Review study on Circulators

Final report

Viegand Maagøe A/S

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Prepared by

Study team:

Larisa Maya-Drysdale, Ulrik Vølcker Andersen and Mette Rames (Viegand Maagøe A/S)

Quality assurance:

Jan Viegand (Viegand Maagøe A/S)

Contract managers:

René Kemna and Roy van den Boorn (Van Holsteijn en Kemna B.V.)

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1. Executive summary

The European Commission regulation (EC) No 641/2009 on ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products was published in August 2009 and the ecodesign requirements entered into force in January 2013. The objective of this regulation is to ensure the placing on the market of technologies that reduce the life-cycle environmental impact of circulators, leading to estimated electricity savings of 23 TWh by 2020, corresponding to 11 Mt CO2-eq, according to the European Commission[1].

According to Article 7 of the regulation, a review of the methodology for calculating the Energy Efficiency Index (EEI), was due in January 2012. As a result of the review (according to Working Document on amendment of the regulation published in April 2011[2]) the European Commission issued a standardisation Mandate (M469) and a Europump Working Group was formed under the Europump Standard Commission in order to deliver the technical basis for necessary standardisation work. With the help of the consultation with the European Heating Industry (EHI), the European Heat Pump Association (EHPA) and the European Solar Thermal Industry Federation (ESTIF), the EN 16297:2012 standard was developed, presenting the general requirements and procedures for testing as well as the calculation of the EEI for standalone circulators and for circulators integrated in products.

The regulation (EC) No 641/2009 was then amended by regulation (EU) No 622/2012 published in July 2012, which also included and extended some definitions to close identified loopholes, and a methodology to calculate the EEI of circulators designed for primary circuits of thermal solar systems and of heat pumps, which were previously exempted from the requirement in the first Tier (January 2013).

This study reviews the scope and ecodesign requirements of the Commission regulation (EC) No 641/2009 and its amendment, Commission regulation (EU) No 622/2012, in light of current developments in the market and technological progress concerning energy efficiency levels and assesses designs for reuse and recycling.

The particular aspects assessed were:

- The scope of the regulation (EC) No 641/2009 with amendment and any potential amendment according to recent developments on the market.
- Energy efficiency requirements and any potential amendment according to recent developments on the market.
- Overview of circulator designs that facilitate their recovery for reuse and recycling, in particular focusing on the legislative framework, both from a waste management and ecodesign perspectives.
- Additional inputs from market surveillance activities that have an impact on the scope and ecodesign requirements.

[1] EUP Lot 11: Circulators in buildings, Issue 5
[2] http://www.eceee.org/static/media/uploads/site-2/ecodesign/products/circulators/proposal-amendment-regulation-apr2011.pdf

The review study shows that the amended regulation has worked well by preparing the market to adopt the energy efficiency requirements. Data shown presents a clear improvement concerning energy efficiency for all circulators in scope, before and after the energy efficiency requirements entered into force. The degree of improvement has occurred more drastically for small standalone circulators, whilst for large standalone and integrated circulators the improvement has occurred more slowly. For large standalone circulators, this is because they are slowly being replaced by smaller sizes according to sales and stock data established and checked with stakeholders. This is assumed to happen because of a larger focus on right sizing combined with reduced heating needs due to increased level of energy saving activities for the buildings. The focus of the manufacturers has been on improving efficiencies of smaller circulators assumed to be due to national campaigns towards households on efficient circulators supported by the voluntary energy labelling established by the industry. For integrated circulators, this is because of the design and size limitations presented by their fitting to the heating appliance, reducing the possibilities for improving their designs for increased energy efficiency. The market shows increased sales for integrated circulators, whilst they have become stagnant (small standalone circulators) or they have decreased (large standalone circulators).

1.1 Scope

The study team proposed no direct changes to the current scope. However, inclusion of drinking water circulators may be considered for further analysis.

Opportunities for removal of the exemption of drinking water circulators were assessed along the study as a potential amendment. However, in spite that drinking water circulators have a potential for improvement, there is an important barrier for harmonising their operational characteristics due to national health regulations. This barrier is the lack of harmonisation at EU level concerning different national regulations across Member States to prevent the formation of Legionella bacteria in the drinking water pipelines. This lack of harmonisation creates a wide range of hydraulic settings to operate the circulators at different flow-time profiles. Without a harmonised flow-time profile that can be applied to all drinking water circulators, it is difficult to establish a methodology to quantify energy efficiency in the same way as it has been done for standalone and integrated circulators.

There is currently not a study known by the study team that presents an overview of the different operational and hydraulic requirements of drinking water circulators at EU level – and it was not possible within the scope of this study to perform it – which would be the basis to assess the possibilities for harmonisation. Without this overview and a subsequent harmonisation, it is not possible to measure and test energy efficiency of drinking water circulators at EU level with the current methodology.

However, other approaches of setting energy efficiency requirements for drinking water circulators may be possible to establish e.g. by using a flat flow-time profile. This option was out of the scope of the review study and has not been further assessed.

1.2 Energy efficiency requirements

Based on the market overview established on energy efficiency levels, it is seen that significant improvements have already taken place since before and after the current regulation took effect.

The margins to reduce further the current EEI levels (i.e. increase energy efficiency levels) is rather small because further improvements to the design would in many cases require design and production investments that would only bring low net economic benefits to the consumers from energy savings.

In order to arrive to this conclusion, three policy options were assessed:

1. Policy option 1: No action – Business as Usual (BAU)
2. Policy option 2: EEI ≤ 0.20 by 2022
3. Policy option 3: EEI ≤ 0.18 by 2022

The study team's LCC (Life Cycle Costs) analyses showed that LCC for policy options 2 and 3 compared to option 1 (BAU) would be reduced with 1-2 % for the standalone circulators and about 5 % for the integrated circulators.

When comparing BAU with policy option 2, the potential energy savings are:

- Small standalone circulators: 0.19 TWh/year in 2025 and 0.37 TWh/year in 2030
- Large standalone circulators: 0.33 TWh/year in 2025 and 0.66 TWh/year in 2030
- Integrated circulators: 0.86 TWh/year in 2025 and 1.78 TWh/year in 2030

When comparing BAU with policy option 3, the potential energy savings are:

- Small standalone circulators: 0.21 TWh/year in 2025 and 0.41 TWh/year in 2030
- Large standalone circulators: 0.39 TWh/year in 2025 and 0.73 TWh/year in 2030
- Integrated circulators: 0.91 TWh/year in 2025 and 1.92 TWh/year in 2030

The assessment of these two policy options gives a total for the circulators in scope of:

- Policy option 2: 1.37 TWh/year in 2025 and 2.81 TWh/year in 2030
- Policy option 3: 1.51 TWh/year in 2025 and 3.06 TWh/year in 2030

Though the saving potentials and the net economic savings for the end-users are not negligible, the uncertainties in the assumed EEI levels and the corresponding costs are too high to recommend a revision of the current EEI levels of requirements. It is expected that more stringent EEI requirements will not drive the market to take significant leaps of design improvements, which at the moment are limited to the technologies found already on the market.

1.3 Designs to facilitate reuse and recycling

The assessment of circulator designs that can facilitate the recovery for reuse and recycling shows that, in spite of the absence of a legal framework that can incentivize manufacturers to design circulators for a higher degree of reuse and recycling, the ongoing circular economy initiatives and the legislative framework established by the WEEE Directive can be used as a platform to increase the recycling of key circulator components.

From an ecodesign perspective, the possibilities of implementing a marking requirement at a vertical level for critical components and materials (i.e. the electronics and rotor of the circulator extended product) has been assessed to be of little benefit. This is because the circulators’ key components, the printed circuit board in the controllers and the permanent magnet in the motor, are either not so easy to disassembly (permanent magnet) or contain very little amounts of highly valuable materials (printed circuit boards). Therefore, the costs to implement a marking requirement would surpass the economic benefit of recovering materials like gold and copper from the printed circuit board and neodymium from the permanent magnet. Furthermore, no recycling of neodymium exists at commercial level in the EU, and according to input from recyclers and experts in the area, there is currently no incentive to change this picture due to the lower price of neodymium. Since the price has shown to fluctuate, it could be valuable to investigate ways to make recycling possible under the circular economy package initiatives as a separate study.

An alternative recommended from this study is to implement an ecodesign marking requirement for content of rare earth elements (REEs) at a horizontal level instead, in order to concentrate the volumes of neodymium entering the recycling facilities not only from circulators but also from other products. This would assure a critical volume of neodymium to be recovered which would make the EU more independent of its supply from other continents which is subject to price fluctuation.

1.4 Market surveillance

Concerning market surveillance, input from stakeholders suggests that a clarification is needed in the regulation stating that circulators intended both for drinking water systems and heating systems are not exempted. This is necessary due to the existing confusion in this respect and considering this it is a relatively easy amendment to implement. Furthermore, the marking of drinking water circulators covered by Annex I, point 2(1d) of the amending regulation (EU) No 622/2012 should be made more visible so it is easier to identify circulators which are only intended for drinking water systems. This also supports the idea to make the requirement language neutral, meaning that the end-users and authorities would need to understand a certain language to identify the intended use of drinking water circulators. A suggestion is to include a pictogram of a tap which is small enough to fit on the pump itself but that can also be shown on the packaging and the product catalogues (both printed and online). However, before investing efforts on improving this marking, it is recommended to engage more Member States on the market surveillance of circulators in scope of this regulation. At the moment only three Member States perform these activities. This would provide a less biased view on whether a language-neutral marking for drinking water circulators is actually needed.

1.5 Overall recommendations

Overall, the recommendations for this study are:

- Do not introduce any amendments to the scope, however, revise the text exempting drinking water circulators for the energy efficiency requirements clarifying that circulators intended both for drinking water systems and heating and cooling systems are not exempted.
- Consider further work on setting requirements for drinking water circulators using a simpler flow-time profile, which would not require harmonisation of national regulations of drinking water systems.
- Consider elaborating on the product information requirement for drinking water circulators (Annex I, point 2(1d)), by including a pictogram, which should be shown on printed and online product catalogues and, if possible, on the nameplate.
- Consider suggesting a horizontal ecodesign requirement for the marking of rare earth elements (REEs) for all motor driven unit product groups.

- Do not introduce any amendments to the energy efficiency requirements as they do not provide sufficient added value in terms of energy savings at EU level and net economic savings for the end-users, when taking into account the high uncertainties in the assumed EEI levels and the corresponding costs.

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2. Introduction to report

This report presents the outcomes of the review study on circulators according to article 7 of the Commission regulation (EU) No 622/2012 amending Commission regulation (EC) No 641/2009.

This study reviews the scope and ecodesign requirements of the Commission regulation (EC) No 641/2009 and its amendment Commission regulation (EU) No 622/2012 in light of current developments in the market concerning technologies, energy efficiency levels and designs for reuse and recycling.

Based on these provisions, the report is divided in the next chapters:

1. General background for the review study
2. Review of scope
3. Review of market and energy efficiency levels
4. Review of designs for recoverability, recyclability and reusability (RRR)
5. Enforcement of regulation
6. Review of requirements
7. General conclusions and recommendations

Chapter 5 is an addition since the enforcement of the regulation was considered to bring light into additional issues that could be addressed when reviewing the requirements.

This review study does not follow all the steps of the MEErP methodology in its full extent (as agreed with the European Commission), but the methodology was used to perform part of the review of the scope and the market, as well as to perform some of the steps in the scenario analyses. However, as per request by the European Commission, this review study is a simplified study which focused on reviewing whether the scope and/or the energy efficiency and product information ecodesign requirements should be changed or made more stringent according to technological progress. In order to perform this review, insights regarding the enforcement of the regulation that could bring light into potential issues were collected from market surveillance authorities and are presented in this report. Additionally, the review of designs for recovery, reuse and recycling (RRR) and the technology roadmap were also carried out according to the request for services by the European Commission. The review of designs for RRR is presented in this report, and the technology roadmap is presented as a separate document[3].

[3] Technology Roadmap in review study of Commission Regulation (EU) No. 622/2012 on Circulators. Draft final report. April 2017.

3. General background

The Commission regulation (EC) No 641/2009 on ecodesign requirements for glandless standalone circulators and glandless circulators integrated in products was published in August 2009 and the ecodesign requirements entered into force in January 2013. The objective of this regulation is to ensure the placing on the market of technologies that reduce the life-cycle environmental impact of circulators, leading to estimated electricity savings of 23 TWh by 2020, corresponding to 11 Mt CO2-eq, according to the European Commission[4].

According to Article 7 of the same regulation, a review of the methodology for calculating the Energy Efficiency Index (EEI), was due in January 2012. As a result of the review and according to Working Document on amendment of regulation published in April 2011[5], the European Commission issued a standardisation Mandate (M469) and a Europump Working Group was formed under the Europump Standard Commission in order to deliver the technical basis for necessary standardisation work. With the help of consultation with the European Heating Industry (EHI), the European Heat Pump Association (EHPA) and the European Solar Thermal Industry Federation (ESTIF), the EN 16297:2012 standard was developed, presenting the general requirements and procedures for testing as well as the calculation of the EEI for standalone circulators and for circulators integrated in products.

The regulation (EC) No 641/2009 was then amended by regulation (EU) No 622/2012 published on July 2012, which also included and extended some definitions to close identified loopholes, and a methodology to calculate the EEI of circulators designed for primary circuits of thermal solar systems and of heat pumps, which were previously exempted from the requirement in the first Tier (January 2013).

Article 7 of regulation (EU) No 622/2012 requests two aspects for review mentioned in the introduction to the report. In this context, the Commission has drafted their Request for Services which includes the review study focusing on the points mentioned previously. Additionally, the development of a technology roadmap to assess potential future technologies in the context of energy efficiency and to identify any potential barriers to a successful market entry for these technologies. This technology roadmap should give the Commission the basis in terms of a technology overview to develop a strategy on future effective support under the EU research framework programme, Horizon 2020, to foster the development and production of energy efficient, novel technologies within the European Union.

[4] EUP Lot 11: Circulators in buildings, Issue 5

[5] http://www.eceee.org/ecodesign/products/circulators/Proposal_amendment_regulation_Apr2011

4. Review of scope

This chapter presents the circulators covered by this review study as well as their categorisation.

The scope of the review includes the circulators mentioned in the regulation[6] and, additionally, those that were considered relevant to include if the outcome of this study would have concluded that the scope of the regulation should be amended. This consideration was based on information provided by stakeholders on technological progress, potential loopholes and any exclusion considered to be irrelevant due to technological progress, present and future. The categorisation was established based on the current regulation and the experiences from the preparatory study[7].

Once the scope of this review was established, the next chapter on review of the market and energy efficiency levels provided more insight on whether the scope should be extended.

4.1 Scope of the regulation

The regulation covers glandless standalone circulators and glandless circulators integrated in products. The circulators covered are those with a hydraulic output between 1 W and 2500 W and designed for use in heating systems or in secondary circuits of cooling distribution systems. The regulation does not apply to drinking water circulators (i.e. circulators specifically designed to be used in the recirculation of drinking hot water) with the exception of the information requirements, particularly about their intended use (Annex I, point 2(1)(d)). Additionally, the regulation does not apply to circulators integrated in products and placed on the market before the 1st of January 2020 as replacement for identical circulators integrated in products, which have been placed on the market before the 1st of August 2015. However, this exemption to circulators integrated in products does not apply to the information requirements concerning the product's intended use (Annex 1, point 2(1)(e)).

According to the regulation, the products in and out of scope are covered by the following definitions:

1. "*circulator*" means an impeller pump, with or without pump housing, which has the rated hydraulic output power of between 1 W and 2 500 W and is designed for use in heating systems or in secondary circuits of cooling distribution systems;
2. "*glandless circulator*" means a *circulator* with the rotor directly coupled to the impeller and the rotor immersed in the pumped medium;
3. "*standalone circulator*" means a *circulator* designed to operate independently from the *product*;
4. "*product*" means an appliance that generates and/or transfers heat;
5. "*circulator integrated in a product*" means a *circulator* designed to operate as part of a *product* carrying at least one of the following design details:
    a. the *pump housing* is designed to be mounted and used inside a product;
    b. the *circulator* is designed to be speed controlled by the product;
    c. the *circulator* is designed for safety features not suitable for standalone operation (ISO IP classes);
    d. the *circulator* is defined as part of product approval or product CE marking;

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[6] EC regulation (EC) No 641/2009 amended by EU regulation (EU) No 622/2012
[7] EUP Lot 11: Circulators in buildings, Issue 5

6. "*pump housing*" means the part of an impeller pump which is intended to be connected to the pipe work of the heating systems or secondary circuits of the cooling distribution system;
7. "*drinking water circulator*" means a *circulator* specifically designed to be used in the recirculation of water intended for human consumption as defined in Article 2 of the Council Directive 98/83/EC (*)[8].

Drinking water circulators are used in water supply systems both for providing hot water and cold drinking water at the tap. In the case of providing hot water at the tap, the aim of the recirculation is to maintain the temperature of the hot water in spite of the heat losses from the pipes and thereby the end-user does not have to wait to get hot water when opening the tap[9,10]. This also reduces the water consumption and in some countries the building regulations include requirements for maximum time before hot water at a certain temperature level is reached.

4.2 Energy efficiency requirements and Energy Efficiency Index (EEI)

According to the regulation both standalone circulators and circulators integrated in products have to comply with energy efficiency requirements defined as a minimum EEI. The EEI value for a circulator is measured and calculated according to Annex II in the regulation (EU) No 622/2012. This methodology applies to all circulators regardless of size and of whether they are standalone or integrated in products.

The annex to the regulation (EU) No 622/2012 introduced a dispensation factor, which is included for the calculation of EEI. This dispensation factor is applied to circulators integrated in products designed for primary circuits of thermal solar systems and of heat pumps. The dispensation factor is based on the specific speed so that a lower specific speed gives a lower factor, meaning that circulators with low specific speeds has less strict requirements.

According to input from stakeholders[9], only a small fraction of circulators in primary circuits in solar systems present high heads and low flows (thus leading to low specific speeds), which are used in small residential sectors for specific applications. Since no more input was obtained about this topic it was considered not problematic and it was therefore not assessed further. Finally, since the review of the EEI calculation methodology was done in 2012 and since it was not the focus of this review study, the assessment of this dispensation factor was considered out of the scope of this study.

4.3 Scope from preparatory study

In the preparatory study[11], three types of circulators are considered:

- Small standalone circulators
- Boiler integrated circulators
- Large standalone circulators

[8] COUNCIL DIRECTIVE 98/83/EC of 3 November 1998 on the quality of water intended for human consumption
[9] Input from stakeholders at stakeholders meeting, available at: http://www.ecocirculatorsreview.eu/downloads/Presentation%20for%20stakeholder%20meeting%20-%2011.11.2016.pdf
[10] https://www.taco-hvac.com/uploads/FileLibrary/100-41.pdf
[11] EUP Lot 11: Circulators in buildings, Issue 5

Small standalone circulators and boiler integrated circulators are also described as domestic circulators while large standalone circulators are also described as commercial circulators. There is no exact size distinction between small and large circulators in the preparatory study, but typical sizes are given in table 1-1 in the preparatory study report (shown here as Figure 1).

Boiler integrated circulators are defined as “circulators that are designed for specific boilers and fitted in them at the factory”[12], and they are therefore a subset of “circulators integrated in products” as defined in EU regulation (EU) No 622/2012.

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

Figure 1: Typical sizes for circulators in scope of preparatory study Lot 11[13].

Figure 1 shows the typical data for each of the three categories which were defined in the preparatory study. The size ranges and selected base case sizes are given as rated electrical power in W. The rated electrical power is not directly linked to hydraulic power of the circulator. A more efficient circulator will have a lower rated power compared to a less efficient circulator with a higher rated power for the same hydraulic power.

In the preparatory study, the selected base cases correspond to circulators with an EEI value of 0.8, according to the Europump voluntary labelling scheme, which is in the borderline of C/D energy class. This 0.8 value has been converted to the EEI values following the EEI definitions in the regulation (EU) No 622/2012, giving different EEI values because the hydraulic characteristics of the three typical circulators provided in Table 1 are different (see Table 1).

Table 1: EEI and hydraulic power of base case circulators in the preparatory study

	Domestic Standalone	Domestic Boiler Integrated	Commercial
$P_{L,average}$	61.4 W[14]	89 W[15]	388 W[16]
EEI old*	0.80	0.80	0.80
P_{hyd}	10.2 W	25.5 W	195 W
EEI new**)	0.90	0.72	0.55

*EEI old refers to the EEI-value established for the Europump’s voluntary labelling scheme

**EEI new refers to the EEI-values based on the definitions in the regulation (EU) No 622/2012

[12] EUP Lot 11: Circulators in buildings, Issue 5, page 13

[13] Ibid., Table 1-1 page 16

[14] Ibid., Table 4-10

[15] Ibid, Table 4-19

[16] Ibid., Table 4-16

4.4 Review of relevant standards

An update of relevant standards was done to assess whether the standards reviewed in the previous preparatory study have been changed since the time of the study (2008), and whether more recently developed standards are applicable to the measurement of energy efficiency of circulators. For the purpose of this review, all the standards which were dealt with in the preparatory study have been assessed and the main outcomes are presented below.

4.4.1 Harmonised standards - performance and testing

EN 16297:2012

Before 2012, EN 1151-1:2006 was the most used standard for performance testing of circulators, until EN 16297[17] superseded it in 2012. The standard EN 16297 consists of three parts which collectively specify all the performance requirements and procedures for testing and calculating the energy efficiency index (EEI) for both standalone circulators (part 1 and part 2) and for circulators integrated in products (part 1 and part 3), which are called:

- EN 16297-1: General requirements and procedures for testing and calculation of energy efficiency index (EEI)
- EN 16297-2: Calculation of energy efficiency index (EEI) for standalone circulators
- EN 16297-3: Energy efficiency index (EEI) for circulators integrated in products

The scope of the three parts of the standard is overlapping the scope of the regulation as it is specified as “for glandless circulators having a rated hydraulic output power of between 1 W and 2500 W designed for use in heating systems or cooling distribution systems.” As such it does not deal with circulators for domestic hot and cold water (i.e. drinking water circulators). However, if a circulator is designed for both domestic hot and cold water and heating (or cooling) systems the standard can still be applied to arrive at a EEI value, considering the hydraulic characteristics while performing the function for heating or cooling systems.

The EN 16297 is a new addition to the relevant standards for the ecodesign requirements on circulators, because it defines how to perform the tests and the evaluation criteria. The existence of EN 16297 ensures that the regulation can be consistently enforced.

EN ISO 9906:2012

EN ISO 9906[18] was updated in 2012, and it specifies how to do hydraulic performance tests for customers’ acceptance of rotodynamic pumps (centrifugal, mixed flow and axial pumps), by determining the following parameters in a testing facility:

- Flow rate
- Head
- Power
- Energy efficiency

[17] EN 16297:2012 on Pumps - Rotodynamic pumps - Glandless circulators, which was prepared by Technical Committee CEN/TC 197 “Pumps” under a mandate given to CEN by the European Commission and the European Free Trade Association
[18] EN ISO 9906:2012 on Rotodynamic pumps -- Hydraulic performance acceptance tests -- Grades 1, 2 and 3

- Net Positive Suction Head (NPSH)

It can be applied to pumps of any size and to any pumped liquids which behave as clean, cold water, and is therefore also relevant for circulators, both those within the scope of the regulation and those exempt from the regulation (incl. drinking water circulators). The scope of this international standard specifies three levels of acceptance[19]:

- grades 1B, 1E and 1U with tighter tolerance;
- grades 2B and 2U with broader tolerance;
- grade 3B with even broader tolerance.

The standard applies either to a pump itself without any fittings or to a combination of a pump associated with all or part of its upstream and/or downstream fittings, and it is therefore relevant to both standalone circulators and to integrated circulators.

The updated EN ISO 9906:2012 is a new addition to the relevant standards for the ecodesign requirements on circulators, because it defines how parameters used in the calculation of EEI are measured.

4.4.2 Harmonised standards – health and safety

EN ISO 12100:2010

EN ISO 12100:2010[20] is a consolidated standard without technical changes from ISO 12100-1:2003, ISO 12100-2:2003 and ISO 14121-1:2007 and all related amendments. The standard thereby specifies basic terminology, principles and a methodology for achieving safety in the design of machinery and principles of risk assessment and risk reduction.[21,22]

This standard is not within the scope of the ecodesign requirements in the circulators regulations, but it does not present indications that limit the possibilities for compliance with the energy efficiency requirements of circulators.

EN 60335

The EN 60335[23] is a standard for general safety requirements for all electrical appliances that are used in domestic households or similar. The basic premise of the standard is that appliances shall be constructed so that normal use does not cause any danger to persons or surroundings, even in the event of carelessness. The focus of the EN 60335 is electric safety, and it consists of a part 1, EN 60335-1 “General requirements” and a series of product group specific standards EN 60335-2-X (1 to 108).[24,25]

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[19] ISO 9906:2012 page 1, Scope
[20] EN ISO 12100:2010 on Safety of machinery – General principles for design – Risk assessment and risk reduction
[21] Table of correspondence between ISO 12100-1:2003, ISO 12100-2:2003, ISO 14121-1:2007 and the new ISO 12100:2010, document from 18th of November 2010
[22] ISO 12100:2010 page v, Foreword
[23] EN 60335 “Household and similar electrical appliances – Safety”
[24] EN 60335-1:2012, page 4, scope
[25] http://www.conformance.co.uk/kbclook/pdf/208.pdf

The part 2-51: "Particular requirements for stationary circulation pumps for heating and service water installations" is covering electric stationary circulation pumps having a rated power input not exceeding 300 W and are therefore covering the smaller circulators within the scope of the regulation.[26]

This standard is not within the scope of the ecodesign requirements in the circulators regulations, but it does not present indications that limit the possibilities for compliance with the energy efficiency requirements of circulators.

4.4.3 Harmonised standards – noise and vibration

The EN 16644:2014[27] specifies a test code for the vibroacoustic characterization of glandless circulators with pump housing having a rated power input up to 200 W[28]. The standard replaces the former EN 1151-2 'Pumps – Rotodynamic pumps – Circulation pumps having a rated power not exceeding 200 W for heating installations and domestic hot water installations. Part 2: Noise test code (vibro acoustics) for measuring structure – and fluid borne noise'[29].

This standard is not within the scope of the ecodesign requirements in the circulators regulations, but it does not present indications that limit the possibilities for compliance with the energy efficiency requirements of circulators.

4.4.4 Standards on drinking water circulators

For circulators used for recirculating domestic hot water, the use of energy conserving measures is limited because of the risk of Legionella growth. The standard series EN 806 1-5, Specification for installations inside buildings conveying water for human consumption, describes all aspects about conveying water for human consumption inside buildings. Among these, there are aspects on how to install and operate recirculation for domestic hot water.

The technical report CEN/TR 16355:2012 'Recommendations for prevention of Legionella growth in installations inside buildings conveying water for human consumption' includes recommendations for avoiding Legionella growth in accordance to EN 806. The recommendation affects the use of circulators by stating that "for a drinking water installation with circulation of hot water, the water in any circulation loop should be minimum 55 °C". This means that if there is any break in the recirculation, the break should last less than the time needed for the water in the pipes to cool down to 55 °C. However, the length and isolation of the pipes may limit the time in which the circulator can be off.

There are several national standards and regulations that regulate how to use a circulator for recirculation of domestic hot water within the EU. As an example of the differences between national requirements, there are the German and the Danish regulations which are described below.

In Germany, the relevant requirements are laid out in DVGW W 551, Drinking water heating and drinking water piping systems; technical measures to reduce Legionella growth; design, construction, operation and rehabilitation of drinking water installations. In this regulation, it is stated that if the

[26] EN 60335-2-51:2012-08, page 6, scope
[27] EN 16644:2014 on Pumps - Rotodynamic pumps - Glandless circulators having a rated power input not exceeding 200 W for heating installations and domestic hot water installations - Noise test code (vibro-acoustics) for measuring structure- and fluid-borne noise
[28] EN 16644:2014, page 6, scope
[29] EN 16644:2014, page 4, foreword

circulator for recirculation of domestic hot water is switched off due to energy conservation measures, the circulator is not allowed to be switched off for more than 8 hours per day.

In the Danish standard, DS 439 Code of Practice for domestic water supply installations, which the Danish law on buildings (i.e. Building Regulation 2015) refers to, the requirements for domestic water installations are lay out. The requirements for recirculation of domestic hot water states that the temperature of domestic hot water in the pipes should be at least 50 °C, but during peak consumption the temperature may be lowered to 45 °C.

In these two examples, the monitored parameters that show compliance with the national requirements are different: in Germany this is regulated by the residence time whilst in Denmark by the water temperature. In spite that Denmark regulates water temperature, same as in the technical report CEN/TR 16355:2012, the temperature levels are different. In the absence of harmonisation amongst the monitored parameters and their levels of requirements, it is not possible to establish a harmonised flow-time profile which is the basis to regulate circulators' energy efficiency, as it is done in the existing regulations 641/2009 and 622/2012.

4.4.5 Legislation on waste management and material efficiency

An assessment of the relevance of different legislations and various initiatives is presented in chapter 4 of this report, where the assessment on designs that facilitate reuse and recycling is done.

4.5 Consideration for scoping and categorisation

4.5.1 Product categorisation

There are four categories of circulators in the current regulation[30]:

- Glandless standalone circulators
- Glandless circulators integrated in products
- Glandless circulators integrated in products designed for primary circuits of thermal solar systems or for heat pumps, with a dispensation factor for low specific speeds
- Glandless drinking water circulators, with no energy efficiency requirements

Because the EEI scheme in the regulation[31] is consistently applicable for all circulators regardless of size (except for drinking water circulators, which are not covered by EEI scheme), there are no reasons for subdividing the circulator categories into 'small' and 'large' circulators for regulatory purpose. However, for the purpose of this review, the stakeholders have recommended that standalone circulators are subdivided into small (primarily for domestic use) and large (primarily used in commercial buildings and in multi household residential buildings).

[30] EC regulation (EC) No 641/2009 with EU regulation (EU) No 622/2012
[31] Ibid.

4.5.2 Size limit

There is no reason to include circulators larger than 2500 W since there is no indication that there exists a market for glandless circulators larger than 2500 W. Furthermore, larger circulators are normally glanded and therefore covered by the regulation for water pumps (547/2012).

4.5.3 Drinking water circulators (for hot water)

There are three main reasons[32] why drinking water circulators are the only type of glandless circulators not covered by the regulation's energy efficiency requirements:

a. Drinking water circulators for hot water systems may need to be switched on most of the time to prevent the occurrence of legionella[33], whilst circulators for heating and cooling systems can be operated at variable speeds and flows including being off for significant parts of the day. It is important to note that the occurrence of legionella is different throughout Europe and the requirements for recirculation of domestic hot water may be different in different countries of the EU.
b. Alternatively, if not switched on continuously, they are often controlled by timers or temperature controls (e.g. thermostats) in an on/off mode meaning that the EEI methodology described in Commission regulation (EU) No 622/2012 cannot be applied since it is based on variable flows over different time periods.
c. When drinking water circulators are controlled by thermostats they would need to be tested for compliance either separately or as a component but by a procedure where the hydraulic performance characteristics are measured and/or adapted separately for the circulator. This testing procedure does not exist.

Because of these reasons, the possibilities of improving the energy efficiency of drinking water circulators are limited since the application of variable speed drives for them is limited (mainly for on/off systems) and cannot be done homogenously across the EU, in particular by countries where the occurrence of legionella is higher and thus the flow must be constant for larger periods of time. According to information from stakeholders, energy savings could be achieved mostly by using high efficiency motor components (e.g. with permanent magnet rotors) coupled with time or thermostatic control. Using the same approach as for heating circulators, a test methodology (e.g. EEI methodology) must be developed. Before this, harmonisation of flow-time variations in the testing method across EU countries is needed because of large difference between them due to different national hygienic requirements primarily based on the occurrence of legionella. This itself should be a separate task for further investigation, if the intention is to develop a methodology to measure energy efficiency.

However, other approaches of setting energy efficiency requirements for drinking water circulators may be possible to establish e.g. by using a flat flow-time profile. This option was out of the scope of the review study and has not been further assessed.

[32] Provided by stakeholders during the consultation process along the duration of the study and after the stakeholders meeting took place.
[33] For more information about legionella in domestic hot and cold water systems see: https://www.irbnet.de/daten/iconda/CIB19813.pdf and http://ecdc.europa.eu/en/healthtopics/legionnaires_disease/ELDSNet/Documents/EWGLI-Technical-Guidelines.pdf

4.5.4 Existing measurement and performance standards

The review of relevant standards shows that with the standards EN 16297 and EN ISO 9906:2012 there is a solid foundation for consistent and appropriate evaluation of the EEI values for circulators, which are used both for compliance and for enforcement.

EN ISO 9906:2012 can be taken as a solid basis to measure the performance parameters used in the calculation of EEI as it was explained in sub-section 4.4.1, but further work would be needed to harmonise and adapt the flowtime profiles in EN 16297 before turning the EN ISO 9906 fully operational for drinking water circulators. See sub-section 4.5.3 for details.

Furthermore, standards concerning health, safety, noise and vibration of circulators do not limit the possibilities for enforcing or amending the current regulations for circulators.

4.6 Proposed scope of review study

Given the considerations explained in previous sections, the proposed scope of this review study is focused on the current scope and categorisation in the regulation with a further sub-categorisation in size according to previous preparatory study Lot 11. Furthermore, in spite that it was concluded not to include drinking water circulators in the regulation at this point in time, their sales and application on the market were investigated to estimate their total energy consumption. In this way it was possible to make a comparison with the energy consumption of circulators currently in scope of the regulation, and an overview of their order of importance could be established.

The product scope used in this review study is:

1. Standalone glandless circulators for use in heating or cooling systems, including:
    a. small standalone circulators
    b. large standalone circulators
2. Circulator integrated in products, including:
    a. integrated in products designed for heating or for cooling
    b. integrated in products designed for primary circuits of thermal solar systems and of heat pumps
3. Glandless drinking water circulators, including:
    a. those used for the circulation of cold drinking water at the tap
    b. those used for the recirculation of domestic hot water at the tap

Concerning the size limits, the typical sizes have changed since the preparatory study Lot 11 as the market trend is towards smaller size in terms of rated power P_1, because the circulators are now more efficient due to the implementation of the regulation[34]. The hydraulic power from the circulators is assumed constant because it depends on the heating system the circulator is connected to. I.e. the circulators are smaller in rated power, while delivery the same hydraulic power (P_{hyd}).

[34] The Commission regulation (EC) No 641/2009 and the Commission regulation (EU) No 622/2012 require circulators to have a EEI ≤ 0.23 since 1 August 2015. The previous energy efficiency requirement was to have a EEI ≤ 0.27 from 1 January 2013 to 31 July 2015. The exemption to these requirements have been for circulators integrated in products and placed on the market no later than 1 January 2020, replacing identical circulators placed on the market no later than 1 August 2015 (article 1 of Commission Regulation (EC) No 641/2009).

The reduction in rated power for the circulators was confirmed by the data collection of the study team of circulators placed on the EU market[35]and by input provided by Europump[36].

When defining the base cases, it was decided to use the hydraulic power rather than $P_{1,max}$, since the changes on maximum rated electrical power occurring over time do not happen linearly. With variable speed drives present in almost all circulators in the market, the $P_{1,max}$ only tells the highest power of the motor but not what the average electricity consumption is ($P_{1,mean}$) or how much water the circulator can actually move, which is the actual function of the circulator. It has therefore been assumed that end-users have the same need for moving water over time, and therefore that the hydraulic effect of the pumps (P_{hyd}) should be close to constant. In this way the base cases can be comparable to past and future scenarios.

The scope and categorisation are shown in Table 2.

Table 2: Definition of base cases for review study

Product category	**Application**	**Product sub-category**	**Use**	**Typical rated power range P_1**	**Typical hydraulic power P_{hyd}**
Standalone circulators	Heating and cooling systems	Small	Domestic	1-100 W	10.2 W
		Large	Commercial and multi-household residential building	100-2500 W	195 W
Circulators integrated in product	Heating and cooling systems Primary circuits of thermal solar systems and of heat pumps		Domestic, commercial and multi-household residential buildings	≤ 2500 W	25.5 W
Drinking water circulators	Domestic hot and cold water systems intended for human consumption			≤ 2500 W	17.7 W

The terms are defined as it follows:

- '*Glandless circulator*' means an impeller pump which has the rated hydraulic output power of between 1 W and 2 500 W with the shaft of the motor directly coupled to the impeller and the motor immersed in the pumped medium.
- '*Glandless circulator for use in heating or cooling systems*' means a *glandless circulator* that is designed for use in heating systems or in secondary circuits of cooling distribution systems.

[35] Performed by the study team during the spring of 2016
[36] Received in July 2016 through a spreadsheet data collection request sent by the study team.

- '*Standalone circulator*' means a circulator designed to operate independently from the *product*.
- '*Circulator integrated in a product*' means a circulator designed to operate as part of a *product* carrying at least one of the following design details:
    a. the *pump housing* is designed to be mounted and used inside a *product*;
    b. the circulator is designed to be speed controlled by the *product*;
    c. the circulator is designed for safety features not suitable for standalone operation (ISO IP classes);
    d. the circulator is defined as part of *product* approval or *product* CE marking;
- '*Product*' means in this context an appliance that generates and/or transfers heat
- '*Pump housing*' means the part of an impeller pump which is intended to be connected to the pipe work of the heating systems or secondary circuits of the cooling distribution system.
- '*Drinking water circulator*' means a *glandless circulator* specifically designed to be used in the circulation of water intended for human consumption as defined in Article 2 of the Council Directive 98/83/EC.

5. Review of market and energy efficiency levels

In this chapter the circulator EU market is described focusing on the proposed scope in chapter 4. The description covers their sales and stock, the costs to consumers throughout their life cycle (i.e. their Life Cycle Cost), their use patterns and their current levels and predictions concerning energy efficiency.

The main objective of this chapter is to get an overview of the circulators' technological progress and include any update on sales, stock and cost to consumers to be used for modelling of the policy options for potential revision of the regulation.

5.1 Sales and stock analysis

The sales and stock analysis establishes the current and predicted annual sales and stock of circulators in scope of this review in EU-28.

A stock model has been developed to estimate the installed stock of circulators in the EU based on annual sales and average life times. Findings from the previous preparatory study[37], the impact assessment study[38], as well as other sources have been consulted to develop the stock model.

5.1.1 Sales

The sales data have been put together from the sources mentioned above.

The total sales of heating circulators from 1990 to 2010 were taken from the impact assessment. The sales data was given for every 5th year, and linear interpolation was used to estimate the sales figures in the years in between. The total sales from the impact assessment are shown in Table 3.

Table 3: Total sales numbers of heating circulators from the Impact Assessment study (2009) in million units

	1990	1995	2000	2005	2010
Total sales	10.22	11.48	12.74	14.00	14.98

[37] AEA Energy & Environment, EUP Lot 11: Circulators in buildings, Report for the European Commission, Appendix 7: Lot 11 - 'Circulators in buildings', Report to the European Commission, ED Number 02287, Issue Number 5, April 2008.

[38] Commission Staff Working Document accompanying the Commission regulation implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for circulators. Brussels, 22.7.2009, SEC(2009) 1017 final.

It was not possible for the study team to obtain sales figures after 2010, nor figures on sales projections until 2030. Instead, the study team has established assumptions for the growth 2011-2030, which gives yearly sales figures for the period after 2010. The growth in circulator sales is seen to be impacted by:

1. Growth in number of households resulting in new dwellings of which some use circulators for heat distribution internally in the dwelling or the whole building for multi-family houses

2. Increased penetration of central heated dwellings and buildings due to increased heating comfort requirements, due to heating systems requiring water-based distribution system such as some types of renewable energy and heat pumps and due to extension of district heating

3. In the case of drinking water circulators, reduction in maximum time to hot water at tap places due to regulation and/or user convenience

Regarding the growth in number of households, the average annual growth from 2010-2016 (2016 was the latest year with growth data) was 0.81 % for all of EU 28 (according to Eurostat[39]). Most of the individual Member States are at this average and filtering out the most southern EU Member States (Greece, Italy, Spain, France, Portugal, Cyprus and Malta), where water-based heating systems are more seldom, the average is 0.79 %.

Based on these figures and and with an assumed 10 % additional growth increase due to increased penetration of central heated dwellings and buildings, a first estimate would be a growth of 0.9 % per year. However, stakeholders and industry experts consulted during the study stated that despite fluctuations seen over time and geography, there is generally no significant growth in sales of circulators in the EU. The experts were of the opinion that most of the circulator market consists of replacement sales when modernising, renovating or replacing old systems.

Combining the study team's estimates with the stakeholders and industry experts' comments, the sales growth rate was assumed to be 0.7 % per year 2011-2020 and linearly decreasing to 0 % in the period 2020-2030. When having no further data or information on drinking water circulators, the same growth rate is assumed for these.

Share of sales between base cases

The percentage distribution between large standalone, small standalone and integrated circulators is based on the 2005 market shares from the preparatory study shown in Table 4.

[39] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lfst_hhnhtych&lang=en

Table 4: 2005 circulator sales in million units and percentage distribution for the three in-scope base cases

Sales distribution 2005	Million units	Percent
Large standalone	1.00	7%
Small standalone	5.50	39%
Integrated	7.50	54%
Total	14.00	100%

Based on information from industry, the sales share of integrated circulators has increased to at least 60% in 2015 compared to the 54% in 2005, and it is expected to continue this way. The increase has primarily been at the expense of sales for small standalone circulators. In some applications, it is not straight-forward to replace a standalone circulator with a new, integrated ECM (Electronically Commutated Motor) circulator because it may involve additional costs for accessories (cables, gaskets, clips etc.) and new components in the heater (such as piping or even controllers if necessary, especially because the dimension of some circulators may have changed for some models). Moreover, it may be necessary to do re-testing and re-certification for the final products (heaters) when the circulator is replaced not with the identical circulator, but with a more efficient circulator. Therefore, in some cases, the entire heating appliance is replaced with one that has an integrated ECM circulator.

It was not possible to get the exact sales distribution of standalone and integrated circulators for all years, and instead, a distribution was estimated for 2015, 2025 and 2030 based on industry statements, see Table 5. Linear interpolation of market shares was used for the years in between.

Table 5: 2005-2030 circulator sales distribution for the three in-scope base cases

Sales distribution	2005	2015	2025	2030
Large standalone	7%	6%	5%	5%
Small standalone	39%	34%	29%	26%
Integrated	54%	60%	66%	69%
Total	100%	100%	100%	100%

Since the sales of drinking water circulators were not included in the impact assessment and no other data were available, they were instead derived from Eurostat Prodcom data[40]. The sales figures for drinking water circulators were calculated as the difference between the Prodcom total sales covering all glandless circulators and the total sales from the impact assessment (covering only standalone and integrated circulators for heating systems). Since the Prodcom data fluctuated significantly compared to the impact assessment data, an average-approach was used to determine that in 2005 the sales of drinking water pumps were around 1.8 million units, corresponding to

[40] Eurostat Prodcom "Sold production, exports and imports by PRODCOM list (NACE Rev. 2) - annual data [DS-066341]", product category: 28131417 - Glandless impeller pumps for heating systems and warm water supply. Link: http://ec.europa.eu/eurostat/web/prodcom/data/database

around 11% of the total market of all glandless circulators as shown in Table 6. This calculation is an approximate, but due to the lack of further data, it is seen as a sufficient approximation. The market share was assumed to remain constant over the years, since the drinking water circulator market is mainly replacement.

Table 6 shows the share of the four base cases including the drinking water circulators.

Table 6: 2005-2030 circulator sales distribution for the four base cases

Sales distribution	2005	2015	2025	2030
Large standalone	6%	5%	4%	4%
Small standalone	35%	30%	26%	23%
Integrated	48%	54%	59%	62%
Drinking water	11%	11%	11%	11%
Total	100%	100%	100%	100%

When compiling the above information of total sales, base case shares and drinking water sales, the circulator sales for all four base cases have been calculated. The resulting sales numbers for every 5th year form 1990-2030 are shown in Table 7.

Table 7: EU-28 circulator sales in million units

Base case	1990	1995	2000	2005	2010	2015	2020	2025	2030
Small standalone circulators	4.02	4.51	5.01	5.50	5.49	5.28	5.11	4.79	4.37
Large standalone circulators	0.73	0.82	0.91	1.00	0.99	0.93	0.89	0.83	0.74
Integrated circulators	5.48	6.15	6.83	7.50	8.51	9.32	10.10	10.89	11.52
Drinking water circulators	1.28	1.44	1.60	1.76	1.88	1.95	2.02	2.07	2.09
Total circulator sales	11.50	12.92	14.34	15.76	16.87	17.48	18.12	18.58	18.71

5.1.2 Stock

In the stock model, the average product life of 10 years defined in the preparatory study[41] was used for all base cases. According to the preparatory study there was, at the time, consensus in the industry that the average lifetime of circulators is at least 12 years. However, due to various factors such as prematurely scrapping (due to replacement costs of smaller circulators in some cases smaller than repair costs), the average lifetime in the preparatory study was set at 10 years. In the current stock model, the statistical standard variation of the lifetime is assumed to be 2 years. This was used to calculate the number of circulators left in stock up to 15 years after sales year, using a normal distribution for their lifetime of 10 years +/- 2 years. These lifetime assumptions were combined with the sales figures described above to obtain the stock model. The stock of all four base cases are shown in Table 8 for every 5th year from 2000-2030.

[41] AEA Energy & Environment, EUP Lot 11: Circulators in buildings, Report for the European Commission, Appendix 7: Lot 11 - 'Circulators in buildings', Report to the European Commission, ED Number 02287, Issue Number 5, April 2008.

Table 8: Number of circulators in use = stock in the EU-28 (million units)

Stock (million units)	2000	2005	2010	2015	2020	2025	2030
Small standalone circulators	45.24	52.60	56.30	56.96	55.50	53.37	50.44
Large standalone circulators	8.23	9.56	10.22	10.28	9.86	9.33	8.64
Integrated circulators	61.69	71.73	79.79	88.86	97.76	106.02	113.92
Drinking water circulators	14.46	16.81	18.37	19.60	20.48	21.19	21.69
Total circulators stock	129.62	150.71	164.68	175.70	183.60	189.91	194.69

5.2 Life Cycle Cost (LCC) for end-users

The LCC for end-users includes purchase price, electricity and other costs of the circulators in scope of this review throughout their whole life cycle.

The LCC of circulators for consumers includes all the costs held by the consumer through the lifetime of the circulator from purchase to disposal broken down to the following five life cycle cost phases:

1. purchase price,
2. installation costs,
3. repair and maintenance costs,
4. electricity consumption costs (i.e. cost of use), and,
5. potential end-of-life costs.

Each life cycle phase and the associated costs are explained in the following sub-sections. All economic calculations are made in constant 2015-prices and costs occurring after the first lifetime year have been discounted to the first year with the discount rate 4 %.

5.2.1 Consumer purchase price

In the absence of industry data on consumer prices, price information for standalone and drinking water circulators were instead found through an internet search, combining online retailer prices with manufacturer data from product catalogues manufactured and placed on the market in 2015[42]. For integrated circulators, the 2015 price is provided by the association of the European Heating Industry (EHI) as an estimate of the cost of the circulator integrated in the purchased heating appliance. EHI estimated that in general, for a wall hung boiler integrated circulator, the price is around 150-200 €.

[42] Manufacturers stated production year in their product catalogues, which mostly correspond to circulators manufactured in 2015, placed on the market in 2015.

The collected price data is found in Table 9 together with the 2005 prices from the Lot 11 impact assessment. The distinction between large and small standalone circulators is made based on the hydraulic power with small circulators between 0 and 21 W (Base case is 10.2 W P_{hyd}) and large between 95 and 295 W (Base case is 195 P_{hyd}). The intervals were chosen based on the base cases from the Impact assessment, to include pumps with approximately the same hydraulic power as the impact assessment and ensure comparability of the prices. The 2005 prices from the Impact Assessment were escalated to 2015 prices according to the annual inflation rates[43] because all the calculations are made in 2015 prices.

In the impact assessment, it was noted that the pump prices (i.e. in 2005) covered a large price variation within each base case with fixed speed circulators available for around half the price of the more expensive brands[44]. However, with the ecodesign requirements in the circulator regulation, which took effect after the impact assessment (i.e. 2009 and 2012), the cheapest and least efficient circulators are no longer available. Therefore there has been a large increase in the average purchase price from 2005 to 2015 in 2015 constant prices. By having removed the worst circulators from the market as an effect of the regulation, the market spread is reduced and it is expected that variation in the purchase price today is minimal.

Table 9: EU-28 average prices of circulators 2005[45] and 2015 (2015 constant prices)

Base cases	Average prices 2005	Average prices 2015[46]
Small standalone circulators	€ 148	€ 233
Large standalone circulators	€ 493	€ 1314
Integrated circulators	€ 148	€ 175
Drinking water circulators	n.a.	€ 847

5.2.2 Installation cost

The installation cost of circulators is related to the time the installer uses to install a standalone circulator in a new heating or drinking water system or the replacement of an identical standalone or integrated circulator in existing heating or drinking water systems. The installation cost covers also general costs such as transport and administration costs for doing this installation but excluding circulator purchase cost. For standalone circulators, the installation cost is assumed to be the same for installation of new as well as replacement circulators.

[43] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hicp_aind&lang=en

[44] Commission Staff Working Document accompanying the Commission regulation implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for circulators. Brussels, 22.7.2009, SEC (2009) 1017 final.

[45] Escalated from Impact Assessment prices: Commission Staff Working Document accompanying the Proposal for a Commission regulation implementing Directive 2005/32/EC with regard to ecodesign requirements for circulators. Brussels, 22.7.2009, Full impact assessment – Part 2, SEC (2009) 1016 final. Table A.3.1 page 9.

[46] Average pump prices based on online data collection of pump prices in 2015.

For integrated circulators and according to input from stakeholders, there are no costs related to the first installation of circulators bought as part of heat appliances, i.e. when installing the boiler or other system that the circulator is part of. Installation costs for integrated circulators occur when a new circulator is bought as replacement to be installed in an existing system. The split between integrated circulators delivered with the heating system and as replacement is estimated by EHI at 59 % and 41 %, respectively. The replacement installation costs are assumed to be the same as for standalone, since replacing a similar circulator model is nowadays designed to be easily removed from the appliance. Furthermore, costs provided by EHI[47] on installation of integrated fit the estimated installation costs for standalone, which were calculated from data in 2005 (see Table 10), based on the impact assessment[48] and escalated to 2015 constant prices.

These data did not include the installation costs for drinking water circulators, but since the same cost was assumed for small and large standalone circulators in the impact assessment, it was assumed also to be the same for drinking water circulators. These costs for standalone and drinking water circulators were extrapolated from 2005 to 2015 based on the average hourly labour costs in Europe each year[49] and escalated to 2015 prices.

It is important to note that replacing an old circulator with a new high efficient one may involve additional costs for accessories (cables, gaskets, clips, etc.) and new components in the heater such as piping or even controllers if necessary, especially because the dimension of some circulators may have changed for some models. It was not possible, however, to quantify this difference as it depends on the individual setup and the replacement solution and was not included in the cost figure.

Table 10: Installation costs for circulators 2005[50] and 2015 (2015 constant prices)

Base cases	Installation cost 2005	Installation cost 2015
Small standalone circulators	€ 111	€ 111
Large standalone circulators	€ 111	€ 111
Drinking water circulators	€ 111	€ 111
Integrated circulators – replacement	€ 110	€ 110
Integrated circulators – in new equipment	€ 0	€ 0

The installation costs presented in Table 10 represent an indication of the range and may thus vary significantly between Member States depending on the national labour cost, complexity of the heating system, etc. However, since the installation costs are assumed the same irrespective of efficiency levels, they do not impact LCC comparison of circulators with different EEI levels, and it is

[47] http://www.ehi.eu/
[48] Commission Staff Working Document accompanying the Commission regulation implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for circulators. Brussels, 22.7.2009, SEC (2009) 1017 final
[49] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=lc_lci_lev
[50] Escalated from 2015 costs based on annual inflation rate

therefore not critical for the scenario analysis of net impact of the policy options. According to information provided by the European Heating Industry association (EHI), it may be necessary to do re-testing and re-certification of the final heating products when the circulator is replaced not with the identical circulator, but with a more efficient circulator. This cost has not been included in the calculation.

5.2.3 Electricity cost

The primary cost for end-users during the use-phase of the circulator's life cycle is electricity. In this section, the calculation of lifetime cost is described.

Calculation of energy consumption

The methodology of calculating the energy consumption of circulators is described in detail in Section 8.2. The calculation is based on one typical size of circulator for each base case, which come from the preparatory study, and where the size is defined by the hydraulic power. See the definition of base cases in Table 2.

The average power consumption at EEI=1 is calculated for each base case based on the hydraulic power and the method in Section 8.2. Afterwards, the annual electricity consumption is calculated using the assumption for the EEI value for each year calculated and for the annual operational time (5000 hours[51]).

The 2015 average EEI values of each base case are shown in Table 11. Since the standalone circulator requirements were implemented in January 2013, it was assumed that there were no circulators left on the market with EEI above 0.27. However, there were still 15 % left in stores with EEI between 0.27 and 0.23, because many old non-compliant circulators can still be found for sale online.

For integrated circulators, the requirements were not introduced until august 2015. The exemption for integrated circulators sold as replacement allowed some of them to be sold with EEI above 0.23 and even above 0.27 and the average EEI is therefore higher for integrated circulators. However, in the first years after implementation of the requirements for integrated circulators, the average EEI level falls to 0.22 as well.

Table 11: 2015 average EEI values of each base case.

EEI interval	Small standalone circulators	Large standalone circulators	Integrated circulators
Average market EEI	0.233	0.220	0.260

For drinking water circulators, the electricity consumption depends on the share of circulators that is equipped with a controller for automatic on/off according to user settings, which was assumed[52] to be 65% in 2015 (increasing towards 85% in 2030). The controller for drinking water circulators shuts it off depending on time and/or temperature. While drinking water circulators without a controller

[51] Assumption from the preparatory study.
[52] Assumptions based on desktop research and data exchange with Europump during the consultation process

run 24/7 all-year round, it was assumed that drinking water circulators with controllers run only half the time year-round.

In Table 12, the annual energy consumption for base case circulators brought on the market in 2015 shown.

Table 12: Annual energy consumption for base case circulators in 2015 based on the assumptions

Base cases	Annual electricity consumption 2015 KWh
Small standalone circulators	77
Large standalone circulators	782
Integrated circulators	161
Drinking water circulators	330

Electricity prices

Electricity prices from the Primes project[53] (provided by the European Commission), available from 2005 to 2050, were used in the calculations. The prices were given in €/toe (tonnes of oil equivalent) for every fifth year. Linear interpolation was used for the years in between.

The Primes price data were given as constant 2013 prices. These were escalated to 2015 prices using the inflation rate of 2013 and 2014, under the assumption that they represented the price of January 1st each year. The electricity prices converted to €/kWh for 2015 are shown in Figure 2.

When calculating the average annual electricity cost for each base case, a weighted average of the electricity price for household and the service sectors was used based on the 2015 sales distribution for circulators to service/industrial and to residential buildings in the EIF report[54], which is 40 % and 60 % respectively.

Since the prices are averages for all EU-28 countries they might vary significantly between the Member States.

[53] PRIMES 2016, provided by European Commission, DG ENER A4
[54] European Industrial Forecasting Ltd 2015, The World Pump Market 2015-2020 Volume I, 15 October 2015.

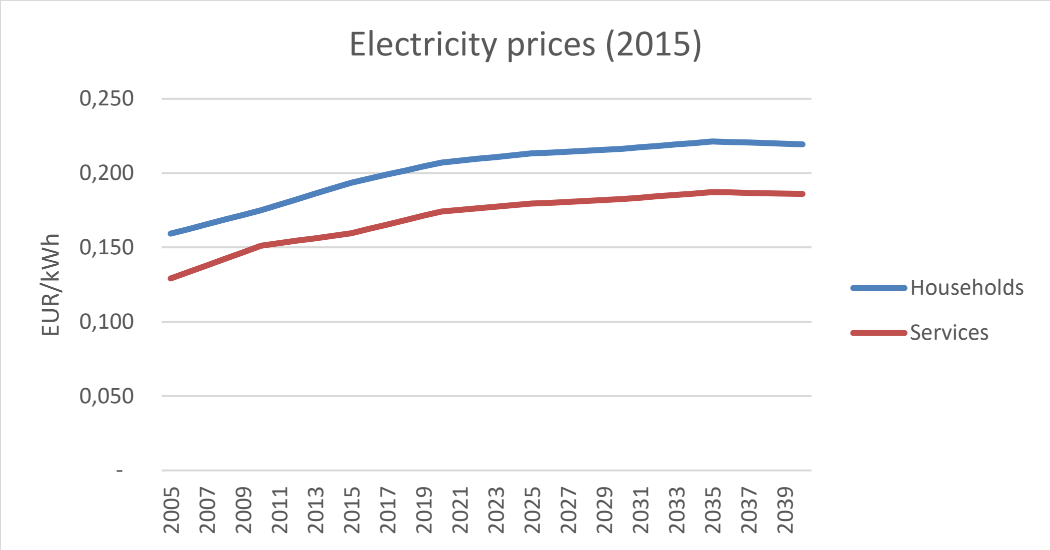

Figure 2: Electricity prices converted to EUR/kWh and as 2015-prices.

Lifetime electricity cost

With the electricity prices shown in Figure 2 and the EEI distribution shown in Table 11, the total use-phase costs of electricity consumption for each circulator type installed in 2015 are shown in Table 14. Note that these costs are for the entire lifetime of the pump, which was assumed to be 10 years for all types, and the electricity costs have been discounted with 4% p.a. (the discount rate) to the first year in the lifetime as per the economic assumptions provided by the European Commission.

Table 13: Electricity cost in use phase of circulators installed in 2015 for their entire lifetime (constant 2015 prices, discounted to lifetime year 1)

Base cases	**Electricity cost EUR 2015 prices**
Small standalone circulators	124
Large standalone circulators	1256
Integrated circulators	258
Drinking water circulators	529

5.2.4 Repair & maintenance costs

In accordance with the preparatory study[55], it is assumed that it is not viable to repair small domestic circulators in Western European countries, while there is some repair market for such circulators in Eastern Europe due to lower labour costs. For larger circulators of more than 750 W, repair such as replacement of the motor is more common. Failure of bearings, however, often leads to replacing of the entire circulator rather than repairing because it is more expensive to replace the bearings. According to industry, it is safe to assume that most small circulators are replaced while large circulators are repaired. However, repair of integrated circulators is not common (both small and large), and often not possible, which is why replacement is the standard. Based on this information, it

[55] AEA Energy & Environment, EUP Lot 11: Circulators in buildings, Report for the European Commission, Appendix 7: Lot 11 - 'Circulators in buildings', Report to the European Commission, ED Number 02287, Issue Number 5, April 2008.

was assumed that 80% of failures in large standalone circulators are repaired compared to 30% in small standalone circulators and 10% in integrated circulators.

The repair rates shown in Table 14 are derived from the percentage of circulators that are repaired because of failure, and the failure rate which is given as number of failures per lifetime. It was not possible to find exhaustive statistics on failure rates, but it was assumed that small circulators fail more often than large circulators, because they are often used by private consumers who pay less attention to maintenance and operation of the circulator. The repair rates are then calculated as number of failures multiplied with how many percent are repaired rather than replaced.

In the preparatory study, it was estimated that repair of circulators would take around 3 hours excluding travel time on average for both small and large circulators. This was confirmed by the industry[56]. For large circulators, the time to replace or repair is dependent on whether or not isolating valves are fitted, since this determines whether or not the system needs to be drained and refilled, as well as other circumstances which might complicate the repair work. It was assumed that typically, the repair time for large circulators would be higher than for small circulators and it was decided to use 4 hours as repair time for large standalone circulators and 2 hours for small standalone circulators. For the small share of integrated circulators that is repaired (10%), a repair time similar to the small standalone circulators was assumed, because only minor time would be added to for removing the covers of the integrated units to get access to the circulator.

The repair times and rates were multiplied with the average labour cost in the EU 28 countries to calculate the repair costs shown in Table 14. The 2015 average labour cost in the EU 28 countries[57] is 25 euros/hour, but it should be noted, however, that there is a large variation in labour costs across Europe, ranging from 4.1 to 41.3 Euro/hour between Member States, according to Eurostat[58]. Furthermore, it is assumed that repairs take place after approximately two thirds of the average lifespan, hence for circulators with a lifespan of 10 years, the repairs in average will happen after 6 years, and the repair costs are discounted accordingly with 4 % p.a. (the discount rate) to the first year in the lifetime as per the economic assumptions provided by the European Commission.

Besides the outright repair work there is little maintenance related to circulators. One of the things that might be needed is oiling of the motor bearings in the circulator. However, for most large circulators automatic oil lubricating devices are assumed to be used[59]. The manual lubrication is mostly relevant for domestic end use, and can often be done by the end-user, hence requiring only the cost of the lubricating oil.

Furthermore, seals might need to be replaced as part of the maintenance, as well as all electrical and moving parts should be checked regularly[60]. These activities, however, are almost exclusively performed only for very large circulators in industrial facilities or the like[61].

[56] Statements from stakeholder meeting
[57] Eurostat, Hourly Labour costs, http://ec.europa.eu/eurostat/statistics-explained/index.php/Hourly_labour_costs
[58] Eurostat, Hourly Labour costs, http://ec.europa.eu/eurostat/statistics-explained/index.php/Hourly_labour_costs
[59] http://www.doityourself.com/stry/how-to-oil-the-motor-bearings-in-a-circulating-pump
[60] http://www.hach.com/pump-seal-replacement-kit-for-yearly-preventive-maintenance-of-probrix-circulation-pump/product?id=9230800501
[61] https://www.ksb.com/ksb-en/Products_and_Services/service-and-spare-parts/Maintenance_and_Repairs/Pump_Service_and_Motor_Service/

Table 14: Repair costs and assumptions for each base case in 2015 (constant 2015 prices, discounted to lifetime year 1)

Base cases	Repair time	Lifetime repair rate	Repair cost, 2015
Small standalone circulators	2 hours	2 failures, 30% repaired	€ 24
Large standalone circulators	4 hours	1 failure, 80% repaired	€ 63
Integrated circulators	2 hours	2 failures, 10% repaired	€ 8
Drinking water circulators	2 hours	2 failures, 30% repaired	€ 24

5.2.5 End-of-life costs

The end-of-life costs paid by the end-user depend on the recycling system in each Member State. However, it was assumed that private consumers as a general rule do not have to pay for disposing of used products in any of the European Member States. In some countries, circulators might be covered by the WEEE Directive[62], however since the Directive is implemented at national level, it is not possible to generalise whether this is the case. It was assumed that regardless of whether circulators are covered by the WEEE Directive or not, there are no direct cost for the consumer in the end-of-life phase. Potential WEEE related costs or taxes will be held by the manufacturer, and ultimately covered through the purchase price.

5.2.6 Total BAU Life Cycle Costs

With the assumptions and data described in this section, the total LCC for each base case are as shown in Figure 3 to Figure 6 for the years 2005 (before regulation), 2015 (after the current regulation with amendment took effect) and 2022 (after the assumed year of effect of the reviewed and amended regulation). For all base cases, the costs for installation, and repair and maintenance are very small and end-of-life costs are zero.

For the three base cases, which are currently in scope of the regulation, the purchase price increased more steeply up to the time of implementation of the regulations (2009 and 2012) because of the extra improvement costs of using VSDs and permanent magnet motors within the circulators in order to improve their energy efficiency to the required levels. The electricity consumption cost decreases in that same period and for all three base cases this results in an overall decrease in total life cycle costs.

Large standalone circulators

For large standalone circulators (Figure 3), the electricity consumption cost constitutes the largest share of the life cycle costs until implementation of the energy efficiency requirements in regulation (EC) No 641/2009. The improvement in energy efficiency due to the regulation reduced the lifetime electricity costs, though the increase in purchase price resulted in a slightly higher LCC after the requirements took effect. However, considering that real electricity prices have increased by 16%

[62] http://ec.europa.eu/environment/waste/weee/index_en.htm

between 2005 and 2015, the 2015 situation without the regulation would have led to a total LCC that is about 7% higher than with the regulation.

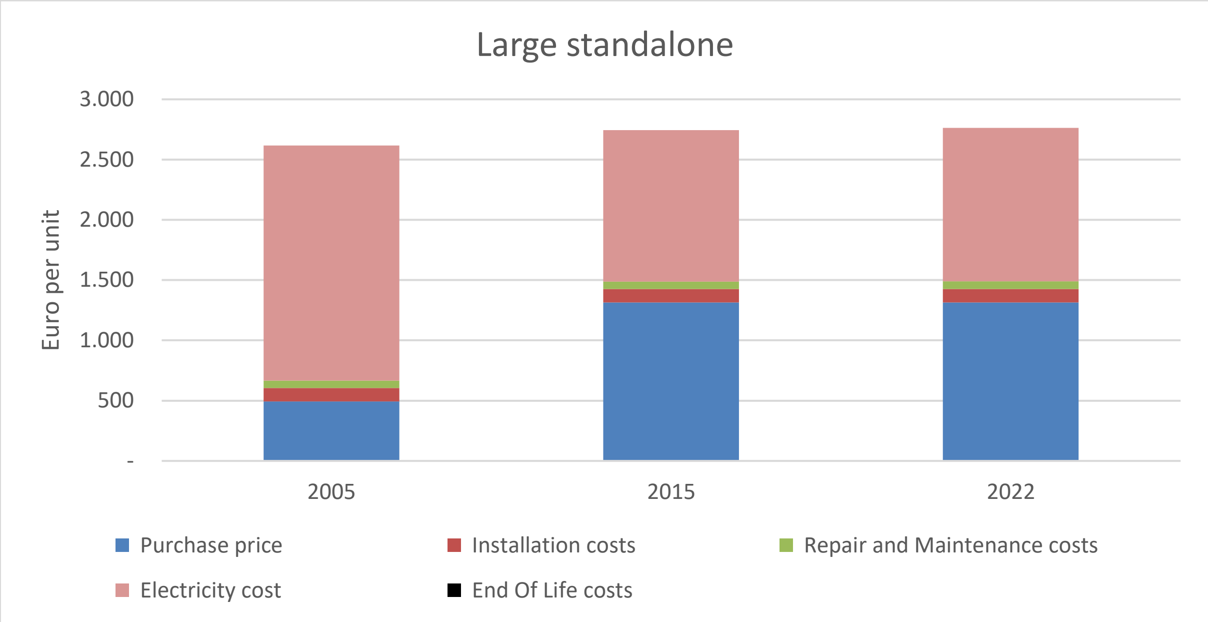

Figure 3: Total Life Cycle Costs for large standalone circulators for 2005, 2015 and 2022 (BAU) (constant 2015 prices)

Small standalone circulators

For small standalone circulators (Figure 4), the installation, and repair and maintenance costs constitute a percentage-wise larger share of the life cycle costs than for large standalone circulators, because both the purchase price and the electricity consumption costs are lower. The total LCC is lower after the requirements took effect. Considering that real electricity prices have increased by 16% between 2005 and 2015, the 2015 situation without regulation (EC) No 641/2009 would have led to higher total costs. Considering the real price increase of electricity between 2005 and 2015, the LCC improvement due to the regulation is even greater.

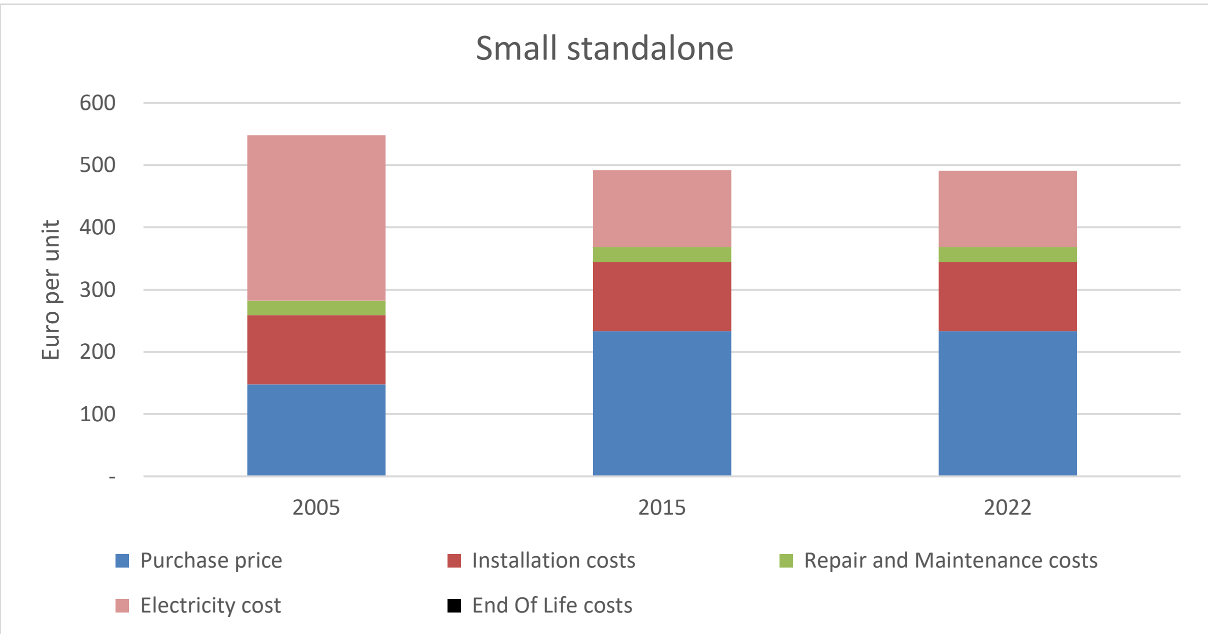

Figure 4: Total Life Cycle Costs for small standalone circulators for 2005, 2015 and 2022 (BAU) (constant 2015 prices)

Integrated circulators

For integrated circulators (Figure 5), the ecodesign requirements were implemented later (in August 2015) and only in one stage, as opposed for standalone circulators where the first Tier was implemented in January 2013 and the second Tier in August 2015. Similarly to the small standalone circulators, the total LCC is lower after the requirements took effect. Considering the real price increase of electricity between 2005 and 2015, the LCC improvement due to the regulation is even greater.

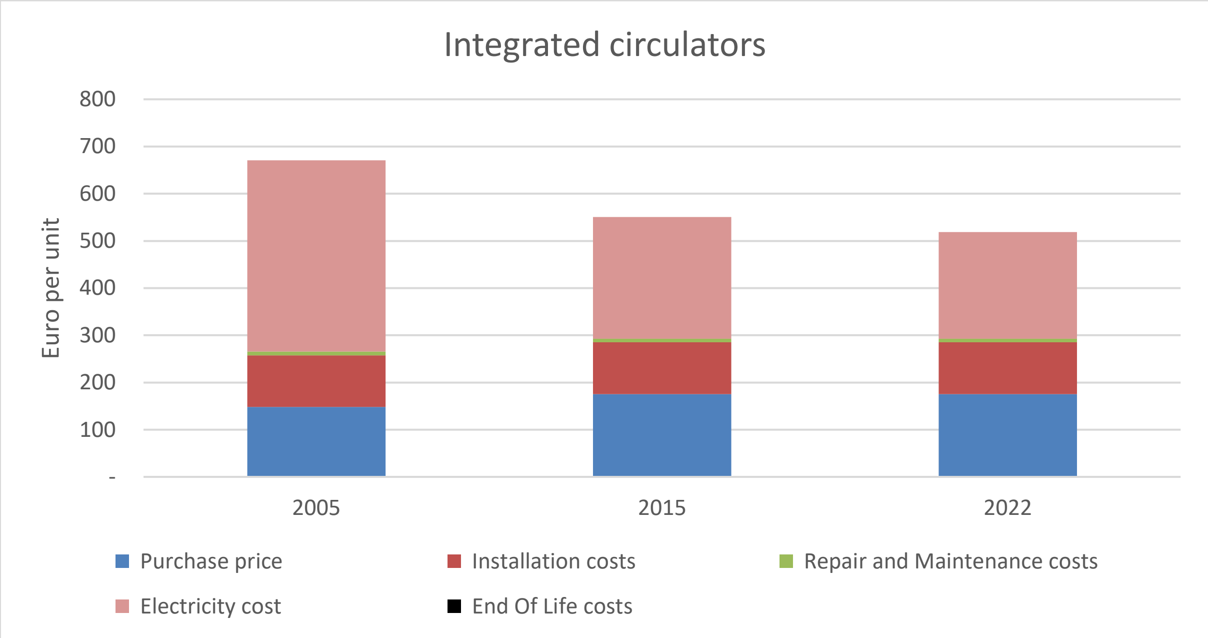

Figure 5: Total Life Cycle Costs for integrated circulators for 2005, 2015 and 2022 (BAU) (constant 2015 prices)

Drinking water circulators

The drinking water circulators are not included in the scope of regulations (EC) No 641/2009 and (EU) No 622/2012. However, the increasing share of circulators equipped with a timer or controller results in a decrease in electricity consumption, but the price increase in electricity (in constant prices) result in more or less unchanged electricity costs over lifetime, see Figure 6.

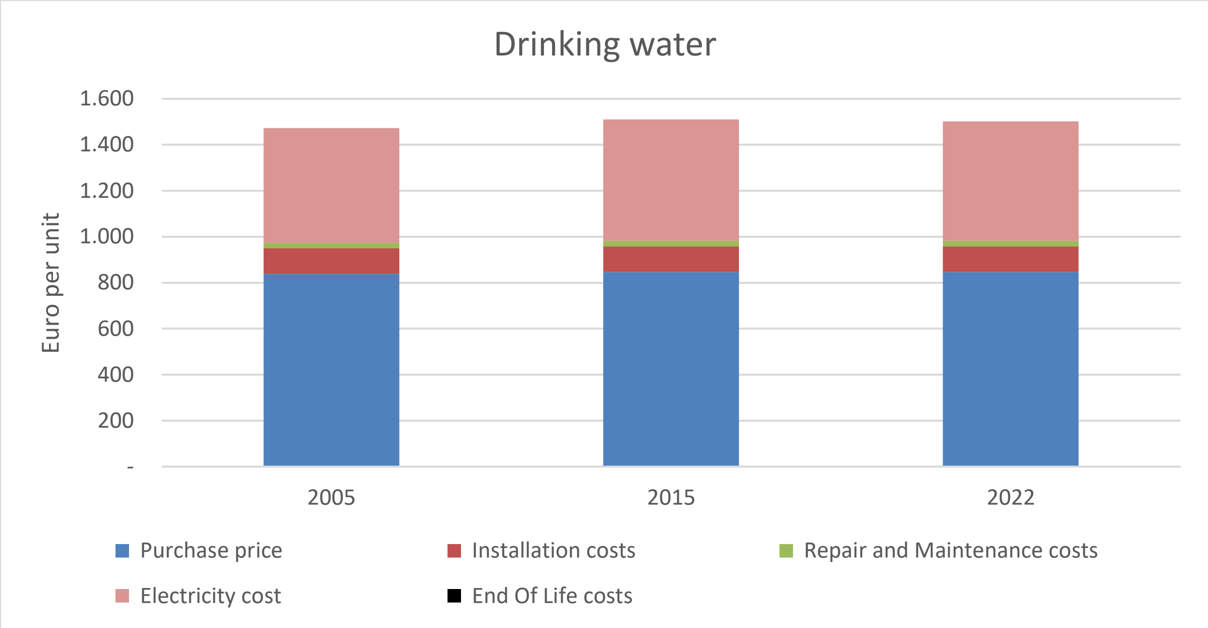

Figure 6: Total Life Cycle Costs for drinking water circulators for 2005, 2015 and 2022 (constant 2015 prices).

5.3 Use patterns

5.3.1 Circulators for heating applications

Circulators are, amongst others, used in heating applications or in cooling applications. In heating applications, their function is to circulate hot water in a heating system, e.g. to circulate hot water from a boiler or central heating system to heating radiators. Figure 7 illustrates the most common uses for circulators in heating applications, including solar thermal panel applications which are relevant due to the compensation factor allowed for primary circuits of thermal solar systems and for heat pumps in Commission Regulation (EU) No. 622/2012. More circulators are shown to illustrate possible positions, although usually a heating system only include one circulator.

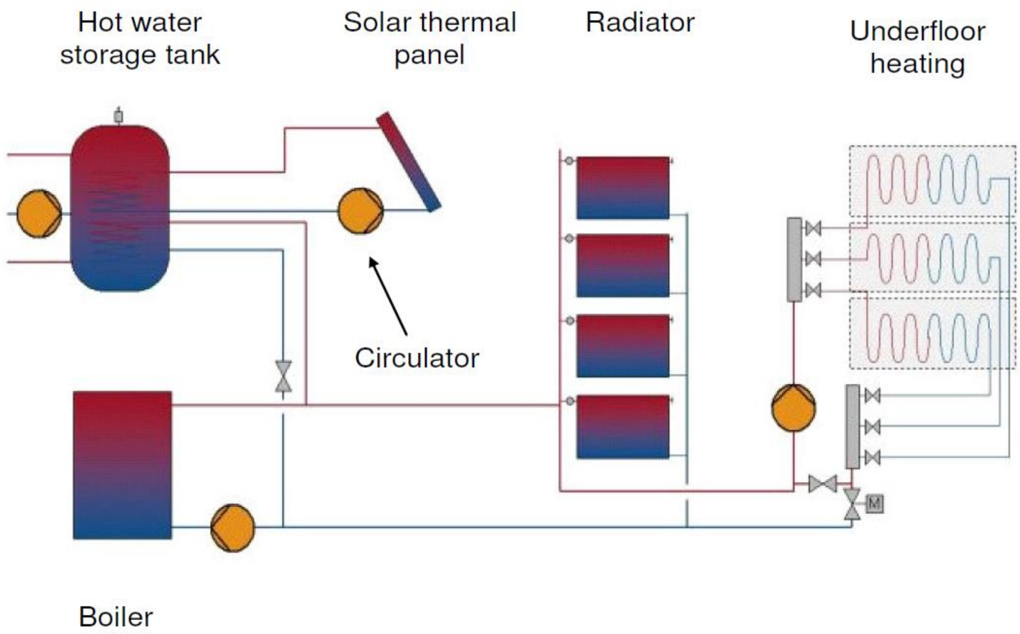

Figure 7: Simplified sketch showing circulator applications in a domestic environment[63]

In a heating application, the flowrate of the hot water is regulated by thermostat valves in order to maintain a certain temperature level of the water in the radiators and in the rooms being heated. The total operation time of circulators in heating systems during a year depends on the climate and the type of heating system. In the preparatory study, it was assumed that for continuous operating circulators running during the entire heating season the average running time in the EU is 5000 hours per year[64].

To describe the variation of the flowrate over time, a flow-time profile has been developed. The flow-time profile, which was originally adopted by the German energy label Blue Angel, is commonly accepted as representative for circulators in EU[65] and is used in the regulation (see Table 16). This flow-time profile was verified to fit well with weather fluctuation in both Southern and Northern Europe[66,67].

Table 15: Flow-time profile for circulators currently used

Flow-rate (share of maximum flowrate)	**25%**	**50%**	**75%**	**100%**
Share of time	44%	35%	15%	6%

During the review study, one of the stakeholders claimed that, because the existing flow-time is relatively old, it is most likely not representative of how circulators are used in today's installations. The stakeholder argued that there is a trend towards more appropriate sizes and better installations of circulators, meaning that the share of time which the circulators operate near maximum flowrate

[63] EUP Lot 11: Circulators in buildings, Issue 5, page 45 Figure 3-1
[64] EUP Lot 11: Circulators in buildings, Issue 5, page 48-54
[65] Classification of Circulators, Europump, February 2003
[66] Rainer Hirschberg, „Bestimmung der Belastungsprofile von Heizungsumwälzpumpen in der Gebäudetechnik", VDMA-Bericht, May 2001
[67] Rainer Hirschberg, „Bestimmung der Belastungsprofile von Heizungsumwälzpumpen in der Gebäudetechnik - Vergleichende Betrachtung für Süd- und Nordeuropa", VDMA-Bericht, Match 2002

is higher today. The stakeholder has therefore proposed a new flow-time profile instead (see Table 17).

Table 16: Flow-time profile for circulators provided by stakeholder

Flow-rate (share of maximum flowrate)	25%	50%	75%	100%
Share of time	15%	35%	35%	15%

Changing the flow-time profile to the one proposed by the stakeholder, would mean that the entire EEI scheme should be re-evaluated to ensure that the EEI values are calculated consistently. The change will mean that achieving high energy efficiency at maximum flowrate will become relatively more important than reducing power consumption at part load when it comes to achieving a good EEI rating.

Before recommending a change in the flow-time profile, it would be needed to assess the proposed profile further. Though the circulators are more appropriately sized, the hydraulic power provided by the circulator to the heating system should still follow the climatic variation over the year for the various climatic zones in EU. This would need a separate analysis outside the scope of this review study and the proposal has not been further considered.

5.3.2 Average and benchmark products

In the past, circulators were typically sold and operated without a variable speed drive (VSD, also called frequency converter). The circulators had either fixed speed or it was possible to adjust the speed of the pump manually in a number of steps (e.g. 3) (as the Grundfos UPS pump shown in Figure 8). Manual speed control requires that the operator accesses the circulator every time the circulator speed has to be changed. In practice this often means that the circulator is operating with the speed it is set to at the installation. It is possible to change the speed corresponding to the seasons, but this requires that the user is aware of the possibility and that the user knows which speed to set the circulator to.

Figure 8: Example of an old circulator with a three step manual speed control on the side of the circulator

Europump launched, in January 2005, a classification and voluntary labelling scheme applied to circulators up to 2500 W in heating applications. The classification was based on an Energy Efficiency

Index (EEI) and it categorised circulators into classes A-G based on the EEI values. Category D was defined as the most common category in 2004 with EEI values between 0.8 and 1.0. Category A being the best with EEI values below 0.4.

With the introduction of the voluntary labelling scheme in 2005, only circulators with variable speed drive could get an energy class A. With the use of a variable speed drive the circulator can regulate the speed automatically according to the user needs without any intervention of the user. Since most circulators are installed in private households where the owner often knows very little about the circulator, it is an important feature which does not require any intervention to operate most efficient. An example of an energy labelled circulator with a frequency converter is shown in Figure 9.

Figure 9: Typical circulator with energy class A label

With the energy efficiency requirements of the regulation (EC) No 641/2009 and the amendment (EU) No 622/2012 from 1st of August 2015, all circulators must have a EEI of 0.23 or less, with EEI less than 0.20 being the benchmark. This means that only a subset of those circulators with energy label A comply with the amended regulation (EC) No 641/2009. All circulators with energy label B-G do not comply. Figure 10 shows an example of a circulator that complies with the amended regulation and that is also a benchmark circulator[68].

[68] In the EU regulation (EC) No 641/2009 the benchmark is specified with the statement: "At the time of the adoption of this regulation, the benchmark for the best available technology on the market for circulators is EEI ≤ 0,20."

Figure 10: Example of a modern high energy efficient circulator with an EEI of less than 0.17 - top front view of the circulator, bottom side view of the circulator with the name plate showing the EEI.

5.3.3 Drinking water circulators

Drinking water circulators are circulators that are used for recirculating domestic hot water, as the system shown in Figure 11. In these kind of systems, cold drinking water is supplied from a waterworks into to the building. The water supply is directly connected to all cold water taps with a pressure from the utility that ensures a constant flow, when a tap is open. The water supply is also indirectly connected to all the hot water taps through the heater with the pressure from the utility. In the water heater, the water is heated and distributed to the hot water taps. The purpose of the recirculation is to ensure that the water for the hot water tap is sufficiently warm within a limited time after opening the tap. Without the recirculation the heat loss from the pipes causes the water in the pipes to be cold and thereby result in cold water from the hot water tap until the hot water from the water heater reaches the tap.

The drinking water circulator operates with a constant flowrate unlike other circulators, and therefore they normally operate without variable speed drives. This means that normally a drinking water circulator is operating at nominal speed 8760 hours/year (24 hours a day). Energy savings for drinking water circulators can be achieved by turning off the recirculation when it is expected that no hot water is used.

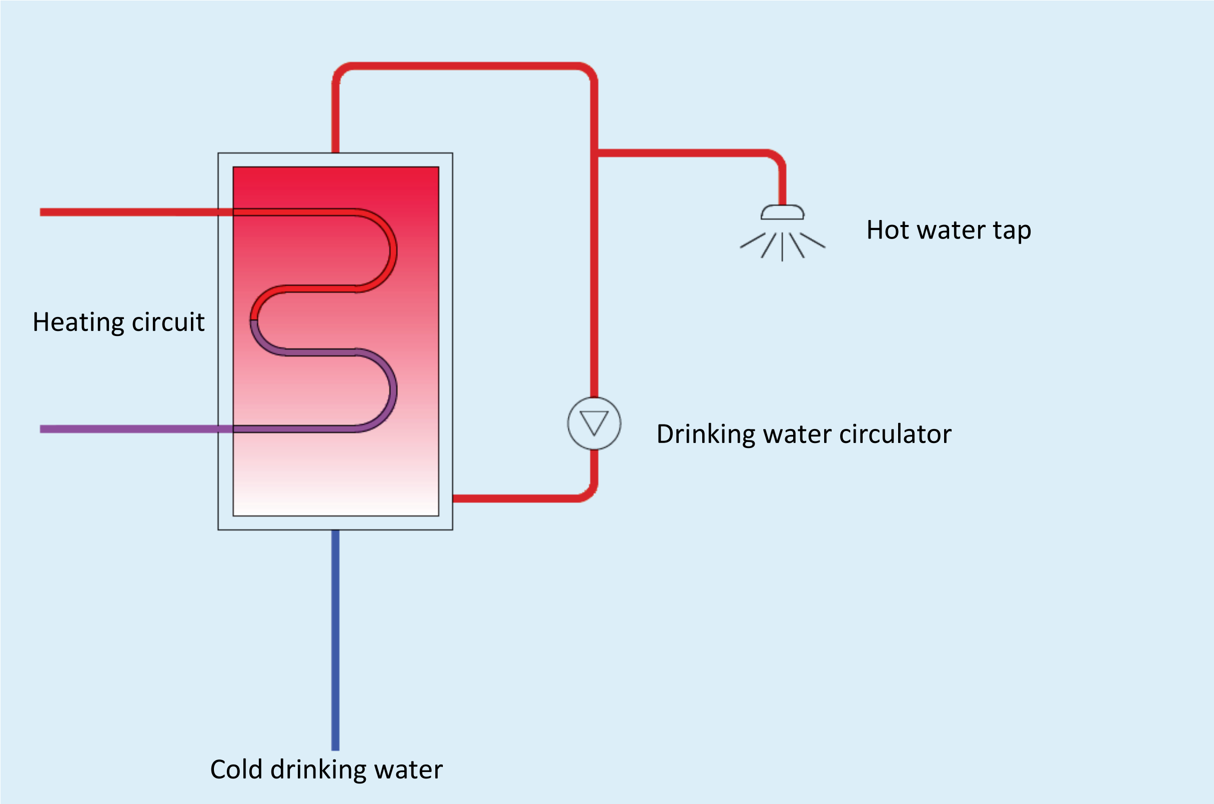

Figure 11: Illustration of a heated drinking water recirculation system[69]

Since drinking water circulators are used in a system that does not have any significant variations in pressure or volume over time, there is no energy saving potential from using variable speed drives (i.e. VSD) when the circulator is correctly sized. Instead, there is a saving potential when it is possible to reduce the operation time of the circulator. By using time control to switch off drinking water circulators when the hot water tap is not in use the operation time can be significantly reduced. For example, in an office building the hot water is not used in weekends or during the night. By limiting the use of the drinking water circulators to the office hours, the operation time could easily be reduced to 1/3 of the time reducing both electricity consumption and heat losses from the pipes. However, in doing so the water temperature in the pipes will decrease and it would take longer time to heat the pipelines if an employee should be working outside office hours. at the beginning of the office hours.

For this reason, some drinking water circulators are sold with timers that can be programmed to turn the circulator on and off at specific times during the day and the week. Turning off the recirculation can however be problematic due to legionella bacteria. Without recirculation and draw off from the tap, the water in the pipes is stationary and heat losses from the pipes results in decreasing temperatures. Stationary water at temperature between 30-40 °C gives legionella bacteria the optimal growth conditions, while water at 50 °C or warmer will kill the bacteria.

[69] Illustration based on figure in the leaflet "Styring af cirkulationspumpe til varmt brugsvand" by Videncenter for energibesparelser i bygninger, December 2015, http://www.byggeriogenergi.dk/media/1704/styring-af-cirkulationspumpe-varmt-brugsvand_ok.pdf

There are different opinions on the required minimum temperature for safe operation of a domestic hot water system. Some argue that the water temperature should be at least 55 °C[70,71] and others that 50°C is enough[72]. Furthermore, others even say that temperatures down to 45 °C are allowed during peak draw off as specified in DS 439:2009 (Danish Standard), Code of Practice for domestic water supply installations[73].

Controller options for drinking water circulators

Drinking water circulators on the market today are sold either:

- without any control,
- with time control,
- with thermostat control, or,
- with both time control and thermostat control.

A time controller can either be manually programmable, where the user can specify at which times the circulator should be operating, or an automatic adaptive controller, which detects the use pattern of the hot water system and switches off when usage is unlikely. Sometimes controllers[74] include a function that ensures that the system is flushed when the circulator has been inactive for 8 hours.

A thermostat control means that the circulator will switch off when the water is above a pre-set temperature and automatically switch on when the water has cooled. If the pre-set temperature is above 55 °C, the use of thermostat can be considered safer to prevent the growth of legionella. However, thermostats often have a default pre-set temperature at about 45 °C[75] and therefore allow the water drop to temperatures that allows legionella growth.

When a combination of a time controller and a thermostat is used, the time control specifies the times when the circulator is off. When the circulator should be on according to the time controller, the thermostat decides whether the circulator should be on or off.

Operation time of drinking water circulators

The operation timer of drinking water circulators depends on how the circulator is controlled. If the circulator is not controlled the circulator will typically run constantly all year round, that is 8760 hours/year.

If the circulator is controlled, either with timer, thermostat or both, the circulator will not run constantly. However, the amount of time it will be running depends on the individual user. To the best knowledge of the study team, there has not been conducted any comprehensive study of how much the operation time is reduced on average by using time control or thermostatic control.

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[70] Maintenance & Operational Procedures for the control of Legionella, water hygiene, 'safe' hot water, cold water, drinking water and non-drinking water, October 2012, South West Yorkshire Partnership NHS Foundation Trust, Chris Curry.
[71] Input from Germany during stakeholder meeting, 11th November 2016
[72] EUROHEAT & POWER Guidelines for District Heating Substations October 2008, https://www.euroheat.org/wp-content/uploads/2008/04/Euroheat-Power-Guidelines-District-Heating-Substations-2008.pdf
[73] www.teknologisk.dk/_root/media/45886_FJV%2002%20Lovgivning.pdf
[74] http://moderncomfort.grundfos.com/int/heating-hot-water/product-range/re-circulation-/comfort-autoadapt-pm/#/features
[75] LEGIONELLA, Installationsprincipper og bekæmpelsesmetoder, Rørcenter-anvisning 017, April 2012 (in Danish)

According to the Danish Energy Agency, it is plausible to reduce the operation time of drinking water circulator in a normal villa to between 8 and 16 hours/day[76], and similar statements are made in a report[77] prepared by the Department of the Environment, Water, Heritage and the Arts in Australia.

However, in Germany, to comply with German regulation (maximum 8 hours switched off per day) the operation time is at a minimum 5840 hours/year. Since the German regulation only applies to Germany it is still plausible to assume that it is possible to reduce the operation time of drinking water circulator to an average of 12 hours/day corresponding to 4380 hours/year. However, this excludes any national requirement on flow control to avoid the growth of Legionella bacteria. It is for this reason, that before conducting such study, it is important to investigate the national requirements and provide energy saving scenarios that comply with the different hygienic requirements. This is outside the scope of this review study, but the study team encourages to perform such study in the future, if drinking water circulators are meant to be included in the circulators regulation in the future.

5.4 Current Energy Efficiency Index (EEI) levels

The EEI is defined in the regulation[78] as:

$$EEI = \frac{P_{L,avg}}{P_{ref}} \cdot C_{20\,\%}, \text{ where } C_{20\,\%} = 0{,}49$$

Here $P_{L,avg}$ is the average electricity power consumption of the actual circulator and P_{ref} is the average power consumption of a reference circulator which is calculated according to its size.

It is specified that "$C_{XX\,\%}$" means a scaling factor that ensures that at the time of defining the scaling factor only XX % of circulators on the market of a certain type have an EEI ≤ 0.20.[79] This means that the scaling factor is chosen so that 20 % of the circulators have an EEI ≤ 0.20 at the time the scaling factor was chosen[80].

Input from stakeholders has indicated that consumers have more awareness about the EEI level when standalone circulators are bought than when integrated circulators are bought. This is due to the fact that integrated circulators are bought as part of the heat appliance and when purchased as new the circulator is not visible and that the EEI marking requirement in the regulation (EU) No 622/2012 is only applicable to standalone circulators (Annex I, point 2a).

This assumption and the fact that the requirements of the regulation were introduced in 2013 and 2015 give an indication of the EEI levels available on the market from 2004 to the present. The estimates were shared with Europump who confirmed these up to the year of 2010 and provided their estimate of the EEI distribution from 2013 to 2030. The input from Europump has been used to form the assumptions of how the EEI market distribution has been happening over the years.

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[76] Styring af cirkulationspumpe til varmt brugsvand, Videncenter for energibesparelser i bygninger, December 2015
[77] Consideration of hot water circulators for inclusion in the WELS Scheme, Coomes Consulting Group Pty Ltd
[78] EU regulation (EC) No 641/2009, Annex II
[79] EU regulation (EC) No 641/2009, Annex II
[80] "To keep the relation to the A-G labelling a calibration factor was introduced to the EEI calculation, which means that the EEI now is calculated as ... where C20 % = 0,49 is chosen such that 20 % the circulators on the market will be below EEI=0.20. For small circulators this also means that a circulator with an EEI of 0.20 will have an annual energy consumption of 20 % compared to the D-rated circulators, which was the base case for the A-G labeling. In this way the scaling factor provides a link between the A-G labelling and the ecodesign requirements." - Lot 11 – Circulators: The stony route to EU regulation 641/2009 (622/2012). Niels Bidstrup, Chief Engineer, Ph. D., Grundfos Holding A/S.

However, it was assumed that the data from Europump represents an optimistic view on the market and therefore the final data used for the scenario analysis has been modified. It was also assumed that, despite the requirements of the regulation entering into force by 1st January 2013 and 1st of August 2015, some circulators not complying with the requirements were still being sold. The corresponding data for 1990-2016 for the assumed EEI distribution are shown in Table 17 and Table 18, and in Figure 12 and Figure 13.

Table 17: Assumed distribution of EEI levels of standalone circulators sold in specific years

EEI interval	1990	1995	2000	2005	2010	2013	2016
EEI > 0.27	99%	98%	97%	95%	70%	10%	0%
0.23 < EEI < 0.27	1%	2%	3%	4%	15%	30%	3%
0.20 < EEI < 0.23	0%	0%	0%	1%	12%	40%	67%
0.17 < EEI < 0.20	0%	0%	0%	0%	3%	18%	25%
EEI < 0.17	0%	0%	0%	0%	0%	2%	5%

Table 18: Assumed distribution of EEI levels of integrated circulators sold in specific years

EEI interval	1990	1995	2000	2005	2010	2013	2016
EEI > 0.27	99%	98%	97%	95%	70%	38%	5%
0.23 < EEI < 0.27	1%	2%	3%	4%	15%	11%	7%
0.20 < EEI < 0.23	0%	0%	0%	1%	12%	41%	70%
0.17 < EEI < 0.20	0%	0%	0%	0%	3%	11%	18%
EEI < 0.17	0%	0%	0%	0%	0%	0%	0%

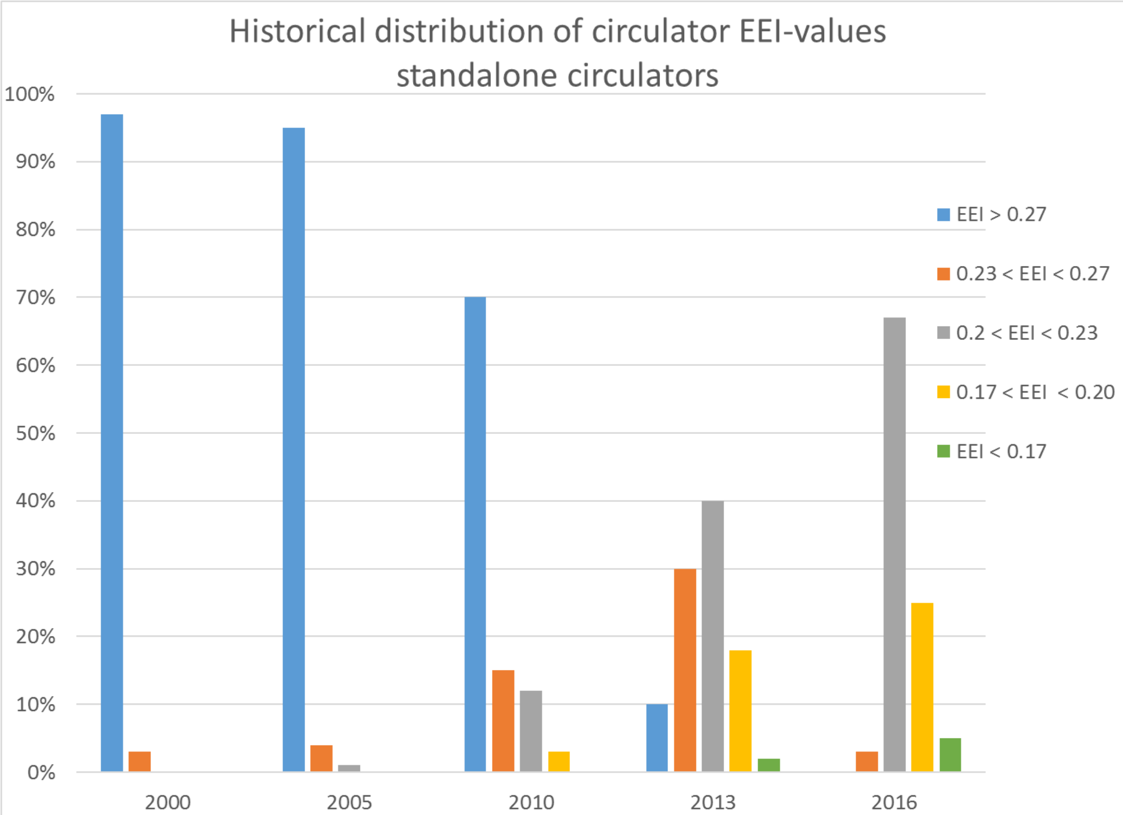

Figure 12: Distribution of EEI values for sold standalone circulators, 2000-2016

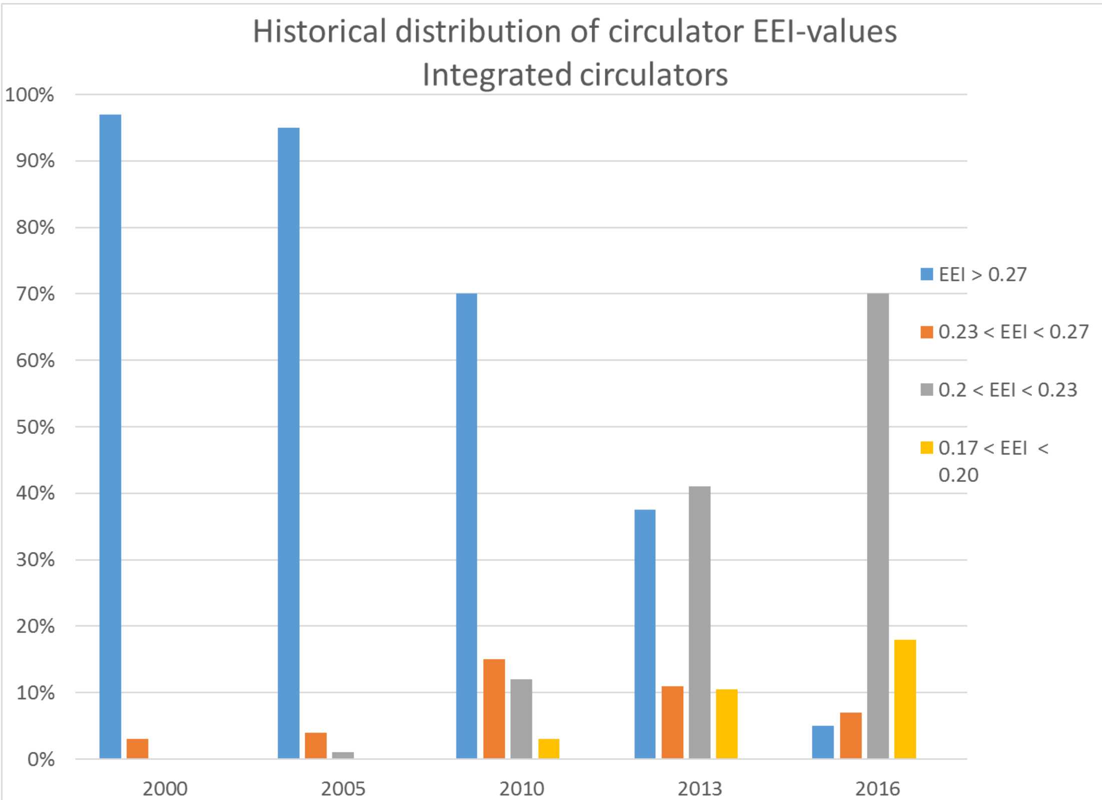

Figure 13: Distribution of EEI-values for sold integrated circulators, 2000-2016

A desktop research investigation was conducted by the study team to establish a current overview of pumps being placed on the EU market and to eventually compare with data predictions confirmed with Europump that were presented previously. The EEI values and pump size (electric power) of 215 pump models with online datasheets were recorded, which are shown in Figure 14. The pump models are mostly standalone circulators and some circulators for which it is unknown whether they are standalone or integrated. These data have been compared with the data provided by Europump showing a good correlation, see Figure 15.

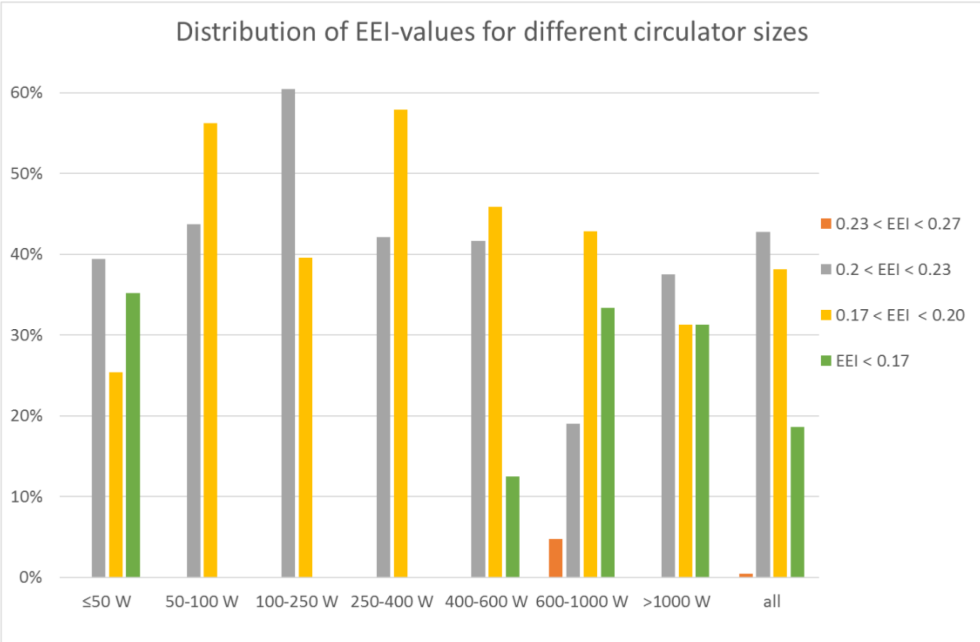

Figure 14: Distribution of EEI-values of pump models placed on the market (2016) for different circulator sizes

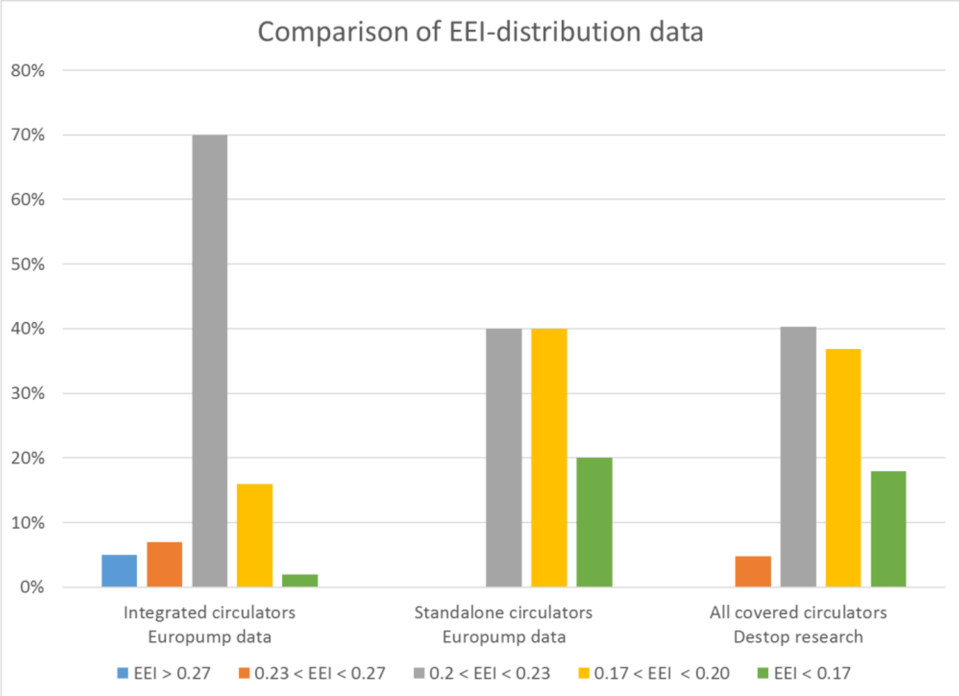

Figure 15: Comparison of EEI datasets Europump (sold circulators) vs. desktop research (circulators placed on the market) - 2016[81]

5.5 Conclusions

The market analysis presented shows that the circulator market tends to use smaller size standalone circulators and eventually, have some of these substituted by integrated circulators. The market growth is low, since most of them are purchased for replacement. The drinking water circulators market represents about 11 % of the total circulators market in the EU and it is predicted to grow very little in the future since it is also mainly a replacement market.

The costs for the end-users throughout the circulators' life cycle are mainly from the purchasing and the use of the circulators (electricity costs), where the trend in the future is expected to be more on the purchase side than on the use side, especially for small standalone circulators. For large standalone circulators this will remain about half/half.

However, in previous years before the regulation (EC) No 641/2009 came into force, the use phase was the dominant. For integrated circulators, the installation costs will still be significant however, the use costs only represent about a third of the life cycle costs. For drinking water circulators, the increasing share equipped with a timer or controller entails that the electricity cost will not increase as much, and the increase in electricity cost will follow the same development as the life cycle costs for other circulator types. The purchase prices for all circulators in scope of the regulation have increased significantly since the regulation came into force, but they are expected to remain almost constant in the future if the energy efficiency requirements in the regulation are not made more stringent. For drinking water circulators, the purchase price is expected to increase because of more

[81] Tthe first two datasets on the left are Europump's and the last on the right is from the desktop research

of them available with time and/or thermostat controllers, but the price is expected to become more or less constant after the circulators with controllers are fully placed on the market.

It is evident that the drinking water circulators present different usage patterns than the circulators used in heating/cooling systems and it is thus perceived that at this point in time it is not possible to remove their exemption in the ecodesign energy efficiency requirements. More work is needed to establish an overview of their flowtime profiles to comply with the different legionella hygienic requirements across the different EU Member States. Furthermore, a harmonisation of these profiles is needed before developing an energy efficiency calculation method due to the current lack of characterisation of their hydraulic performance which can be used at a standardised level.

Since the introduction of the voluntary labelling scheme in 2005 the overall energy efficiency of the circulators used in heating and cooling systems has rapidly increased. The regulation with the mandatory minimum energy efficiency requirements (i.e. EEI) was necessary to continue the trend in the market towards more energy efficient circulators, since the labelling scheme was about to become obsolete with most new circulators being labelled A in the Europump's voluntary labelling scheme. The current market shows that even the current benchmark value of 0.20 is not sufficient to indicate which circulators are the most energy efficient. As of present, several circulator models have EEI values of 0.17 or less, which means that they consume about 15 % less electricity compared to a benchmark circulator and about 30 % less than a circulator that is just good enough to meet the energy efficiency requirements.

6. Review of designs for Recoverability, Recyclability and Reusability (RRR)

The main objective of this chapter is to present an overview of circulator designs, which can facilitate the reuse, recycling and/or recovery of the circulator or some of its components. Since the focus of the current regulation of circulators has been on energy efficiency, the information in this regard is very new for this product group, and it was therefore not possible to present this overview at a base case level but rather for the whole product group. Furthermore, this overview was done by assessing the current legislative framework concerning end-of-life of circulators, with the reasoning that it is important to assess the barriers and opportunities that exist for their reuse, recycling and recovery. Finally, some suggestions on how to tackle the end-of-life of circulators from an ecodesign perspective are presented, in particular concerning the regulation (EC) No 641/2009 and the regulation (EU) No 622/2012.

6.1 Background for requirements on information about end-of-life

According to Article 7 of both the (EC) No 641/2009 and the (EU) No 622/2012 regulations, this review shall include the assessment of design options that can facilitate reuse and recycling. The current ecodesign requirement in this respect is from the (EU) No 622/2012 regulation, which states as one of the product information requirements (annex I, point 2c):

"information concerning disassembly, recycling, or disposal at end-of-life of components and materials, shall be made available for treatment facilities on standalone circulators and on circulators integrated in products;"

Furthermore, at the end of the requirements it stands that "manufacturers shall provide information on how to install, use and maintain the circulator in order to minimise its impact on the environment" and that the "the information concerning disassembly, recycling, or disposal at end-of-life (amongst the other information requirements) shall be visibly displayed on freely accessible websites of the circulator manufacturer."

Comments from Non-Governmental Organizations (NGOs) before the Consultation Forum[82] of regulation (EC) No 641/2009 questioned the choice to drop any generic requirement on design for recycling, and referred to the preparatory studies on motors[83] and on fans[84]. In these preparatory studies, generic ecodesign requirements were suggested to make the disassembly and the recovery of valuable materials easier. These requirements as suggested did not proceed further. However, product information requirements were included in regulation 640/2009 on electric motors and regulation 327/2011 on fans driven by motors with an electric input power between 125 W and 500 kW as it follows:

- In the regulation 640/2009, in Annex I, point 2-11, information relevant for disassembly, recycling or disposal at end-of-life must be visibly displayed on the technical documentation of motors as well as of products in which motors are incorporated, and on free access websites of manufacturers of motors and of products in which motors are incorporated.

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[82] Position of ECOS, EEB, CAN-Europe, INFORSE-Europe, Greenpeace and WWF on the EC Working Documents on possible ecodesign requirement for electric motors, pumps, circulators and ventilation fans. Brussels, 21 May 2008.

[83] EuP Lot 11 Motors Final Report. ISR – University of Coimbra. February 2008.

[84] EuP Lot 11: Fans for ventilation in non residential buildings. Final Report. Fraunhofer Institute Systems and Innnovation Reseach. April 2008.

- In the regulation 327/2011, in Annex I, point 3-12, information relevant for facilitating disassembly, recycling or disposal at end-of-life must be visibly displayed on the technical documentation of fans and free access of websites of manufacturers of fans.

Because article 7 of the electric motors regulation 640/2009 specifically requests that resource efficiency, reuse and recycling should be included in a revision of the Regulation, the ongoing Impact Assessment is expected to elaborate further in this area. This is not the case for the fan Regulation 327/2011.

These three products are similar in terms of material use and the fact that they are all motor driven units[85]. For this reason, they are comparable in relation to focus points for material recoverability and thus have been looked at together by NGOs as mentioned previously, although their designs and possibilities for disassembly are different and should be assessed separately.

When looking at their product information requirements relevant to end-of-life, they are observed very similar except for the level of detail of the information provided, where for circulators this is at the material and component level whilst for motors and fans this is unspecified meaning it could be sufficient to show this at the product level, and for the target group that receives this information.

Although the product information requirements in regulation (EU) No 622/2012 on circulators (annex I, point 2) state that the information shall be visibly displayed on freely accessible websites of the circulator manufacturer, the specific requirement on information at end-of-life states this should be available for treatment facilities. This could be the reason why so few manufacturers actually show this information on their websites, as it is described in more detail in section 6.3.1. This indicates that removing this specific target group (i.e. treatment facilities) may result in more manufacturers actually disclosing their information.

Finally, it is also important to notice that electric motors are incorporated in circulators, and thus the information requirements on motors (regulation 640/2009) are applicable to the motor part of the circulators. It is not known why there is a lack of this information, but one of the probable causes may be the lack of enforcement of these requirements. No comments were provided in this respect when market surveillance authorities were interviewed (see outcomes in section 7), but since the motor regulation may be amended, it may be better to wait for the outcomes of its review to define whether the lack of compliance of this requirement will still be valid in the future. The importance of the information requirements from the motor regulation is the content of neodymium in the more efficient motors. However, it is not known whether a generic information requirement as that which exists today gives the information necessary to target the recycling of the component that contains neodymium (i.e. the permanent magnet).

[85] Policy guidelines for motor driven units (MDUs). Part 1: Analysis of standards and regulations for pumps, fans and compressors. Energy efficient end-use equipment – International Energy Agency. October 2016.

6.2 Legislative framework on designs for RRR

In 2011, the European Commission published a communication document explaining the opportunities and barriers to make Europe resource efficient[86]. The document is part of the Europe 2020 Strategy and its flagship initiative on "A Resource Efficient Europe"[87].

In 2015, the European Commission published a communication document with an EU action plan for the Circular Economy[88]. Of particular relevance to this study is the emphasis by the Commission on the circular economy aspects which must be systematically assessed as part of the product design requirements under the Ecodesign Directive. In particular concerning reparability, durability, upgradability, recyclability, or the identification of certain materials or substances. It is herein stated that these aspects will be assessed on a product by product basis in new preparatory studies and reviews in close cooperation with relevant stakeholders. However, it may be more efficient to target some of these requirements at horizontal level as it was investigated and concluded by a preparatory study to identify resource-relevant product groups and horizontal issues[89].

The next sections describe the legislative framework wherein circulators may be managed, once they reach their end-of-life. This has an influence on the incentives to increase their reuse, recycling and recovery at their end-of-life.

6.2.1 Extended Product Responsibility (EPR) schemes

EPR schemes create incentives to recover products, such as circulators, at their end-of-life to increase the purity of the materials that can be recovered and the possibility to reuse some of its components due to reduced risk of damage. These incentives are created by increasing the concentration of materials with higher economic value as well as by reducing the waste collection costs.

The annex to the proposal for amending the different EU waste legislations[90] and the WEEE Directive[91] are the only policy documents specifying the scope of EPR schemes. The proposal for amending the EU waste legislation specifies that it is Member States' responsibility to develop and apply EPR schemes and it specifies several aspects the Member States must take into account when doing so (i.e. definition of business model(s), definition of measurable targets for prevention, pre-treatment, reuse, recycling and/or recovery, definition of geographical coverage and establishing an enforcement mechanism including sanctions). To complement this, the WEEE Directive sets 45% of total weight collected (concerning the measurable targets previously described) as the minimum

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[86] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS: Roadmap to a Resource Efficient Europe. September 2011. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0571&from=EN

[87] COM(2011) 21

[88] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS: Closing the loop – An EU action plan for the Circular Economy (including Annex). December 2015. Available at: http://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_1&format=PDF and http://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_2&format=PDF

[89] Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC. Task 2: Supplementary Report "Identification of resource-relevant product groups and horizontal issues". BIO by Deloitte (BIO), Oeko-Institut and ERA Technology. 15 September 2014.

[90] http://ec.europa.eu/environment/waste/legislation/a.htm

[91] DIRECTIVE 2012/19/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 4 July 2012 on waste electrical and electronic equipment (WEEE) (recast)

collection rate (from 2016) which will increase to 65% in 2019. However, both policy documents leave it up to the Member States to establish financial schemes to achieve this, which are rather important on incentivizing manufacturers to establish EPR schemes to contribute to a higher collection rate.

6.2.2 Circular economy indicators

The European Commission has an ongoing work on developing material efficiency indicators that can be used horizontally across different product groups, and that can be incorporated in ecodesign regulations[92]. Metrics could be used in this way as starting point to define specific parameters that are relevant to each product group. The Joint Research Centre (JRC) is commissioned to develop these indicators[93], and has since 2010 been developing and improving the "Resource Efficiency Assessment of Products" (REAPro) method which is meant to be robust and applicable to all Energy related Products (ErPs) through individual assessments of the applicability of these metrics for each product group. This is a result of the standardisation mandate which emphasized the absence of relevant metrics for material efficiency. The individual assessments carried out by JRC follow a harmonised methodology: (1) characterisation of the product group, (2) assessment against selected criteria for the product group (e.g. recoverability), (3) identification of the product group's hot spots and (4) identification of improvement measures for the product and assessment of policy measures for material efficiency.

The material efficiency metrics developed for each product group shall reflect the aspects that are relevant for each ErP, but they should aim to cover at least one of the next criteria:

- Recyclability/Recoverability: improving this performance ensures that products and resources contained will be recycled/recovered at the end-of-life and boosts the market for secondary raw materials.
- Content of dangerous chemical substances: improving this performance ensures a non-toxic circular economy.
- Recycled/re-used content: improving this performance ensures a market for secondary raw materials / components.
- Durability/reparability/re-usability: improving this performance extends the use of raw materials.
- Content of key resources, including critical raw materials (CRM), precious and scarce materials: improving this performance contributes to better management of raw materials in Europe highly dependent on the import of these.

As it is indicated by JRC, the first step of assessing whether these indicators are applicable is to characterize the product group, i.e. to identify materials and design features that can facilitate e.g. higher recovery, reuse and/or recycling rates. For the purpose of this review study, this analysis (as defined by JRC) is presented in section 6.3.

[92] Through a standaridsation mandate (M/543): 'Commission implementing decision of 17.12.2015 on a standardisation request to the ESO as regards to eco-design requirements on material efficiency aspects for ErPs in support of the implementation Directive 2009/125/EC'. The deadline for adoption (i.e. the relevant organisations making a standard available to its members of the public) is the 31st of March, 2019.

[93] http://rmis.jrc.ec.europa.eu/?page_id=1186

6.2.3 Increasing plastic recycling

The proposal for amending the different EU waste legislations**Error! Bookmark not defined.** only sets pre-treatment targets (i.e. preparing for reuse and recycling) for plastic contained in packaging waste which is not relevant to the review conducted in this study. There are no other concrete actions planned for increasing the collection and recycling of plastics contained in products so far, and the annex to the EU action plan for the Circular Economy[94] states that the development of the EU strategy will take place until 2017 (exact date is still unknown).

6.2.4 Recovery of Critical Raw Materials (CRM)

The European Commission has two scheduled activities as part of their EU action plan on Circular Economy that are related to CRM, and which are relevant for setting ecodesign requirements on material efficiency:

- Improving exchange of information between manufacturers and recyclers on electronic products started this year
- Mapping critical raw materials in the EU by 2017

As a starting point for these activities, the Commission has developed a list of CRM[95] as part of the Raw Materials Initiative[96], where 20 materials are listed together with their main producers, sources of import in to the EU, their sustainability index and their end-of-life recycling input rate. One of the materials listed is actually a materials group called Rare Earth Elements (REE) which includes yttrium, scandium, and lanthanides (lanthanum, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium)[97]. REE are relevant to circulators because neodymium is part of the ferro alloy magnet located in high efficient motors which are increasingly being used in circulators (i.e. permanent magnet motors).

6.2.5 The WEEE Directive

The Directive 2012/19/EU on waste electrical and electronic equipment (WEEE) is the only relevant piece of legislation where specific requirements may apply for circulators in scope of regulation (EC) No 641/2009 and its amendments in regulation (EU) No 622/2012. However, when following the specific aspects covered by the WEEE Directive, especially concerning scope, it can be argued that circulators are exempted.

The definitions in the Directive concerning products in scope that apply for circulators are 'Electrical and electronic equipment' (EEE), used by consumers and intended for professional use', 'Waste electrical and electronic equipment' (WEEE), 'WEEE from private households' and equipment not

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[94] http://eur-lex.europa.eu/resource.html?uri=cellar:8a8ef5e8-99a0-11e5-b3b7-01aa75ed71a1.0012.02/DOC_2&format=PDF
[95] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS On the review of the list of critical raw materials for the EU and the implementation of the Raw Materials Initiative. May 2014. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0297&from=EN
[96] COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL. The raw materials initiative — meeting our critical needs for growth and jobs in Europe. November 2008. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52008DC0699&from=EN
[97] Critical raw materials for the EU. Report of the Ad-hoc Working Group on defining critical raw materials (2010). Available at: http://www.euromines.org/files/what-we-do/sustainable-development-issues/2010-report-critical-raw-materials-eu.pdf

specifically designed and installed as part of large-scale fixed installations and which can fulfil its function even if it is not part of those installations, should be included in the scope of this Directive (preamble paragraph 9). Some exclusions may be also applicable to circulators in scope of the current regulations, in particular equipment which is specifically designed and installed as part of another type of equipment that is excluded from or does not fall within the scope of this Directive, which can fulfil its function only if it is part of that equipment (Article 2, paragraph 3b).

To add to these contradictory statements, a study reviewing changes in the scope[98] touches on some of the issues described previously, which are also clarified in the FAQ document on the WEEE Directive[99]. The clarifications in these documents indicate that circulators may be covered within the scope of WEEE. Furthermore, under the Danish Producer Responsibility Scheme, electrical pumps are covered under the producer responsibility program[100] including pumps used for circulation in heating facilities (i.e. circulators).

According to input from stakeholders[101], the interpretation of the WEEE Directive may be done differently by different Member States due to the fact that it is a Directive, which requires the Member States to introduce national legislation. Furthermore, FAQ documents are guidelines to explain further the Directive but cannot be accountable as legislation. Because of this and added to the contradiction of terms in the Directive concerning the relevance of products like circulators under the scope of WEEE, it is concluded that circulators in scope of this review may or may not be covered depending on the national application of the Directive. It is thus not possible to track end-of-life routes for these products that can incentivize the recovery, reuse and recycling of circulators that goes beyond their design and the economic value of their materials.

6.2.6 End-of-Waste criteria

The 'End-of-Waste' concept was established in the revised Waste Framework Directive in 2008, and it is applied to waste that can be recovered and that has a value in the market place, so it can be integrated again into a new product and in this way, contribute to a circular economy. Some materials are highly recyclable nowadays, and some of them are relevant for circulators. For example, global recycling rates[102] for iron, aluminium and copper range from 52 to 90% (iron), 42 to 60% (aluminium) and 43 to 53% (copper), while European recycling rates for steel[103] range from 74-95%.

According to the Waste Framework Directive, certain specified waste cease to be waste when it has undergone a recovery operation (including recycling) and complies with specific criteria, in particular:

i. the substance or object is commonly used for specific purposes;

[98] Review of the scope of the Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE). Final report commissioned to BIO Intelligence Service by the European Commission, DG Environment. October 2013.
[99] Frequently Asked Questions on Directive 2012/19/EU on Waste Electrical and Electronic Equipment (WEEE). April 2014. Available at: http://ec.europa.eu/environment/waste/weee/pdf/faq.pdf
[100] https://www.dpa-system.dk/en/WEEE/Products/WEEEscopingofproducts
[101] Provided at stakeholders meeting. See minutes at http://www.ecocirculatorsreview.eu/downloads/Minutes%20stakeholders%20meeting%20-%2011.11.2016.pdf
[102] Recycling rates of metals. A status report. UNEP, 2011. Available at: http://www.unep.org/resourcepanel/portals/24102/pdfs/metals_recycling_rates_110412-1.pdf
[103] EUROFER – The European Steel

ii. there is an existing market or demand for the substance or object;
iii. the use is lawful (substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products);
iv. the use will not lead to overall adverse environmental or human health impacts.

The relevance of 'End-of-waste' to facilitating circulators designs for higher degree of RRR, is that when having harmonised criteria[104,105] for defining aluminium, iron, steel and copper scrap as secondary materials and not as waste, a bigger market is expected for these materials with an increased economic benefit and thus keeping incentives to use these materials in the design of circulators. The waste definition is also challenging the movement of circulators' end-of-life because some of their materials are considered waste while others not. However, when not sourced properly for a higher recovery or when mixed with other materials considered waste, this results in an increased complexity in takeback initiatives e.g. if pumps that have reached its useful lifetime are considered waste which decrease the level of incentive to recover the circulator. Furthermore, when waste is transported through borders the cargo has to be declared in each country it crosses. And the companies receiving the waste/old products have to be approved for receiving waste[106]. However, with the higher and cheaper availability of composite materials including plastics, a challenge exists on incorporating otherwise high recyclable materials such as aluminium, iron and copper in circulators designs. To achieve the aim of a more efficient use of our resources, a higher percentage of recycled content should be expected in the highly recyclable materials. But the fact that not enough scrap is available in the markets, presents also a challenge to incorporate the scrap in more of the products using these materials, e.g. in circulators.

6.3 Designs for RRR of circulators

Based on the review of relevant legislative framework presented in the previous section, the next aspects of the design of circulators are considered relevant for facilitating a higher degree of recoverability, recyclability and reusability:

- Materials used in the product design, including:
    - their environmental impact
    - their potentials for recovery, recycling and reuse
    - their economic value in the market
- Metrics to measure the level of recoverability of these materials in the product design
- Extended Producer Responsibility (EPR) schemes and Take-back systems
- The barriers for recovery, recycling and reuse

6.3.1 Designs and use of materials in circulators currently on the market

Back in 2008, the preparatory study Lot 11 listed bills of materials (BOMs) for three of the presented base cases (small and large standalone circulators, and boiler integrated circulators). The list of materials was in any case very similar for the three products, with the exception of one component (volute in standalone circulators compared to pump/valve housing in integrated circulators) and the

[104] COUNCIL REGULATION (EU) No 333/2011 of 31 March 2011 establishing criteria determining when certain types of scrap metal cease to be waste under Directive 2008/98/EC of the European Parliament and of the Council. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32011R0333&from=EN

[105] COMMISSION REGULATION (EU) No 715/2013 of 25 July 2013 establishing criteria determining when copper scrap ceases to be waste under Directive 2008/98/EC of the European Parliament and of the Council. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0715

[106] Communication with Peter Meulengracht Jensen from Grundfos

demand of materials (see Figure 16). The preparatory study does not cite the source of these BOMs, but according to MEErP these should represent the average circulators in the market. Furthermore, these BOMs do not include variable speed drives (i.e. frequency converters), as back then the energy efficiency requirements based on variable flow were not yet in place and it is thus assumed that the average circulators in the market did not have electronics.

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

Figure 16: Bill of materials of base cases for Lot 11 preparatory study

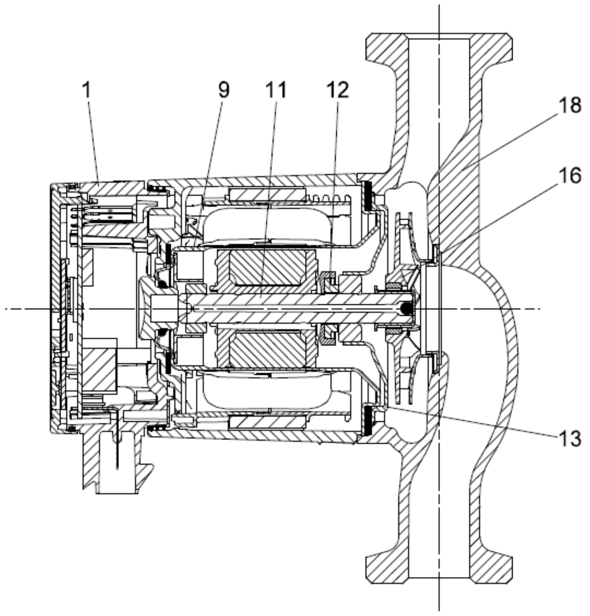
The preparatory study shows also a couple of 'real world' examples which seem to have been used as reference to develop the BOMs. These design examples are only from one manufacturer (Grundfos, UPS models[107], which are not used as much in the recent years), but at the time of this review study, information on product designs from other manufacturers could not be retrieved from freely accessible websites (see Figure 17, Figure 18, Figure 19 og Figure 20). The designs are observed similar as detailed in Figure 20, where the controller is observed at the front of the circulators, followed by part of the pump's housing covering the hydraulic components (i.e. rotor, shaft, thrust, bearing plate and impeller including the bearings), with the inlet and outlet at the back and covered by the rest of the housing. It is assumed that these are standalone circulators according to the definition in the circulators regulation.

Some of the components are assumed to be modular, meaning that they could be disassembled with certain ease (e.g. the controller and the part of the housing protecting the rotor, shaft, thrust and bearing plate). See Figure 18 for a sectional drawing showing these components.

[107] http://www.grundfos.com/service/encyclopedia-search/grundfos-large-upscirculatorpump.html

Figure 17: Overview of MAGNA and ALPHA Grundfos' circulator pumps[108]

[108] ALPHA pumps are recommended to operate at variable flow meaning different pressures and heads (i.e. 'Trin 1, 2 eller 3'), whilst MAGNA pumps are at constant pressure (i.e. 'Konstant tryk') and higher heads than ALPHA pumps. Available at: https://product-selection.grundfos.com/search-result.html?scope=Literature&searchstring=cirkulationspumpe



Pos.	Description	Material	EN/DIN W. - Nr.	AISI/ ASTM
1	Controller complete	Composite, PC		
9	Rotor can	Stainless steel	1.4301	304
	Radial bearing	Ceramics		
11	Shaft	Ceramics		
	Rotor cladding	Stainless steel	1.4301	304
12	Thrust bearing	Carbon		
	Thrust bearing retainer	EPDM rubber		
13	Bearing plate	Stainless steel	1.4301	304
16	Impeller	Composite, PP or PES		
18	Pump housing	Cast iron Stainless steel	EN-JL 1020 EN 1.4308	A48-25 B
	Gaskets	EPDM rubber		

Figure 18: Sectional drawing and material specification of Grundfos' Alpha2 L circulators[109]

[109] Available at: http://product-selection.grundfos.com/catalogue.product%20families.alpha2.html?custid=GDK&familycode=ALPHA2&lang=DAN&time=1474870997615

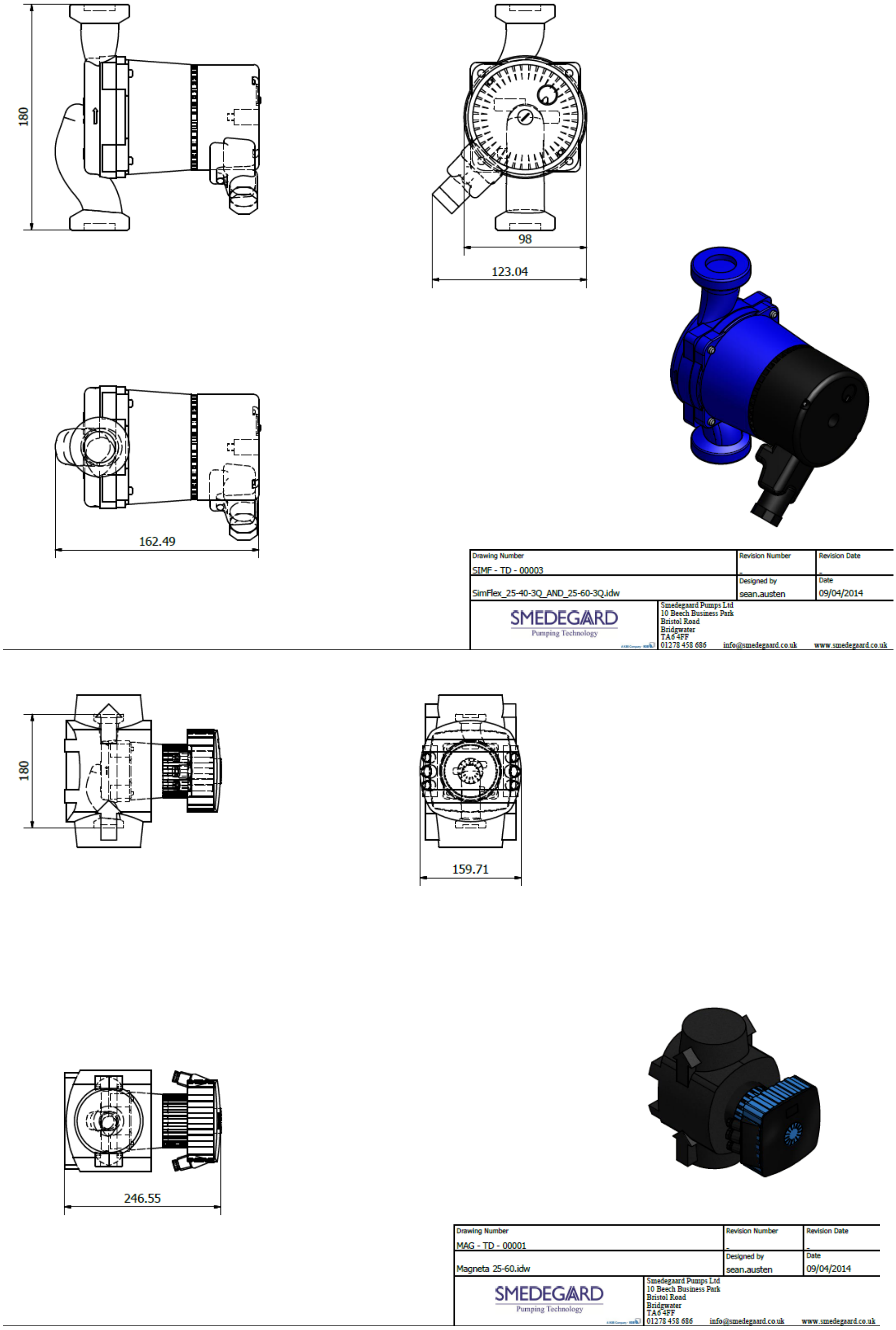


Figure 19: CAD & BIM drawings for two of Semedegaard's SimFlex[110] and Magneta[111] ErP compliant circulator pumps

[110] Available at: http://smedegaard.dk/downloads/cad-tegninger/simflex-erp-compliant/
[111] Avaiable at: http://smedegaard.dk/downloads/cad-tegninger/magneta-erp-compliant/

Figure 20. Overview of WILO's Stratos[112] and Yonos[113] circulator pumps

Only information from two manufacturers[114,115] about disassembly and disposal at end-of-life has been found in freely accessible websites in spite of that the product information requirement specifies: '…the information listed above shall be visibly displayed on freely accessible websites of the circulator manufacturer…', regarding '…disassembly, recycling, or disposal at end-of-life of components and materials…'. These manufacturers state that their circulators' main materials (i.e. copper, cast iron, aluminium, electronics, composite materials, steel, brass) are highly recyclable. Although, one of them states that this depends on the national possibilities for recycling.

Table 19 compiles the information provided by these two manufacturers, matching the assemblies (i.e. assemblies of components) to those shown in Figure 17. Information on weights is not shown as this varies according to the sizes of the products, but the information on components and materials as well as for end-of-life is representative either for the two most sold circulators in Europe (manufacturer 1) or they are shown as representative for all of the manufacturers' circulators (manufacturer 2). Finally, manufacturer 1 shows end-of-life information concerning only about disassembly at component level, whilst manufacturer 2 does concerning only recyclability at material level. It is assumed that manufacturer 1 only shows information where disassembly is challenged, as it states in its website that the disassembly of their products can largely be done by means of hand tools.

[112] Available at: http://productfinder.wilo.com/com/en/c000000010002929a00040023/product.html#tab=range_description and http://productfinder.wilo.com/com/en/c000000100003766000040023/product.html#tab=range_description
[113] Available at: http://productfinder.wilo.com/com/en/c0000003a0003b16700010023/product.html#tab=range_description and http://productfinder.wilo.com/com/en/c0000001f0001875f00040023/product.html#tab=range_description
[114] http://www.wilo.com/en/recycling/
[115] http://www.grundfos.com/products/product-sustainability/product-recycling.html

Table 19: Circulators' assemblies, components, materials and end-of-life information by two manufacturers (EU-market)

Assembly	Component	Material (manufacturers 1 and 2)	End-of-life remarks (manufacturer 1)	End-of-life remarks (manufacturer 2)
Controller complete	Nameplate	Composite, PA 66	none	98% recyclable
	Controller housing	Composite PC/ASA* or PA 66	none	99% recyclable
	Controller electronics	PCB** with SMD*** components	none	Recycling of electronics
	Cooling composite	Polyphenylene sulfide	none	n.a.
	O-rings	EPDM rubber	none	Thermal exploitation
	Outer bearing ring	Aluminium	The stator is heat-shrink fitted into the stator housing.	n.a.
	Stator housing	Aluminium or Stainless steel or Silumin****	The stator is heat-shrink fitted into the stator housing	99% recyclable
	Stator windings	Copper wire	The stator is heat-shrink fitted into the stator housing	99% recyclable
	Stator lamination	Black iron	none	n.a.
	Stator base material	PET/PBT	none	n.a.
Rotor can	Rotor can	Stainless steel or Composite	The front-bearing is shrink fitted into the rotor can	99%-100% recyclable
Radial bearing	Radial bearing	Ceramics	none	n.a.
Shaft	Shaft	Aluminium ceramics or Stainless steel	none	99% recyclable
Rotor	Rotor cladding	Stainless steel	none	90%-99% recyclable

Assembly	Component	Material (manufacturers 1 and 2)	End-of-life remarks (manufacturer 1)	End-of-life remarks (manufacturer 2)
	Rotor	Sintered NdFeB***** /stainless steel or Black iron/copper/stainless steel or Composite	none	90%-99% recyclable
Thrust	Thrust bearing	Carbon composite	none	98% recyclable
	Thrust bearing retainer	EPDM rubber	none	Thermal exploitation
Bearing	Bearing plate	Stainless steel or Brass	The front-bearing is shrink fitted into the rotor can	99% recyclable
	Radial bearing	Ceramics	none	n.a.
Impeller	Impeller	Composite (Polyethersulfone) or Stainless steel	The impeller is shrink fitted onto the shaft	99% recyclable
Pump housing	Pump housing	Cast iron or Stainless steel or Brass	none	99% recyclable
Others	Screws and gaskets	Various materials (<5% weight)	none	99% recyclable

*PC/ASA = Polycarbonate/Acrylonitrile styrene acrylate; ** PCB = Printed Circuit Board; *** SMD = Surface Mounting Device; **** Silumin = a group of casting aluminum–silicon alloys; ***** Sintered NdFeB = Ferroy alloy magnet (i.e. permanent magnet) containing Neodymium; n.a. = component not cited by manufacturer 2, thus end-of-life comment is not applicable.

It is noticed that eight out of a total of twenty-two components listed by these manufacturers are made mostly of metals that are highly recyclable (iron, aluminium, copper, iron). However, their accessibility at a component level will determine whether they can be recovered during the disassembly process. When manufacturer 1 refers to ‘shrink-fitting’, it is assumed that these components are fitted under vacuum (and sometimes heat) conditions, and it is thus difficult to recover them. This is the case for four of these components. Based on information from a manufacturer[116], there is a trend to use more composite materials than metals (especially aluminium, iron and steel) due to their improved properties and their cheaper accessibility in the market.

Five out of a total of twenty-two components listed by these manufacturers are made of plastic composites, thermoplastics or rubbers. Although manufacturer 2 claims that two of them are highly recyclable, it is known from information provided by recyclers and metal refineries and smelters that when plastics are sealed, screwed and/or glued with metals or electronics, it is very likely that they are combusted and their heating content is used for thermal recovery.

Four of the components are made of unknown or a mix of materials, while the controller is partly made of PCBs/SMDs sub-components. If circulators would be in scope of the WEEE Directive, these are parts that would be recovered as they would be sorted separately and sorted out from the rest of the waste stream in higher concentrations. Especially for these components which contain highly valuable metals such as gold and copper (only if >10 cm^2 according to the WEEE Directive).

The rotor can be made of a mixture of steel and iron containing neodymium, which is classified as 'rare earth metal (REM)' or 'rare earth element (REE)'[117] as previously stated. According to a major circulators manufacturer, the presence of neodymium in the rotor contributes to a higher energy efficiency of the motor and without neodymium the levels of energy efficiency of circulators would be lower (i.e. higher EEI values) and may not achieve the desired levels according to the regulation. Furthermore, according to a preparatory study commissioned by the European Commission[118], an increasing number of energy efficient motors use magnets containing REE. This study suggests to include ecodesign requirements for the marking of motors regarding their magnet use and magnet type, in order to facilitate future REE recycling potentials. This is because it is currently quite difficult to identify devices with magnets without any product-specific information which hinders the reuse and recycling of these materials. Finally, the study also mentions that other electrical equipment such as fans and pumps contain REE for the same purposes as for motors. However, in spite that the possibility exists to incorporate a potential amending marking requirement, this same study also suggests to incorporate this requirement at a horizontal level as rare earth magnets are only used in high energy efficient devices. The study exemplifies a potential mandatory requirement at horizontal level of marking of products containing REE above a certain weight (>10 g) as well as information on the type of REE (e.g. SmCo, FeNdB). This could increase the concentration and thus availability of these components at the recycling waste stream to pay-off the costs of disassembly and/or recycling. However, as it will be explained later, the absence of recycling process of neodymium at a commercial scale in the EU is an important barrier. As long as this does not exist, the possibilities for recycling are very low no matter if the collection rate increases.

Concerning electronics and according to the same manufacturer, the possibilities for recovering electronics are reduced when these materials are only available in small volumes. This is the case for circulators made by this manufacturer, since the volume of circulators per year recovered by them

[116] The manufacturer chooses to be anonymous. Information provided by a telephone interview.
[117] https://en.wikipedia.org/wiki/Rare_earth_element
[118] Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC. Task 2: Supplementary Report "Identification or resource-relevant product groups and horizontal issues". BIO by Deloitte (BIO), Oeko-Institut and ERA Technology. September, 2014.

through a take-back system is not enough to pay-off for the costs of recovering the electronics. Large economies of scale are necessary to increase the profits from re-selling precious metals present in the PCB/SMD[119] (see Table 20 for a typical composition in WEEE). However, this problem could be tackled if the manufacturer would decide to join an existing EPR scheme in the different Member States, if those exist, such is the case of Denmark where electric pumps are said to be covered by the Danish Producer Responsibility system.

Table 20: Typical composition of Printed Circuit Boards in WEEE[120]. WRAP (2014)

Material	Composition (% by weight)
Non-metallic e.g. glass-reinforced polymer	70%
Copper	16%
Solder (containing tin)	4%
Iron, ferrite (from transformer cores)	3%
Nickel	2%
Silver	0.05%
Gold	0.03%
Palladium	0.01%
Other (bismuth, antimony, tantalum, etc.)	<0.01%

Those materials appointed as the key resources are REEs and precious metals due to the criticality in terms of availability or their economic value. The REEs are located in the centre of the circulator while it seems like the controller and thereby also the PCB and other electronics are located in the front of the product according to the designs shown previously. This seems to be a general tendency among the assessed circulators. So, it is assumed that most products across the different manufactures more or less share the same design with a controller in front and few screws to assemble the product[121]. This assembly method also fits very well with design for disassembly since few screws are used and snap fits are preferred[122]. In many ways circulators are already prepared for an easy disassembly (Figure 21 shows an exploded view of a small standalone circulator).

The controller and printed circuit board are in this case assembled with snap fits which will ease the disassemble sequence and allow easy separation of these components before any other processing. The value of each printed circuit board is though questionable since it is assumed that the quantities

[119] A typical composition of a PCB is provided at 'Techniques for Recovering Printed Circuit Boards (PCBs). WRAP, 2014. Available at: http://www.wrap.org.uk/sites/files/wrap/Techniques%20for%20recovering%20printed%20circuit%20boards%2C%20final.pdf

[120] Variations exist for different sizes of PCBs, but the shown composition is based on those found the most in WEEE.

[121] Assumptions confirmed through communication with Peter Meulengracht Jensen from Grundfos

[122] Design for disasembly. Choido 2005. Avialable at: http://www.activedisassembly.com

of precious metals are lower than the presented composition in typical WEEE. The printed circuit board is assumed to be low grade and the value is thereby limited[123]. On the other hand, the recyclers performing mechanical disassembly and/or mechanical shredding are already very efficient in recycling metals and to some degree the printed circuit board, while the recycling industry have expressed an interest in the opportunity of pre-processing their waste if it is financially beneficial[124].

Figure 21: Exploded view of Grundfos ALPHA2 circulator

Even though the exploded view of the APLHA2 pump from Grundfos reveals a design with few screws, the magnet is expected to be more difficult to remove due do the assumption that sealed and tightened components are assembled under vacuum pressure. The amount of REEs in the magnet are also a concern since the exact composition and thus amount of neodymium are unknown (see Table 21 for a typical composition of permanent magnets). The amount of neodymium in a pump equivalent to the Alpha2 is around 10-20 grams[125].

Table 21: Typical composition of permanent magnets [126]

Elements	Nd	Dy	Pr	Fe	B	Co	C	N	Other
Wt%	23-25	3.5-5	0.05-5	62-69	1	0-10	0-0.14	0-0.1	1-2

The possibility to mark circulators containing neodymium has been discussed with a major manufacture of circulators. Their opinion was that a marking, even though it sounds simple, would have an impact on the production cost due to differentiation of product. Especially in comparison with the potential outcome which in their view was limited. Though they shared the empathy for a product passport since more knowledge of the waste equals to increased recycling potentials avoiding downgrading[127].

6.3.2 EPR schemes and Take-back systems

As discussed previously, EPR schemes are often incentivised by increasing the collection target of WEEE at national and European level. As mentioned previously, circulators are part of the Danish Producer Responsibility system, meaning that they are part of the Danish EPR scheme both under

[123] Assumptions confirmed through communication with Peter Meulengracht Jensen from Grundfos
[124] Communication with Steen Hansen from Stena Recyling in Denmark. See http://www.stenarecycling.com/about-stena-recycling/
[125] Communication with Peter Meulengracht Jensen from Grundfos
[126] Electrochemical recovery of rare earth elements from magnet scraps- a theoretical analysis, V. PRAKASH et al. Avaialable at: http://www.eurare.eu/docs/eres2014/thirdSession/VenkatesanPrakash.pdf
[127] Communication with Peter Meulengracht Jensen from Grundfos

category 6 (electrical and electronic tools) for the circulator unit including the engine and when the controller electronics are integrated in the circulator, and under category 9 (monitoring and control instruments) for the controller electronics when they are not integrated in the circulator.

Furthermore, it has been assessed that circulators may also be categorised under category 1 (large household appliances) if defined as electric heating appliances. In Denmark, only 12% of the marketed WEEE under category 6 is collected and 11% under category 9[128], indicating that these waste streams are not easy to collect (assuming the picture is not very different at EU level).

Because of the different recycling targets set by the EU not only concerning WEEE but also other waste streams such as packaging waste, construction waste and municipal waste, some other Member States have also put EPR systems into place. Individuals have a very important role to play in these schemes as householders are asked to separate the waste into different material types which ensures the higiest possible quality material. However, it is difficult for householders to separate products that are a complex assembly of different materials, which is the case for circulators. It is therefore needed under such EPR schemes collectors which are trained to separate further valuable materials from the general waste and that have direct business relationships with treatment facilities that can take the different waste streams (such as 'The Green Dot'[129]). In this case it may also be more beneficial that the manufacturers establish their own take-back system, to assure the proper collection and recovery of the most valuable materials. However, this implies a functioning business model that provides the economic incentives to spend on establishing such a system.

One of these examples is a take-back system established by Grundfos at national level (Denmark) for circulators. This take-back system was established some years ago, with the initial focus of recovering REE (neodymium and dysprosium) due to increased prices of these raw materials[130]. However, the interest has expanded to other materials and components such as the PCB/SMD and the aluminium. The business model is exclusive to the B2B sector directly managed with distributors of the pumps. Nowadays, the take-back system operates through a discount program. This is coordinated by four of the major distributors throughout Denmark, who sell new pumps to installers when they return their old pumps. These old pumps are then manually disassembled by socially disadvantaged people in a centralized location, who focus on collecting the high valuable materials (REE, PCB/SMD, aluminium) that are sent for recycling[131]. Grundfos' interest on the recovery of small components lies in the balance between costs and return from selling these materials after recycling. Nowadays it is still difficult to recover clean fractions of most of these metals, so the recovery price for selling 1 kg of mixed metals is not much (max. 40 Eurocents). If these materials were sold as clean fractions, the recovery price would be higher. Furthermore, since the circulators have a long lifetime (min. 10 years), the amount of collected circulators per year is not that high (max. 10,000 per year). If the volumes would be higher, the costs of recovering the materials/components would be lower in comparison to the price of the recovered materials. This would also increase the possibility to recover more clean fractions of materials which could be re-sold instead of sent to recycling avoiding the recycling cost. Finally, the current disassembly is manual as the volumes are low and it wouldnt pay off for a mechanical disassembly. However, if mechanical disassembly would be implemented

128 Screening of waste streams for WEEE and batteries. Danish EPA project number 1848. 2016. Available at (in Danish): http://www2.mst.dk/Udgiv/publikationer/2016/04/978-87-93435-62-9.pdf

129 http://www.gruener-punkt.de/en/ and http://www.pro-e.org/index.html

130 http://www.lbanalyse.dk/wp-content/uploads/2015/11/Opl%C3%A6g-om-Challenge-Water1.pdf (in Danish)

131 http://dk.grundfos.com/recycling.html#et_miljøvenligt_koncept (in Danish)

the efficiency of the recovery process would increase and thus a higher possibility would exist to recover clean fractions of high valued materials.

6.3.3 Current barriers for RRR

The challenge for considering design requirements that increase the RRR of circulators is to quantify potential suggestions with the future waste handling system and posibilties to recover materials and resources. The reuse of components are by the manufacturer Grundfos expected to be unfeasable due to the long lifetime of circulators. There is a tradeoff between long lifetime and reuse of components. When a product has a long and effective lifetime, the applicabilty of the used components decreases due to changes in the design and the general tear and wear.

Accordingly, the key components considered as main targets for recovery and recycling are the printed circuit board and the permanent magnet containing neodymium since the printed circuit board contains precious metals and the magnet contains REEs. Some parts of the circulator made of metals are already highly recyclable as discussed in previous sections. The possibilties to remove the printed circuit board and reach a high recyling rate is assumed to be better than the posibilities to remove the magnet. The design of circulators allows easy access to remove them but the low volume decreases the feasibilty. If the printed circuit boards are removed and processed at an integrated smelter-refiner like Umicore, over 95% of the precious metals and copper are recovered [132].

Recycling of the magnet is also challenging due to the current low value and volume of the REEs. In Figure 22[133], the price development of rare earth elements is shown. In conjunction with the lack of feedstock and inexistent collection system for end-of-life magnets, there are no reliable commercial recycling facilities in Europe. This means that, indeed, neodymium cannot be recycled on a commercial scale in Europe at the moment[134].

[132] Communication with Umicore
[133] Udland, Myles (2014, September 17), Rare Earth Metals Were Supposed To Be The 'Can't-Lose' Investment Of The Decade -- Look How That Turned Out. Business Insider. Available at: http://www.businessinsider.com.au/molycorp-decline-in-2014-2014-9
[134] Communication with Gwendolyn Bailey, Katholieke Universiteit Leuven

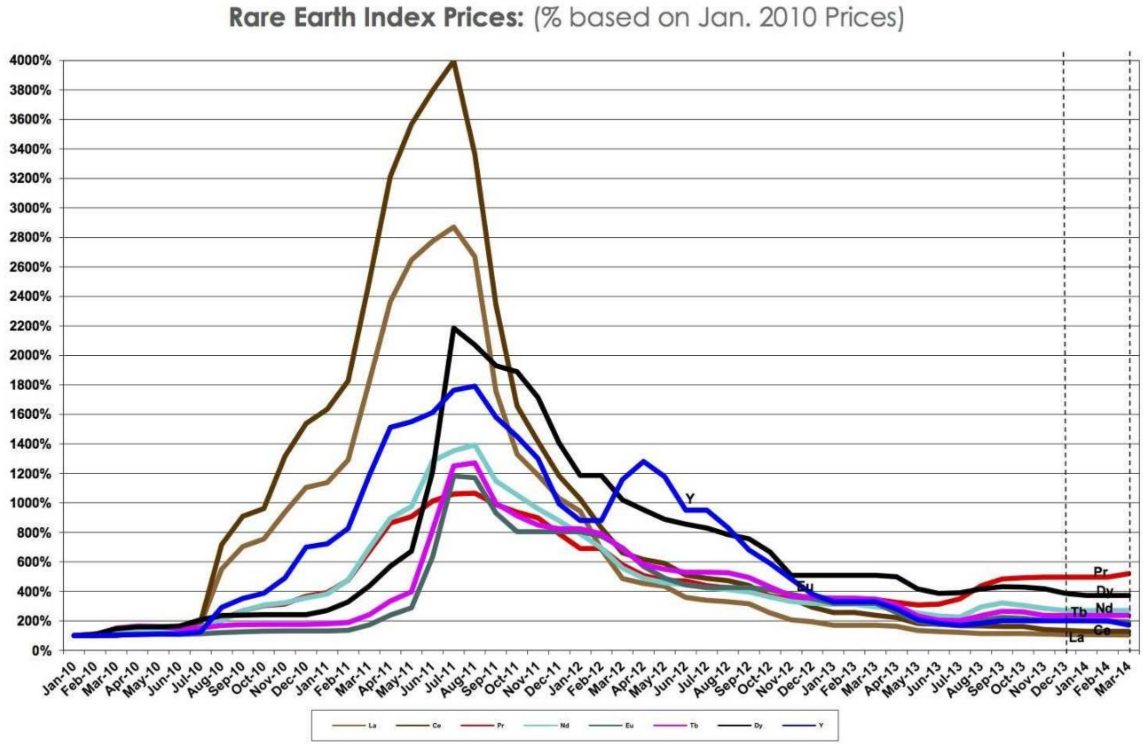


Figure 22: Price development of REEs

There is currently only one recycling facility available in Europe located in La Rochelle, France, but the capacity is limited and they have stopped their REE lamp phosphorus recycling process as it was no longer profitable. If more recycling companies would implement technologies to recover small amounts of REEs, then perhaps the electronics industry would first benefit since there is an increasing amount of electronic products containing REEs appearing already in the waste stream. The REE magnets from larger applications (e.g. from motor driven units) will not be available in mass quantities to recycle for at least another decade more[135].

A requirement of a marking of circulators at product group level are thus assumed to have a low impact and high price for the manufacture compared to the potential outcome[136]. Specially in comparsion with the current lack of recyling facilities in Europe and limted amount of REEs in circulators.

6.4 Conclusions

As discussed, the current information requirement in the regulation (EC) No 641/2009 (incl. its amendment) clearly states that information concerning disassembly, recycling or disposal at end-of-life of components and materials shall be made available for treatment facilities, but it also states that the information shall be visibly displayed on freely accessible websites of the circulators manufacturers. This requirement was not found fulfilled at the level it is required by any circulator manufacturer. The availability of this information would establish the baseline needed to develop specific material efficiency requirements, either at a vertical or at horizontal level, to increase reuse and recycling of these products, components and materials.

[135] Communication with Gwendolyn Bailey, Katholieke Universiteit Leuven
[136] Communication with Peter Meulengracht Jensen from Grundfos

However, with the information found in this review, it is possible to say that the focus concerning material efficiency should be on the recovery of components made of REE, as well as on the electronics due to the resources criticality and their economic value. The components of the circulators containing high amounts of aluminium, iron and steel, are assumed to be already highly recoverable, although a proper disassembly step before mechanical shredding may increase the share of reused and recycled metals. The recovery could be for reuse, in particular for REE and other clean fractions of metal like iron, and for recycling, in the case the material is downgraded. Another focus on material efficiency could be on the information about the content of Critical Raw Materials, in particular for REE. The recovery of plastics and composites is not foreseen feasible as a first step, but since the trend is to use more plastic in the circulators, it could be something to investigate in the future.

The designs seem to be already suitable for disassembly and recovery of key components (i.e. the printed circuit boards and the magnets). However, there is a possibility that the magnets are vacuum sealed (information not confirmed by any manufacturer) and thus they will be more difficult to recover. The access to printed circuit boards seems to be feasible due to their location and assembly on the circulators designs investigated herein. The current investigated designs indicate that it is possible to dismount and recover the electronics from the controller (and with more work the magnet) from the pump housing. The impact of a potential removal is though challenging to quantify with the current end-of-life information available.

However, the recovery of these components seems currently not feasible by most of the recyclers (for printed circuit boards) and by none for the magnets. This is due, in the case of magnets, to the lower concentration of neodymium in the waste stream as well as the lack of economic incentives to develop recycling facilities at commercial scale in the EU which can increase the economic return per kg of neodymium and thus reduce the recycling costs. In the case of printed circuit boards this is simply due to the absence of a disassembly step in many cases where the circulators are sent to shredding right after collection. In this case it would be beneficial that the circulators would be covered by an EPR scheme at Member State level to increase the concentration and the reach of printed circuit boards at the recycling facility.

Concerning ecodesign requirements, it is suggested that these are targeted at horizontal level to make a real effect on the recovery of the critical components, in particular the magnets containing neodymium. In the meantime, it is suggested to remove the target group from the specific product information in the regulation (EU) No 622/2012 (i.e. '…*for treatment facilities*…') specified[137] in the amendments to Annexes I and II to the Regulation (EC) No 641/2009, point 2 1(c). The product information requirements clearly state that the information shall be visibly displayed on freely accessible websites of the circulator manufacturer, which contradicts the currently specified target group (i.e. treatment facilities).

[137] In the Commission Regulation (EU) No 622/2012, L 180/6

7. Market surveillance

In order to identify potential loopholes in both regulations (i.e. (EC) No 641/2009 and (EU) No 622/2012), market surveillance authorities from the EU Member States were consulted and asked for their experiences from market surveillance activities for circulators. The focus was to ask about their experiences with manufacturers utilizing potential loopholes in the regulation and its amendment. The goal was to assess whether the regulation could be improved to mitigate the potential loopholes.

The request for information was sent to all publicly available contact points of Market Surveillance Authority (MSA) members of the ecodesign ADCO group[138]. Most Member States gave no reply, or stated that they had not made market surveillance activities directly targeting circulators. According to two of the Member States that had targeted circulators in market surveillance, there is a loophole in the exemption of drinking water circulators from the regulation[139], which implied that some circulators were, wrongfully, not labelled with the EEI value. This loophole regarding drinking water circulators will be explained in the first part of this chapter.

Another potential loophole, mentioned by industry stakeholders, was related to the exemption of integrated circulators placed on the market before January 2020 as replacement of identical integrated circulators in products placed on the market before January 2015[140]. This loophole of integrated spare part circulators is dealt within the last half of this chapter.

Finally, in this chapter, the exemption of spare part circulators and the termination of it in 2020 will be discussed with regard to potential complications it might induce according to stakeholders.

7.1 Potential loophole: Drinking water circulators

The utilization of the drinking water loophole experienced during market surveillance, consists in suppliers claiming that their products are not in scope of the regulation because they could be used for drinking water (as well as heating circulation). These suppliers claimed that their products were designed for both drinking water and for heating/cooling systems, and therefore were not in scope. The market surveillance authorities consulted on the matter all agreed that the regulation clearly states that drinking water circulators are "specifically designed to be used in the recirculation of water intended for human consumption"[141], and that "specifically designed" does not apply for circulators with more than one usage[142].

Furthermore, the MSAs argued that with the product information requirements effective from January 2013, stating that drinking water circulators shall have the information "This circulator is suitable for drinking water only" on the packaging and in the technical documentation, only circulators with this text can be exempted from the requirements on energy efficiency. In other words, MSAs agreed that circulators *also* intended for drinking water, cannot use this as a loophole as they cannot mark their product as "suitable for drinking water *only*", and it would thus be in scope of the regulation.

[138] ECOdesign ADCO group contact details of all member state representatives, available at: http://ec.europa.eu/DocsRoom/documents/11081/attachments/1/translations/en/renditions/native , August 25 2016.
[139] Regulation (EC) (EC) No 641/2009 Article 1.2(a)
[140] Regulation (EC) (EC) No 641/2009, Article 1.2(b)
[141] Drinking water for human consumption defined in Article 2 of the Council Directive 98/83/EC.
[142] EU Frequently Asked Questions (FAQ) on teh Ecodesign Directive 2009/125/EC, February 2016.

However, despite the MSAs agreeing on how the regulation should be enforced, the ADCO opinion is not legally binding. A suggestion to mitigate the drinking water loophole, is thus to clearly state in the regulation, that circulators that can be used for both drinking water and heating systems are not exempted for the regulation, but only those designed exclusively for drinking water are.

7.1.1 Definition of drinking water circulators

Another thing that was noted by stakeholders in the review process, is that the definition of drinking water circulators is not 100% clear. The current definition reads: "*'drinking water circulator' means a circulator specifically designed to be used in the recirculation of water intended for human consumption as defined in Article 2 of the Council Directive 98/83/EC*[143]*"* However, the word "recirculation" leaves some uncertainties of which pumps are exactly in scope and which are not. For instance, some drinking water circulators are not designed for "recirculation" but e.g. for tank loading of drinking water, or something else. Europump suggests to define drinking water circulators as circulators that are in contact with drinking water, and therefore must be approved by different drinking water standards such as WRAS[144], ACS[145], KIWA[146], DVGW[147], KTW[148] or UBA[149].

7.1.2 Clear labelling

Since the ecodesign regulation targets the manufacturers, it cannot be controlled how the pumps are actually used by installers or private persons after it has been placed on the market. However, it can be stated that producers and retailers must not market the drinking water circulators for heat systems (except if they are intended for both uses, and complies with EEI requirements). Hence, circulation pumps for drinking water, that are not labelled with an EEI value, must instead be labelled as drinking water-only circulators, so it becomes unambiguously clear to the retailer, installer, and other actors, that the pump is only for drinking water, so if they install a product in a different application, they are legally responsible for any consequence.

The regulation states that the packaging and technical documentation of drinking water pumps should display the text "This circulator is suitable for drinking water only". The problem with labelling defined as text is the lack of language neutrality, meaning that products sold in different countries need to have different labels with the same text in multiple languages[150]. This problem is reduced by the fact that the marking should only be displayed on the packaging and in the technical documentation, which would in either case be made for different languages. However, some manufacturers still suggest a language neutral graphic labelling, such as the one developed by Grundfos in Figure 23, which includes the illustration of a water tap and the text "This circulator is suitable for drinking water only" and is placed on the packaging. The idea is that only the water tap-icon should be necessary.

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[143] Regulation (EC) (EU) No 622/2012
[144] https://www.wras.co.uk/plumbing_professionals
[145] http://www.lati.com/en/regulations/acs.html
[146] https://www.kiwawater.com/
[147] https://www.dvgw.de/themen/wasser/wasserqualitaet/
[148] http://www.ensinger-online.com/vn/products/stock-shapes/quality-and-compliance/product-conformity-declarations/drinking-water-declarations/ktw-guidelines/
[149] http://www.umweltbundesamt.de/en/topics/water/drinking-water/distributing-drinking-water/guidelines-evaluation-criteria#textpart-1
[150] Information provided by stakeholders

Figure 23: Grundfos pictogram of drinking water circulator

Using a pictogram instead of a piece of text that has to be translated, could enable marking of the pump itself, rather than just the packaging. As consumers rarely see the packaging when e.g. buying online, this would make it more visible to them. Alternatively, it should be mandatory to show the "drinking water only" symbol on the website where pumps are sold. In either case, for the label to be effective, an increased market surveillance effort from the member states is needed. Even though a language neutral pictogram displayed directly on the product might be more effective and easier to use for consumers, it is not recommended to change the regulation until member states report on an increase in market surveillance activities.

7.1.3 Including drinking water pumps in the regulation

Another way to avoid the loophole related to drinking water circulators is to include them in the scope of the regulation. This would eliminate the risk of producers misunderstanding the regulation, and thinking that pumps designed for both drinking water and heating systems do not have to comply with EEI requirements, whether this is done deliberately or by accident.

However, drinking water circulators are not operated in the same way as heating circulators, as they have no variable speed drive, but are either controlled by a timer, temperature sensor, or both, to on or off mode. Hence, the loading profile used in the EEI calculation cannot be used for drinking water circulators, and including them in the regulation would therefore require another EEI measure. The including the drinking water circulators in the regulation by means of an EEI limit, would therefore require a new calculation and testing standard to be developed.

Under the assumption that drinking water circulators have a constant market share of around 11 % of all circulators discussed in this study, the total energy consumption of drinking water circulators will increase to a level above that of small standalone circulators in 2030. Figure 24 shows this for the BAU scenario, but it is even more pronounced in the scenarios with stricter requirements for standalone and integrated circulators. This is because the integrated circulator share increases at the expense of standalone circulators, whereas drinking water circulators remain at the same market share, and do not decrease in energy consumption.

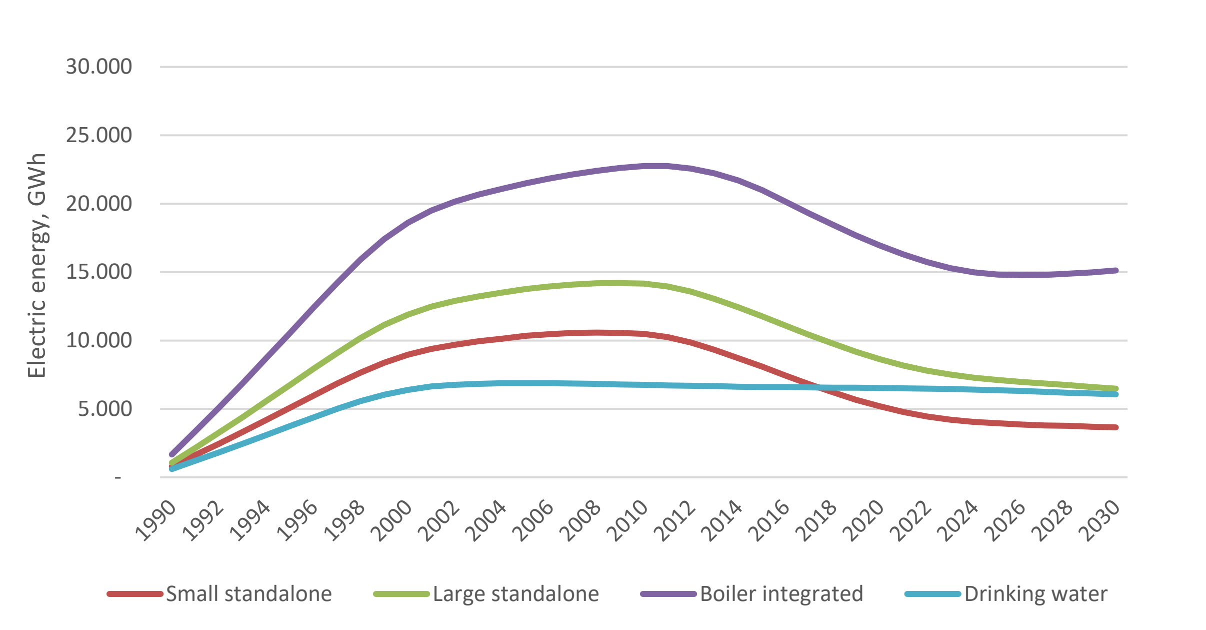

Figure 24: Total energy consumption of circulators in the BAU scenario, divided on base cases from 1990 to 2030

7.1.4 Recommendations

Since MSAs reported that some pumps were sold without an EEI value, without clearly stating that it was only for drinking water, and that some producers argued that the EEI was not needed when the pumps were *also* for drinking water, it is highly recommended to clarify the regulation on this point. It should be clear that circulators applicable for both drinking water and heating systems have to live up to the EEI requirements. Furthermore, it is recommended to label drinking water circulators unequivocally with a uniform symbol of a particular minimum size to be displayed where the product is sold, that be on physical packages, on the nameplate or on web shops.

However, on the long-term, it is recommended to develop an appropriate approach to include drinking water circulators in the scope of the regulation e.g. a standard for an EEI measurement of them. This could be ensured by including in a review clause a requirement to analyse a possible inclusion of these circulators during the next review of the regulation.

As a general recommendation, increased market surveillance activities for circulators are needed to decrease the utilisation of loopholes. Only three Member States have answered that they have targeted circulators in their document control activities since the regulation 641/2009 took effect, according to information provided at the stakeholders meeting[151]. It was not possible for the study team to find any other countries who did market surveillance on circulators in the entire period the regulation has been active. This has not been enough to ensure correct marking and use of EEI values on circulators. In order to get a less biased overview on the need for such a language-neutral marking requirement, more experience from market surveillance authorities is needed which should be taken into account in case of introducing this requirement.

7.2 Potential loophole: Spare part circulators

The potential loophole with regard to replacement circulators integrated in products is sometimes seen utilised for standalone circulators, that are clearly defined as in scope of the regulation, but are

[151] Member States did not provide details on how these activities take place.

not marked with the EEI value according to the requirements. As opposed to the case of the drinking water loophole, these instances have nothing to do with unclear formulation of the regulation. For a circulator to be sold as spare part and hence exempted from the regulation, it should be labelled for which specific product it is sold (e.g. the product number of the boiler) as required in Article 1, 2(b) of Regulation (EU) No 622/2012. If it is not clearly indicated which product or system the circulator is a spare part for, it should comply with the EEI requirements. According to the industry members present at the stakeholder meeting, there are a number of pumps on the market sold as “spare part” and thus not complying with the EEI requirements, which are not clearly labelled with which system they fit into, and which are not shaped and constructed as typical integrated circulators. There is therefore reason to doubt that these are indeed spare part integrated circulators. According to the market surveillance authorities who have performed market control, it is often very difficult to determine what the pump is intended for. There are many old pumps still sold with no EEI labelling, and it is difficult to separate these from those sold (mistakenly) as spare part circulators.

Since the exemption of spare part circulators from the EEI requirements will expire in 2020, the potential loophole will also disappear, which will make it easier for market surveillance authorities to perform market surveillance, since there will be no ambiguity regarding this loophole, but all circulators, sold as spare parts or not, will have to live up to the EEI requirements. It is thus the conclusion that this loophole will automatically disappear in 2020. However, to make sure that the EEI values are indeed present and requirements are followed, increased market surveillance is needed, as described above for the drinking water loophole.

7.2.1 Expiration of the spare part exemption

As mentioned above, Regulation (EU) No 622/2012 states that: “circulators integrated in products and placed on the market no later than 1 January 2020 as replacement for identical circulators integrated in products and placed on the market no later than 1 august 2015, except as regards the product information requirements of Annex I, point 2(1)(e).”

This means, that from January 2020, the exemption is no longer valid, and all integrated circulators brought to the market have to comply with the EEI requirements, also the ones that are sold as spare parts. The loophole described will therefore no longer exist, and there is therefore no need to amend or change the wording of the regulation to eliminate this loophole.

7.2.2 Potential concerns regarding expiration of the exemption

During the review process, stakeholders from the boiler manufacturing industry expressed concern regarding the expiration of the integrated spare part circulator exemption in 2020. The concern regarded the fact that boilers need to live up to various directives in regard to their CE marking[152], and if the circulator in the boiler had to be changed due to failure after 2020, it would have to be changed to a newer, more efficient model than the original one. The concern was then, whether the boiler should be tested again with the new circulator, and in that case by which standards, and how, since the boiler would be installed in a building, and not possible to test in the lab.

Since the CE marking regards products *when placed on the market*, it is not necessary to re-test the boiler if a spare part is changed, but only the circulator itself should comply with ecodesign requirements, when put on the market. Since the regulation and expiry of the exemption has been

[152] For example the Gas Appliance Directive (‘GAD’ 90/396/EEC), the Electromagnetic Compatibility Directive (‘EMC’ 2004/108/EC), and the Low Voltage Directive (‘LVD’ 73/23/EEC)

known since 2009, the boiler industry has gradually ensured that boilers installed between 2009 and 2015 fit with ecodesign compliant spare parts as boilers put on market after 2015 need to be fitted with ecodesign compliant circulators. And for the boilers installed in the beginning of this period, when the ecodesign efforts began, it is possible to have non-compliant circulators as spare parts until 2020, i.e. almost 10 years. Even though the period from 2015 (when boilers could still be placed on the market with non-compliant circulators) to 2020 (when non-compliant circulators can no longer be sold as spare parts) is only five years, as noted by EHI to the European Commission in 2013[153], the requirements have been known to come since 2009, and together with the ecodesign and energy labelling regulations for heaters in 2013[154] (requirements form 2015) this should ensure that boilers put on the market were prepared for the ecodesign requirements for circulators.

When the exemption expires in 2020, there are strategies that boiler manufacturers can follow in case of defect non-compliant circulators. A simple option is to place enough (non-compliant) spare part circulators on the market before 2020 to meet the expected need. Taking into account that the circulator regulation was implemented in 2009, and the heater regulation in 2013, this should have provided manufacturers with enough time to estimate the need for spare parts. It would also help justify whether the expiry of the exemption would cause any problems in practice, if such aggregated data were available on the sales volume of spare part circulators sold for non-compliant heater (i.e. before 2015). It has been seen for other products how a regulation has caused manufacturers to stock up non-compliant products (i.e. compliant before the effective date of the requirements), which afterwards turned out not to be needed, because implementation of the requirements did not bring any difficulties[155].

Another option is to develop backwards compatible circulators in conformity with new ecodesign requirements and other legislation. This could for instance be relevant for circulators for wall hung boilers, where the safety is based on functions in the circulator such as detection of low flow or lack of water based on temperature and pressure measurements. Again, the time frame in the regulation should be enough for manufacturers to develop a strategy and if necessary new backwards compatible products to solve such issues. Indeed, the circulator industry in general agreed that many of the ecodesign compliant circulators can readily be installed in older boilers.

The European Heating Industry (EHI) association expressed concern in relation to the case spare part circulators in terms of the financial impact on end-users if spare parts were not available. They argue that for some old boilers, the lack of compatible spare part circulators could result in the entire boiler needing to be changed, inflicting extra costs on end-users. However, this could be avoided by following the strategies explained above and either stock enough spare parts or develop backward compatible spare parts.

As a third solution, repairing the circulator instead of replacing it, might be a viable solution. Repair is usually not performed on integrated circulators, because it is cheaper to replace them, but in case of no spare parts available, repair might be feasible compared to changing the entire boiler. In other

[153] EHI: at a meeting with the responsible Policy Officer from the European Commission and Europump in May 2013, EHI already stressed that "Product manufacturers have concerns about the short period for spare parts of 5 years between 2015 and 2020"
[154] https://ec.europa.eu/growth/single-market/european-standards/harmonised-standards/ecodesign/space-heaters_en
[155] According to stakeholders this was for instance the case for electric motors in correlation with ecodesign requirements of IE3 for electrical motors

cases, where the circulator is not compatible with e.g. the controller in the boiler, it would be enough to change the controller together with the circulator.

Nevertheless, the cases in which entire boilers would need to be changed due to lack of spare part circulators are expected to be very limited in number, in light of the described options manufacturers have to mitigate them and make sure spare parts can be available, also after 2020. In addition, these few cases can be expected to concern the oldest boiler in the stock, i.e. those put on the market early after the implementation of the ecodesign regulation in 2009, limiting the actual effect it would have. Also, the exchange boiler would have to be compliant with both heater and circulator ecodesign requirements, making it more energy efficient than the old boiler from before 2015. Hence both the quantity and cost of these instances are expected to be very low.

The size of the loophole that was ascertained regarding spare part circulators is difficult to estimate, since only very few countries have performed market surveillance for circulators. However, it is not estimated to be large enough to implement changes in the regulation before the exemption automatically expires in 2020.

Regarding the exemption itself, EHI has suggested to postpone the expiry until 2025 to ensure spare part availability for boilers placed on the market up to 2015. This was suggested to avoid potential complications when replacing integrated circulators in older boilers, which were originally equipped with non-compliant circulators. This would presumably happen only in very few cases, but there has been no data available on how large a share of currently installed boilers that might have to be changed prematurely due to unavailable spare parts.

7.2.3 Recommendations

Based on the time the industry has had to adapt to the requirements (since 2009) and the fact that spare parts should be available in up to ten years after placing the boiler on the market (according to EHI), there should be no problem in ending the exemption in 2020, 11 years after the requirements were known by industry in 2009.

The specific concern with regards to EEI requirements on spare part circulators is the ability to live up to the EMC (Electro Magnetic Compatibility) Directive[156], which is a part of the CE marking requirements. According to the “blue guide”[157] published by the EU Commission, only new products need to be tested for compatibility, and “Products which have been repaired or exchanged (for example following a defect), without changing the original performance, purpose or type, are not to be considered as new products according to Union harmonisation legislation. Thus, such products do not need to undergo conformity assessment again, whether or not the original product was placed on the market before or after the legislation entered into force”[158].

The concern of EHI is that the EEI compliant circulators use synchronous motors, while most older-type circulators used asynchronous motors with different electrical characteristics that might affect the boiler's compliance with legislation like ECM or low voltage, if this is considered a change in “original performance, purpose or type” of the boiler. From the study team’s technical point of view and based on inputs from stakeholders, boilers do not have to be re-tested. However, according to

[156] http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32014L0030&locale=en
[157] http://ec.europa.eu/DocsRoom/documents/12661/attachments/1/translations/en/renditions/native
[158] Page C 272/17.

EHI this might lead to the boiler having to be re-tested after installing a new, compliant circulator, and they are currently (April 2017) running tests to obtain data on the differences. An assessment by jurists and other legal experts might be necessary to determine whether there is a need for retesting, but as the number of cases is expected to be very low considering the 11 year period for adaption, retesting is not considered enough to postpone the expiry of the exemption.

8. Review of energy efficiency requirements

According to the information presented in previous chapters, this summarizes the potential amending ecodesign requirements that could be part of future amendments to Commission regulation (EC) No 641/2009.

The potential revised requirements subject for the analysis have been identified according to:

- technological progress,
- existence of harmonised definitions, methods and/or standards,
- current and future market in terms of stock, costs and usage of circulators,
- current and future energy efficiency levels,
- current and future practices in terms of designs for recovery, reuse and recycling.

These requirements are:

1. More stringent energy efficiency requirements by lowering EEI levels by 2022.
2. Clarification of definitions and sentences to avoid potential loopholes and to improve enforcement of the regulation, which have been explained in section 7.
3. Amendment of product information requirement concerning disassembly, recycling or disposal at end-of-life, which have been explained in section 6.

Potential amendments concerning scope were not considered feasible at this point in time. In particular on the removal of the exemption of drinking water circulators – unless an appropriate approach to include them without harmonising the various drinking water requirements in the Member States – and on the extension of the time period for the exemption of integrated circulators used for replacement. The reasons for this have been explained in previous chapters.

During the collection of data and information of EEI distributions for all the base cases, it was evident that standalone and integrated circulators have shown significant improvements in terms of energy efficiency. Furthermore, the assumptions confirmed by industry as well as data collected by the study team showed that a significant share of the EU market is already below EEI < 0.20, particularly standalone circulators (see Figure 12). For integrated circulators, the same data showed that about 70% is at least in the range of the benchmark level (EEI ≤ 0.20, see Figure 13). Therefore, more stringent energy efficiency requirements were analysed in the selected policy options.

8.1 Scenario description

Based on these considerations, it was decided to assess three policy options:

1. No changes on the requirements in the regulation: BAU
2. Make requirements more stringent at the EEI benchmark level in the current regulation: EEI ≤ 0.20
3. Make requirements more stringent at a level 10% lower than current EEI benchmark level: EEI ≤ 0.18[159]

[159] This was based only on an assumed reduction of 10 % and considering observed values during the EEI market distribution data collection. Values lower than 0.18 occurred rarely for integrated circulators, and thus 0.18 was defined as the lowest limit.

Since the process for amending the regulation takes about 1 to 2 years (2 years is the worst-case scenario considering this is a relatively small amendment) including Consultation Forum and an impact assessment, a realistic implementation date for these two policy options as Tier III for Annex I, point 1 in the 641/2009 regulation is 1 January 2022.

This gives a period of 3-4 years to catch up with higher efficiencies, which is considered sufficient since the methodology for calculating energy efficiency as well as the technologies are already in place. This gives place for the integrated circulators to achieve higher levels of efficiency, in particular those sold for replacement which will be removed from the exemption in 2020.

8.2 Calculation of energy consumption of circulators

The energy consumption of the circulators was calculated using the base cases from the preparatory study which was also used in the previous sections of this report see Table 22, which also includes the average power consumption using the flow-time profiles and at various improvement levels.

For each type of standalone and integrated circulators one typical size is selected as representative for all circulators of that type. To help selecting the typical size, the findings of preparatory study Lot 11 were used. In that report several typical sizes were selected for small standalone circulators, large standalone circulators, and boiler integrated circulators (see Table 23).

Table 22: Average power consumption according to the preparatory study Lot 11

	Small standalone circulators	Large standalone circulators	Boiler integrated circulators
Hydraulic power Phyd	10.2 W	195 W	25.5 W
Standard (baseline)	61.4 W	388 W	89.0 W
Improved	46.0 W	323 W	70.8 W
Variable speed	44.2 W	313 W	64.0 W
PM motor (permanent magnet)	15.2 W	148 W	22.0 W

When an old circulator is replaced with a new more energy efficient circulator, the average power consumption will be lower for the new circulator. The parameter which remains constant is the hydraulic power, when it is assumed that the system remains unchanged. Therefore, it is assumed that the average power consumption ($P_{L,avg}$) (based on the flow-time profiles) of the typical circulator placed on the market is reduced over time, but the maximum hydraulic power (P_{hyd}) of the typical circulator is constant.

The baseline for the standalone and integrated circulators in the preparatory study was chosen as circulators with an EEI value of 0.8 for the energy labelling scheme. Using this, the maximum hydraulic power (P_{hyd}) can be calculated via the definitions of the previous voluntary energy label:

$$EEI = \frac{P_{L,avg}}{P_{ref}}$$

$$P_{ref} = 2.21 \cdot P_{hyd} + 55 \cdot (1 - e^{-0.39 \cdot P_{hyd}})$$

The calculated reference power and hydraulic power are shown in Table 24.

In the regulation (EU) No 622/2012, the reference power and EEI are defined differently compared to how they are defined in the voluntary energy labelling scheme. For this review study, it was more relevant to consider the EEI of the regulation and therefore the reference power and EEI values were calculated accordingly with the given circulator sizes (hydraulic power), which are also shown in Table 23.

$$EEI = \frac{P_{L,avg}}{P_{ref}} \cdot C_{20\%}, \text{where } C_{20\%} = 0.49$$

$$P_{ref} = 1.7 \cdot P_{hyd} + 17 \cdot (1 - e^{-0.3 \cdot P_{hyd}})$$

Table 23: Calculated reference power, hydraulic power, EEI and average power consumption for EEI=1

	Small standalone circulators	Large standalone circulators	Integrated circulators
Reference Power (energy label)	76.5 W	485 W	111.3 W
Hydraulic Power	10.2 W	195 W	25.5 W
Reference Power (regulation)	33.5 W	348 W	60.3 W
EEI (regulation – baseline circulator)	0.90	0.55	0.72
Average power consumption (EEI=1)	68.5 W	711 W	123 W

EEI makes it very simple to scale the average power consumption when the EEI value is given. This is because EEI is proportional to the average power consumption. Therefore, the average power consumption of a circulator with EEI = 0.23 is equal to 0.23 times the average power consumption of a circulator with EEI=1:

$$P_{L,avg,EEI=X} = P_{L,ave,EEI=1} \cdot X$$

To calculate the energy consumption of the entire stock of circulators in scope of this review study (excl. drinking water circulators), each type of circulator is subdivided into intervals of EEI-values. Five intervals have been chosen:

- Non-compliant, EEI > 0.27
- Compliant until Aug. 2015, 0.23 < EEI ≤ 0.27
- Compliant, 0.2 < EEI ≤ 0.23
- Benchmark, 0.17 < EEI ≤0.2
- Best, EEI ≤ 0.17

For each interval, the average EEI-value is assumed to be the average of the lower and upper bounds of the interval. For 'best, EEI ≤ 0.17' the average EEI is assumed to be 0.17 since it is considered not possible to achieve lower levels for most of the current and future circulators on the market. For

'Non-compliant, EEI > 0.27' the upper bound is assumed to be the EEI-values shown in Table 24, which are different for each type. The average EEI-values for each interval can then be used to calculate the average market EEI for each circulator base case, when the market EEI distribution is known, which is shown in Table 25 and in the following paragraphs.

Table 24: Average EEI values for each type of circulator for each EEI interval

	Small standalone	Large circulator	Integrated
Non-compliant	0.585	0.41	0.495
Compliant until Aug. 2015	0.25	0.25	0.25
Compliant	0.215	0.215	0.215
Benchmark	0.185	0.185	0.185
Best	0.17	0.17	0.17

8.3 Energy consumption and savings potentials

8.3.1 Policy option 1: BAU

In order to calculate the past, present and future energy consumption of standalone and integrated circulators in scope of the regulation, the average EEI levels were calculated as shown in Figure 25 for the BAU scenario (Business as Usual), where no action is taken, i.e. no changes will be done to the regulation. Here it can be seen the average EEI levels have decreased dramatically after the regulation came into place but that they will be at almost the same average level by 2030, if no action is taken.

In BAU, the efficiencies are unlikely to decrease further, because the physical limits of the hydraulics in the pumps does not allow for more than minor improvements according to industry experts.

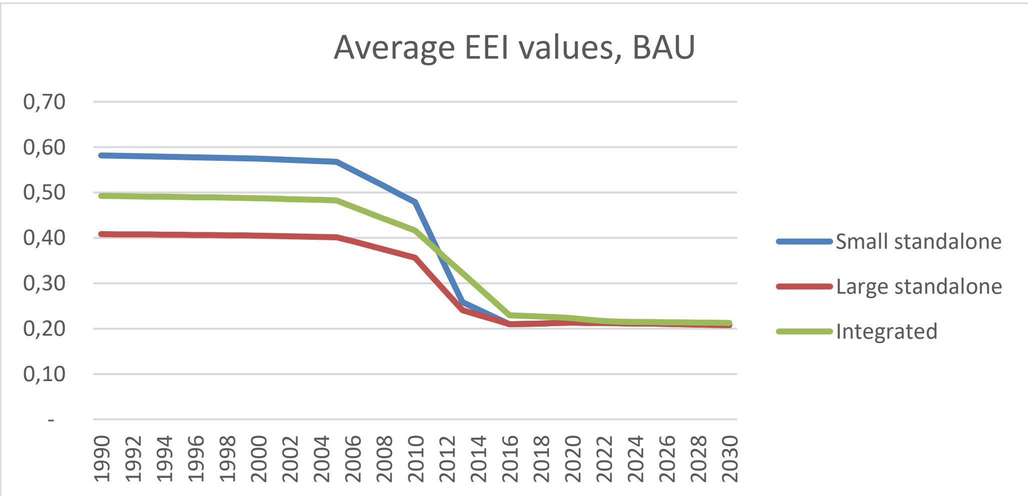

Figure 25: EEI distribution for Business as Usual (BAU) policy option

The average EEI levels for the three base cases shown in Figure 25 are based on the assumed distributions shown in Table 25 and Table 26. The average EEI level for small and large standalone circulators varies despite the similar market distribution for all standalone, shown in Table 26. This is due to the different assumptions for small and large circulators of the average EEI value in the interval above 0.27, which is 0.585 and 0.41 for small and large standalone circulators, respectively (see Table 25).

Table 25: EEI market distribution of standalone circulators in the BAU scenario from 2005 to 2030

EEI interval	2005	2010	2015	2020	2025	2030
EEI>0.27	95%	70%	3%	0%	0%	0%
0.23<EEI<0.27	4%	15%	12%	0%	0%	0%
0.2<EEI<0.23	1%	12%	58%	82%	76%	68%
0.17<EEI<0.20	0%	3%	23%	15%	20%	25%
EEI<0.17	0%	0%	4%	3%	4%	7%
Average EEI	0.57	0.48	0.23	0.21	0.21	0.21

Table 26: EEI market distributions of integrated circulators 2005 to 2030

EEI interval	2005	2010	2015	2020	2025	2030
EEI>0.27	95%	70%	16%	2%	0%	0%
0.23<EEI<0.27	4%	15%	8%	5%	0%	0%
0.2<EEI<0.23	1%	12%	60%	83%	85%	80%
0.17<EEI<0.20	0%	3%	16%	9%	13%	17%
EEI<0.17	0%	0%	0%	1%	2%	3%
Average EEI	0.48	0.42	0.26	0.22	0.21	0.21

For the extrapolation of EEI distribution until 2030, the industry organisation Europump was more optimistic about the development of EEI levels in the market in the BAU scenario, and suggested the estimations shown in Table 27 and Table 28. However, since it was the previous ecodesign requirements that drove the market change already seen, it was considered unlikely that the average EEI value would decrease as much without stricter requirements. It was therefore decided to modify the forecasts for the BAU scenario to more cautious levels shown in Table 25 and Table 26.

Table 27: Estimation of EEI distribution forecast provided by Europump, for standalone circulators

EEI interval	2010	2016	2020	2025	2030
EEI>0.27	70%	0%	0%	0%	0%
0.23<EEI<0.27	15%	0%	0%	0%	0%
0.2<EEI<0.23	12%	40%	30%	20%	10%
0.17<EEI<0.20	3%	40%	45%	55%	65%
EEI<0.17	0%	20%	25%	25%	25%
Average EEI	0.42	0.20	0.19	0.19	0.18

Table 28: Estimation of EEI distribution forecast provided by Europump, for integrated circulators

EEI interval	2010	2016	2020	2025	2030
EEI>0.27	70%	5%	0%	0%	0%
0.23<EEI<0.27	15%	7%	0%	0%	0%
0.2<EEI<0.23	12%	70%	80%	76%	70%
0.17<EEI<0.20	3%	18%	20%	24%	30%
EEI<0.17	0%	0%	0%	0%	0%
Average EEI	0.42	0.23	0.21	0.21	0.21

8.3.2 Policy option 2: EEI ≤ 0.20 by 2022

In comparison, the EEI averages of the second policy option (EEI ≤ 0.20) are shown in Figure 26 for the three base cases. A small decrease in EEI due to more stringent EEI requirements can be seen around 2022. The EEI levels are expected to stabilize at 0.18 in 2025 and stay there until 2030. The reason for the levels to be lower than 0.20 is to reflect the fact that many circulator manufacturers will aim at lower EEI levels to make sure they comply, as it is expected that the range of tolerance will be lower. It can also be noticed that the three EEI levels are expected to be identical by 2030, as in the BAU scenario, but at a lower level.

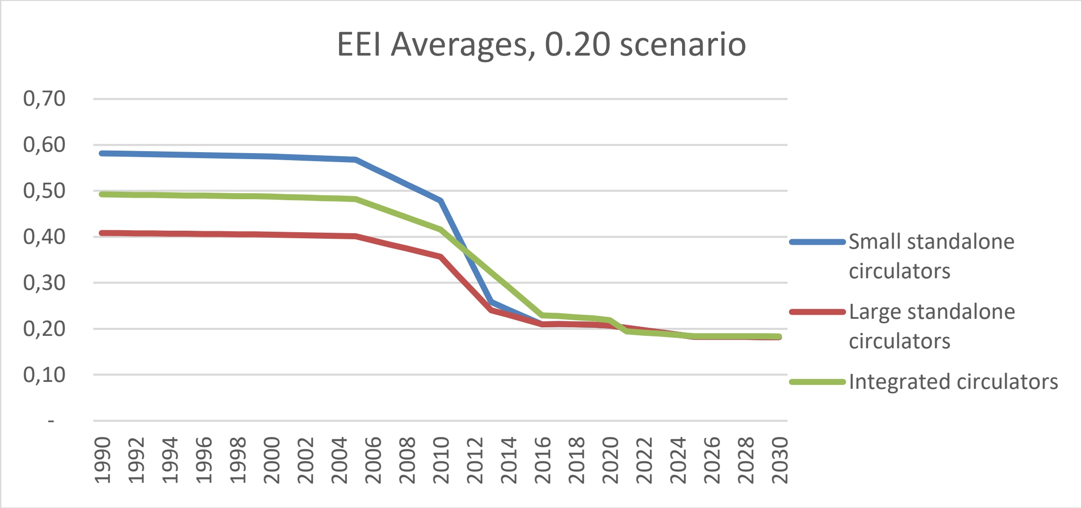

Figure 26: EEI distribution for EEI=0.20 policy option

The average EEI levels shown for the second policy option in Figure 26, are based on the EEI distributions shown in Table 29 and Table 30. The distribution is assumed to be the same as in the BAU scenario until year 2017. Hence the tables show the same distribution for 2015.

Table 29: EEI market distribution of standalone circulators in the Policy Option 2 scenario from 2015 to 2030

EEI interval	2015	2020	2025	2030
EEI>0.27	3%	0%	0%	0%
0.23<EEI<0.27	12%	0%	0%	0%
0.2<EEI<0.23	58%	65%	0%	0%
0.17<EEI<0.20	23%	28%	85%	80%
EEI<0.17	4%	7%	15%	20%
Average EEI	0.23	0.21	0.18	0.18

Table 30: EEI market distribution of integrated circulators in the Policy Option 2 scenario from 2015 to 2030

EEI interval	2015	2020	2025	2030
EEI>0.27	16%	1%	0%	0%
0.23<EEI<0.27	8%	3%	0%	0%
0.2<EEI<0.23	60%	73%	0%	0%
0.17<EEI<0.20	16%	21%	95%	90%
EEI<0.17	0%	2%	5%	10%
Average EEI	0.26	0.22	0.18	0.18

8.3.3 Policy option 3: EEI ≤ 0.18 by 2022

Finally, the EEI distributions if the third policy option is implemented (EEI ≤ 0.18) are shown in Figure 27. A small decrease in EEI due to more more stringent EEI requirements can be seen by 2022. The EEI levels are expected to continue decreasing to 0.17 until 2030. This is due to the same reason explained in the previous policy option i.e. to make sure the manufacturers produce compliant products but within a smaller range of error, since it is expected that at this level the range is even smaller. It is expected that both small and large standalone circulators reach at identical levels by 2030 (average EEI=0.17), while the integrated circulators will be just at the limit of compliance. This is because it is expected that will be more difficult for them to reach this higher level of efficiency.

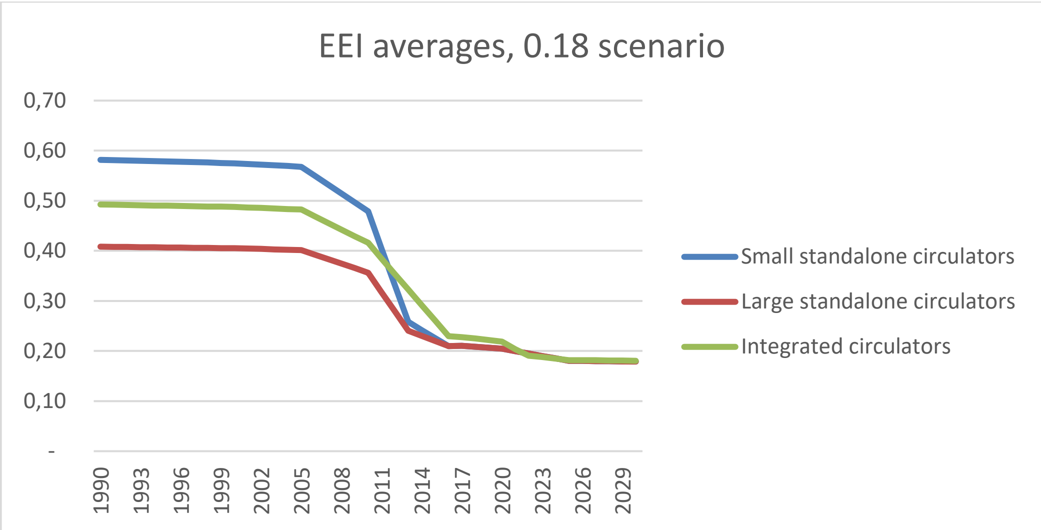

Figure 27: EEI distribution for EEI=0.18 policy option

The EEI averages shown in Figure 27 are based on the distributions of EEI levels on the market shown in Table 31 and Table 32. Again, the distribution until year 2017 is assumed to be the same is in the BAU scenario and Policy Option 2 scenario.

Table 31: EEI market distribution of standalone circulators in the Policy Option 3 scenario from 2015 to 2030

EEI interval	2015	2020	2025	2030
EEI>0.27	3%	0%	0%	0%
0.23<EEI<0.27	12%	0%	0%	0%
0.2<EEI<0.23	58%	60%	0%	0%
0.17<EEI<0.20	23%	30%	70%	60%
EEI<0.17	4%	10%	30%	40%
Average EEI	0.23	0.20	0.18	0.17

Table 32: EEI market distribution of integrated circulators in the Policy Option 2 scenario from 2015 to 2030

EEI interval	2015	2020	2025	2030
EEI>0.27	16%	2%	0%	0%
0.23<EEI<0.27	8%	5%	0%	0%
0.2<EEI<0.23	60%	71%	0%	0%
0.17<EEI<0.20	16%	20%	80%	70%
EEI<0.17	0%	2%	20%	30%
Average EEI	0.26	0.22	0.18	0.18

8.3.4 Comparison of scenarios

To compare the scenarios the EEI values were used to calculate the average power consumption of each base case in each scenario, by using the sum-product of the market distributions of circulators and the average EEI values for each EEI interval shown in the tables above for each base case and each policy option. The average power (electric power, in watts) of the base cases thus varies over the years with the EEI averages. To calculate the power consumption of the entire stock for each year, the sale years of all circulators in the stock were matched with the power consumption of circulators sold that year and multiplied with the yearly average operation time. This yearly "active" time was assumed to be 5,000 hours as in the Lot 11 preparatory study.

Since the stock model is based on a normal distribution of circulators lifetimes calculated over 15 years and the first year with sales data is 1990, the graphs in the below paragraphs are shown only for the years after 2005, since this is when the stock model stabilises.

Small standalone circulators

The trend in energy consumption until 2030 for small standalone circulators is shown in Figure 28 for each of the policy options. It shows the impact of policy options 1 and 2 compared to BAU with larger decrease in energy consumption mainly after 2022, when the requirements are assumed to take effect. Part of the decrease is due to fall in stock after 2013 because they are being substituted with integrated circulators. Potential savings for second policy option are expected ranging around 0.19 and 0.37 TWh/a by 2025 and 2030 respectively and for third policy option around 0.21 and 0.41 TWh/a by 2025 and 2030 respectively. The impact of the current regulation is also clear to see.

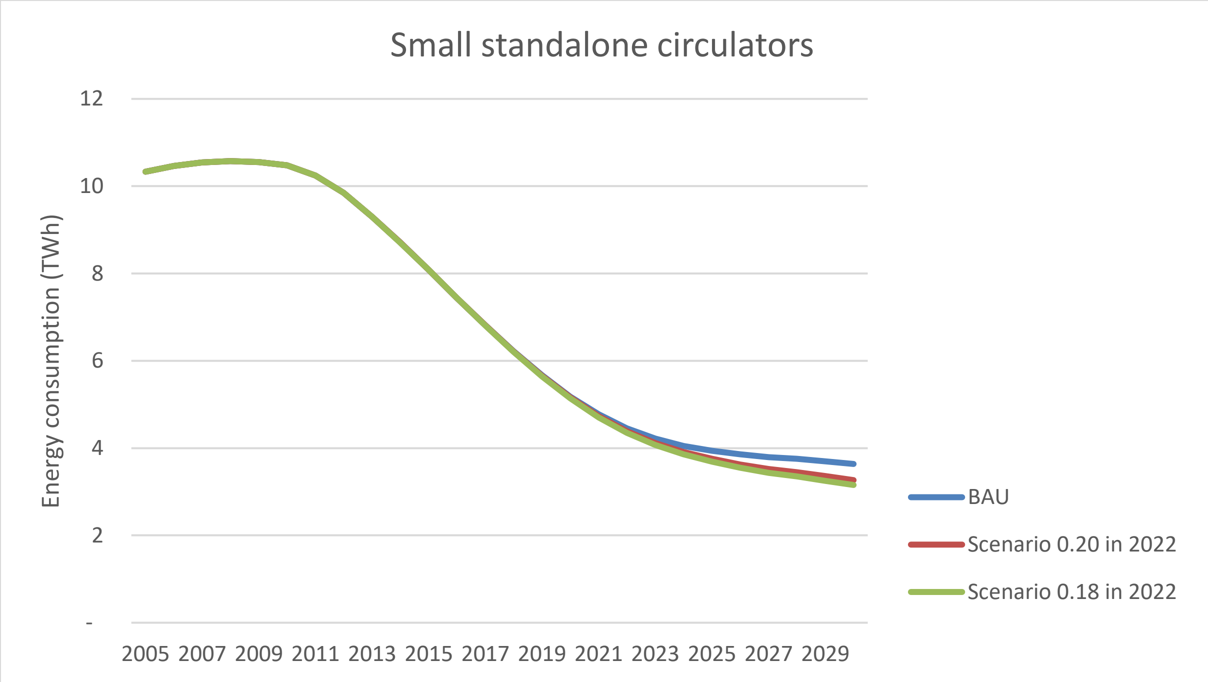

Figure 28: Energy consumption of small standalone circulators in the three policy options (2005-2030).

Large standalone circulators

The trend in energy consumption until 2030 for large standalone circulators is shown in Figure 29 for each of the policy options. It shows the impact of policy options 1 and 2 compared to BAU with larger decrease in energy consumption mainly after 2022, when the requirements are assumed to take effect. Part of the decrease is due to a small fall in stock after 2013 because they are being substituted with small or integrated circulators. Potential savings for second policy option are expected ranging around 0.33 and 0.66 TWh/a by 2025 and 2030 respectively and for third policy option around 0.39 and 0.73 TWh/a by 2025 and 2030 respectively. The impact of the current regulation is also clear to see.

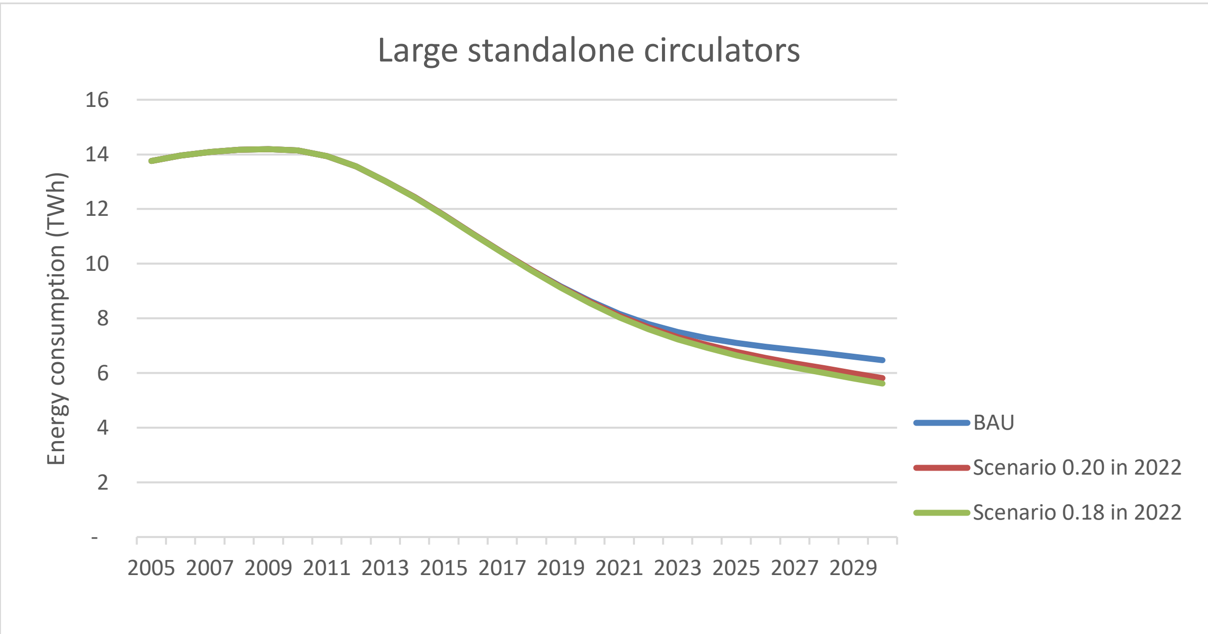

Figure 29: Energy consumption of large standalone circulators in the three policy options (2005-2020).

Integrated circulators

The trend in energy consumption until 2030 for integrated circulators is shown in Figure 29 for each of the policy options. It shows the impact of policy options 1 and 2 compared to BAU with larger decrease in energy consumption mainly after 2022, when the requirements are assumed to take effect. The stock increases integrated circulators are substituting standalone circulators, which is the reason why the energy consumption falls less compared to the other types of circulators. Potential savings for second policy option are expected ranging around 0.93 and 1.83 TWh/a by 2025 and 2030 respectively and for third policy option around 0.91 and 1.92 TWh/a by 2025 and 2030 respectively. The impact of the current regulation is also clear to see.

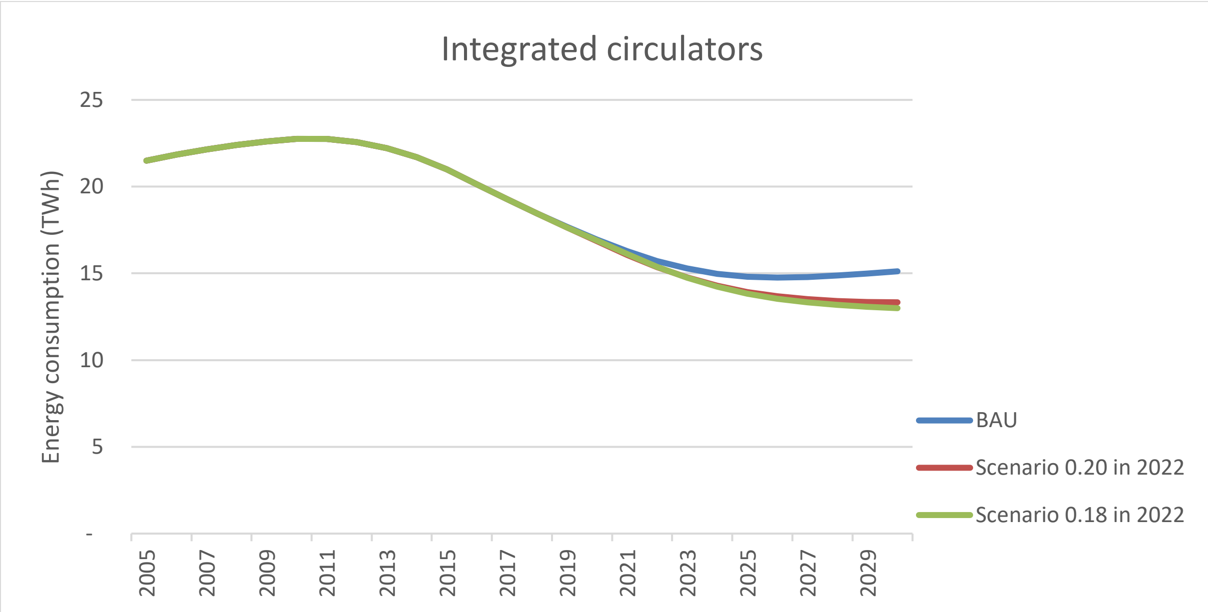

Figure 30: Energy consumption of integrated circulators in the three policy options.

All circulators

The trend in energy consumption until 2030 for all circulators is shown in Figure 31 for each of the policy options. It shows the impact of policy options 1 and 2 compared to BAU with larger decrease in energy consumption mainly after 2022, when the requirements are assumed to take effect.

Potential savings for second policy option are expected ranging around 1.44 and 2.86 TWh/a by 2025 and 2030 respectively and for third policy option around 1.51 and 3.07 TWh/a by 2025 and 2030 respectively. The impact of the current regulation is also clear to see.

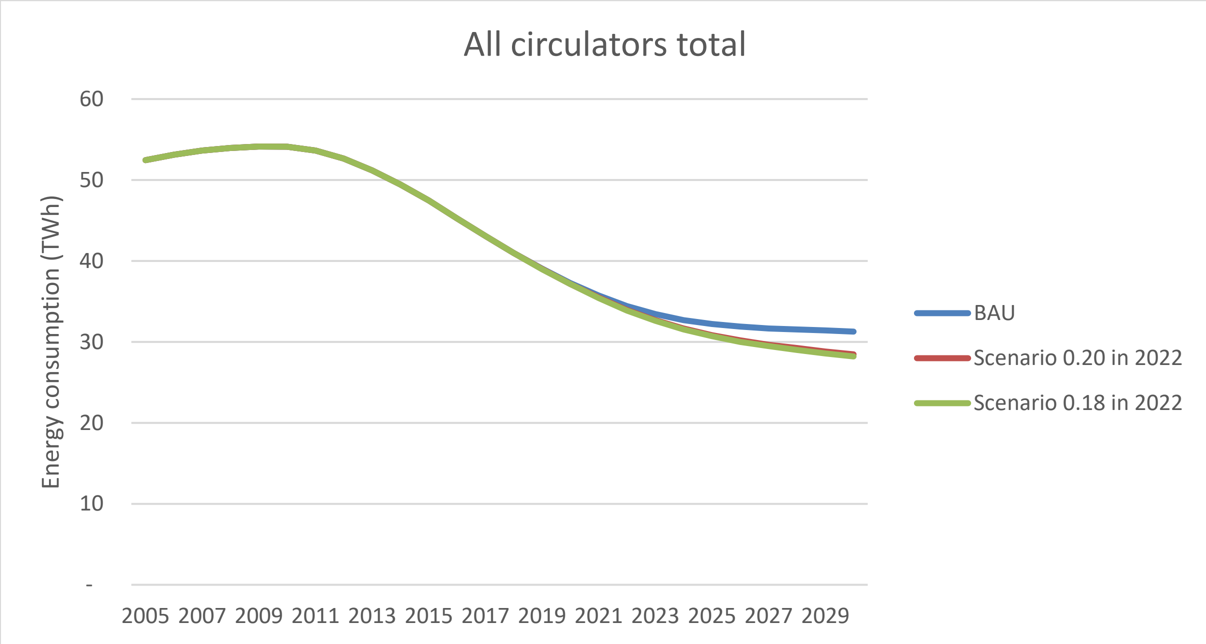

Figure 31: Energy consumption of all circulators in scope of the regulation in the three policy options.

8.4 Life cycle costs

By making the EEI requirement levels more stringent, the life cycle costs for the consumer will be affected. This is only relevant for the purchase price and the use phase due to lower electricity costs. The other costs, i.e. installation, repair & maintenance and end-of-life costs, are not affected and will therefore remain constant. In the below sections the increase in purchase cost and decrease in electricity cost (due to energy savings) is explained.

8.4.1 Purchase price

Data on purchase prices for circulators currently placed on the market (2015-2016) do not show correlation with EEI levels indicating that more efficient circulators are not necessarily more expensive. However, this does not show the earlier historic development and correlation between price and efficiency, but only a snapshot of the market as it is now. In this snapshot the correlation cannot be found because the ecodesign regulation has left only the most efficient circulators on the market and the low-priced, low-efficiency circulators are no longer present, hence the current market shows only small price and efficiency differences.

Table 33 shows the average 2016 prices for circulators with EEI below or equal to 0.20 (i.e. more efficient) and those with EEI above 0.20 (i.e. less efficient). The collected data for circulators currently on the market show that standalone circulators with EEI below 0.20 have a lower average price than standalone circulators with EEI above 0.20. The prices for integrated circulators are estimated by EHI as being between 150-200 € (with the lowest price for the less efficient ones), which were assumed to be the upper and lower end of the EEI range on the market, with the overall average being 175 € in 2016.

Table 33: EU-28 average prices of circulators[160] (2015 constant prices)

Base cases	Average prices 2016 (all)	Average prices 2016 (EEI⩽0.20)	Average prices 2016 (EEI>0.20)
Small standalone circulators	€ 414	€ 345	€ 504
Large standalone circulators	€ 1314	€ 1253	€ 1373
Integrated circulators	€ 175	€ 200[161]	€ 150[162]

The average prices being lower for the most efficient circulators (EEI ⩽0.20) is, however, based on an average of very scattered data, which is shown in Figure 32 for standalone circulators in the size intervals $P_{1,max}$=100-150 W and $P_{1,max}$=150-200 W. The same graphs were made for other size ranges with the same scattered result, thus only one is shown to exemplify the lack of correlation.

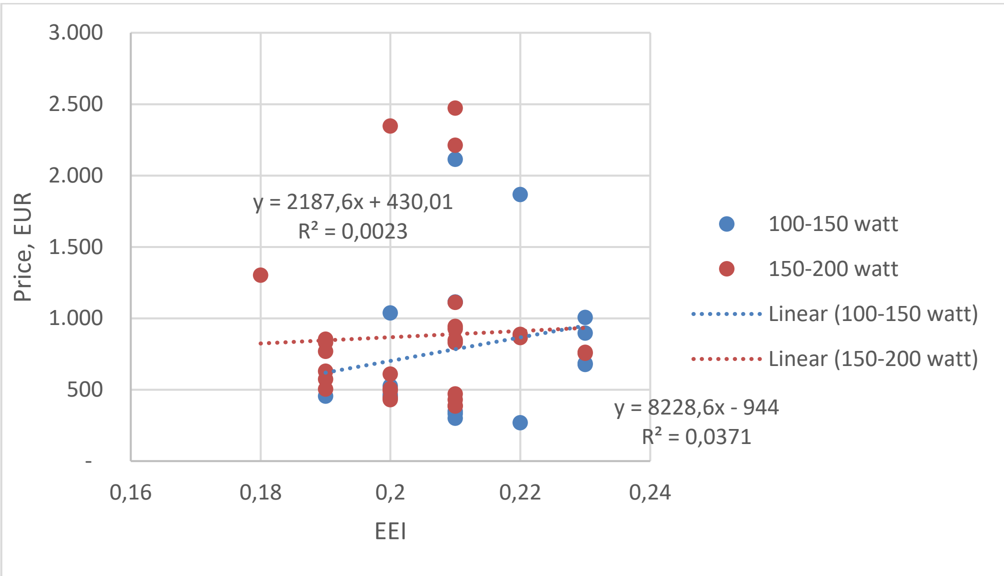

Figure 32: Price vs. EEI data for pumps in size intervals P_{1max}=100-150 W and P_{1max}=150-200 W (2015 constant prices).

The implementation of the ecodesign requirement of EEI ≤ 0.23 has left only the 5-10% most efficient circulators on the market[163] and the EEI range of circulators today is therefore very narrow, ranging from around 0.17 to 0.23. With the EEI levels varying so little, other parameters such as brand, additional functions, material, isolation and noise have larger influence on the price compared to the efficiency. These parameters are all the reasons why the price has a very low linear correlation to EEI

[160] Average are based on the data collection carried out for this review study

[161] Price range of 150-200 EUR/unit provided by European Heating Association (EHI), and upper price assumed to be for the most efficient integrated circulators according to information from EHI

[162] ibid

[163] Information provided by stakeholders along the course of this review study

as seen in Figure 32, which shows that even though some circulators with EEI ≤ 0.20 are more expensive, this is not a general trend for all circulators on the market.

Some circulators on the market today already achieve EEI levels below 0.20, with many manufacturers targeting the benchmark level (EEI=0.20) to make sure their circulators comply with the requirement level (EEI=0.23)[164]. Furthermore, the system needs might cause constraints in the design of the circulators, in particular for integrated circulators, which need to fit a particular product such as a heating appliance. Standalone circulators may also face some design constraints according to their application like the required specific speed and lift (i.e. head), the installation space, maximum pressure and pipe connection. Because of these differences in system needs, there are some circulators which require more design considerations and thereby higher costs to achieve higher levels of efficiency while others do not.

The overall average of prices of circulators above and below EEI 0.20 (in 2016) can therefore not be used to conclude any correlation between EEI and price.

Looking at historical price and efficiency development, however, a correlation is present. To determine the cost of lowering the EEI levels for all circulators, it is thus necessary to look at the historical development of price and EEI. The historical price is taken from Lot 11 and compared to current price data collected for this study. Since the Lot 11 study, the prices of circulators have increased while the EEI value has decreased, in large part due to the implementation of ecodesign regulation. The changes in price and EEI from 2005 to 2015 can be seen in Table 34.

Table 34: Comparison of average prices and EEI levels for circulators placed on the market (2005 and 2015).

	Price data (2015 constant prices)			**EEI data**		
	2005 (Lot 11)	**2015 (collected)**	**Difference**	**2005 (Lot 11)**	**2015 (collected)**	**Difference**
Small circulators	€ 148	€ 233	+ € 85	0.57	0.23	- 0.34
Large circulators	€ 493	€ 1314	+ € 821	0.40	0.22	- 0.18
Integrated circulators	€ 148	€ 175	+ € 27	0.48	0.26	- 0.22

Based on these data, it can be estimated that lowering the average EEI levels with 0.34 from 2005 to 2015 for small circulators caused the price to increase by 85 EUR, and hence a price for a given increase in EEI can be deducted – but with high uncertainties. Similarly is made an estimate for the large circulators. These estimations based on the historical trend of average prices and EEI levels clearly show that lowering the EEI levels caused average purchase price increase.

[164] ibid

Based on this historical trend, an estimation was made for the three base cases with the BAU scenario as baseline, in order to estimate the average purchase price increase when lowering the EEI levels as described in the policy options 2 and 3, as presented in section 8.1. This is shown in Table 35 where the prices are stated for the year of the revised regulation taking effect, which is 2022. The estimations were made based on constant price in the BAU scenario, and the price increase in policy option 2 and 3 are therefore solely due to EEI decrease.

Table 35: Estimated average purchase price under each policy option (2022) (constant 2015 prices).

	PO 1: BAU	PO 2: EEI ⩽ 0.20		PO 3: EEI ⩽ 0.18	
	2022 price	**2022 price**	**Price increase**	**2022 price**	**Price increase**
Small circulators	€ 233	€ 237	1.7 %	€ 238	2.1 %
Large circulators	€ 1314	€ 1383	5.3 %	€ 1406	7.0 %
Integrated circulators	€ 175	€ 178	1.7 %	€ 178	1.7 %

The estimated increase in average purchase prices by 2022 is assumed to occur due to the extra design and production costs when improving the current technology to produce more efficient circulators. The design costs occur due development work, materials, component and increased need for prototype testing to increase the efficiency of the pump. A large part of the design process consists in trial-and error approach once the basic design criteria (size, specific speed, etc.) has been determined for a circulator model, and therefore requires extensive testing, as hydraulic efficiency cannot be determined to more than around 5% certainty with CFD (computational fluid dynamics). The increase in production costs occurs due to enhancing the wet rotor motor by e.g. increasing the content of rare earth metals in the rotor to achieve a stronger magnetic field. Also, the use of more efficient electrical motors and control systems will contribute to the higher production cost and thus higher purchase price[165].

8.4.2 Electricity consumption costs during use

In each policy option, the average EEI in the market was forecasted based on the proposed EEI levels, and the costs for electricity consumption were based on the forecasted electricity prices from Primes[166] and lifetime energy consumption of the circulators. The lifetime (10 years) electricity consumption cost is calculated for each base case for an average circulator sold in 2022, based on average EEI with each year after purchase discounted using a 4 % annual discount rate (see Table 36). The cost difference is calculated using the BAU electricity cost as baseline.

[165] Based on information provided by industry
[166] PRIMES 2016, provided by European Commission, DG ENER A4

Table 36: Lifetime electricity cost for each base case in the three policy options in 2022 after the revised requirements in PO2 and PO3 take effect (2015 constant prices, discounted to lifetime year 1).

	PO 1: BAU	PO 2: EEI ⩽ 0.20		PO 3: EEI ⩽ 0.18	
	2022	2022	Cost difference	2022	Cost difference
Small circulators	€ 123	€ 114	-7 %	€ 113	-8 %
Large circulators	€ 1275	€ 1183	-7 %	€ 1170	-8 %
Integrated circulators	€ 226	€ 199	-12 %	€ 198	-12 %

As shown in Table 36 the cost of electricity consumption will decrease between 7-12 % in policy options 2 and 3, when compared to the BAU scenario. It should be noted though, that the absolute decreases account for the total electricity consumption in the circulator's lifetime and is thus spread over a period of 10 years on average and discounted accordingly.

8.4.3 Consumer life cycle costs

The overall changes in total life cycle cost in the two policy options compared to BAU are shown in Table 37. The results show that the overall life cycle costs will decrease for all of the base cases, even though the savings are small.

Table 37: Total life cycle costs in each policy option for the three base cases (constant 2015 prices, discounted to lifetime year 1).

	PO 1: BAU	PO 2: EEI ⩽ 0.20			PO 3: EEI ⩽ 0.18		
	2022 LCC	2022 LCC	Difference		2022 LCC	Difference	
			(EUR)	(%)		(EUR)	(%)
Small circulators	€ 491	€ 486	€ -5	-1 %	€ 486	€ -5	-1 %
Large circulators	€ 2764	€ 2742	€ -22	-1 %	€ 2751	€ -13	0 %
Integrated circulators	€ 519	€ 495	€ -24	-5 %	€ 495	€ -24	-5 %

If no change in the regulation is implemented, the total life cycle costs of small standalone circulators are expected to fluctuate solely due to fluctuation in electricity prices, whereas implementing one of the policy options, would result in a decrease of total LCC from around 2020. This can be seen in Figure 33, which shows the development of total life cycle costs for small standalone circulators from 2015 to 2030. In both policy option 2 and 3 cases, the total life cycle costs decrease from 2015 to

2030. The fluctuations in the period are due to the assumptions on the EEI development and fluctuation in electricity prices.

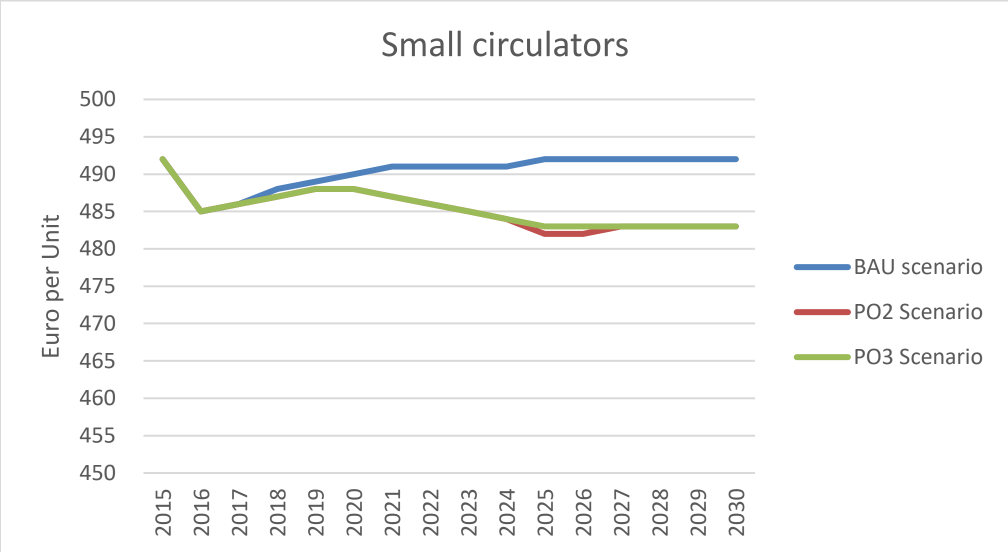

Figure 33: Development in total life cycle costs for small standalone circulators in each policy scenario (2015 to 2030) (2015 constant prices).

A breakdown of the development of the costs per life cycle stage are shown in Figure 34 for PO2, where the EEI requirement is EEI $\leqslant$ 0.20 and in Figure 35 for PO3, EEI $\leq$ 0.18. Here it can be seen that the total LCC is impacted by an increase in purchase price, but at the same time a decrease in electricity costs.

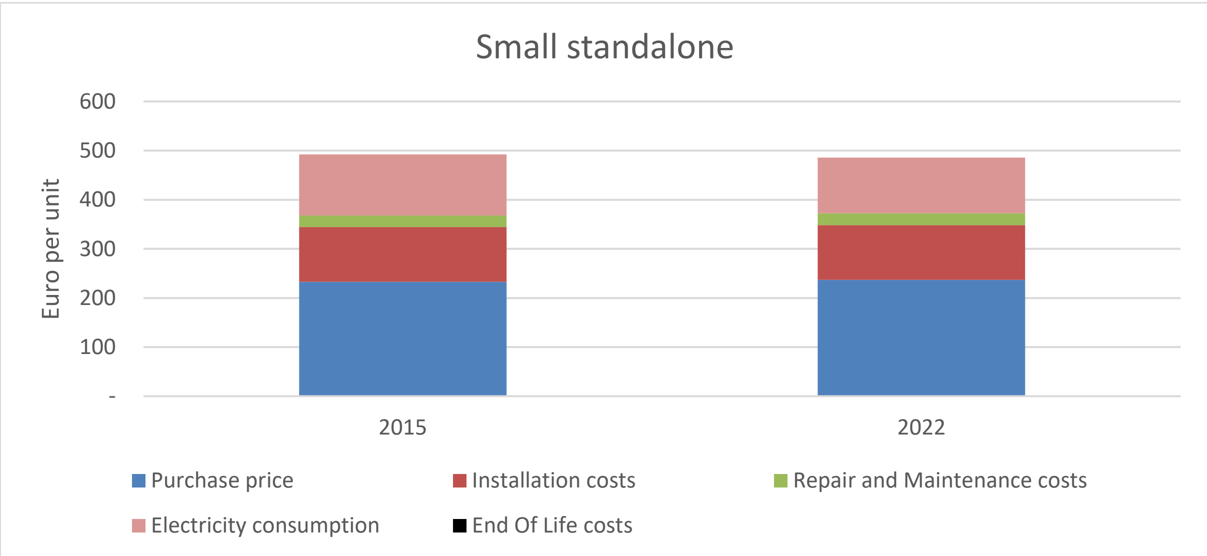

Figure 34: Development in life cycle costs in policy option 2 (EEI ≤ 0.20) for small standalone circulators for 2015 and 2022 (2015 constant prices).

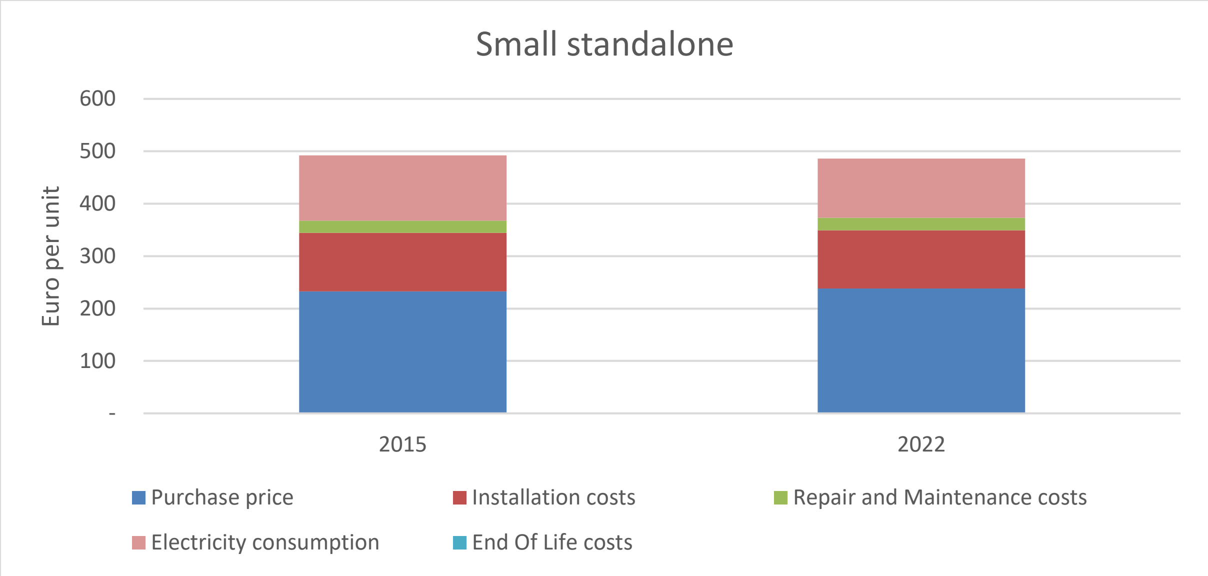

Figure 35: Development in life cycle costs in policy option 3 (EEI ≤ 0.18) for small standalone circulators 2015 and 2022 (2015 constant prices).

For the large circulators, the total life cycle costs decrease from 2020 to 2030 in the two policy option scenarios compared to BAU as shown in Figure 36. The fluctuations in the period are due to the assumptions on the EEI development and fluctuation in electricity prices.

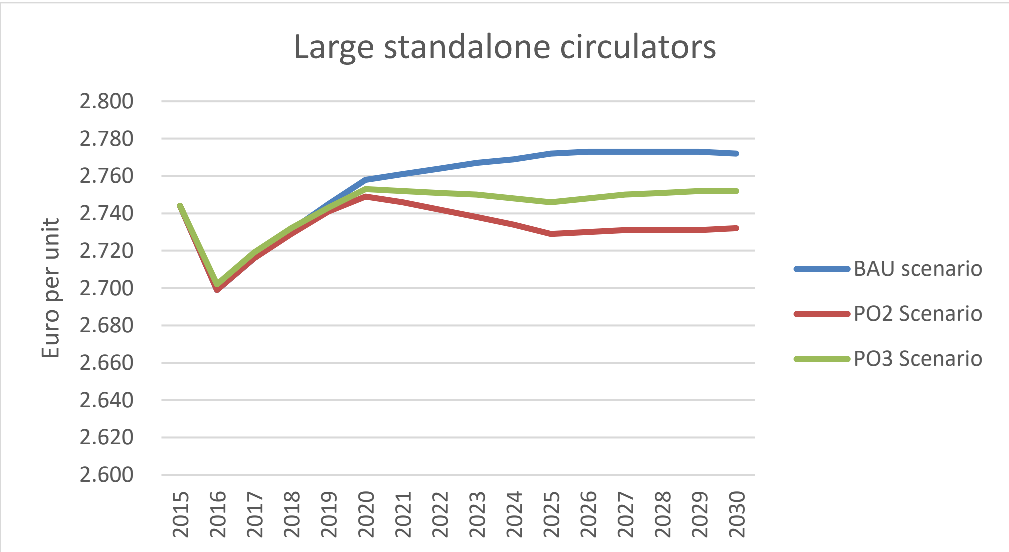

Figure 36: Development in total life cycle costs from 2015 to 2030 for large standalone circulators in each scenario (2015 constant prices).

A breakdown of the development of the costs per life cycle stage are shown in Figure 37 and Figure 38 for PO2 and PO3, respectively. Here it can be seen that the total LCC is impacted by an increase in purchase price as well as a smaller decrease in electricity consumption costs.

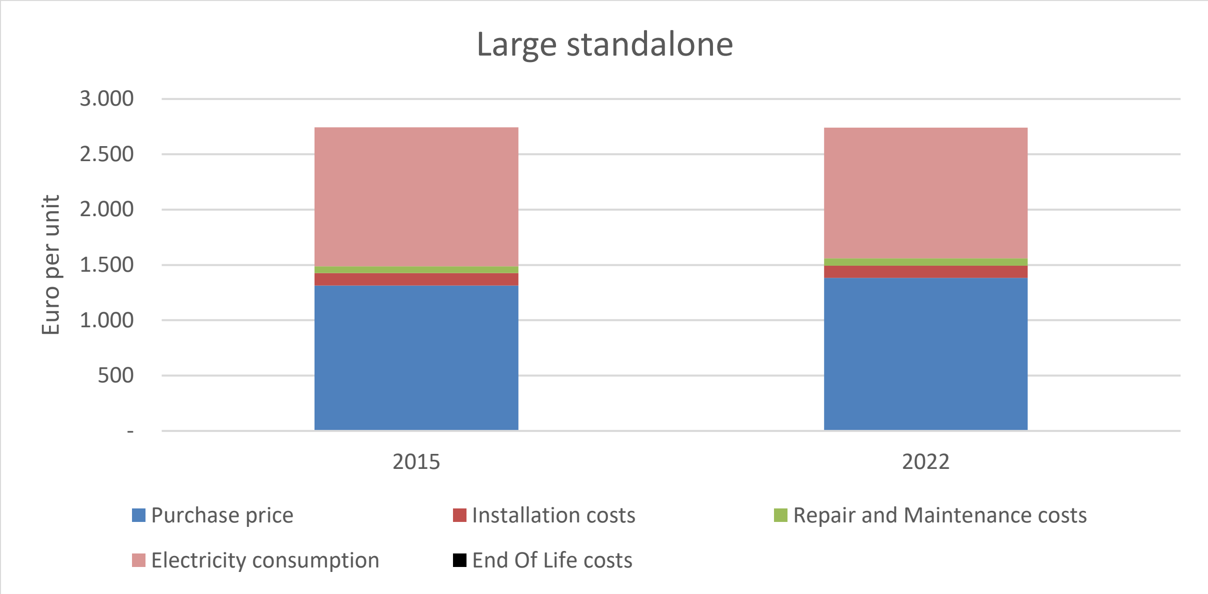

Figure 37: Development in life cycle costs in policy option 2 (EEI ⩽ 0.20) for large standalone circulators for 2015 and 2022 (2015 constant prices).

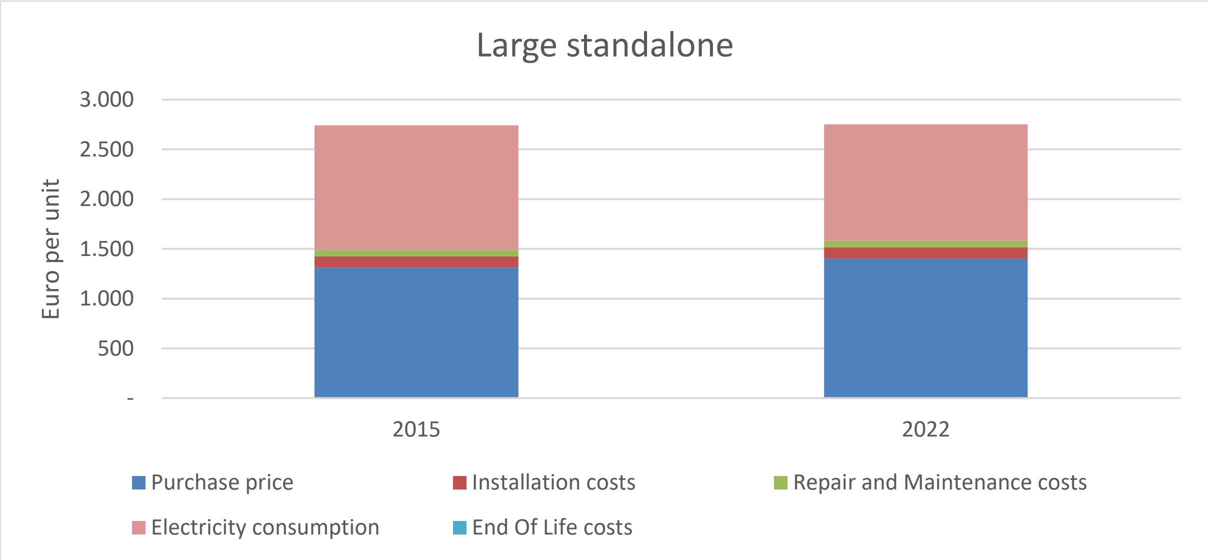

Figure 38: Development in life cycle costs in policy option 3 (EEI ⩽ 0.18) for large standalone circulators for 2015 and 2022 (2015 constant prices).

The integrated circulators show the largest life cycle cost savings, about 5 % in both scenarios. This is because the price increase (in constant prices) estimated based on industry information is smaller than for the standalone circulators, and therefore the electricity savings are larger in relative terms, than the purchase price increase. The life cycle cost development for integrated circulators is shown in Figure 39.

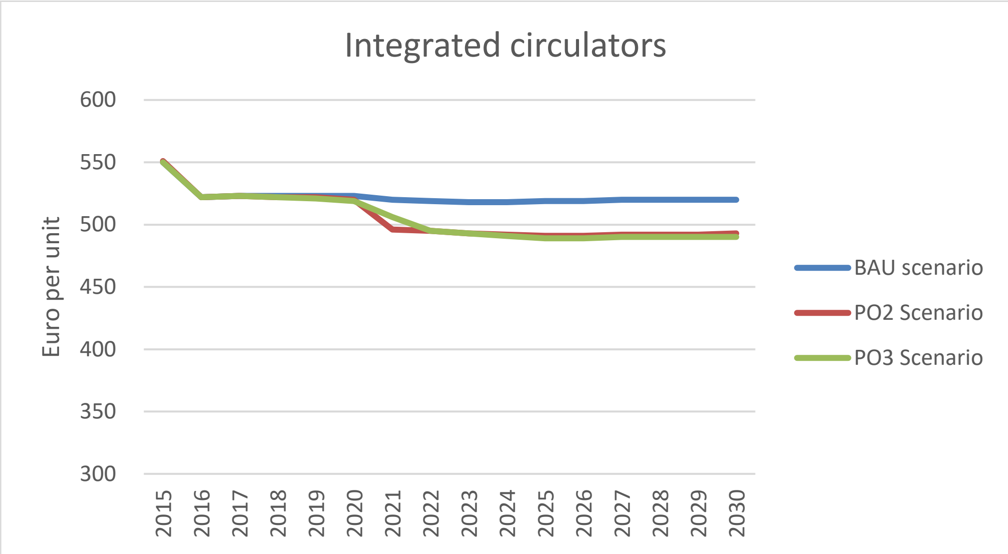

Figure 39: Development of total life cycle costs for integrated circulators from 2015 to 2030 for each scenario (2015 constant prices).

A breakdown of the development of the costs per life cycle stage are shown in Figure 40 and Figure 41 for PO2 and PO3, respectively. Here the smaller increase in purchase price can be seen, which is superseded by the decrease in electricity consumption costs.

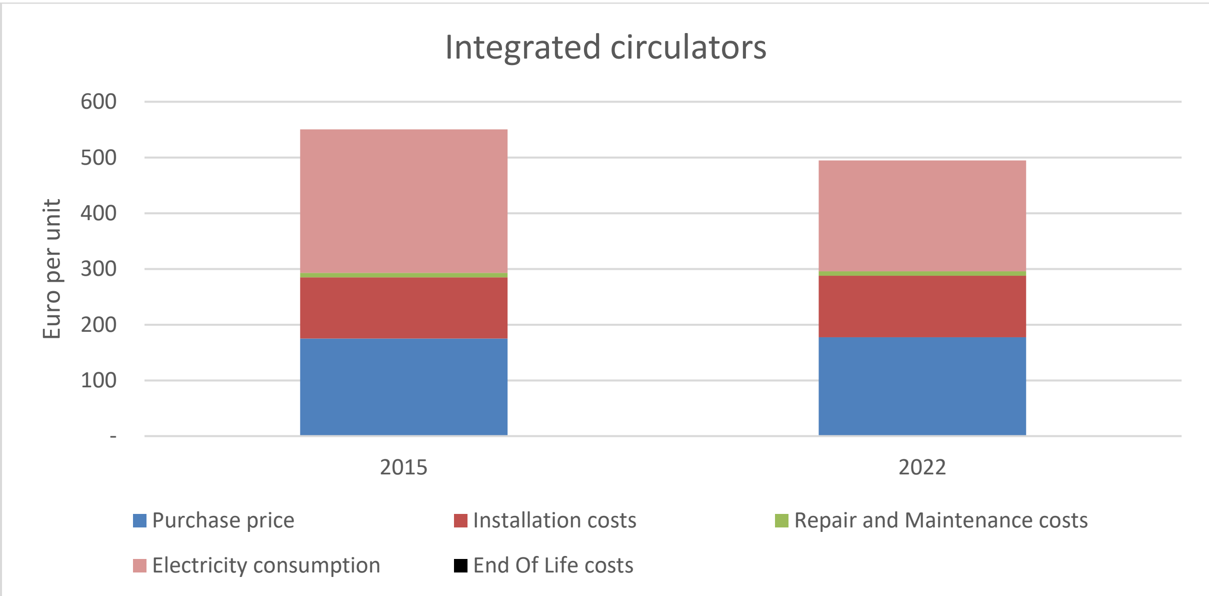

Figure 40: Development in total LCC for integrated circulators in policy option 2 (EEI ⩽ 0.20) for 2015 and 2022 in the PO2 scenario (2015 constant prices).

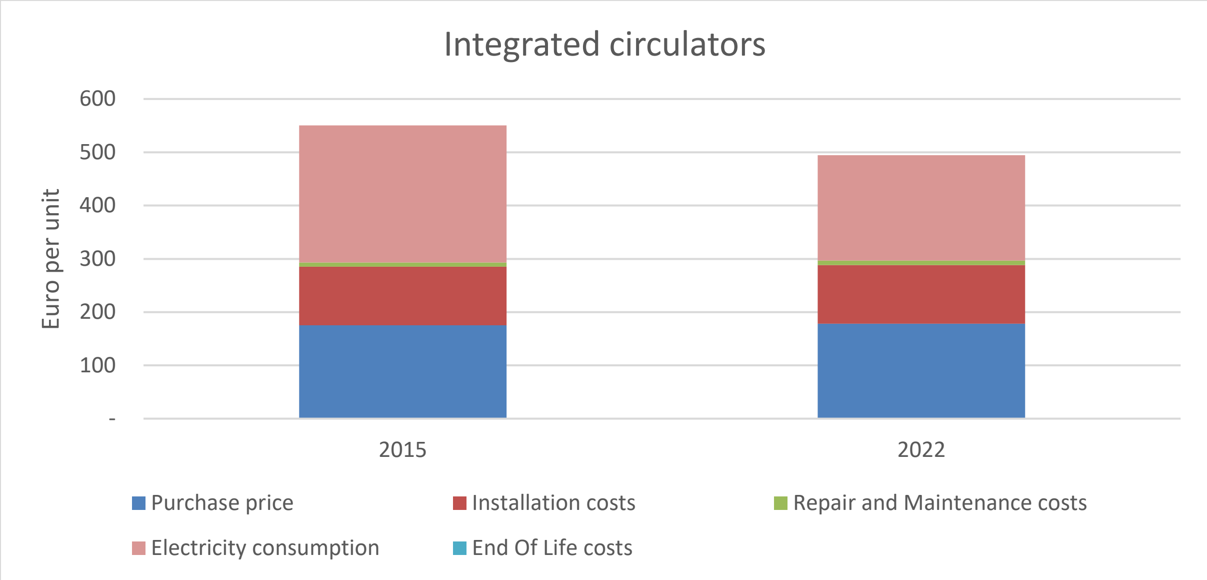

Figure 41: Development in total LCC for integrated circulators in policy option 3 (EEI ≤ 0.18) for 2015 and 2022 in the PO3 scenario (2015 constant prices).

8.5 Conclusions

According to the results presented in this chapter, it can be concluded that by making the EEI requirement levels more stringent, the potential energy savings are limited to 2.8 TWh/year and 3.1 TWh/year with EEI levels of ≤0.20 and ≤0.18 respectively by 2030. These savings are not negligible, however, the uncertainties in the assumed EEI levels and the corresponding costs are too high compared with the potential savings.

More ambitious levels are not possible according to information from stakeholders, which has been discussed throughout this report. When looking at the life cycle costs based on historical trends from the previous preparatory study, the forecasted benefits of saving electricity costs to the consumer for circulators when including an increased purchase cost remain limited (i.e. from around 1 up to 5 %).

9. Overall conclusions and recommendations

In line with article 7 of the Commission regulation (EU) No 622/2012 amending Commission regulation (EC) No 641/2009, this review study has focused on assessing the scope and ecodesign requirements in light of technological progress, by assessing the current market and energy efficiency levels and the possibilities for improvement. Additionally, this review study has focused on assessing whether design options that can facilitate reuse and recycling exist, and the possibilities for improving the current ecodesign requirements in this respect. This additional item is also in line with article 7 of the Commission regulation (EU) No 622/2012 amending Commission regulation (EC) No 641/2009.

9.1 Review of the regulation

Generally, this review study shows that the amended regulation has worked well by preparing the market to adopt the energy efficiency requirements that entered into force in two tiers: 1 January 2013 and 1 August 2015. Data shown in this study presents a clear improvement concerning energy efficiency for all circulators in scope, before and after the energy efficiency requirements entered into force. The largest improvements already started occurring one year after the first regulation was published (in 2010), and they continued occurring at a similar level of magnitude until around 2014. This shows the strong effect of the regulation. The degree of improvement is the most evident for small standalone circulators, whilst for large standalone and integrated circulators the improvement has occurred more slowly. For large standalone circulators, this is mainly because they are slowly being replaced by smaller sizes and thus there has been a stronger focus on energy efficiency for small standalone circulators. For integrated circulators, this is because of the design and size limitations the heating appliance exerts on them, reducing the possibilities for improving their efficiency. When looking at the sales trends, it is possible to see that the market for integrated circulators is increasing, whilst it has become stagnant for small standalone circulators and it has reduced for large standalone circulators. However, even with the slower degree of improvement, there is room for further improvement for small standalone, large standalone and integrated circulators in the future. Although, the scale of improvement is much more limited compared to what has occurred until now.

9.2 Review of scope

The conclusions from reviewing the scope show that no changes should be done. In spite that drinking water circulators have a potential for improvement (since it is expected that many still operate at constant flow in the EU market), there is an important barrier for harmonising their operational characteristics due to health reasons. This barrier is the existence of different national regulations across Member States, enacted to prevent the formation of Legionella bacteria in the drinking water pipelines. Currently, the study team do not know of any studies that present an overview of these requirements at EU level, which would be the basis to assess the possibilities for harmonisation. Harmonisation may be needed to establish flowtime profiles which themselves would be the basis for developing a methodology to calculate and measure energy efficiency.

However, other approaches of setting energy efficiency requirements for drinking water circulators may be possible to establish e.g. by using a flat flow-time profile. This option was out of the scope of the review study and has not been further assessed.

9.3 Review of enforcement activities

From an enforcement point of view, input from stakeholders suggests that a clarification is needed in the regulation to state that circulators intended both for drinking water systems and heating systems are not exempted. The study team assesses this is necessary due to the existing confusion in this respect and considering this is a relatively easy amendment to implement. Furthermore, it has been suggested that the marking of drinking water circulators covered by Annex I, point 2(1d) of the amending regulation (EU) No 622/2012 should be made more visible so it is clearer to identify circulators which are only intended for drinking water systems. This also supports the idea to make the requirement language neutral. A suggestion has been to include a pictogram and it has been assessed that it could be made small enough to fit on the pump itself and that can also be shown on the packaging and the product catalogues (both printed and online).

9.4 Review of designs that can facilitate reuse and recycling

The assessment of circulator designs that can facilitate the recovery for reuse and recycling shows that, in spite there is no legal framework that incentivizes manufacturers to design circulators in this way, the ongoing circular economy initiatives and the legislative framework established by the WEEE Directive can be used as a platform to increase the recycling of key circulators components.

These products are indeed not easy to collect separately by average households at their end-of-life, so from a waste management perspective, the existence of take back systems or extended product responsibility schemes is critical, to increase their chances to be sorted out from the generic metal or household waste and recover more of their components for recycling.

From an ecodesign perspective, the possibilities of implementing a marking requirement at a vertical level has been assessed to be of little benefit. This is because the circulators' key components, the printed circuit board in the controllers and the permanent magnet in the motor, are either not so easy to disassemble (permanent magnet) or contain very little amounts of highly valuable materials (printed circuit boards). Therefore, it was qualitatively assessed according to diverse input from manufacturers and recyclers, that the costs to implement a marking requirement would by far surpass the economic benefit of recovering materials like gold and copper from the printed circuit board and neodymium from the permanent magnet.

Furthermore, no recycling of neodymium exists at commercial level in the EU, and according to input from recyclers and experts in the area, there is currently no incentive to change this situation due to the lower price of neodymium. Since the price has shown to fluctuate, it is still recommended to investigate ways to make recycling possible. An alternative recommended from this study is to implement an ecodesign marking requirement for content of rare earth elements (REEs) at a horizontal level instead.

This would assure a critical volume of neodymium to incentivize its recycling. The study team suggests to do it for all the product groups so the volume is highly increased by having electronic products in, also because of the longer lifetime of motor driven units and since the occurrence of permanent magnets is relatively new in these products. However, ongoing activities are pursuing marking of REEs at vertical level for some electronic product groups. An alternative could be to implement a horizontal marking requirement for motor driven units, including electric motors.

9.5 Review of energy efficiency requirements

Based on the market overview regarding energy efficiency levels, both historical and current levels, it appears that the EEI levels have developed towards more efficient circulators rather quickly since 2010, both for standalone and integrated circulators. The review carried out during this study shows that most of the circulators currently placed on the market comply easily with current requirement levels, with more than half already at benchmark levels or lower (EEI=0.20).

However, the margin to lower the current EEI levels (i.e. increase energy efficiency levels) is rather small because of system design constraints that reduce the possibilities to improve the circulators' design to become more efficient. This margin appeared to be around an EEI level of 0.18, which is 10% below the current benchmark level. The review of the EEI levels showed that at most, only 15% of the standalone circulators placed currently on the market can go below 0.18. Therefore, three policy options were assessed:

4. Policy option 1: no action - Business as Usual (BAU)
5. Policy option 2: EEI ≤0.20 by 2022
6. Policy option 3: EEI ≤0.18 by 2022

When comparing BAU with policy option 2, the potential energy savings are:

- Small standalone circulators: 0.19 TWh/year in 2025 and 0.37 TWh/year in 2030
- Large standalone circulators: 0.33 TWh/year in 2025 and 0.66 TWh/year in 2030
- Integrated circulators: 0.86 TWh/year in 2025 and 1.78 TWh/year in 2030

When comparing BAU with policy option 3, the potential energy savings are:

- Small standalone circulators: 0.21 TWh/year in 2025 and 0.41 TWh/year in 2030
- Large standalone circulators: 0.39 TWh/year in 2025 and 0.73 TWh/year in 2030
- Integrated circulators: 0.91 TWh/year in 2025 and 1.92 TWh/year in 2030

The assessment of these two policy options gives a total for the circulators in scope of:

- Policy option 2: 1.37 TWh/year in 2025 and 2.81 TWh/year in 2030
- Policy option 3: 1.51 TWh/year in 2025 and 3.06 TWh/year in 2030

Though the saving potentials and the net economic savings for the end-users are not negligible, the uncertainties in the assumed EEI levels and the corresponding costs are too high to recommend a revision of the current EEI levels of requirements. It is expected that more stringent EEI requirements will not drive the market to take significant leaps of design improvements, which at the moment are limited to the technologies found already on the market.

9.6 Overall recommendations

Overall, the recommendations for this study are:

- Do not introduce any amendments to the scope, however, revise the text exempting drinking water circulators for the energy efficiency requirements clarifying that circulators intended both for drinking water systems and heating and cooling systems are not exempted.

- Consider further work on setting requirements for drinking water circulators using a simpler flow-time profile, which would not require harmonisation of national regulations of drinking water systems.
- Consider elaborating on the product information requirement for drinking water circulators (Annex I, point 2(1d)), by including a pictogram, which should be shown on printed and online product catalogues and, if possible, on the nameplate.
- Consider suggesting a horizontal ecodesign requirement for the marking of rare earth elements (REEs) for all motor driven unit product groups.
- Do not introduce any amendments to the energy efficiency requirements as they do not provide sufficient added value in terms of energy savings at EU level and net economic savings for the end-users, when taking into account the high uncertainties in the assumed EEI levels and the corresponding costs.