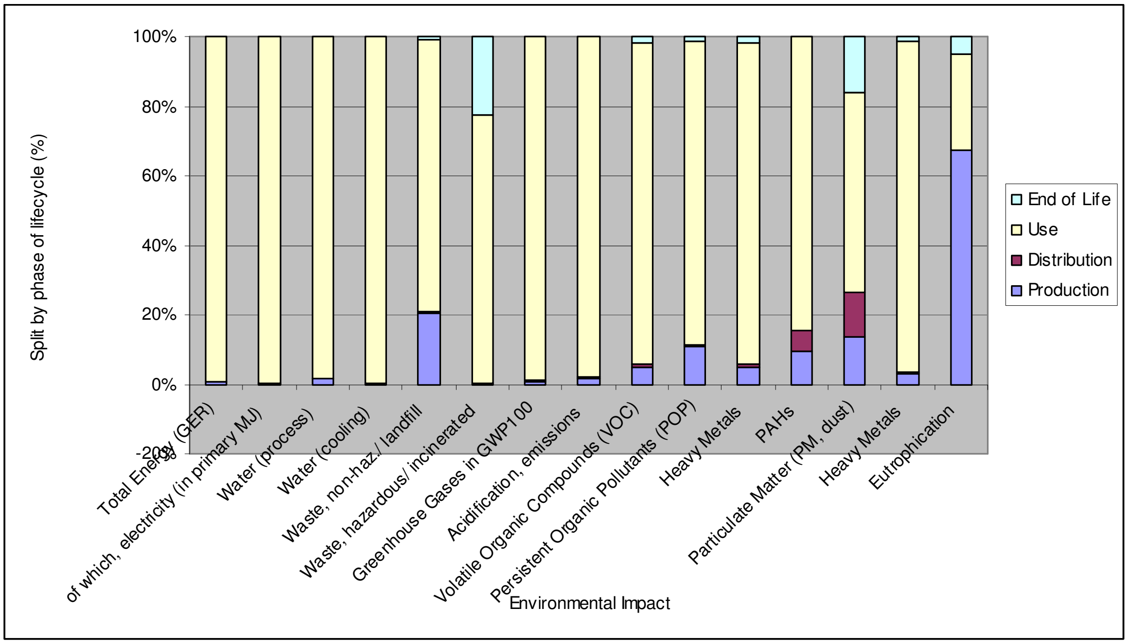


Figure 5-1 Environmental impact by phase of lifecycle - 65W standalone circulator

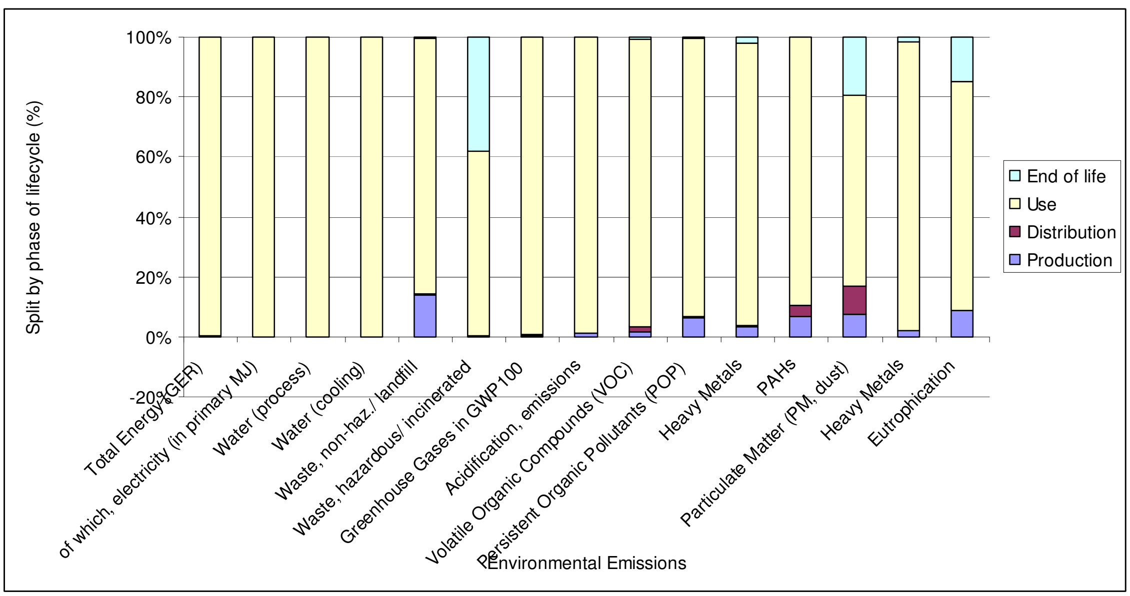


Figure 5-2 Environmental impact by phase of lifecycle - 90W boiler integrated circulator

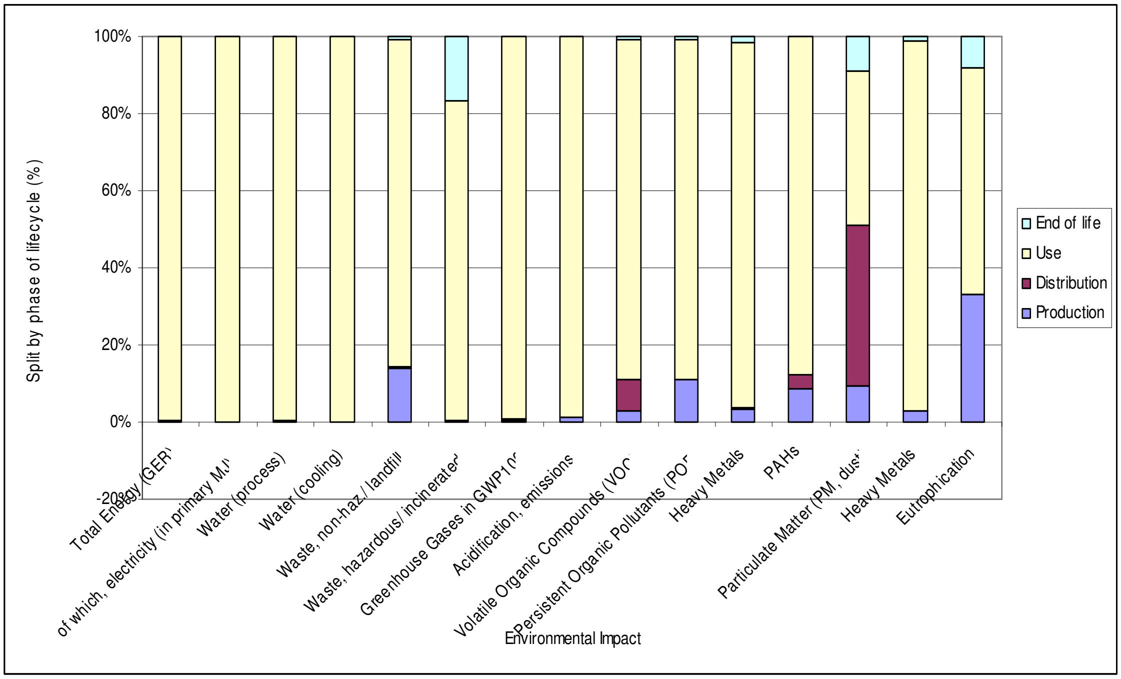


Figure 5-3 Environmental impact by phase of lifecycle – large (450W) standalone circulator

Key Points:

- The Use phase dominates for all categories of emissions.[30]
- The proportions of the environmental impacts in each lifecycle phase are similar for each circulator.
- Because the impact of material selection and use only contributes slightly to the total lifecycle eco-impact, reducing the usage of materials is a commercial issue for manufacturers rather than an important eco-impact issue.

The conclusion of this is that the focus of the study should be on the "In Use" phase of the circulator lifecycle, as this is where the greatest impact of the product comes from. What this means in practical terms is that it is the energy performance of the product that is critical to reducing the environmental impact of the products.

5.5 EU25 Total Systems Impact

Circulators are always part of a much larger heating (or cooling) system, and so the concept of total systems impact is not seen as being particularly useful in relation to this study. Such system considerations are accounted for in the Boiler study (Lot 1). More specifically, the performance of the circulator will have two indirect impacts on the wider "system":

Additional thermal losses from inefficient circulators will cause the room in which the circulator is sited to heat up – very little of this waste heat will be used for (useful) water heating.

Variable speed control will alter the heat transfer performance of the boiler, but this is complex and beyond the scope of the circulator study.

[30] The apparent exception to this is eutrophication (acidification) where the factor for stainless steel in the model is unrealistically high compared to more normal accepted values (eg SimaPro). Hence the results for eutrophication are misleading, as the In Use phase should really dominate.

5.6 Summary

This section has used the MEEUP methodology to analyse the environmental impact of each basecase circulator, environmental impact of the total stock of circulators, and the total (financial) lifecycle cost to the User of each of the three types considered. The results of this analysis show that of all the environmental impacts, it is the “In Use” phase that dominates, and so it is the energy performance that is focus of the following sections of this report.

The calculation of total emissions is based on current breakdown of stock by type. However, it is evident from statistics supplied that the energy performance of product has increased over the last ten years (the average product lifetime). Therefore the outputs from the MEEUP model will slightly under-estimate current total energy usage.

6 Technical Analysis for Best Available Technology

This section looks beyond products that are currently on the market to consider what products might be available in the future.

6.1 State of the Art in Applied Research for the Product

The main feature of the circulator market is that with the recent launch of permanent magnet variable speed circulators, there are not obviously any further developments that will lead to a major change in efficiency of the product as it is currently regarded. However, there are technological options that could reduce the demand for circulators:

6.1.1 Alternatives to wet heating systems

Change from wet heating systems to direct fossil fuel (single point fireplaces) or electrical heating. This could happen in the long term if the relative cost of gas or other fossil fuel becomes too high compared to electricity costs. This is outside the scope of this study and so is not considered any further.

6.1.2 Heat engine driven pumps

The development of pumps driven by Stirling or similar heat engines that use the difference between boiler and ambient temperature to directly pump the fluid without intermediate conversion to electrical energy. They would need no external power supply. These are at a very early stage of development, but if all problems can be overcome then they would mark a radical alternative to the conventional electrically driven circulator. [31]

6.2 State of the Art in Component level (prototype test and field trial level)

A new system based decentralized approach for circulators is discussed in several publications. Here the circulator is mounted directly on the radiator as a replacement of thermostatic control valves in order to optimise flow to each zone in the dwelling.

Insufficient data is currently available to make a proper assessment of this technology, but the local control of flow to precisely match heating requirements would certainly give the possibility of reducing thermal energy consumption, in particular through the reduction in control error of traditional TRVs.

It is estimated that the circulators themselves might consume 1.5W of electrical power. However, there are other negative environmental and cost factors that would need to be taken account of in order to complete a full investigation.

- Additional material and packaging costs
- Additional installation time due to cabelling
- Additional use of cable and wiring accessories

[31] For example, http://www.thermofluidics.co.uk

An important benefit is that it means that hydraulic balancing is no longer required. Because there is no independent data on this at the time of writing, it was decided that it is not appropriate to include this as a design option in this study, but this should be re-visited once early user experience has been gained.

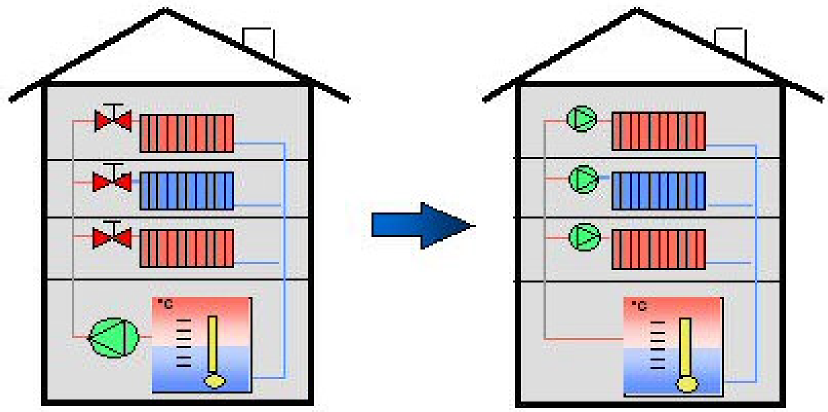


Figure 6-1 Illustration of the use of de-centralised pumps.

6.3 State of the Art in Best existing product technology outside the EU

There are no products known of outside the EU that are better than those currently available. This is because the EU is the main user of this type of heating system, and hence the main user (and manufacturer) of circulators.

6.4 Summary

The main feature of the circulator market is that with the recent launch of permanent magnet variable speed circulators, there are not obviously any further developments that will lead to a major change in efficiency of the product as it is currently regarded. However, chapter 7 shows the large energy saving potential from a wider adoption of the improved efficiency products that already exist.

Looking further into the future, significant reductions in energy consumption are more likely to come from alternative system designs that place different requirements on the function of the circulator:

- Direct Electrical heating systems. This is not being advocated as a desirable change from an environmental perspective, but if more of these systems were installed, these would not require any circulators.
- Localised circulators. Smaller, very low power circulators, that would have a similar total electrical power consumption, but which could enable boiler fuel savings. In this case. In this case the energy consumption of the circulator is much less important than that of the savings in boiler fuel.
- A possibility that there could be a heat engine driven pump that would use waste heat from the boiler instead of electrical power as its power source.

7 Improvement Potential

This section reviews the design options that there are for improving the current designs of circulators beyond the basecase reference designs. By considering the total economic lifecycle cost to the user, and comparing this with the environmental impact of each design option, the attractiveness of the different options can be compared on an equal basis.

Because the initial MEEUP analysis showed that the environmental impact is dominated by the “In use” phase energy cost, other environmental impacts are not considered further in this section. This means that the different options can be considered purely in terms of cost to the consumer and energy savings.

All analysis is undertaken relative to the basecase reference models used earlier. However, it was recognised that electricity prices may vary, and so the analysis has been repeated for both higher and lower electricity prices. Sensitivity analysis is also undertaken on different operating scenarios due to systems working with different annual running hours or control methods.

Article 12 of the EuP Directive states that “implementing measures shall not have a negative impact on …(c) the affordability and lifecycle cost to the user”. This analysis will show the lifecycle costs to the user for all products, and will also consider the impact of its interaction with the wider system.

Four design options are considered, with the baseline case being used as the reference:

- Improved design - Conventional technology
- Induction motor - Variable speed
- Permanent magnet - Variable speed
- Permanent magnet - Fixed speed

The Permanent magnet circulator is considered in both variable and fixed speed control modes, as the control method will have a major influence on the energy performance.

7.1 Identifying Design Options

The low absolute efficiencies of even the best circulators is a reflection of the difficulties in designing pumps and motors to be efficient in these small sizes. The latest sales data from Europump (figure 1.9) does however show the very significant improvement in efficiencies that has recently occurred. The following technological improvements are evaluated in this section;

Improved design – conventional technology

There are several aspects to this:

- Improved design/manufacture, for example smoother finishes or the use of pressed stainless steel impellers.
- Improved efficiency of the motor through for example use of more electrical wire to reduce resistive losses.
- Better sizing of housings, as designs may be compromised by using a reduced impeller in a slightly over-sized volute. This can be achieved by manufacturing a wider range of sizes of housings, but there is an obvious cost to the manufacturer.

Induction motor - Variable speed

Control of the speed of the circulator to more closely match actual flow to demand can save a varying amount of energy, depending on system configuration and operating profile, but the 35% average quoted is a reasonable representation of all types.

Permanent magnet motor - Variable speed

Permanent magnet motors are more efficient than induction motors, and have in-built variable speed control with the additional energy savings that this brings. They therefore offer the most efficient drive solution for smaller circulators in variable flow systems.

Permanent magnet motor – Fixed speed
In systems with fixed flow, its lower energy losses at full speed mean that it is still beneficial to use a Permanent Magnet motor, even though the full benefits of much reduced low flow operation can not be realised.

7.2 Costs and environmental benefits of design options

This section calculates the additional costs of each of the identified design options, which are then used in chapter 7.3 as an input to the economic (LCC) analysis of each technology option.

7.2.1 65W standalone and 90W boiler integrated circulator

Ref	Design Option	Cost (%)	Cost (Euros)	Additional Cost (Euros)
1	Baseline	100	120	0
2	Speed Control (induction motor)	135	162	42
3	PM/Variable speed	200	240	120
4	Improved design – conventional technology	120	144	24

Table 7-1 Costs of improved design options

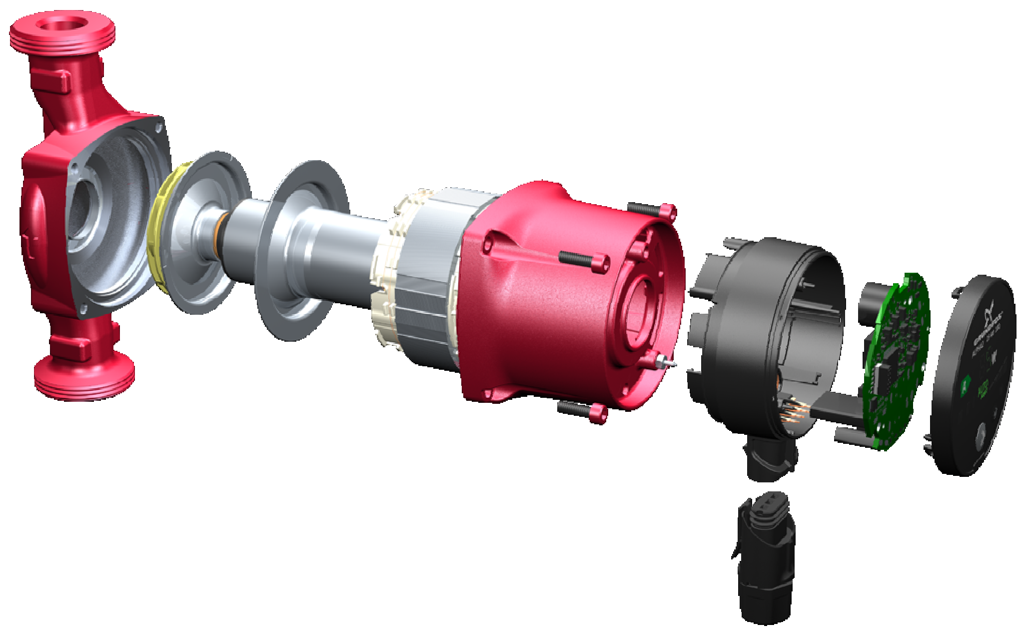


Figure 7-1 Exploded view of a Permanent Magnet circulator, showing the additional electronics and PM motor.

The lowest energy technology is the PM VS circulator, but there is a need to assess the other environmental impacts of this technology, as they do contain different materials.

A BOM for a typical Permanent Magnet (PM) circulator is shown in table 7-2. Figure 7-2 compares the environmental impact of this with the baseline model. This shows that despite the additional electronics used, the environmental impact is less than that of the standard basecase circulator in all categories.

	65 Watt PM Circulator, Standalone		27/09/2006	CG
Pos nr	**MATERIALS Extraction & Production Description of component**	**Weight in g**	**Category** Click &select	**Material or Process** select Category first !
1	Impeller	8.0	1-BlkPlastics	**4-PP**
2	Volute	912.0	3-Ferro	**23-Cast iron**
3	Copper windings	302.0	4-Non-ferro	**28-Cu winding wire**
4	Stator (rest)	253.0	3-Ferro	**24-Ferrite**
5	Rotor (rest)	130.0	3-Ferro	**24-Ferrite**
6	Shaft	21.0	3-Ferro	**25-Stainless 18/8 coil**
7	Motor housing	206.0	4-Non-ferro	**27-Al diecast**
8	Paint	24.0	5-Coating	**39-powder coating**
9	Operating instructions	250.0	7-Misc.	**57-Office paper**
10	Terminal box	77.0	1-BlkPlastics	**10-ABS**
11	Can	110.0	3-Ferro	**22-St tube/profile**
12	Bearing bracket + End Shield	98.0	3-Ferro	**23-Cast iron**
13	Packaging (recycled paper)	131.0	7-Misc.	**56-Cardboard**
14	Screws Etc.	15.0	3-Ferro	**23-Cast iron**
15	Misc material	125.0	3-Ferro	**23-Cast iron**
16	Misc material	125.0	1-BlkPlastics	**4-PP**
17	Printed circuit board	51.0	6-Electronics	**44-big caps & coils**
18	O-ring	6.0	1-BlkPlastics	**1-LDPE**

Table 7-2 BOM of a typical small (65W) Permanent Magnet standalone circulator

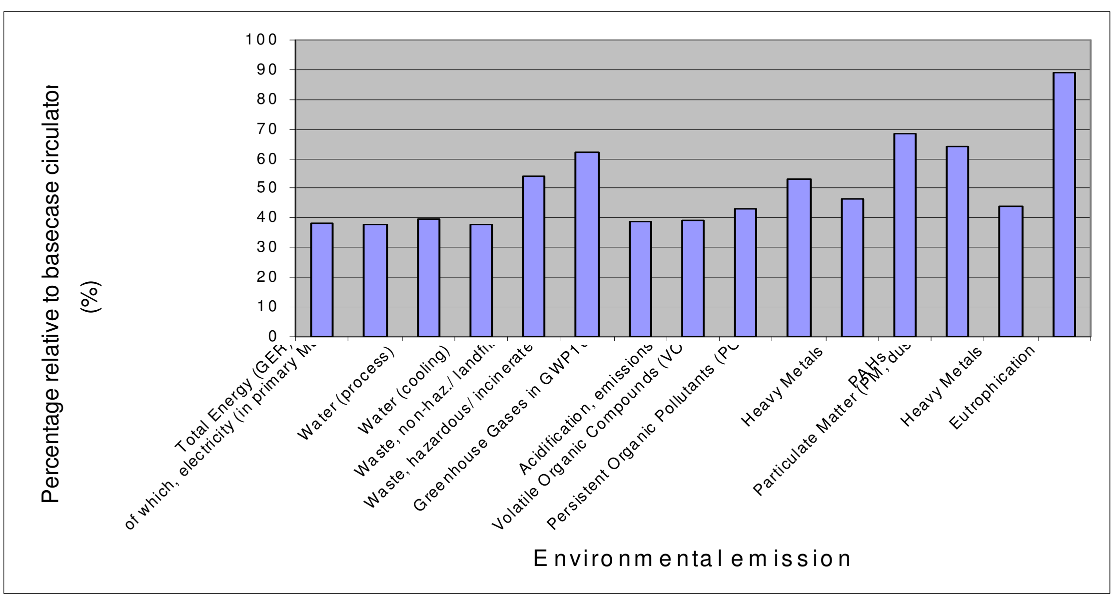


Figure 7-2 Comparison of the environmental impact of a PM and baseline circulator

7.3 Analysis LLCC and BAT

This section identifies the economic costs (to the consumer) and energy savings that are possible for each circulator type. Using the basecase model as the reference, it identifies the different groups of design options that are plausible for each type of circulator.[32] The LCC is calculated at a range of different operating modes and at both the average electricity price and at the high and low prices, as discussed in section 2.4.2.

The lifecycle cost is calculated as the sum of the purchase price plus the annual cost of energy times the product life (adjusted with a discount factor as in the MEEUP model).

7.3.1 Small 65W standalone circulator

Note that the LCC comprises the sum of the lifetime cost of energy and the purchase plus installation cost. Because it is assumed that they will be replaced rather than repaired if there is a problem, no maintenance costs are included in the LCC calculation.

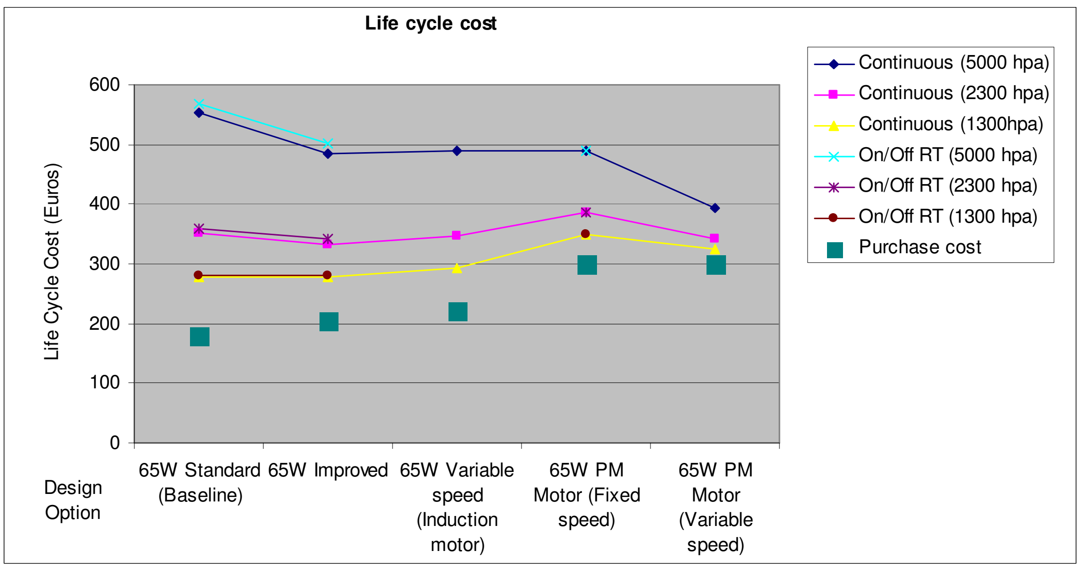


Figure 7-3 LCC Analysis: Economic and Energy analysis of different design options for improving circulators (electricity = 0.135 euros/kWh) – small 65W standalone circulator. 10 year life.

[32] The analysis in this circulators study is based on a number of discrete operating scenarios, which means that the LCC analysis is of a different nature from eg the Motors study where it is calculated simply as a function of running hours / electricity prices.

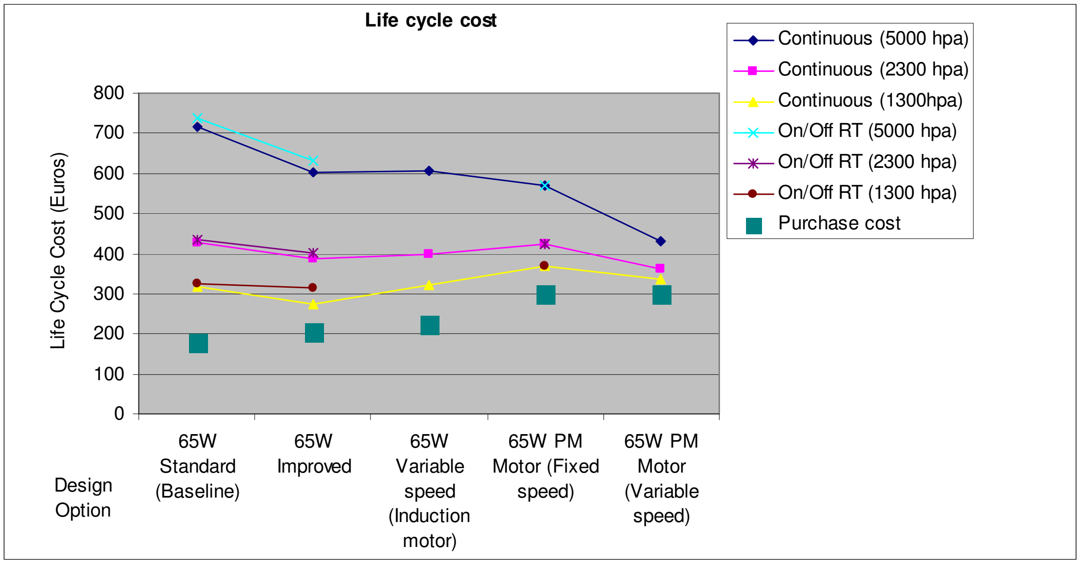


Figure 7-4 LCC Analysis: Economic and Energy analysis of different design options for improving circulators (electricity = 0.135 euros/kWh) – small 65W standalone circulator. *Comparison for a 15 year life.*

Tables 7-4 to 7-6 show the varying impact on LCC (Euros) of different electricity prices. *Note that the gaps on this table are for options that are not relevant for these products/applications. Also note that this table gives LCC values for each combination of technology/operating scenarios, whereas the MEEUP is calculated based on the weighted average (eg table 5-10).*

Design Option	Continuous (5000 hpa)	Continuous (2300 hpa)	*Continuous (1300hpa)*	*On/Off RT (5000 hpa)*	On/Off RT (2300 hpa)	*On/Off RT (1300 hpa)*
65W Standard (Baseline)	553	352	*277*	*569*	359	*281*
65W Improved	483	333	*277*	*502*	341	*281*
65W Variable speed (Induction motor)	491	346	*292*			
65W PM Motor (Fixed speed)	488	387	*349*	*488*	387	*349*
65W PM Motor (Variable speed)	392	342	*324*			

Table 7-3 LCC analysis - Electricity = 0.135 euros/kWh (Average price assumed in modelling) – small 65W standalone circulator, (Euros)

Design Option	Continuous (5000 hpa)	Continuous (2300 hpa)	*Continuous (1300hpa)*	*On/Off RT (5000 hpa)*	On/Off RT (2300 hpa)	*On/Off RT (1300 hpa)*
65W Standard (Baseline)	373	269	*230*	*382*	273	*232*
65W Improved	349	271	*242*	*358*	275	*244*
65W Variable speed (Induction motor)	361	286	*258*			
65W PM Motor (Fixed speed)	398	345	*325*	*398*	345	*325*
65W PM Motor (Variable speed)	348	322	*312*			

Table 7-4 LCC analysis - Electricity = 0.07 euros/kWh (Assumed low price) – small 65W standalone circulator, (Euros)

Design Option	Continuous (5000 hpa)	Continuous (2300 hpa)	*Continuous (1300hpa)*	*On/Off RT (5000 hpa)*	On/Off RT (2300 hpa)	*On/Off RT (1300 hpa)*
65W Standard (Baseline)	815	472	*345*	*842*	485	*352*
65W Improved	680	423	*328*	*711*	437	*336*
65W Variable speed (Induction motor)	679	432	*341*			
65W PM Motor (Fixed speed)	621	448	*383*	*621*	448	*383*
65W PM Motor (Variable speed)	457	372	*341*			

Table 7-5 LCC Analysis - Electricity = 0.23 euros/kWh (Assumed high price) – small 65W standalone circulator (Euros)

Figure 7-4 shows the total lifetime energy consumption of the different technology options under the different control modes.

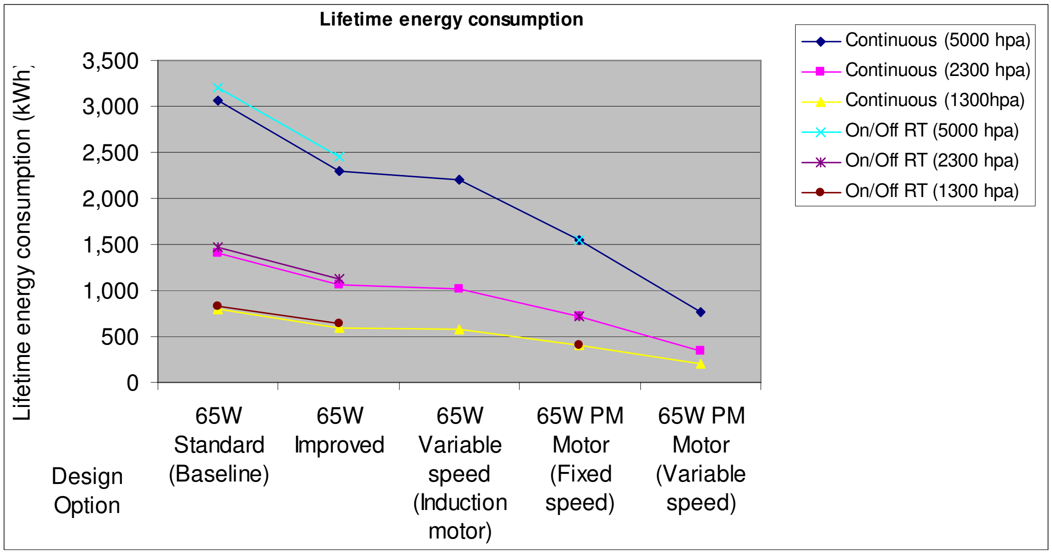


Figure 7-5 Lifetime energy consumption of the different technological options under different operating conditions.

7.3.2 Impact of policy options - 65W Standalone Circulator

From the previous analysis, two policy options are considered for these circulators;
(i) Making the "Improved" type the minimum allowable standard for all standalone circulators
(ii) Make Permanent Magnet type the minimum allowable standard for all standalone circulators

It is considered that sales of standalone circulators will remain static, as the growth in boiler sales will be satisfied by the slow transition to boiler integrated circulators. Table 7-6 shows the estimated (by AEAT) business as usual distribution of circulators by control (2020), then 8-2 and 8-3 the energy use situation under the two chosen scenarios:

Circulator type & control	Continuous (5000 hpa), %	Continuous (2300 hpa), %	On/Off Room Temp (2300 hpa), %
65W Standard (Baseline)	14	2	3
65W Improved	36	5	10
65W Variable speed (Induction motor)	5	3	
65W PM Motor (Fixed speed)			2
65W PM Motor (Variable speed)	15	5	

Circulator type & control	Continuous (5000 hpa), kWh pa	Continuous (2300 hpa), kWh pa	On/Off Room Temp (2300 hpa) kWh pa
65W Standard (Baseline)	2364	155	243
65W Improved	4554	291	620
65W Variable speed (Induction motor)	608	168	0
65W PM Motor (Fixed speed)	0	0	0
65W PM Motor (Variable speed)	627	96	0
Total Energy Use	**9,726 GWh pa**		

Table 7-6a/b Distribution by application and energy consumption of small standalone circulators (%), (ie NO further policies introduced)

Circulator type & control	Continuous (5000 hpa), %	Continuous (2300 hpa), %	On/Off Room Temp (2300 hpa), %
65W Standard (Baseline)			
65W Improved	30	5	10
65W Variable speed (Induction motor)	30	5	
65W PM Motor (Fixed speed)			5
65W PM Motor (Variable speed)	10	5	

Circulator type & control	Continuous (5000 hpa), kWh pa	Continuous (2300 hpa), kWh pa	On/Off Room Temp (2300 hpa) kWh pa
65W Standard (Baseline)	0	0	0
65W Improved	3795	291	620
65W Variable speed (Induction motor)	3647	280	0
65W PM Motor (Fixed speed)	0	0	196
65W PM Motor (Variable speed)	209	96	0
Total Energy Use	**9,133**	**GWh pa**	

Table 7-7 a/b Distribution by application and energy consumption of small standalone circulators (%) - scenario where the "Improved" type is the minimum that can be sold.

Circulator type & control	Continuous (5000 hpa), %	Continuous (2300 hpa), %	On/Off Room Temp (2300 hpa), %
65W Standard (Baseline)			
65W Improved			
65W Variable speed (Induction motor)			
65W PM Motor (Fixed speed)			15
65W PM Motor (Variable speed)	70	15	

Circulator type & control	Continuous (5000 hpa), kWh pa	Continuous (2300 hpa), kWh pa	On/Off Room Temp (2300 hpa) kWh pa
65W Standard (Baseline)	0	0	0
65W Improved	0	0	0
65W Variable speed (Induction motor)	0	0	0
65W PM Motor (Fixed speed)	0	0	588
65W PM Motor (Variable speed)	2926	288	0
Total Energy Use	**3,803**	**GWh pa**	

Table 7-8 a/b Distribution by application and energy consumption of small standalone circulators (%) - scenario where the Permanent Magnet motor type is the only type that can be sold.

Using the annual energy use of each type shown in table 4-11, the total energy use of small standalone circulators was calculated and shown in column two of Table 8-4. By deducting the energy savings likely anyway under the bau scenario, the additional energy savings expected under the two scenarios are calculated.

Scenario	Annual Energy Consumption once stock completely replaced by new split (GWh pa)	Energy savings relative to basecase (GWh pa)
Business as usual	9726	
Improved is the only type that can be sold	9133	593
Permanent Magnet is the only type that can be sold	3803	5923

Table 7-9 Projected total energy consumption and savings under different policy scenarios for small standalone circulators, assuming a total change of stock to the scenarios described.

7.3.3 Boiler Integrated (90W) circulator

This analysis uses exactly the same methodology as that for the standalone (65W) circulator in section 7.3.1.

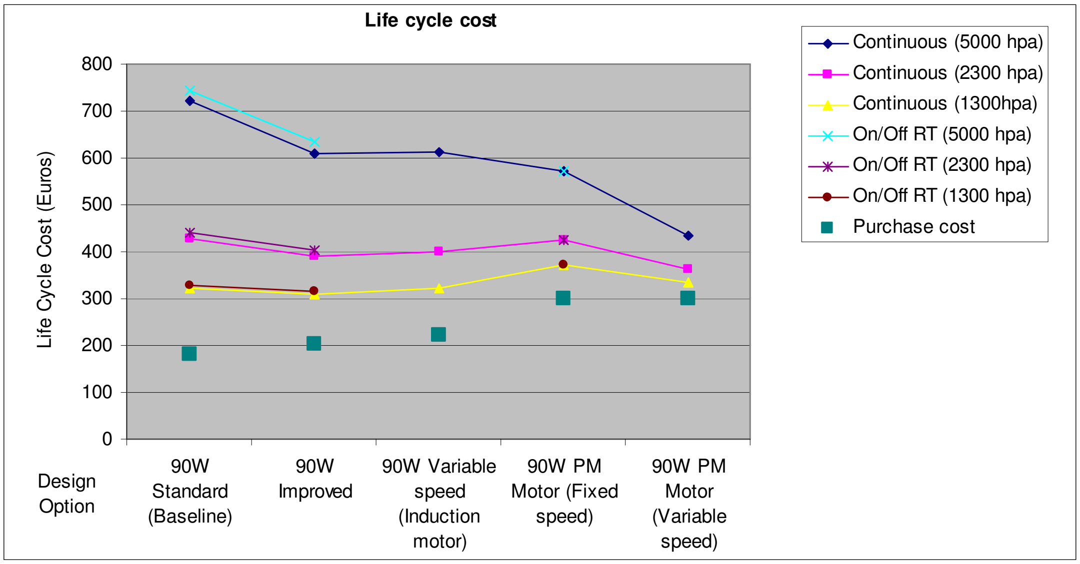


Figure 7-6 Life cycle cost curves for different circulator options under different operating/electricity price scenarios

Design Option	Continuous (5000 hpa)	Continuous (2300 hpa)	Continuous (1300hpa)	On/Off RT (5000 hpa)	On/Off RT (2300 hpa)	On/Off RT (1300 hpa)
90W Standard (Baseline)	721	429	321	744	439	327
90W Improved	609	390	309	636	403	316
90W Variable speed (Induction motor)	611	401	323			
90W PM Motor (Fixed speed)	573	426	371	573	426	371
90W PM Motor (Variable speed)	434	362	335			

Table 7-10 LCC analysis - Electricity = 0.135 euros/kWh (Average price assumed in modelling), (Euros)

Design Option	Continuous (5000 hpa)	Continuous (2300 hpa)	Continuous (1300hpa)	On/Off RT (5000 hpa)	On/Off RT (2300 hpa)	On/Off RT (1300 hpa)
90W Standard (Baseline)	460	309	253	472	314	256
90W Improved	414	301	259	428	307	262
90W Variable speed (Induction motor)	424	315	274			
90W PM Motor (Fixed speed)	442	365	337	442	365	337
90W PM Motor (Variable speed)	369	332	318			

Table 7-11 LCC analysis - Electricity = 0.07 euros/kWh (Assumed low price), (Euros)

Design Option	Continuous (5000 hpa)	Continuous (2300 hpa)	Continuous (1300hpa)	On/Off RT (5000 hpa)	On/Off RT (2300 hpa)	On/Off RT (1300 hpa)
90W Standard (Baseline)	1,101	604	420	1,140	622	430
90W Improved	894	522	383	939	542	395
90W Variable speed (Induction motor)	885	527	394			
90W PM Motor (Fixed speed)	765	514	421	765	514	421
90W PM Motor (Variable speed)	528	405	359			

Table 7-12 LCC Analysis - Electricity = 0.23 euros/kWh (Assumed high price), (Euros)

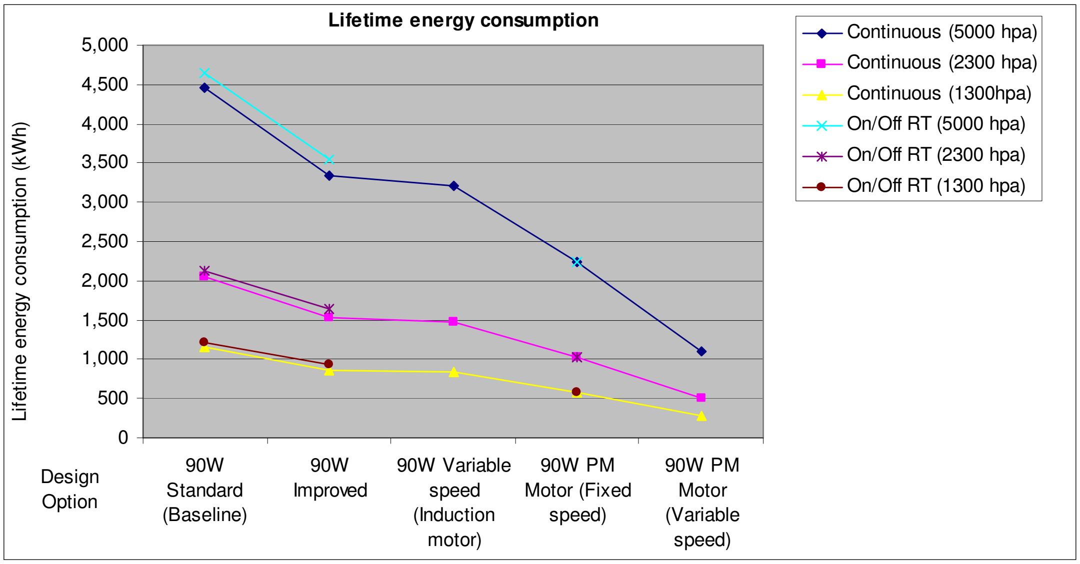


Figure 7-7 Lifetime energy consumption of different 90W Boiler Integrated circulators under different controls / operating hours

7.3.4 Large 450W standalone circulator

This analysis is the same as for the smaller circulators, but it is simplified due to On/Offf control not being used on these large circulators.

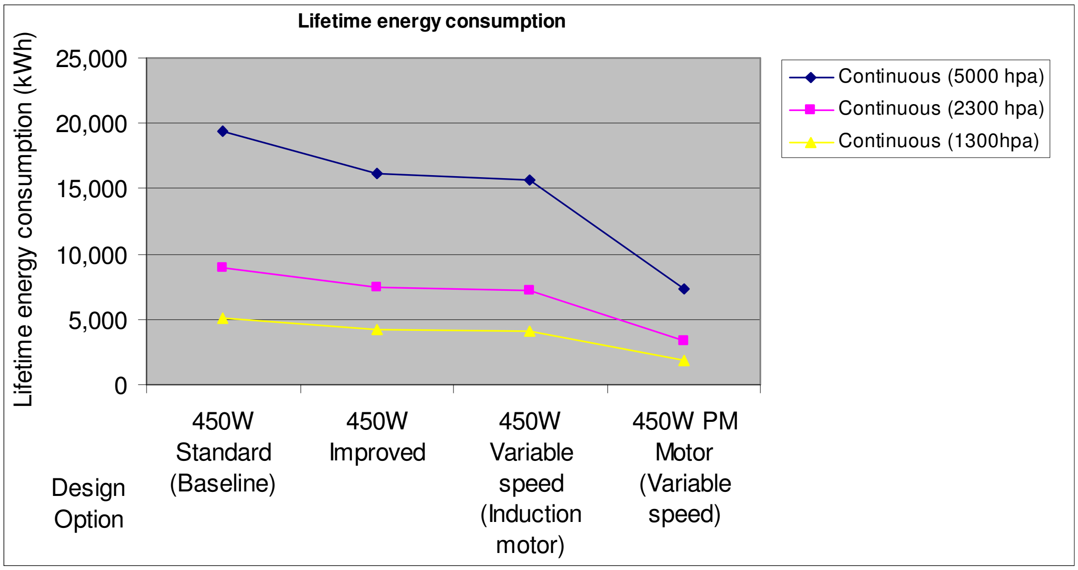


Figure 7-8 Annual energy consumption of different design options with different controls and operating hours.

Design Option	Continuous (5000 hpa)	*Continuous (2300 hpa)*	*Continuous (1300hpa)*
450W Standard (Baseline)	2,817	*1,544*	*1,073*
450W Improved	2,472	*1,413*	*1,020*
450W Variable speed (Induction motor)	2,581	*1,555*	*1,174*
450W PM Motor (Variable speed)	1,599	*1,114*	*934*

Table 7-13 LCC analysis - Electricity = 0.135 euros/kWh (Average price assumed in modelling), (Euros)

Design Option	Continuous (5000 hpa)	*Continuous (2300 hpa)*	*Continuous (1300hpa)*
450W Standard (Baseline)	1,682	*1,022*	*778*
450W Improved	1,527	*978*	*775*
450W Variable speed (Induction motor)	1,666	*1,134*	*936*
450W PM Motor (Variable speed)	1,166	*914*	*821*

Table 7-14 LCC analysis - Electricity = 0.07 euros/kWh (Assumed low price), (Euros)

Design Option	Continuous (5000 hpa)	*Continuous (2300 hpa)*	*Continuous (1300hpa)*
450W Standard (Baseline)	4,476	*2,307*	*1,504*
450W Improved	3,853	*2,048*	*1,379*
450W Variable speed (Induction motor)	3,920	*2,170*	*1,522*
450W PM Motor (Variable speed)	2,232	*1,405*	*1,098*

Table 7-15 LCC Analysis - Electricity = 0.23 euros/kWh (Assumed high price), (Euros)

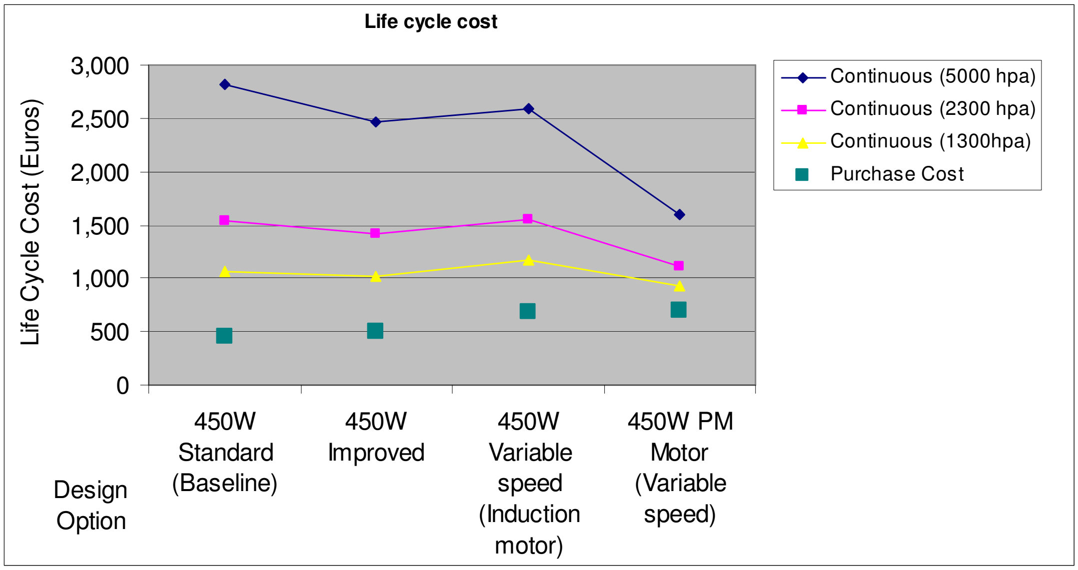


Figure 7-9 Life cycle cost curves for different circulator options under different operating scenarios, 0.135 euros/kW. 10 year life

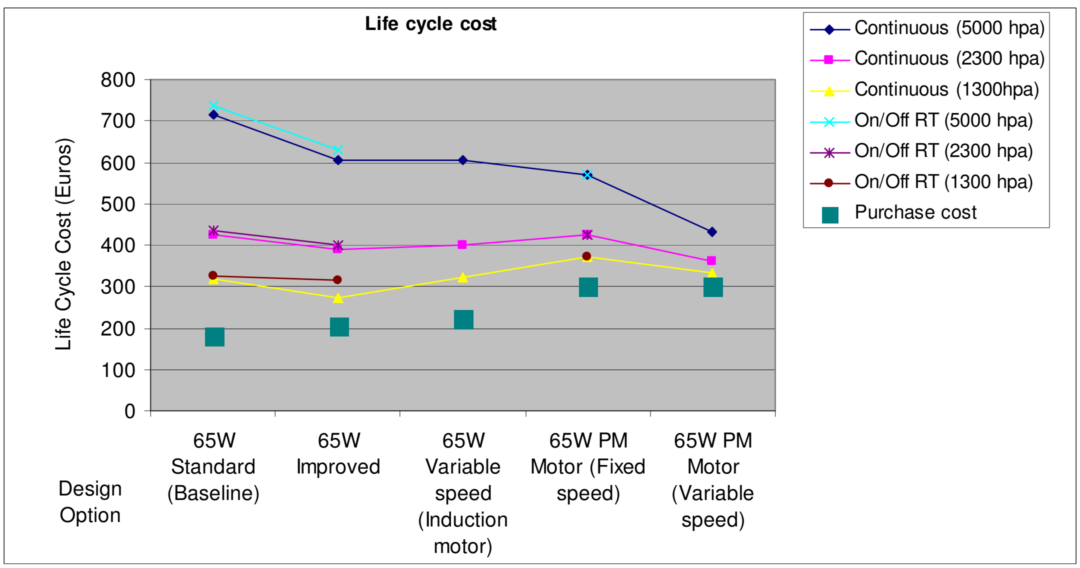


Figure 7-10 Life cycle cost curves for different circulator options under different operating scenarios, 0.135 euros/kW. 15 year life for comparison.

7.3.5 Impact of Policy Options - Large (450W) Standalone Circulator

From the previous analysis, two policy options are considered for these circulators;

(i) Making the “Improved” type the minimum allowable standard for all standalone irculators
(ii) Make Permanent Magnet type the minimum allowable standard for all standalone circulators

It is considered that sales of standalone circulators will remain static, as the growth in boiler sales will be satisfied by the slow transition to boiler integrated circulators.

The first table shows the baseline energy consumption, then 8-6 and 8-7 the energy use situation under the two chosen scenarios, (5,000 hrs pa).

Circulator type & control	%
450W Standard (Baseline)	25
450W Improved	55
450W Variable speed (Induction motor)	5
450W PM Motor (Variable speed)	15

Circulator type & control	Annual Energy Consumption (GWh pa)	
450W Standard (Baseline)	4,850	
450W Improved	8,883	
450W Variable speed (Induction motor)	783	
450W PM Motor (Variable speed)	1,110	
TOTAL	15,625	GWh pa

Table 7-16 a/b Distribution by application and energy use of large standalone circulators (%) (basecase scenario)

Circulator type & control	%
450W Standard (Baseline)	0
450W Improved	70
450W Variable speed (Induction motor)	10
450W PM Motor (Variable speed)	20

Circulator type & control	Annual Energy Consumption (GWh pa)	
450W Standard (Baseline)	0	
450W Improved	11,305	
450W Variable speed (Induction motor)	1,565	
450W PM Motor (Variable speed)	1,480	
TOTAL	14,350	GWh pa

Table 7-17 a/b Distribution by application and energy use of small standalone circulators (%) - scenario where the "Improved" type is the minimum that can be sold.

Circulator type & control	%
450W Standard (Baseline)	0
450W Improved	0
450W Variable speed (Induction motor)	0
450W PM Motor (Variable speed)	100

Circulator type & control	Annual Energy Consumption (GWh pa)	
450W Standard (Baseline)	0	
450W Improved	0	
450W Variable speed (Induction motor)	0	
450W PM Motor (Variable speed)	7,400	
TOTAL	7,400	GWh pa

Table 7-18 a/b Distribution by application and energy use of small standalone circulators (%) - scenario where the Permanent Magnet motor type is the only one that can be sold.

Table 7-19 calculates the projected energy savings on a similar basis to that used in table 7-9.

Scenario	Annual Energy Consumption once stock completely replaced by new split (GWh pa)	Annual energy consumption in 15 years time (est) (GWh pa)	Energy savings relative to basecase (GWh pa)
Business as usual	15,625	19,531	
Improved is the only type that can be sold	14,350	17,938	1,594
Permanent Magnet is the only type that can be sold	7,400	9,250	10,281

Table 7-19 Projected energy consumption and savings under different policy scenarios for large standalone circulators.

7.4 Long term targets (BNAT) and systems analysis

At the current time, a permanent magnet motor with control electronics and improved hydraulics is regarded as “state of the art”, with no prospect of anything other than minor improvements at R&D stage. It is therefore not possible to suggest what long term targets (BNAT) beyond the current “state of the art” might be.

Although strictly out of the scope of this study, external system effects would impact circulator energy consumption:

Boiler heat exchanger design
For manufacturers of boilers, a high resistance heat exchanger represents a lower cost way to transfer heat energy from the combustion chamber to the radiator system water. Reducing this resistance will reduce the energy consumption of the circulator, but will impact the cost/performance of the heat exchanger.

Specification of circulator in boiler integrated designs
In order to minimise the risk of a circulator being unable to cope with the occasional high resistance system, the designer will specify a circulator which deliberately has excess head capability.

Improving insulation of dwellings
Improved thermal insulation will reduce the running hours of the boiler and hence of the circulator.

Education
Because they cost relatively little, installers are reluctant to spend much time in the correct specification of circulators. Most circulators are therefore over-sized, with 3-speed circulators usually left in the maximum speed position as the default. Encouraging installers to take a bit more time in selecting the right sized circulator would save energy with existing technology.

Reduction in wet central heating systems
As fossil fuels are depleted, prices will inevitably increase, although its hard to know by how much or when. Long term there could be more of a reliance on electrical (dry) air systems, which would not need any circulator power.

7.5 Summary

This section has evaluated the Life Cycle Costs of the following design options; variable speed (conventional motor), variable speed (permanent magnet motor) and improved design of existing circulators.

The analysis gives the following key results:

- **Under average operating conditions (electricity = 0.135 euros/kWh) and the most typical conditions of 5,000 hours pa, both "improved" and permanent magnet circulators give a reduction in LCC to the consumer.** Even for systems working just 2,300 hours pa, these options still show a reduction in LCC to the consumer, although the PM circulator in fixed speed mode is not attractive. This is the case when using on/off room thermostat control, which is a poorer system that should not anyway be encouraged, and as it occurs mostly in countries (eg UK and Eire) with higher electricity prices, few consumers would in practice experience a higher LCC from moving to this type of circulator. **The suggestion by some stakeholders that the average life of a circulator is 15 years or more (compared to the 10 years assumed in this analysis) would further emphasis the economic benefits to the user of purchasing PM circulators.**
- In all cases, the Permanent Magnet circulator has the lowest annual energy consumption, and the baseline circulator (standard design, fixed speed) the highest.
- The ranking of the lifetime energy consumption of the different types of circulator is the same irrespective of the duty.
- The benefits of the variable speed (induction motor) circulator are not hugely greater than that of the improved standard circulator, and are considerably less than can be gained from use of a PM circulator. This is reflected in the declining market share of induction motor variable speed circulators.

Although outside the scope of this study, the following changes in system design could impact circulator usage and energy consumption in the future:

- Boiler heat exchanger design
- Specification of circulator in boiler integrated designs
- Improving insulation of dwellings
- Reduction in wet central heating systems

8 Policy, Impact and Sensitivity Analysis

8.0 Overview

8.0.1 Summary

This chapter summarizes the outcomes of all previous tasks relevant for this chapter, it looks at suitable policy means to achieve the savings potential e.g. implementing LLCC as a minimum and BAT as a promotional target, using legislative or voluntary agreements, labelling and promotion. It draws up scenarios in the period 1998 – 2020 quantifying the improvements that can be achieved vs. a Business-as-Usual scenario. It makes an estimate of the impact on consumers as described in Appendix 2 of the Directive, explicitly. In a sensitivity analysis of key cost-effectiveness parameters, the robustness of different possible outcomes are analysed. Possible impacts in the pump manufacturing industry are also presented.

The principle recommendation of this study is to set the minimum energy efficiency level at EEI <0.30, as the minimum standard allowed to be sold in the EU. This level is corresponds with the proposed new A* level of the Europump voluntary scheme, which makes it a very practical definition for the industry and consumers. . This would save 13.0TWh pa by 2020, based on the earliest possible start date of 2012. In addition, it is recommended that some changes are made to the voluntary Europump labelling scheme to take account of changes in the market since it was first introduced

The current class A should be split into class A, class A* and class A**, as class A is no longer sufficiently challenging to manufacturers. For larger circulators, existing technology (BAT) can only achieve class A*, and so it is recommended as the minimum standard that can be sold.

An alternative option would be to make class B circulators the minimum standard that can be sold in the EU, which if implemented in 2012 would lead to energy savings of 1.75TWhpa by 2020.

Policy Option	Date
Existing labelling scheme to be made mandatory, including the definition of a new A* and A** category of premium product	2010
Include actual calculated typical energy performance on the energy label	2010
Make class A* the MEPS (CE mark)	2012
OR Make class B the MEPS (CE mark)	2012

Table 8-1 Summary of policy recommendations

8.0.2 Circulators – overview

Circulators in buildings are used primarily for pumping water in central heating systems, with <1% used for other applications such as solar water heating or chilling systems. They range in size from 25W – 2500W, and are always sold as an integrated pump:motor assembly. The circulator market is somewhat unusual in that circulators are almost exclusively manufactured and sold within the EU. There are an estimated 140M circulators in the EU-25, with few used outside of Europe. The total current energy use of circulators in EU-25 is 53.2 TWhpa. In this study we distinguish between two types (formal definitions in 8.1.5):

- The "Standalone" circulator (figure 8-2) is separate from the boiler and is purchased as a separate product. The typical size of a circulator used in a single house is 65W, and that of commercial or residential buildings is 450W, of which there are 6.5M sold pa.

- The "Boiler Integrated" circulator is supplied to the user already integrated into the boiler. It has a typical power consumption of 90W, of which there are 7.5M sold pa.

The Environmental Impact analysis on the all relevant environemental impacts identified in the EC MEEUP model shows that in all cases it is the in use phase that dominates, and so improving the energy performance of the products is key to reducing the lifetime environmental impact.

Although the study analysed the circulators, as defined in Chapter 8.1.1, on the basis of the primary function, four technical products can be distinguished[33]:

1 – Standard (basecase)

This is the most popular type of circulator that uses a fixed speed induction motor.

2 – Improved

This is the same as the basecase circulator, but will have lower losses due to improvements in the hydraulics and/or motor.

3 - Variable speed (induction motor)

This uses thyristor control to alter the speed of the induction motor.

4– Permanent Magnet circulator (considered to be the currently Best Available Technology, or BAT).

This uses a much more efficient type of motor that is always driven by control electronics that allow the speed to be varied. Even in on/off room thermostat control systems which have to work in fixed speed mode, this still gives energy savings over standard induction motor driven circulators. To understand the economics of the different options under different operating scenarios, the analysis in this section is undertaken separately for fixed and variable speed operation (table 8-2).

The energy efficiency levels used in this analysis are those used in the Europump voluntary labelling scheme.. Also, the efficiency classes are known by the industry and its customers, which makes their use practical. The revised energy efficiency values proposed are shown in figure 8.1.

[33] Fixed speed circulators are sometimes known as *uncontrolled*, and variable speed circulators as *controlled*.

Class	Energy Efficiency Index (EEI)
A**	EEI < 0.20
A*	0.20 ≤ EEI < 0.30
A	0.30 ≤ EEI < 0.40
B	0.40 ≤ EEI < 0.60
C	0.60 ≤ EEI < 0.80
D	0.80 ≤ EEI < 1.00
E	1.00 ≤ EEI < 1.20
F	1.20 ≤ EEI < 1.40
G	EEI ≤1.40

Figure 8-1 Proposal for a revised circulator labelling scheme

Figure 8-2 Small standalone circulator

There is an existing technical standard EN 1151on circulator performance measurement, which is currently under revision. This revised standard will allow measurement of circulator performance to a tolerance that is adequate for defining a CE minimum standard, and also define how to measure variable speed circulators. It is expected that a draft of this will be published in advance of the first Consultative Forum meeting. There is also an existing voluntary labelling scheme for standalone circulators up to 2,500W, which is found to be adequate for the current mix of products on the market.

The actual energy saved will vary from system to system, but under all common operating profiles the use of improved standard circulators and those with Permanent Magnet variable speed control is economically attractive. Possible changes in the wider system to which they are connected could have a much larger impact on EU circulator energy consumption than any further improvements in circulator technology itself, but detailed consideration of this is outside the scope of this report.

Circulators are excluded from WEEE and RoHS legislation, but even so, all existing designs appear from our research to be compliant.

Circulators in different countries run under different scenarios, with the continuous operating profile representing the typical continental mainland operation (70% of systems), with the balance representing mainly UK and Ireland. Each technology option is evaluated using the different operating profiles so as to allow comparisons of the different types under realistic operating conditions. The Blauer Engel flow distribution is described in the following section.

Control option	Annual running hours	Flow profile
Continuous	5,000	Blauer Engel
On/Off Thermostatic Radiator Valve (TRV) control	2,300	Blauer Engel
On/Off control	2,300	100% or OFF

Table 8-2 The three assumed circulator operating profiles considered in this study.

8.1 Policy and scenario analysis

8.1.1 Precise definition of the types of circulators covered (Annex VII part 1 of the Directive)

The definition of products to be included in the scheme is all circulating pumps “circulators” that are:

- Primarily designed for space heating applications. (Some circulator types may also be suitable for other applications such as cooling, heat pumps and solar heating.)
- Electrical power consumption not exceeding 2500W. In the case of twin pumps, this is the rating of each individual pump.
- Wet running (glandless). This means that the motor is running in the fluid that is being pumped.
- Of centrifugal design. (Other designs would be allowable if the same quality level is reached with respect to comfort, reliability, noise and life time.)

- Only standalone types are included. These are circulators sold for installation outside of the boiler. (Circulators supplied to the consumer fitted within the boiler “boiler integrated circulators” are not included).

In order to encourage innovation, no limitations on the physical design of circulators are stipulated.

8.1.2 Existing initiatives

Existing EU initiatives impacting circulators are reviewed in this section:

- Europump voluntary circulator labelling commitment.
- European Commission Energy Plus Pumps scheme.
- National initiatives

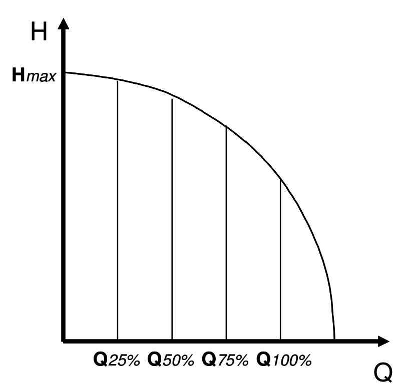
8.1.2.1 Circulator Labelling Commitment[34]

The leading European circulator manufacturers, represented by Europump, in January 2005 launched a classification and voluntary labelling scheme applied to comprised circulators up to 2500W in heating applications. Information on the impact of the scheme to date is shown in Figure 8-7.

The Energy Efficiency Index (or EEI) on which this scheme is based is calculated as follows (detailed example in Appendix 1):

1.) A reference power consumption for the particular mechanical power consumption is found from a defined reference curve (Appendix 1).

Flow (%)	Time (%)
100	6
75	15
50	35
25	44



[34] also ‘Ecopump - Circulators Labelling Commitment’, www.europump.org

Figure 8-3 Standalone Circulator load profile as described by the German *Blauer Engel* energy labelling scheme

2.) The (electrical) energy consumption of the particular circulator is calculated using the "energy weighted" method that takes account of the energy consumption of the circulator at the 25%, 50%, 75% and 100% flow points, as determined by a standard time-flow profile curve, (figure 8-3).

3.) The ratio of the calculated mean electrical power to the reference power is known as the Energy Efficiency Index, or EEI.

The existing Europump voluntary circulator labelling scheme is based on this method, and uses the thresholds shown in figure 1-10.

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

Figure 8-4 The Energy Efficiency Index for the existing voluntary labelling scheme

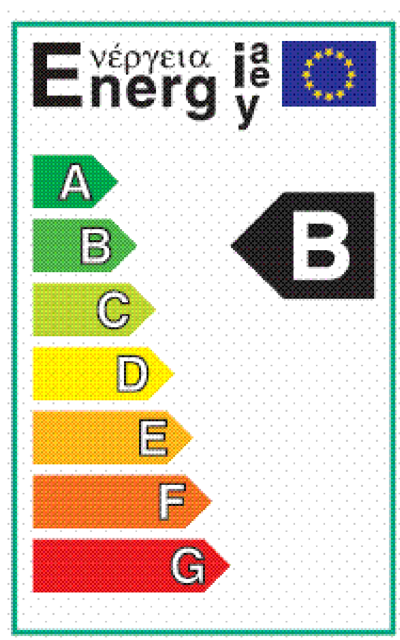


Figure 8-5 Label for the Europump voluntary labelling scheme

Figure 8-7 presents the most recent data on circulator sales, by class.

8.1.2.2 Energy Plus Pumps

The Energy Plus Pumps scheme is a marketing initiative to promote higher efficiency circulators, and is supported by the Intelligent Energy programme of the European Commission. See www.energypluspumps.eu.

The short-term objective of the project is to bring even more *(high efficiency)* products to the market, to support their rapid break-through and thereby to reduce their prices through mass production. It aims to do this by presenting comprehensive and transparent information which will influence buyers and ultimately lead to procurement initiatives.
The ultimate long-term objective is to transform the market so that the new technology will become the standard technology, at prices close to those of today's pumps. Figure 8-6 is an extract from the Energy Pumps Plus web-site that shows the scope of the work.

The Energy+ goal will be achieved through the methods of technology procurement that have been successfully tested in the European Energy+ project for energy-efficient refrigerators and freezers.
The overall idea of this process is to get confidence between the participating parties and create awareness of the benefits of energy-saving technologies.

Procurement Declaration
Particularly large institutional buyers will be invited to sign the procurement declaration to express their serious intention to invest in energy-saving and ecological technology of Energy+ products.

Supporter Declaration
National, regional and local energy agencies, environmental and consumer NGO, energy companies, and other organizations interested in the subject are asked to sign the supporter declaration for help Energy+ with dissemination of information and campaigning activities.

Development and Lists of Energy+ products
Energy+ invites manufacturers of circulators or condensing boilers to induce the development or integration of high-efficiency circulation pumps, to list these products and to present them for the Energy+ Award.

Awards
Energy+ grants three different awards: first, for the best energy-efficient circulator, second, for the best energy-saving condensing boiler, and third, for the best supporting campaign.

Dissemination of information
Having an especially important role dissemination will be achieved through presenting the project at the ISH fair in Frankfurt, by information folders and posters about the project, listing of the product, partners and supporters on the Energy+ pumps website (www.energypluspumps.eu).

Training of installation contractors
Finally, installation contractors will be involved receiving easy-to-us materials about the new technology and being trained how to sell the high-efficient pumps based on life-cycle costs.

Figure 8-6 Scope of the Energy Pumps Plus scheme

A key aspect is a listing of superior pumps, which are those <300W which meet Class A efficiency, an example of which is given in figure 1-13, (for clarity only three of the circulators on this particular listing are shown). This type of product is classified as Permanent Magnet (Fixed or variable speed) in the detailed analysis in this study.

8.1.2.3 Legislation at member state level

In **Denmark**, Heating systems must be designed with lowest possible pressure loss, taking into account the functionality and economics of the heating system. Selection and control of pumps must ensure the lowest possible electricity consumption of the pump.

Pumps must be automatically controlled according to the flow and pressure demand at the actual duty point. Excluded are pumps which operate in constant flow systems, for example those with heating coils in air conditioning systems. The pump control must not limit the ability to achieve the desired comfort level or minimum flow rate requirements.
In **Germany** legislation requires the installation of speed controlled circulators in heating systems larger than 25kW (heating power).

Outside the European Community, in **Switzerland** there is a recommendation to use Variable speed circulators.

We were unable to find any other relevant legislation in third countries. This reflects the fact that wet heating systems are largely restricted to European Countries. There is a small but growing market in these systems in the USA.

While the above initiatives are positive, they are not in themselves sufficient to transform the wider EU market, and so EU regulation is justified.

8.1.2.4 Historic sales of circulators, by class

This shows that there has been a big shift from class D to class B circulators, with class A also increasing slightly. A basic interpretation would be that the introduction of the labelling scheme has led to this positive shift in the market, but in reality this coincided with manufacturers launching new ranges of products, so it is difficult to estimate the impact of the labelling scheme. While the recent minor sales in class A and significant increase in the sales of class B products has been driven by this combination of a voluntary labelling scheme and manufacturers launching new products, it is thought that this growth in improved products will be limited without further market stimulation.
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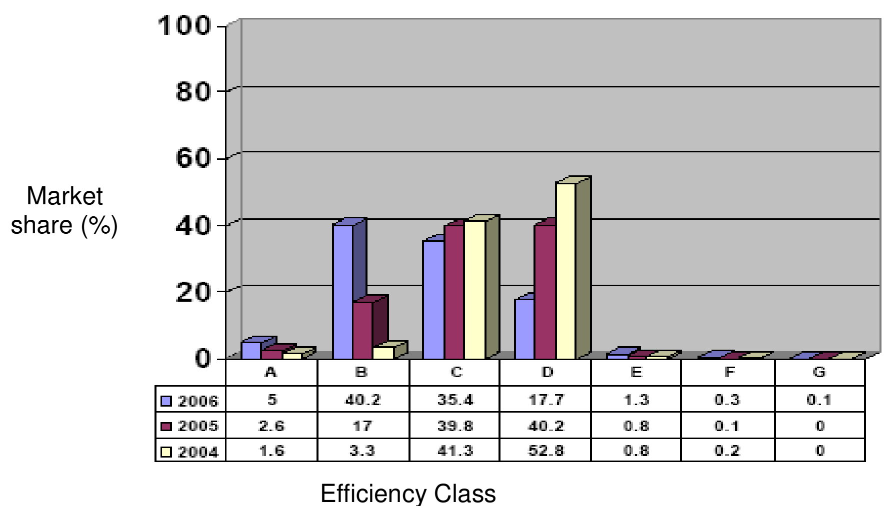


	A	B	C	D	E	F	G
2006	5	40.2	35.4	17.7	1.3	0.3	0.1
2005	2.6	17	39.8	40.2	0.8	0.1	0
2004	1.6	3.3	41.3	52.8	0.8	0.2	0

Figure 8-7 Breakdown of sales, by efficiency class, for standalone circulators <2.5kW. [35]

[35] Report from Europump published July 2007.

8.1.2.5 Additional impact of an Ecodirective (2 policy scenarios and business as usual cases shown)

The following tables summarise the estimated 2022 energy consumption and additional savings possible for small and large standalone circulators under the scenarios of class B and class A* circulators being made the only type that can be sold from 2012. (2022 is chosen here because it is equal to the five year transition time thought to be the absolute minimum feasible plus the ten year life time after which it is assumed that the total stock is changed.)

Real life (BAT) circulators were used in the MEEUP analysis. The models chosen had an EEI of 0.2 (small) and 0.3 (large) respectively. Under the existing labelling scheme these are all classed as class A. The A* MEPS proposed under scenario 3 is more ambitious, but in reality the energy savings from setting the MEPS at class A will be very similar. This is because:
- By market share, the major manufacturers already have A* or better products available. Having made the technology leap necessary, there is little or no cost advantage in offering products which only just meet the class A level.
- The proposed extension to the existing labelling scheme will encourage manufacturers to make products that meet the A* / A** criteria. (Such a split of the A category in order to differentiate the very best circulators is important in order that there is a tool for the promotion of such circulators.)
- In the analysis that follows, A* is used as the BAT for large circulators, and A** as the BAT for small circulators. But as discussed here, setting the MEPS for both sizes of circulators at A* or even A, will result in very similar energy savings.

Note that the energy savings stated usually refer to the energy savings with respect to the business as usual (bau) scenario. This is justified on the basis that it is unreasonable to claim energy savings from any implementing measures for improvements in efficiency of product sold that would have occurred anyway.

Scenario 1 – Business as Usual (bau)
This assumes that there is no additional EU or national regulatory actions. An estimate has been made of the projected impact of current regulation, which will lead to a further decrease in energy use, as shown below.

Scenario 2 – Class B is the minimum that can be sold
From 2012, only circulators that meet or exceed class B as defined in the Europump labelling scheme. This corresponds to an efficiency level of 0.40<EEI<0.60.

(In the analysis, the basecase EEI value was used for the calculation of energy consumption of <u>large</u> “improved” and “induction variable speed” motors. However, it has since become apparent that there are many examples of this type of technology on the market that meet or exceed the class B level. It is therefore recommended that class B is also made the minimum for large circulators under this scenario. The energy saving impact following is therefore an under-estimate).

Scenario 3 –Class A* technology is the minimum that can be sold
From 2012, only circulators that meet or exceed class A* as defined in the proposal for revision of the Europump labelling scheme.

Scenario	Annual Energy Consumption once stock completely replaced by new split (GWh pa)	Energy savings relative to basecase (GWh pa)
Scenario 1: Business as usual	9726	
Scenario 2: Class B is the MEPS 0.60≤ EEI < 0.40	9133	593
Scenario 3: Class A* is the MEPS 0.20 ≤ EEI < 0.30	3803	5923

Table 8-3 Projected total 2022 energy consumption and savings under different policy scenarios for small standalone circulators

Scenario	Annual Energy Consumption once stock completely replaced by new split (GWh pa)	Energy savings relative to basecase (GWh pa)
Scenario 1: Business as usual	19531	
Scenario 2: Class B is the MEPS 0.60≤ EEI < 0.40	17938	1594
Scenario 3: Class A* is the MEPS 0.20 ≤ EEI < 0.30	9250	10281

Table 8-4 Projected total 2022 energy consumption and savings under different policy scenarios for large standalone circulators, with 2022 savings adjusted to take account of increased stock.

8.1.2.6 Eco-impact of different policy options for reference years

The eco-impact of each policy option can be calculated in terms of the energy saving only. The estimated energy saving consumption for each reference year (2010, 2015, 2020) is shown below, with figures 8-8 projecting back to estimated consumption from 1990.

	Business as usual (GWh pa)	Class B is the MEPS (GWh pa)	Class A* is the MEPS (GWh pa)
Projected energy consumption (2022)	9,726	9,133	3,803
Projected energy consumption (2020)	10,107	9,632	5,368
Projected energy consumption (2015)	11,059	10,881	9,282
Projected energy consumption (2010)	11,630	11,630	11,630

Table 8-5 Summary of energy consumption for small standalone circulators for reference years and 2022.

	Business as usual (GWh pa)	Class B minimum (GWh pa)	Class A* minimum (GWh pa)
Projected energy consumption (2022)	19,531	17,938	9,250
Projected energy consumption (2020)	19,354	18,079	11,129
Projected energy consumption (2015)	18,910	18,432	15,826
Projected energy consumption (2010)	18,092	18,092	18,092

Table 8-6 Summary of energy consumption for large standalone circulators for reference years and 2022.

To check that the class A** (small) circulator used as the basecase model does not have an adverse eco impact, the total eco impact of the class A** circulator was compared to that of the standard circulator (below). In all categories of emissions it was found that the class A** (small) circulator had lower emissions.

The 2020 energy saving relative to the business as usual scenario from making class B the minimum (small and large circulators) is 1.75 TWhpa, and from making class A* the minimum is 13.0 TWhpa.

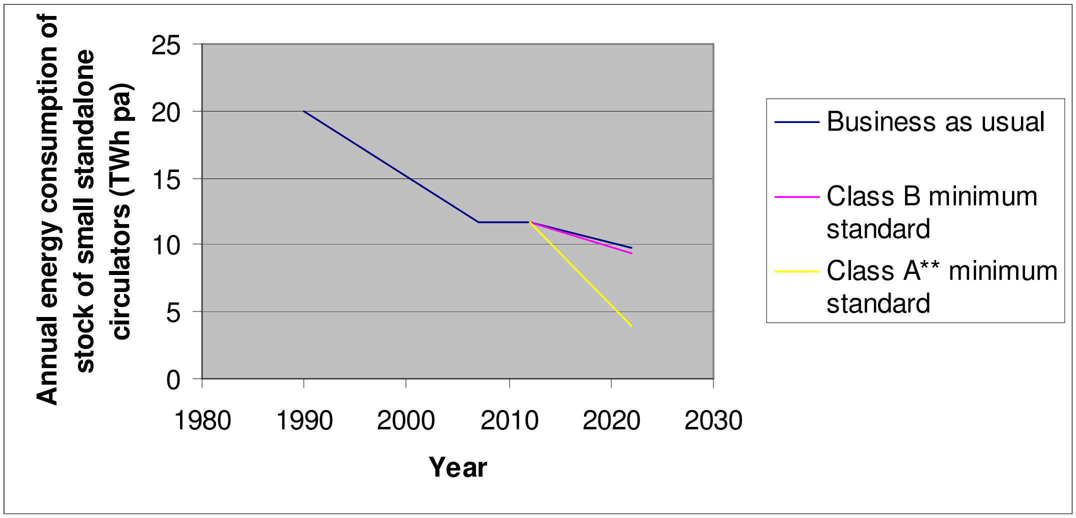


Figure 8-8 Energy saving projections for different policy scenarios, assuming implementation in 2010, for small standalone circulators projected back to 1990

Note. The apparent small energy saving for the Class B circulator shown in figures 8-7and 8-8 is because even under the BAU scenario a decrease in energy consumption of circulators is expected, and hence the lines are closer together than might be expected at first sight.

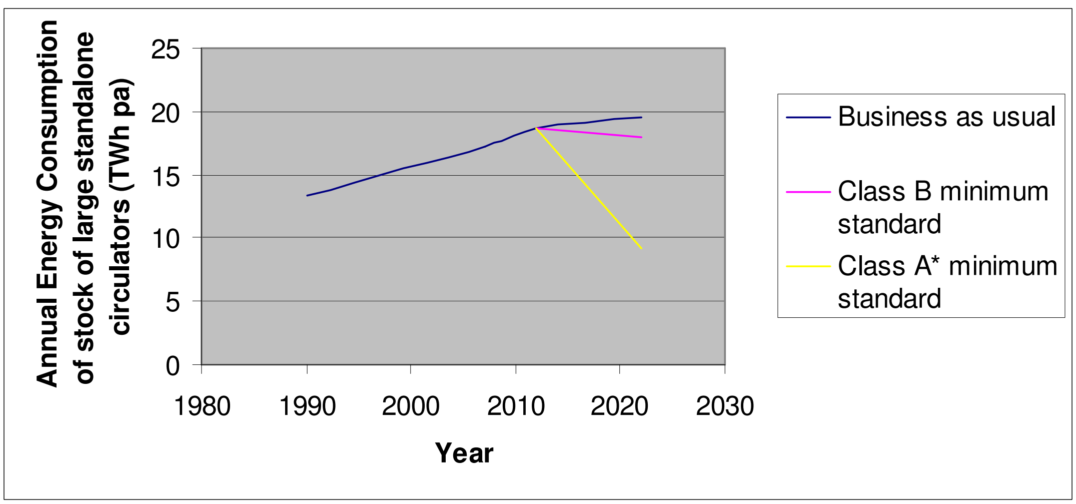


Figure 8-9 Energy saving projections for different policy scenarios, assuming implementation in 2010, for large standalone circulators

The market for large circulators is assumed to be growing at 1.5% per annum. It is similarly assumed that all circulators will be replaced by those of the basecase average for each type, not of the minimum efficiency for a given category.

8.1.2.7 Boiler Integrated Circulator (90W)

Because boiler integrated circulators are sold as part of a boiler that is itself an Energy Using Product, eco design measures are best considered as part of any regulations on the boiler. It should be stated that historically the manufacturers of boiler integrated circulators have been the largest buyer of variable speed circulators, and so there is an expectation that they will follow positive changes in the standalone circulator market without additional specific policies being applied to them. This trend can be expected to be reinforced with the possible MEPS introduced on boilers, as suggested in the Lot 1 study.

Option of premature replacement of circulators

Given the short time to the suggested date of introduction of the implementing measures, it is not thought that financial incentives to prematurely replace older circulators with class A circulators is a useful option.

Based on an estimate of 3.5 hours to fit a new circulator, it would cost at least 100 euros labour plus the cost of the new circulator to make the change. However, it is an inconvenience to have this done, with the householder seeing no secondary benefit in addition to the energy saving. Despite the attractive energy savings shown in the LCC analysis, it is estimated that there would be few users prematurely replacing their circulator with an improved one. However, for example offering subsidies on class A circulators so that they can be sold at the same price as standard circulators might tempt some users to make the change. But under either scenario there would be a large proportion of “freeriders”, ie those users who need a new pump anyway claiming financial support.

8.1.3 Recommended changes to the Labelling scheme

Split of class A

Because the class “A” category in the existing voluntary labelling scheme is very wide (for all sizes of circulators), the study proposes two additional classes as shown in figure 8.2. This will encourage the development of products past the minimum level for class A and help manufacturers to work within a transparent legislative framework during the coming ten years or so. This will also reduce the administrative cost, when the future classes can be defined in one implementing measure only. However, should market developments require, the levels could be updated at a later stage.

Once class A* has become the minimum standard that can be sold, the existing A-G voluntary labelling scheme will be updated based on the above proposal. This should be seen very positively as an example of how labelling can contribute to transforming a market and how it can provide the industry a transparent legislative framework and ensure an adequate labelling class for the most innovative industry right at the introduction of new more efficient products. It could then be replaced by a new labelling scheme where the current class A is the minimum shown. This would mean that the class B and below would become obsolete, although this may also be shown on the revised energy label.

The A* level is based on what can be achieved in larger circulators, and A** what can be achieved by smaller circulators. But because there is not any major technological difference between what is a large and small circulator, it is unreasonable to set different MEPs for the different sizes. **Therefore A* should be defined as the MEPs for all sizes, with A** used as a promotional or labelling level for superior small circulators**.

To help differentiate the performance of different circulators in advance of the split of class A circulators into new classes, the actual calculated energy consumption based on operation for 5,000 hours pa should be shown alongside the class label.

Standby Power

Only a small proportion of large circulators incorporate a “standby” function, which offers one or both of the following functions:

- On a few (poorly designed) systems, the circulator will run even when all radiator valves are closed. This is necessary in this configuration to ensure that flow will start as soon as a valve opens. This is not regarded as being part of a true “standby” mode, rather it is a “safety mode” as defined within the parallel EUP study on the subject. Such a mode is excluded from the EUP proposals.

- On some larger systems, the circulator will be controlled by an external Building Management System, and so will have a permanent small “standby” power. However, the energy savings from this external control will greatly exceed that of this additional power consumption. This mode would be subject to the EUP Standby measures.
It is though agreed that there is little point in also including the standby mode in the EEI calculation.

8.1.4 LCC analysis of the different technology options

As shown in the Life Cycle Cost (LCC) analysis shown in the section on sensitivity analysis (8.3), the Best Available Technology (BAT) is, in the majority of cases, also the Least Life Cycle Cost (LLCC) option. There was insufficient data to calculate the performance of the Best Not Available Technologies identified (BNAT), as there are no test results available. Accordingly, Class A* (large circulators) and class A** (small circulators) is both the BAT and LLCC option, and BNAT (anything with an EEI > 0.20), is not considered any further

8.1.5 Basis of legislation – the EU Circulator Labelling Scheme

There is an existing circulator labelling scheme (Appendix 1), which it would be good to use as the basis of legislation if possible. This is based on the circulator Energy Efficiency Index (EEI), (Figure 8-2), and gives a fair indication of the energy performance of the circulator under real life conditions. For the small standalone circulator, table 8-7 shows how the class of the models shown do align neatly with the labelling system. Any measures should not though be technology specific, as they should allow any current or future technology that meets the EEI criteria to be entitled to the label.

Therefore any legislation could use the existing labelling scheme as the basis for the defined minimum performance standards.

Class (existing scheme)	Energy Efficiency Index	Class under proposed revised scheme	Circulator type & control
D-G			
C	0.8	C	**65W Standard (Baseline)**
B	0.60	B	**65W Improved**
	0.58	B	**65W Variable speed (Induction motor)**
A	0.39	A	**65W PM Motor (Fixed speed)**
		A*	
	0.199	**A****	**65W PM Motor (Variable speed)**

Table 8-7 Comparison of 65W (small) circulator technology with the existing EEI labelling scheme.

But for the large standalone circulator, the “Improved” option falls towards the top of the class C band, and so using class C to define the minimum standard for the “improved” scenario would not lead to any significant change at all, (table 8-8).

Class (existing scheme)	Energy Efficiency Index	Class under proposed revised scheme	Circulator type & control
D-G			
C	*0.8*	C	**450W Standard (Baseline)**
	0.66	C	**450W Improved**
	0.64	C	**450W Variable speed (Induction motor)**
B		B	
A		A	
	0.3	**A***	**450W PM Motor (Variable speed)**
		A**	

Table 8-8 Comparison of 450W (large) circulator technology with existing EEI labelling scheme.

The existing labelling scheme is therefore not appropriate for defining an "improved" large circulator minimum energy performance standard. However, if class A* is to become the minimum allowable performance level, then this weakness in the labelling scheme will not matter in the longer term.

This existing voluntary Europump labelling scheme should be made mandatory, including the new definitions of A* and A, which would mean that control should be taken over by the European Commission.**

8.1.6 The ecodesign requirement for the circulators covered, implementing date(s), staged or transitional measures of periods. (Annex VII part 2 of the Directive)

The environmental impacts of circulators have been studied in detail in the following categories as detailed in Annex I sections 1.1 and 1.2 of the EUP Directive. The result of this work is that it is only the energy efficiency of the circulator that should be the subject of regulatory action.

This is illustrated in figure 8-9.

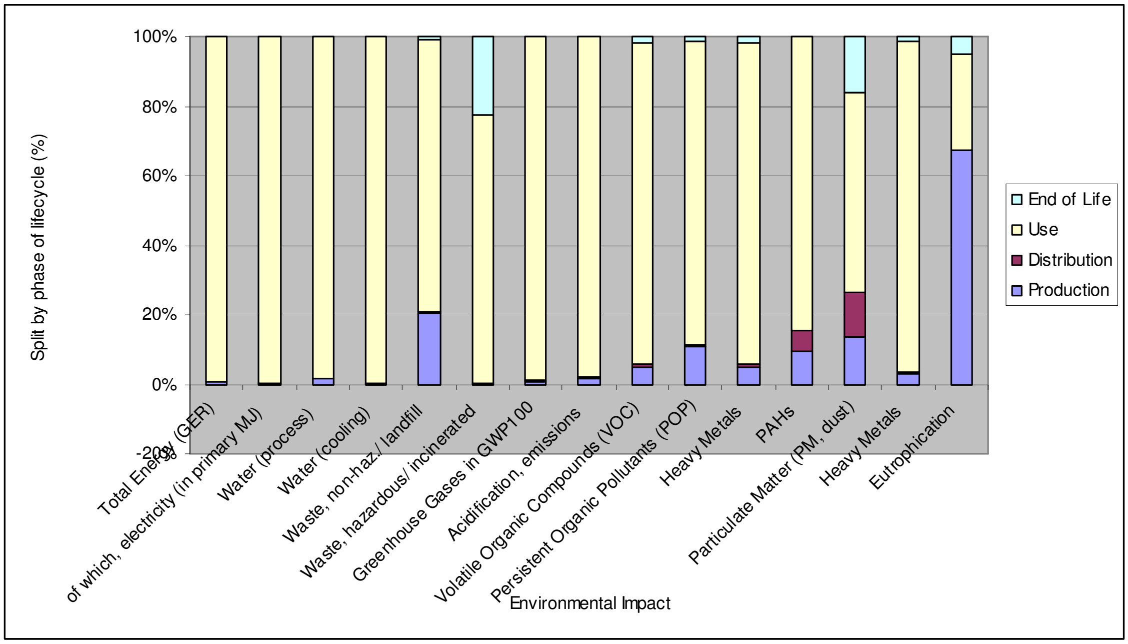


Figure 8-1 Environmental impact by phase of lifecycle - 65W standalone circulator

8.1.7 The ecodesign parameters of circulators to which no ecodesign requirement is necessary (Annex VII part 3)

Generic ecodesign requirements aim at improving the environmental performance of EuPs, focusing on significant environmental aspects thereof without setting limit values. Reducing the energy consumption of circulators will reduce the different emissions caused by the generation of electricity at power stations. Limiting values on energy efficiency will effectively set limits on some of the emissions listed below. **Therefore there is no need for defined limiting values on any other ecodesign parameters.**

WEEE and RoHS

Neither WEEE or RoHS legislation applies to these products. Despite this, as the end-of-life of circulators is an important issue, the materials content in all designs means that they are in any case compliant. In section 7.2 the MEEUP analysis is applied to the newer PM variable speed circulator that includes a Permanent magnet motor and electronic control PCB, but even the materials of this newer product are still RoHS compliant.

8.1.8 Requirements on installation and maintenance of the EUP (Annex VII part 4 of the Directive)

Based on the study, there is no need for additional installation or maintenance requirements of circulators that have a direct relevance on the circulator's environmental performance. Guidance provided in product documentation as presented today is sufficient.

Best practice in the installation of circulators and design of the entire boiler system should be followed for all central heating systems in order to minimise energy consumption and maximise the lifetime of the circulator. Lot 11 Boiler study includes such information.

8.1.9 Measurement standards to be used (Annex VII part 5 of the Directive)

The relevant standard for performance testing of circulators is EN 1151-1:2006 '*Pumps – Rotodynamic pumps – Circulation pumps having a rated power not exceeding 200W for heating installations and domestic hot water installations. Part 1: Non automatic circulation pumps, requirements, testing, marking'.*

This standard is applicable to circulators rated 200W and less, it states that circulators rated 200W and less as being generally for domestic use whilst those larger than 200W are generally for use in commercial or residential buildings. The classification methodology for the Europump Circulators Classification Scheme[36] uses this test standard, despite the range of circulators covered by the scheme being rated up to 2500W.

This is currently being revised by CEN to take account of the need for tighter tolerances and the need to be able to measure variable speed circulators. It is expected that a draft of this will be released in advance of the first Consultation Forum meeting. *It was not possible within the study to define precisely how tight it is practical to make the tolerances, but any proposals from CEN should be carefully reviewed to check that the new requirements will be adequately tight to underpin the recommended policy options. These tolerances will impact the minimum bandwidth for the revision of the labelling scheme.*

8.1.10 Details for conformity assessment under Decision 93/465/EEC (Annex VII part 6 of the Directive)

The circulators in scope of this regulatory action shall be subject to conformity assessment under Directive 93/465/EEC module A, (internal production control).

8.1.11 Requirements of the information to be provided by manufacturers (Annex VII part 7 of the Directive)

Manufacturers will need to make available the following documentation to facilitate the checking of the compliance of the circulator with the implementing measure:

- Full results of performance tests to EN1151.
- Calibration certificates of measurement equipment.
- In the case where performance is calculated from other models of a similar type, full details of these calculations.

8.1.12 Duration of the transitional period for placement of compliant EUP's on the market (Annex VII part 8 of the Directive)

Making either class A* or class B the minimum would require considerable additional R&D effort on the part of manufacturers to design and put into production models meeting these standards. For class A*, in addition to re-designing the hydraulic stage, new types of motor and electronic assemblies will need designing. For the smaller companies without this expertise, this would represent a major technological step forward. Even for larger companies who currently have many class A* models, to convert ALL designs to this class will take some time.

Class B would still require new designs of circulators, but the technology would not be a "stepping stone" to class A*, as class A* is quite different in design. Hence there is no advantage in a stepped "class B and then class A*" approach.

It is recommended that 5-8 years (five years minimum) is allowed in order to make class A* the minimum standard allowed.

[36] Industry Commitment: To improve the energy performance of Stand Alone Circulators through the setting up of a classification scheme in relation to energy labelling, Europump, January 2005 (www.europump.org)

8.1.13 Date for the evaluation and possible revision of the implementing measures (Annex VII part 9 of the Directive)

Growth in sales of current class A and B circulators means that in order to encourage further development of product efficiency, the current class A efficiency band should be split as proposed above. This will create a new minimum efficiency level that can be promoted through a revision of the existing Europump voluntary labelling scheme.

Due to the recent rapid increase in sales of class A circulators, it is important to define values for classes above the class A. It is suggested that this situation is reviewed five years after the introduction of the new label and MEPS.

8.1.14 Distribution of products

The 10 year lifetime assumed in the study is in turn assumed to lead to a 10 year complete stock turnover. Some reports put the life time at nearer 15 years, which would reduce the rate of energy savings by a third – but the final savings achieved would be the same.

The decrease in sales shown from 1990 is due to the shift to boiler integrated circulators. From 2007 it is assumed that the market for small standalone stays static, but that for larger circulators continues to increase at 1.5% pa.

8.1.15 Growth rates and substitution effects

The projections are based on no changes or substitutions up to 2022. There are though several factors that might impact this estimate:

Increase in other forms of heating, for example biomass or electric heating. With current costs this is unlikely, but should the price of gas or oil increase sharply, then this might lead to fuel switching and hence a decrease in sales of circulators.

The commercialisation of stirling engine driven circulators driven by “waste” heat from the boiler could lead to circulators with zero electrical energy consumption. It is too early to speculate on the likely success of this innovation.

Decentralised circulators fitted to small groups of radiators in place of a single circulator will lead to many more units being sold, but it is too early to speculate whether there would be a net change in electrical energy consumption.

Sales of boiler integrated and large circulators are assumed to grow at 1.5% pa. It is further assumed that all future growth in the small circulator market will be of boiler integrated types, with sales of the standalone type remaining static.

8.1.16 Total environmental impact of the eco-design measures

The basecase circulators were characterised in terms of their bill of materials and energy performance, and then the eco-impact of each phase of lifetime compared. For all types of circulator the following results were found:

- The Use phase dominates for all categories of emissions.[37]
- The proportions of the environmental impacts in each lifecycle phase are similar for each circulator.
- Because the impact of material selection and use only contributes slightly to the total lifecycle eco-impact, reducing the usage of materials is a commercial issue for manufacturers rather than an important eco-impact issue.

[37] The apparent exception to this is eutrophication (acidification) where the factor for stainless steel in the model is unrealistically high compared to more normal accepted values (eg SimaPro). Hence the results for eutrophication are misleading, as the In Use phase should really dominate.

The conclusion of this is that the focus of the study should be on the "In Use" phase of the circulator lifecycle, as this is where the greatest impact of the product comes from. What this means in practical terms is that it is the energy performance of the product that is critical to reducing the environmental impact of the products.

To be confident that the eco –impact of the permanent magnet circulator (BAT) is indeed less than that of the standard circulator, emissions of the two were compared in each category, and in each the permanent magnet circulator was found to have lower emissions, (figure 8-10).

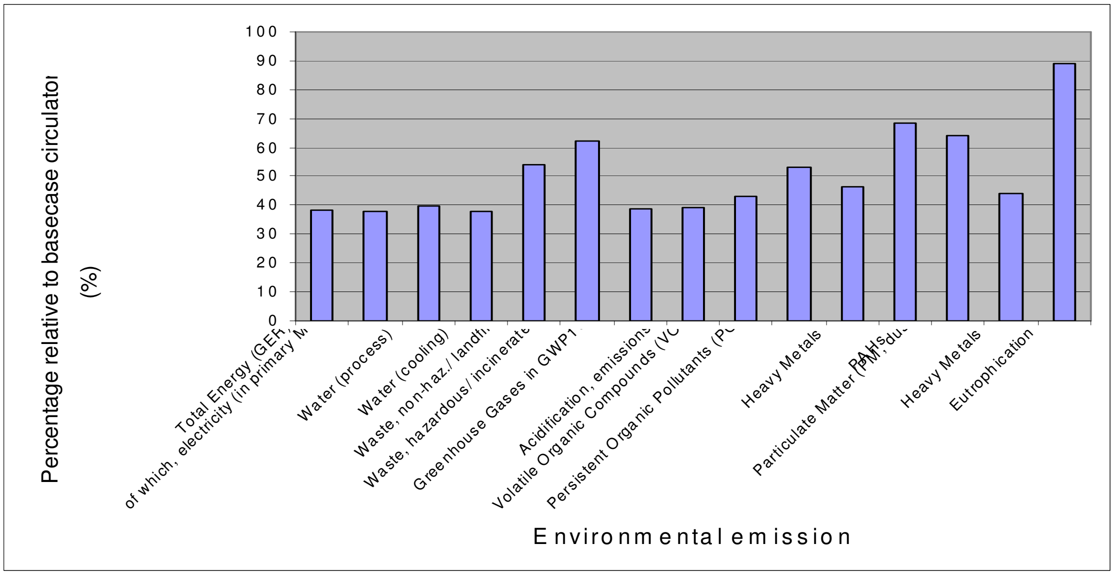


Figure 8-2 Comparison of the eco-impact of a Permanent Magnet (class A**) circulator compared to the standard circulator, showing how the eco-impact is less for all types of emission.

8.1.17 Harmonised standards – health and safety

The following are the key harmonised standards applying to circulators, none of which are considered to impose difficult design constraints on standard or improved products:

EN ISO 12100-2:2003, Safety of machinery – Basic concepts, general principles for design – Part 2: Technical principles (ISO 12100-2:2003)

EN 60335-1:2002/A2:2006 Safety of household and similar electrical appliances: General requirements.

EN 60 335-2-51: 2003 Specification for safety of household and similar electrical appliances. Particular requirements for stationary circulation pumps for heating and service water installations.

8.1.18 Harmonised standards – Noise and Vibrations

EN 1151-2:2006 *'Pumps – Rotodynamic pumps – Circulation pumps having a rated power not exceeding 200W for heating installations and domestic hot water installations. Part 2: Noise test code (vibro acoustics) for measuring structure – and fluid borne noise'.*

EN 1151-1:2006: This is the most common standard for performance testing of circulators and is formally titled:
EN 1151-1:2006 '*Pumps – Rotodynamic pumps – Circulation pumps having a rated power not exceeding 200W for heating installations and domestic hot water installations. Part 1: Non automatic circulation pumps, requirements, testing, marking'.*

This test is regarded as a type test, as it should be applied to several samples of the same type of pump. There are some weaknesses in this standard:

- **The permissible tolerance on the operating head (at the zero flow point) is large (+/- 10%).**
- **The standard does not specify <u>any</u> tolerances for the equipment used to measure the flow.**
- **The standard does not provide any specific guidance as to how efficiency should be determined.**

To calculate pump efficiency, the ratio of hydraulic power to the mechanical shaft power must be determined. Hydraulic power cannot be measured directly and is calculated by measuring the operating head and flow. The wide tolerance in operating head as permitted by the test standard will result in a wide spread of the final calculated efficiency value. This error will be carried through to calculations of energy consumption: for small circulators with typical input powers under 100W and operating heads under 5 metres the wide head tolerance may not impact the absolute energy consumption figures significantly, however as circulator sizes increase so their corresponding power consumption increases and the absolute error in energy consumption becomes large.

One explanation given for the wide head[38] tolerance is that it is difficult to manufacture small circulators to tight tolerances. In addition the relative losses in the motor element due to bearings and friction, and a wide stator to rotor gap – to allow fluid passage – are relatively high.

With increasing circulator size, the relative losses due to these factors is reduced.

Europump specify EN1151-1 as the test standard for all circulators in their labelling scheme (including circulators up to 2500W). However *when calculating efficiency (and energy consumption) of the larger circulators consideration must be given to the wide tolerance in the standard.*

EN9906:1999 Rotodynamic pumps - Hydraulic performance acceptance tests - Grades 1 and 2
The standard EN9906 is currently undergoing redrafting and will have a section relating to pumps rated down to 200W.

EN1151-3: A new annex to standard EN1151-3 is currently being drafted for application on variable speed controlled circulators.

The study group is unaware of any standards relating to circulators larger than 200W.

Due to the deficiencies associated with the EN1151-1:2006 test standard the following recommendations are made[39]:

- The tolerance on head measurement should be reviewed[40] and a tolerance published for the first time on flow measurement.
- A new or revised test standard for fixed speed integrated (combined motor pump) circulators in the size range 200W to 2500W is developed.

However, it should be noted that because of the way the Europump voluntary circulator labelling scheme calculates the energy performance (EEI), the final error in calculation of the EEI value will be less than these wide tolerances might imply.

This tolerance is critical for specifying the minimum bandwidth when devising revisions to the labelling scheme. Although the 0.2-0.3 gap is smaller than the bandwidth of 0.2 at lower levels, because the performance line used in calculating the EEI has an offset, this 0.1 gap is proportionately larger.

Energy Performance of Buildings Directive 2002/91/EC
The Directive is set to promote the improvement of energy performance of buildings with four requirements to be implemented by the Member States:

[38] Output pressure
39 CEN/TC 197/SC4/WG1 "Circulation Pumps" is currently revising EN1151, and has its next meeting scheduled for January 8th, 2008
[40] For circulators up to 200W, the current tolerance is thought by some manufacturers to accurately represent the total tolerance on manufacturing spread plus measurement uncertainty. For larger circulators the tolerance does need altering, as it is not possible to simply "scale up" from that applying to small circulators.

- General framework for a methodology of calculation of the integrated performance of buildings
- Setting of minimum standards in new and existing buildings
- Energy Certification of Buildings
- Inspection and assessment of heating and cooling installations.

One requirement of the EC Energy Performance of buildings Directive is that air conditioning systems with a capacity of greater than 12kW must be inspected regularly. This may have implications for some circulator systems.

http://ec.europa.eu/energy/demand/legislation/buildings_en.htm

The German standard DIN 18599 quotes electrical consumption per square meter per year, which has an impact on the selection of circulator.

There is a draft European standard (15362), which is the equivalent of the above German standard.

General EC safety and environmental legislation applicable to circulators includes the following:

Low Voltage Directive (LVD) 73/23/EEC
For the purposes of this Directive "electrical equipment" means any equipment designed for use with a voltage rating of between 50 and 1 000 V for alternating current and between 75 and 1 500 V for direct current.
http://ec.europa.eu/enterprise/electr_equipment/lv/direct/73-23.htm

General Product Safety Directive (GPSD) (2001/95/EC)
The Directive applies to products intended for or likely to be used by consumers. It obliges producers to place only "safe" products on the market.
http://ec.europa.eu/consumers/cons_safe/prod_safe/gpsd/currentGPSD_en.htm

Machinery Directive 98/37/EC
This directive provides the regulatory basis for the harmonisation of the essential health and safety requirements for machinery at a European Union level. Essentially performing a dual function, the Directive not only promotes the free movement of machinery within the Single Market, but also guarantees a high level of protection to EU workers and citizens.
Machinery is described in the Directive as "an assembly of linked parts or components, at least one of which moves, with the appropriate actuators, control and power circuits, etc., joined together for a specific application, in particular for the processing, treatment, moving or packaging of a material". The manufacturer is responsible for verifying whether a particular product falls within the scope of the Machinery Directive.
http://ec.europa.eu/enterprise/mechan_equipment/machinery/index.htm

Electromagnetic Compatibility (EMC) Directive 89/336/EEC as amended by 91/31/EEC and 93/68/EEC.
Since January 1 1996, most electrical and electronic products to be sold in the EC must be constructed so that they do not cause excessive electromagnetic interference and are not unduly affected by electromagnetic interference.
http://ec.europa.eu/enterprise/electr_equipment/emc/directiv/text2004_108.htm

8.2 Impact analysis industry and consumers

8.2.1 Timing of policy measures

As discussed in section 8.1.12, it is recommended that 5-8 years (five years minimum) is allowed in order to make class A the minimum standard of circulator allowed.

However, no matter how long a transitional time is given, there are likely to be some very small manufacturers who are unable or unwilling to find the capital necessary in order to develop and launch class A* circulators. This could lead to some companies going out of business with subsequent loss of jobs locally.

Of the nine manufacturers who have signed the A-G labelling commitment agreement, which covers more than 85% of the market in EU, six appear to already produce class A circulators in some styles.

8.2.2 Impact on jobs in the EU

The proposed A* minimum standard demands the use of new technologies that will raise the level of technical skills within EU manufacturers. The greater complexity of these is expected to lead to a small net increase in jobs within the EU, and an overall increase in skill levels. It is though possible that there would be a migration of jobs from small manufacturers unable to make the necessary investment to reach the A* standard to manufacturers who are able to make the change. The EU circulator market is dominated by EU manufacturers, and so it is not foreseen that there will be a net loss of jobs to non-EU countries. Demand for circulators will not change with initial purchase cost, as there are no alternatives and repair is impractical, and hence there will be no loss of jobs due to a change in market size. Installers are already familiar with permanent magnet variable speed circulators (the only type currently able to reach the proposed MEP levels), and so will not be impacted when these become the MEPs.

8.2.3 Cost to Consumer - affordability

The total additional cost to users, assuming 100% take-up for each option, is shown in tables 8-9 and 8-10 below.

(In this study, “small” is defined as any circulator up to 200W, and “large” as any circulator 200W – 2,500W. There is no distinct change in the products at this size, rather this is a rough indication of the change from single residential home heating to a larger system. The implementing measures suggested apply to all sizes of circulators, ie both the “small” and “large” used as the basis of the analysis in this report). Figure 8-12 gives the corresponding typical LCC analysis.

Class	Design Option	Purchase Cost * (Euros)	Typical lifetime cost of energy (Euros)	Sales (% of total, 2006)	Sales (Mpa), 2006	Additional cost to the consumer of making this level the MEPS (Meuro pa), relative to basecase
C/D	65W Standard (Baseline)	120	414	20	1.1	
B	65W Improved	144	310	35	1.925	**26.4**
B	65W Variable speed (Induction motor)	162	298	40	2.2	80.1
A**	65W Permanent Magnet	240	103	5	0.275	**487.7**

Table 8-3 Cost to consumers of making different technology options the minimum allowable standard, (small 65W standalone circulator). * Non energy costs such as maintenance and installation are independent of technology. Based on 5,000 hrs pa continuous operation and electricity cost of 0.135 euros/kWh.

This additional cost to the consumer is thought to be pessimistic, as the cost premium for class A circulators is likely to fall as volumes increase by up to say, 30%. (Note that this table excludes the financial benefits of the energy savings from the use of more efficient circulators, it is only considering the purchase costs). The 120 euro cost premium equates to 8.3 euros pa, which even in the cost sensitive domestic market is not thought to represent a problem of affordability to the consumer. This should in any case be compared to the LCC to the consumer of the class A technology that is similar or slightly less than that for the existing technology.

The large circulator is used in commercial or larger residential applications, where the 240 euro price premium would not be significant.

Class	Design Option	Purchase Cost (Euros)	Typical lifetime cost of energy* (Euros)	Sales (% of total, 2006)	Sales (Mpa), 2006	Additional cost to the consumer of making this level the MEPS (Meuro pa), relative to basecase
C/D	450W Standard (Baseline)	400	2619	20	0.2	
C	450W Improved	450	2180	35	0.35	**10**
C	450W Variable speed (Induction motor)	620	2113	40	0.4	103.5
A*	450W Permanent Magnet	640	999	5	0.05	**122.5**

Table 8-4 Cost to consumers of making different technology options the minimum allowable standard, (large 450W standalone circulator). * Non energy costs such as maintenance and installation are independent of technology. Based on 5,000 hrs pa continuous operation and electricity cost of 0.135 euros/kWh.

Figure 8-17 gives the corresponding typical LCC analysis.

Even if the cost premium did present a problem, there are no feasible alternatives to the use of circulators in wet heating systems.

8.2.4 Analysis of the results

An additional 13.0 TWh pa could be saved (2020) by making class A* circulators the mandatory minimum standard, and 1.8 TWh pa from making class B circulators the mandatory minimum standard. Note that these savings cannot be added together, as the class A circulators incorporate features of the improved design. In addition, further savings can be expected as sales of class A circulators into boiler integrated applications grow as a result of such legislation on standalone circulators.

There will be an initial cost to manufacturers to design and produce these circulators, but once in production, it is expected that market forces would lower the price, and hence profit margins would be similar to at present.

The consumer will have to pay a price premium for the class A* circulator, but they will still see reduced total costs of ownership through lower energy bills.

8.2.5 Summary – Average energy consumption of each basecase circulator

The following table shows the average annual energy consumption of each of the basecase circulators, which is used as the input to the MEEUP model:

Basecase type	Average Annual energy consumption (kWh pa)	Total energy consumption of the stock (TWh pa) 2010
Small (65W) standalone circulator	212	11,658
Large (450W) standalone circulator	1,710	17,070
Boiler integrated (90W) circulator	325	24,392
TOTAL		**53,120**

Table 8-5 Annual energy consumption (2007) of different types of circulator

8.3 Sensitivity analysis of the main parameters

The following analysis shows that under all usual combinations of operating hours, control systems and electricity prices, the policy scenarios suggested are still economically justifiable.

The majority (70%) of small standalone (typically 65W, in this study assumed to be up to 200W) circulators are running for 5,000 hrs pa. This is represented by the top line in each of the following LCC graphs in section 8.3, and in all cases shows a clear reduction in LCC when moving from basecase to class A* technology.

A further 15% of small standalone circulators are running for 2,300 hrs pa (continuous). This is represented by the middle lines in each of the following LCC graphs (figures 8-11 to 8-20). For the normal and high electricity prices this shows a clear reduction in LCC when moving from basecase to class A* technology. For the extreme (low) price of 0.07 euros / kW the LCC increases in all cases, but this would be extremely rare. Similarly, the extreme low running hours of just 1,300 hrs pa also shows an increase in LCC with the move to class A*.

There are several factors that would further improve the financial attractiveness to the consumer of moving to a class A* circulators:

- It is thought that the lifetime of a circulator may be as long as 15 years compared to the 10 year statistical average calculated in this study. This is analysed in figures 8-11/14 and 8-16/19 .

- It is estimated that an increase in sales of class A* or B circulators would lead to a decline in price by as much as 30% in the long term.

- Any increase in electricity price would also see the LCC of moving to more efficient circulators decrease. Such a trend can be visualised by moving comparing the LLC curve at the average electricity price of 0.135 euros/kWH to that of the maximum considered price of 0.23 kWhpa.

Not shown is the impact of lifetime of the product on the change of product stock. The assumption used in the analysis, in the absence of any firmer data, was that circulators have a life of 10 years, with all failing at this time. Hence any implementing measures would achieve their full effect within 10 years of implementation. By way of comparison, if the lifetime was 15 years, it would take 15 years for the full impact to be seen, and hence the energy saving at 2020 would be less than that estimated.

Note that the proposal for the class A* MEPs has an EEI of 0.3, is actually lower than that achieved by the modelled small (BAT) circulator (0.199). It is possible therefore that manufacturers would design small circulators to meet class A* rather than the class A** assumed in the model. However, given the focus on energy efficiency as a marketing tool, and the availability of A** circulators already on the market, it is thought that in practice smaller circulators will be class A**. For the larger large circulator market, an EEI of 0.3 represents BAT, and so this is not an issue.

8.3.1 Life Cycle Costing analysis

It is observed that the price premium for class A* products is currently very high, reflecting the need for manufacturers to get a return on their investment costs. But if the class A* was made the mandatory minimum standard, then the rapid increase in volume and increased competition from new suppliers would be expected to reduce the price considerably, perhaps by up to 30% (AEAT estimate). This would reduce the life cycle cost to consumers and hence make such improved products even more financially attractive than shown in the following scenarios.

For each size of circulator, the total lifecycle cost of ownership, assuming a 2% discount rate, is shown for six operating scenarios. The squares on each plot show the purchase cost, which increases with improving performance of circulator. The Least Life Cycle Cost (LLCC) to the consumer is the lowest point on the lines. The lifetime energy consumption is also shown for each of the circulators under each operating scenario. The results of the analysis of these graphs is shown in 8.3.2.

The efficiency class corresponding to each of the different technologies in the following sections is shown in tables 8-3 and 8-4.

Small Circulator

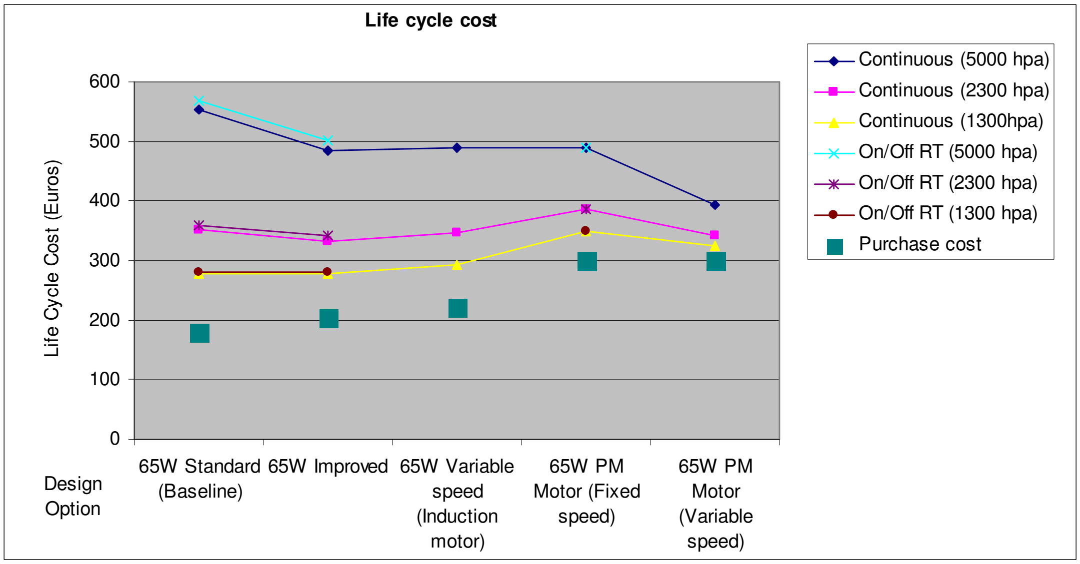


Figure 8-3 LCC Analysis: Economic and Energy analysis of different design options for improving circulators (electricity = 0.135 euros/kWh) – small 65W standalone circulator. 10 year life.

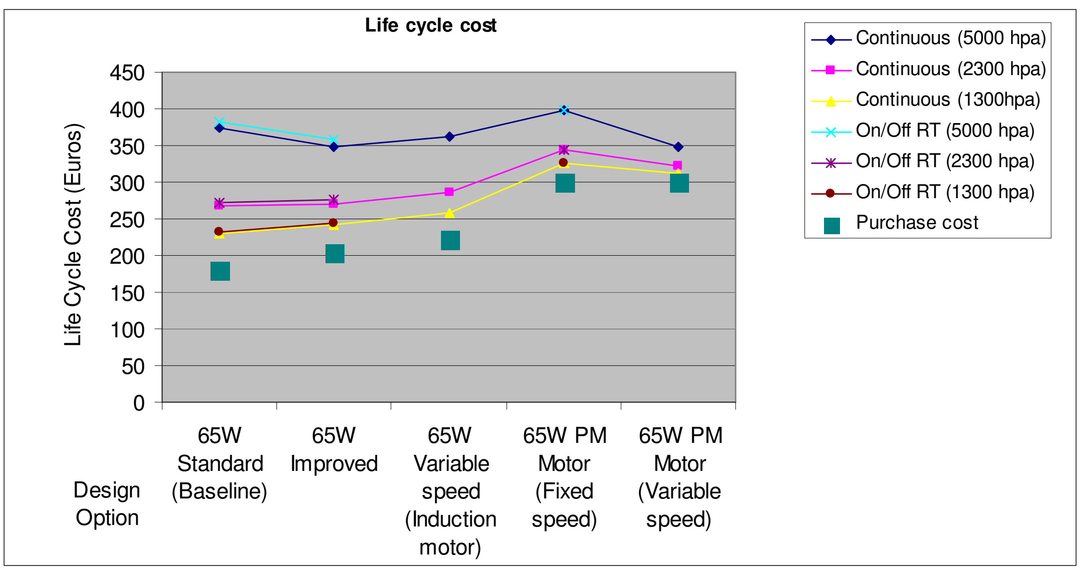


Figure 8-4 LCC Analysis: Economic and Energy analysis of different design options for improving circulators (electricity = 0.07 euros/kWh) – small 65W standalone circulator. 10 year life.

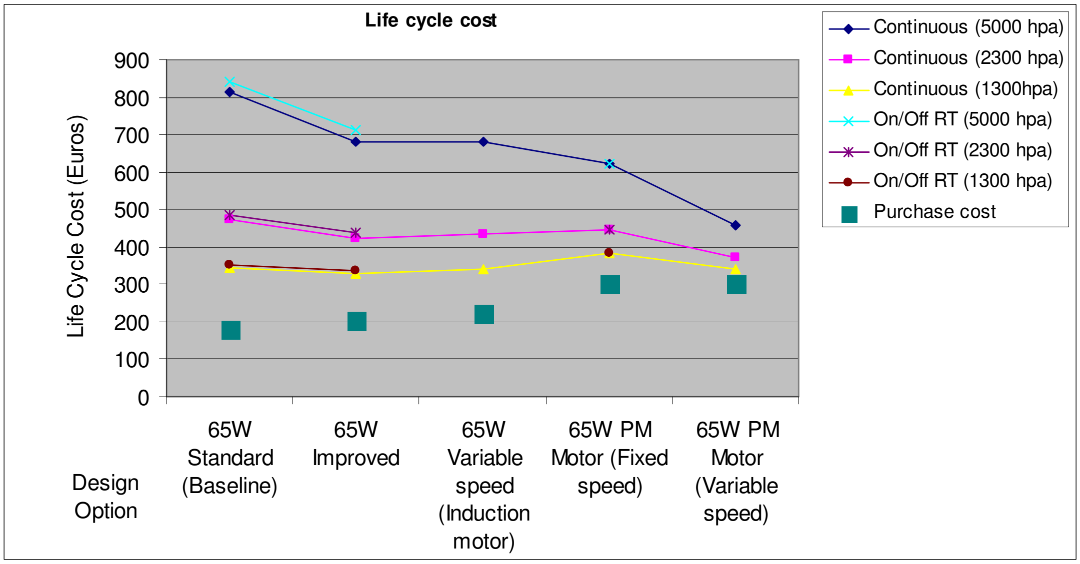


Figure 8-5 LCC Analysis: Economic and Energy analysis of different design options for improving circulators (electricity = 0.23 euros/kWh) – small 65W standalone circulator. 10 year life.

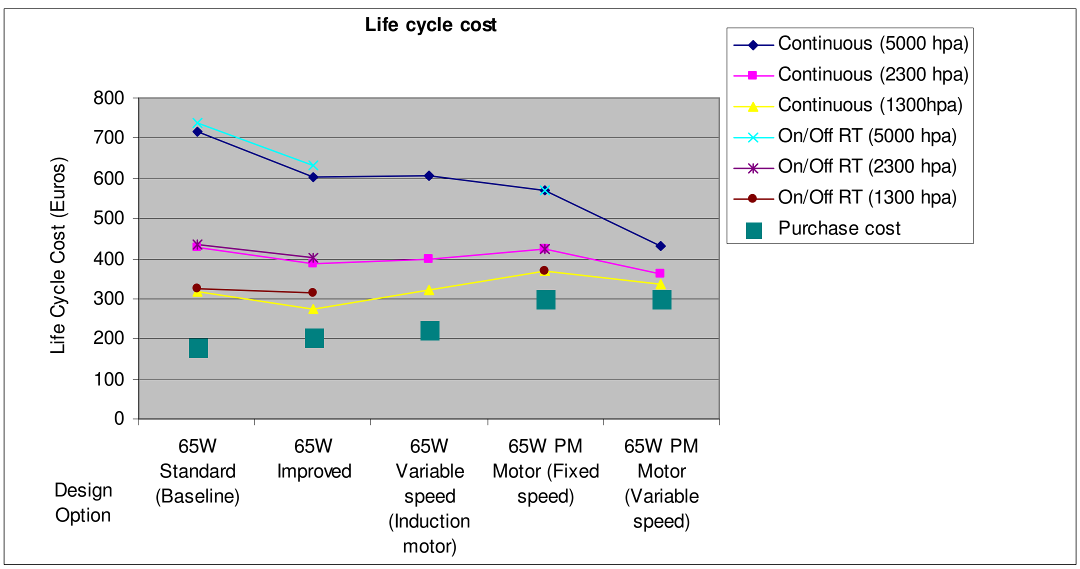


Figure 8-6 LCC Analysis: Economic and Energy analysis of different design options for improving circulators (electricity = 0.135 euros/kWh) – small 65W standalone circulator. Comparison for a 15 year life.

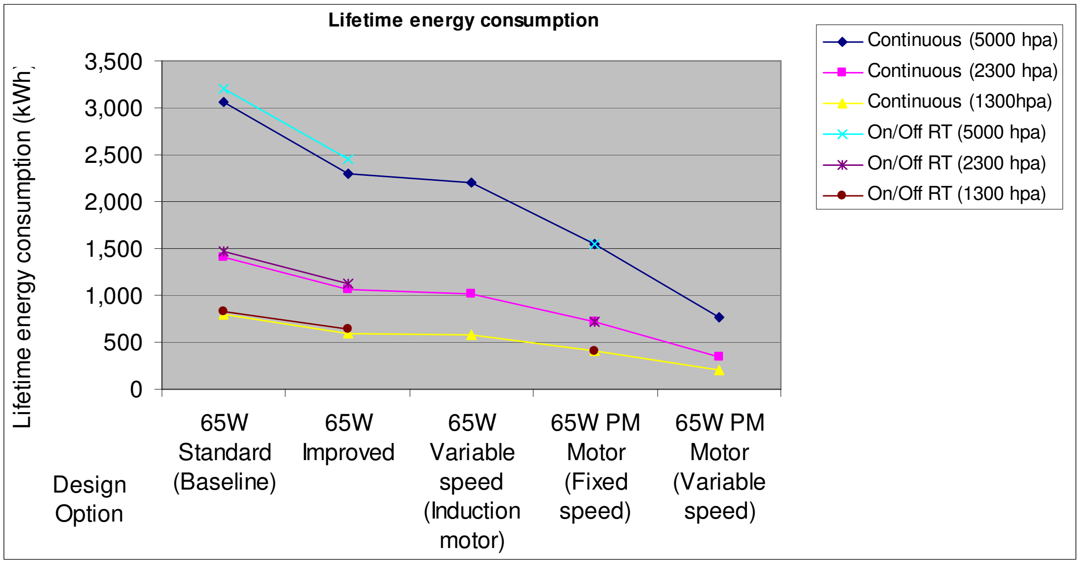


Figure 8-7 Lifetime energy consumption of the different technological options under different operating conditions.

Large Circulator

The same analysis is shown here for the large standalone circulator;

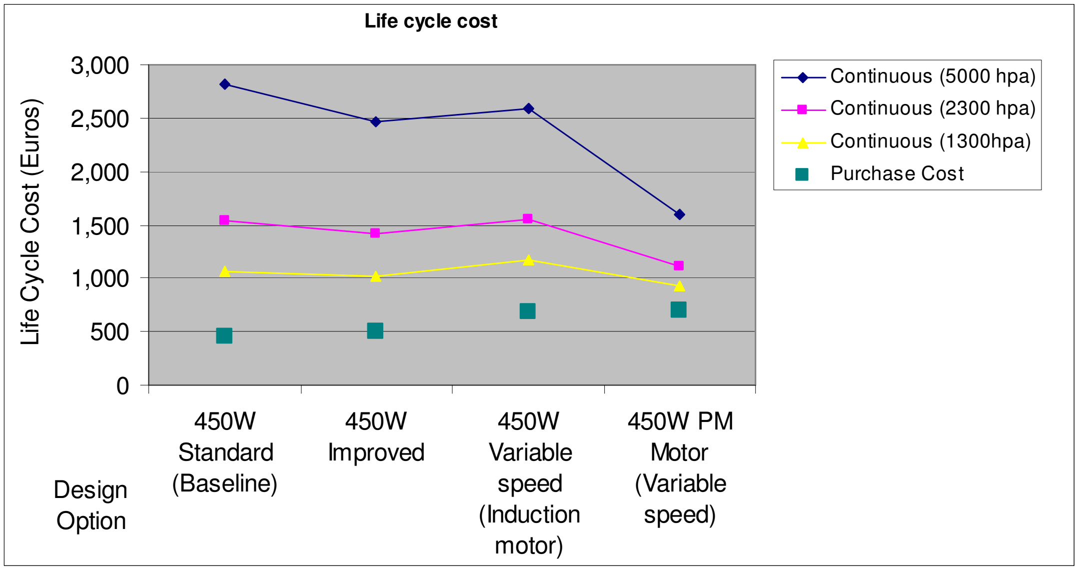


Figure 8-8 Life cycle cost curves for different circulator options under different operating scenarios, 0.135 euros/kW. 10 year life

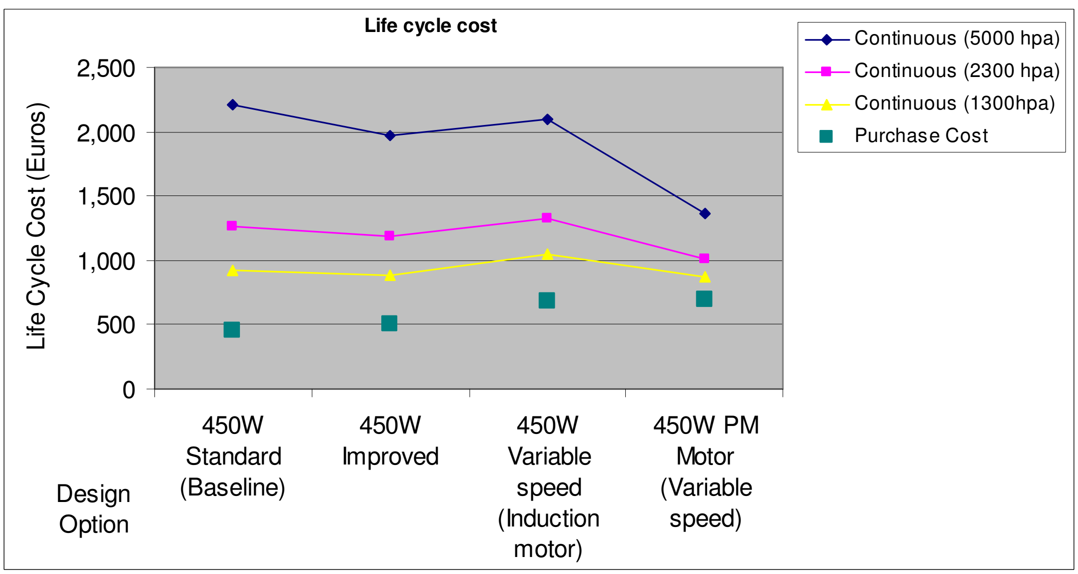


Figure 8-9 Life cycle cost curves for different circulator options under different operating scenarios, 0.07 euros/kW. 10 year life

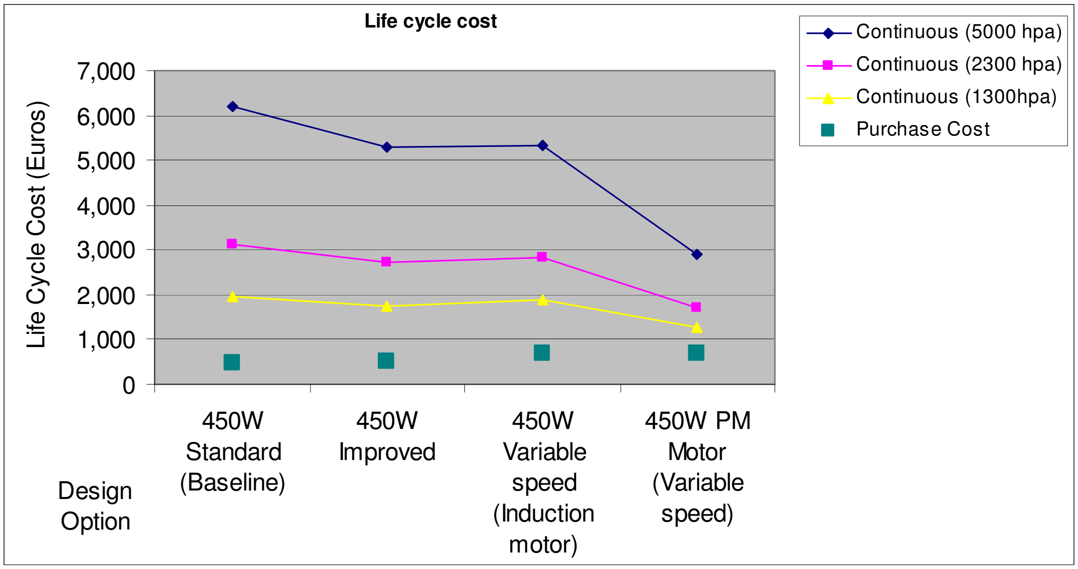


Figure 8-10 Life cycle cost curves for different circulator options under different operating scenarios, 0.23 euros/kW. 10 year life

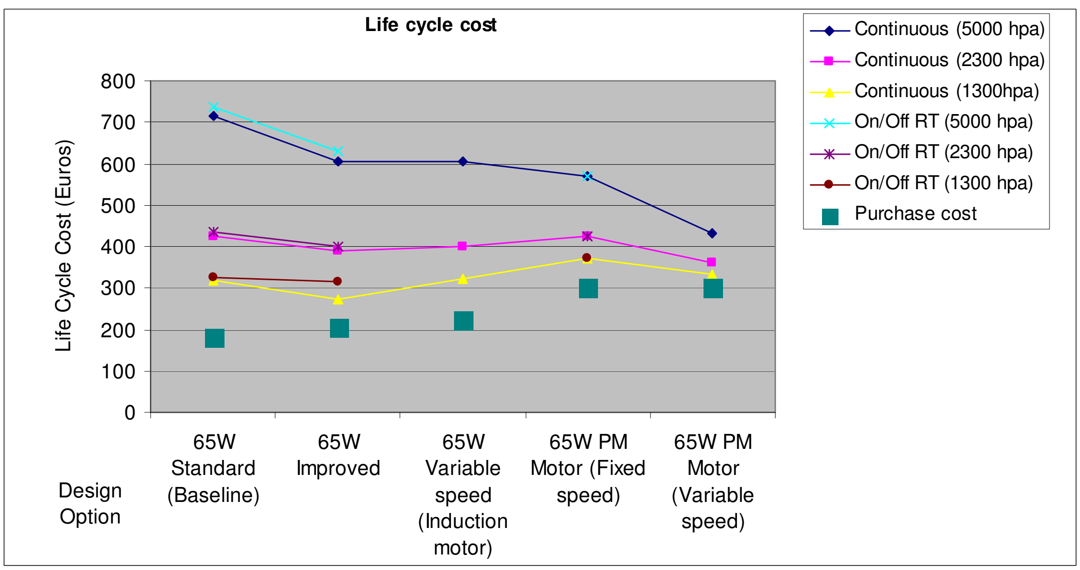


Figure 8-11 Life cycle cost curves for different circulator options under different operating scenarios, 0.135 euros/kW. <u>15 year life for comparison.</u>

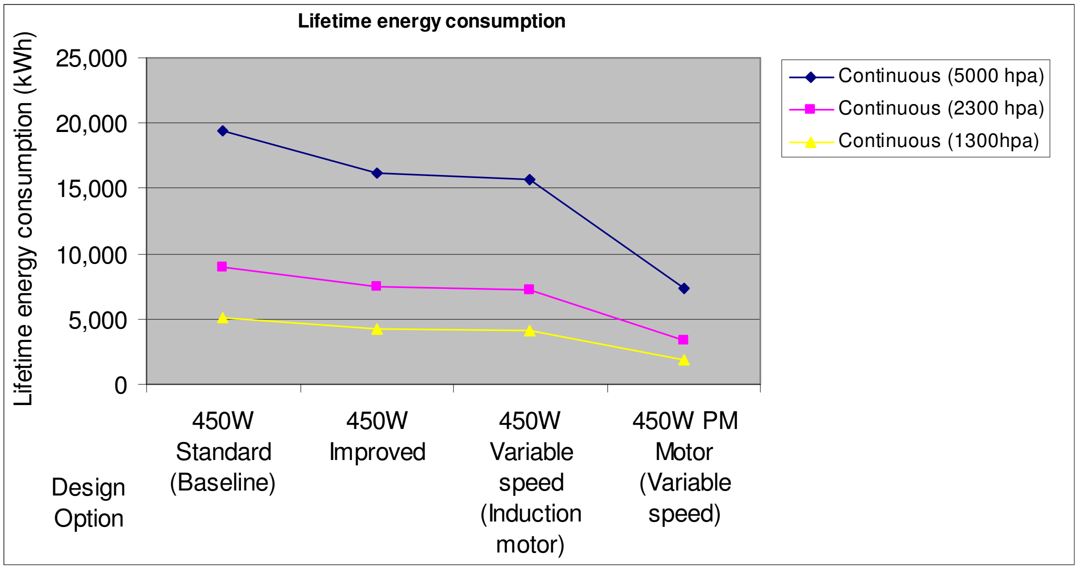


Figure 8-12 Annual energy consumption of different design options with different controls and operating hours.

8.3.2 Summary of the results:

- **Under average operating conditions (electricity = 0.135 euros/kWh) and the most typical conditions of 5,000 hours pa, both class B and class A* circulators give a reduction in LCC to the consumer.** Even for systems working just 2,300 hours pa, these options still show a reduction in LCC to the consumer, although the current class A* (permanent magnet) circulator in fixed speed mode is not attractive. This is the case when using on/off room thermostat control, which is a poorer system that should not anyway be encouraged, and as it occurs mostly in countries (eg UK and Eire) with higher electricity prices, few consumers would in practice experience a higher LCC from moving to this type of circulator. **The suggestion by some stakeholders that the average life of a circulator is 15 years or more (compared to the 10 years assumed in this analysis) would further emphasis the economic benefits to the user of purchasing class A* circulators.**
- In all cases, the class A* (or above) circulator has the lowest annual energy consumption, and the baseline circulator (standard design, fixed speed) the highest.
- The ranking of the lifetime energy consumption of the different types of circulator is the same irrespective of the duty.
- The benefits of the variable speed (induction motor) circulator are not hugely greater than that of the improved standard circulator, and are considerably less than can be gained from use of a class A* circulator. This is reflected in the declining market share of induction motor variable speed circulators.

8.4 Summary of Policy Recommendations

1.) The minimum allowable energy performance for all standalone circulators should be that defined as Class A* in the revised Europump voluntary labelling scheme. At least five years notice should be given of this in order to allow all manufacturers adequate time to design and manufacture compliant products, (2012). This will lead to ultimate energy savings of 15.6TWhpa by 2022, with savings of 13.0TWh pa by 2020.

2.) Because Class B circulators use a different technology to Class A* circulators, they do not represent an incremental developmental step on the way to designing a Class A* circulator. It is therefore concluded that it would cause manufacturers considerable additional work for little gain if Class B was stipulated as being the interim minimum standard of circulator. Hence a direct move to Class A* is seen as being the best option for manufacturers (and consumers).

3.) Circulators should be subject to the maximum standby power targets in the EUP Lot 6 on Standby power consumption.

4.) Because the class “A” category in the existing voluntary labelling scheme is very wide, it is recommended that it is further split into three categories so as to encourage the development of products past the minimum level for class A. The revised efficiency levels (represented by Energy Efficiency Index or EEI values) are as follows:

Class	Energy Efficiency Index (EEI)
A**	EEI < 0.20
A*	0.20 ≤ EEI < 0.30
A	0.30 ≤ EEI < 0.40
B	0.40 ≤ EEI < 0.60
C	0.60 ≤ EEI < 0.80
D	0.80 ≤ EEI < 1.00
E	1.00 ≤ EEI < 1.20
F	1.20 ≤ EEI < 1.40
G	EEI ≤1.40

To help differentiate the performance of different circulators in advance of the split of class A circulators into new classes, the actual calculated energy consumption based on operation for 5,000 hours pa should be shown alongside the class label.

Once class A* has become the minimum standard that can be sold, the existing A-G voluntary labelling scheme will become redundant. This should be seen very positively as an example of how labelling can contribute to transforming a market. It could then be replaced by a new labelling scheme spanning class A to class A**– with decisions on the nomenclature to be used being defined at the same time.

5.) Class A** circulators could attract the “Top Ten” label or other mark to distinguish them as being the best available products on the market.

6.) The existing voluntary Europump labelling scheme should be made mandatory, with control therefore being taken over by the European Commission.

7.) The existing voluntary labelling scheme does not apply to boiler integrated circulators. Because of the complexities of analysing this product it is considered that for now it is adequate to allow improved circulators to be chosen as part of the total electrical consumption of the boiler. This proposal is elaborated in the Lot 1 final report. Unfortunately the phasing of the reports meant that the total electrical energy criteria detailed in the Lot 1 calculations were unable to take account of the final results of this Lot 11 study. Accordingly, sales of permanent magnet (or equivalent energy consumption) boiler integrated circulators should be periodically reviewed to check that sales are proportionately similar to those of standalone circulators. If they are not, then this policy should be reviewed.

8.) EN 1151-1:2006 '*Pumps – Rotodynamic pumps – Circulation pumps having a rated power not exceeding 200W for heating installations and domestic hot water installations* has several weaknesses that need to be addressed for it to be used as the basis of an implementing measure

- **The permissible tolerance on the operating head (at the zero flow point) is large (+/-10%).**
- **The standard does not specify any tolerances for the equipment used to measure the flow.**
- **The standard does not provide any specific guidance as to how efficiency should be determined.**
- **A methodology needs to be defined for an improved way for assessing the performance of variable speed circulators.**

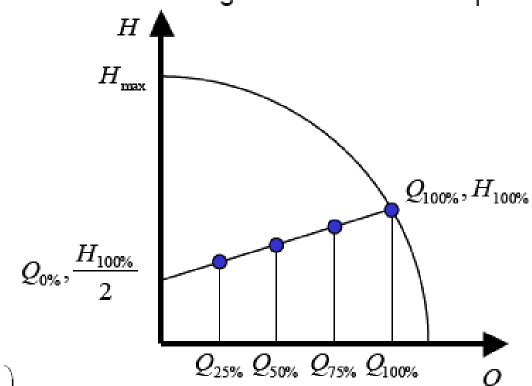
APPENDIX 1 Method of classifying circulator performance, Europump classification scheme

Annex II

COMMON AND STANDARD CLASSIFICATION OF COMPRISED CIRCULATORS AS AGREED IN THE SELF-COMMITMENT

To obtain an overview of the method described for the classification of comprised circulators, the classification method is described hereunder[1]:

1. Measure the pump on maximum setting
2. Find the point where $Q \cdot H$ is maximum according to EN 1151-1 and define the flow and head at this point as $Q_{100\%}$ and $H_{100\%}$ [2].
3. Calculate the hydraulic power P_{hyd} at this point.
4. Calculate the reference power as $P_{ref} = 2.21 \cdot P_{hyd} + 55 \cdot \left(1 - e^{-0.39 \cdot P_{hyd}}\right)$
5. Define the reference control curve as the straight line between the points



$(Q_{100\%}, H_{100\%})$ and $\left(Q_{0\%}, \frac{H_{100\%}}{2}\right)$

6. Select a setting of the pump (free choice) ensuring that the pump on the selected curve reaches $Q \cdot H$ = max point according to EN 1151
7. Measure P_1 and H at the flows $Q_{100\%}, 0.75 \cdot Q_{100\%}, 0.5 \cdot Q_{100\%}, 0.25 \cdot Q_{100\%}$ [3] [4].

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[1] For twin pumps the measurements and calculations are performed in a single pump operation if this is a selectable mode of operation. The selection of motor head for single pump operation is optional.

[2] It is allowed to use interpolated values, but it must be possible to measure values between ±5% of the interpolated values.

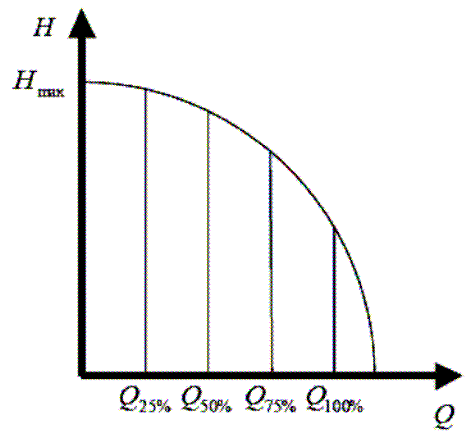
[3] Interpolated values are permitted but is must be possible to measure values between 0% and - 5% of interpolated values respecting the settling time of the pump.

[4] Flows are measured from 100% to 25%. Average values of the calculated EEIs based on measurements of decreasing and increasing flows i.e. 100% to 25% and from 25% to 100% respectively, are permitted.

8. Calculate at these flows
$$P_L = \frac{H_{ref}}{H_{meas}} \cdot P_{1,meas} \quad , if \quad H_{meas} \le H_{ref}$$
$$P_L = P_{1,meas} \quad , if \quad H_{meas} > H_{ref}$$
, where H_{ref} is the head on the reference control curve at the different flows

9. Using P_L and this load profile

Flow [%]	Time [%]
100	6
75	15
50	35
25	44



10. Calculate the weighted average power $P_{L,avg}$ as

$$P_{L,\,avg} = 0.06 \cdot P_{L,\,100\%} + 0.15 \cdot P_{L,\,75\%} + 0.35 \cdot P_{L,\,50\%} + 0.44 \cdot P_{L,\,25\%}$$

11. Calculate the Energy Efficiency Index as: $EEI = \frac{P_{L,avg}}{P_{ref}}$

List of Abbreviations

BAT	Best available technology
BEP	Best efficiency point
BEQ	Best efficiency flow
BI	Boiler Integrated
BE	(Blauer Engel) A standardised circulator flow profile
BNAT	Best not available technology
BOM	Bill of materials
CO_2	Carbon Dioxide
DCF	Discounted Cash Flow
DHW	Domestic Hot Water
DIN	Deutsches Institut fur Normung eV
EEE	Electrical and electronic equipment
EEI	Energy Efficiency Index
EIA	Environmental impact assessment
EN	European technical standard
ESOB	End Suction Own Bearings
EU	European Union
EUP	Energy using product
ISO	International standards organisation
H	Head
LCC	Life cycle cost
LLCC	Least life cycle cost
m	meters
m^3/h	Meters cubed per hour
MEEUP	Method for the Evaluation of Energy using Products
PM	Particulate Matter
PM	Permanent Magnet
ROHS	Restriction of hazardous substances (directive)
RT	Room Temperature
N_S	Specific speed
SAVE	Specific action for vigorous energy saving (EC programme)
TOR	Terms of reference
TRV	Thermostatic Radiator Valve
VSD	Variable speed drive
WEEE	Waste electrical and electronic equipment directive

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