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Preparatory study of Ecodesign and Energy Labelling measures for High Pressure Cleaners

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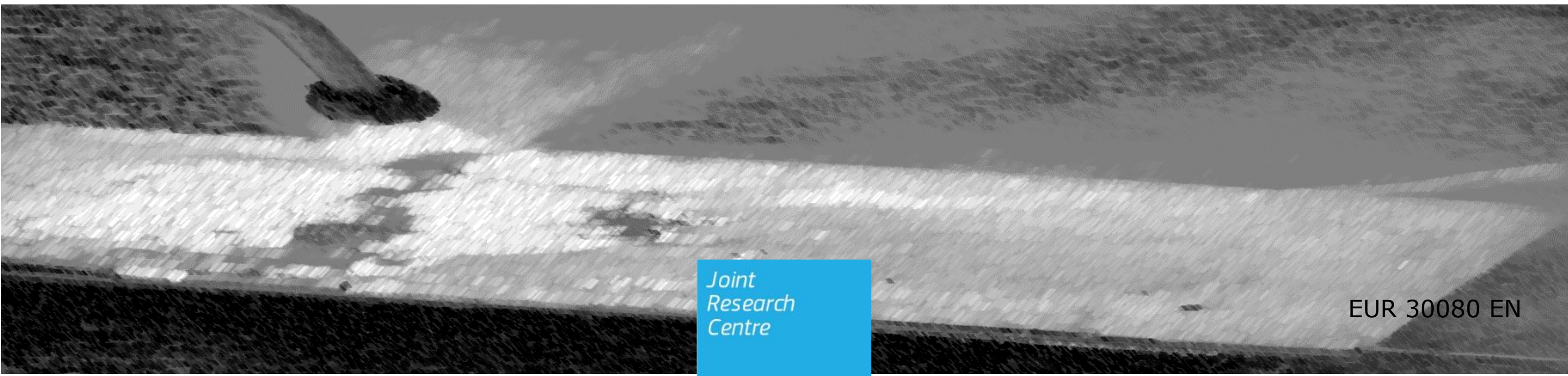

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Table of Acronyms

GHG	Greenhouse gas
MEErP	Methodology for Ecodesign of Energy-related Products
NACE	Nomenclature used in the European Union
HPC	High Pressure Cleaner
IECEE CB	International Electrotechnical Commission Electrical Engineering Certification Body
EN	European Norm
ISO	International Standardization for Organisation
IEC	International Electrotechnical Commission
EMC	Electromagnetic compatibility standards
ANSI	American National Standards Institute
CPC	Cleaning Performance Program
LCA	Life Cycle Assessment
LCC	Life Cycle Cost

Abstract

Following the Ecodesign Working Plan 2016-2019[1], the European Commission launched in 2018 a preparatory study for the product group 'high pressure cleaners'. The preparatory study follows the Commission's Methodology for the Evaluation of Energy related Products (MEErP). It consists of: Scope definition, standard methods and legislation, Market analysis, Analysis of user behaviour and system aspects, Analysis of technologies, Environmental and economics, Design options and Policy analysis and scenarios The comprehensive analysis of the product group following the steps above will provide the technical and scientific evidence for policy-making decisions. The research is based on available scientific information and data, uses a life-cycle thinking approach, and has engaged stakeholder experts in order to discuss key issues, and to the extent possible reach consensus on the proposals.

[1] Communication from the Commission COM(2016) 773

Introduction

Background

The European Commission has launched a preparatory study of Ecodesign and Energy Labelling measures for High Pressure Cleaners (HPC). This product group was identified within the Ecodesign Working Plan 2016-2019[2].

The current report covers all tasks of the Methodology for Ecodesign of Energy-related Products (MEErP)[3] used for this preparatory study. The methodology consists of seven well-defined tasks; Tasks 1 to 4 are focused on data retrieval and initial analysis, and Tasks 5 to 7 concentrate on modelling and modelling analyses aiming at providing sufficient background information to decide whether and which potential Ecodesign and Energy Labelling requirements should be set for the product group. Figure 1 presents an overview of all MEErP tasks to be followed in the HPC preparatory study.

Task 1 *– Scope definition, standard methods and legislation*

Task 2 *– Market analysis*

Task 3 *– Analysis of user behaviour and system aspects*

Task 4 *– Analysis of technologies*

Task 5 *– Environmental and economic assessment of base cases*

Task 6 *– Assessment of design options*

Task 7 *– Assessment of policy options*

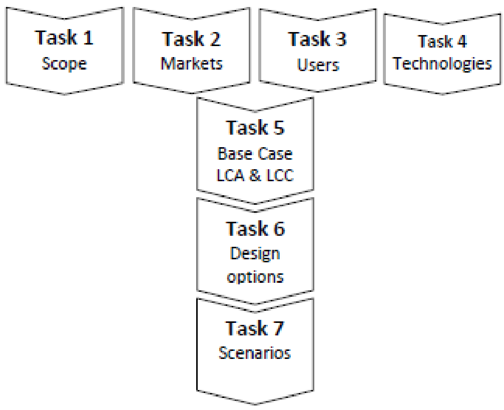


Figure 1. MEErP structure

The research is based on available scientific information and data provided by stakeholders and experts, following a life-cycle thinking approach and engaging stakeholder experts in order to discuss key issues and to develop a wide consensus.

Stakeholder consultation throughout the study

During preparatory studies, stakeholders are continuously consulted. An online communication system - BATIS - has been set up for easy exchange of documents between the registered stakeholders forming the Technical Working Group (TWG). This approach was applied to the current study too.

Questionnaires for gathering information on scope, definitions, and issues of relevance, as well as templates for the collection of relevant data, e.g. regarding energy and water consumption values, the definition of base cases and design options, and the discussion on policy options were distributed to the TWG during the study process. Furthermore, the project team visited different manufacturers and test laboratories to investigate the overall product group, and product subgroups in detail, and to be completely up-to-date with the latest technical and market developments. Formal stakeholder consultations carried out were a 1st Technical Working Group (TWG) meeting held on 3 May 2018 in Brussels and a 2nd stakeholder meeting held as a webinar over 2 days (23 and 24 January 2019). A 3rd stakeholder meeting was held on 17 June 2019. Additionally industry associations and manufacturers were consulted throughout the study on more specific issues as needed.

[2] Communication from the Commission Ecodesign Working Plan 2016-2019.
https://ec.europa.eu/energy/sites/ener/files/documents/com_2016_773.en_.pdf

[3] "Methodology for Ecodesign of Energy-related Products. MEErP 2011. Methodology Report. Part 1: Methods". Prepared for the European Commission, DG Enterprise and Industry by COWI and VHK (2011) and Material-efficiency Ecodesign Report and Module to the Methodology for the Ecodesign of Energy-related Products (MEErP) (2013).

1 Task 1: Scope, legislation and standardisation

Task 1 comprises the identification of the scope (categories, subcategories, etc.), definitions, system boundaries, test standards and existing regulation. Regulations and standards are investigated both within the EU and internationally. Its results consist of the definition of a preliminary scope, with a special focus on the products' performance, in combination with the energy and resource efficiency of HPCs during their use phase. Other life-cycle and product aspects such as production, maintenance, durability, reparability, recyclability and product End-of-Life (EoL) treatment are also considered.

1.1 Product scope

The following subsections provide an analysis of existing definitions of HPCs, as used for example in European statistics, EU legislation, and standards. The product scope is also based on the preliminary stakeholder feedback regarding the initially proposed scope and definitions. Based on this information and further research and evidence, a preliminary product scope is presented as the basis for discussion at the first stakeholder meeting.

1.1.1 Existing definitions and categories

This section describes existing definitions, categories and subcategories based, inter alia, on Eurostat PRODCOM categories, standards and labelling categories.

1.1.1.1 PRODCOM categories

The PRODCOM database is the official source of information on the production and sales of products in the EU according to the MEErP methodology.

Since 2008 the PRODCOM database nomenclature has been NACE Rev. 2.0[4], which means that the data registered for HPCs falls under the category "28.29.22.30 – Steam or sand blasting machines and similar jet-projecting machines (excluding fire extinguishers, spray guns and similar appliances)". However, this category also includes products other than HPCs for various purposes, including specialised industrial applications. As such, the category is considered as not totally representative of the HPC market.

Table 1 lists the nomenclature headings corresponding to the products relevant for this study. However, the PRODCOM database does not have quantified data per subcategory, which means that the data cannot be disaggregated. Thus, additional market data and estimations are needed.

Table 1. Product subcategories used in the PRODCOM database

PRODCOM nomenclature	Description
84.24.30.01	Water cleaning appliances with built-in motor, with heating device
84.24.30.05	Water cleaning appliances with built-in motor, without heating device, of an engine power <= 7.5 kW
84.24.30.09	Water cleaning appliances with built-in motor, without heating device, of an engine power >= 7.5 kW
84.24.30.10	Steam or sand blasting machines and similar jet projecting machines, compressed air operated
84.24.30.90	Steam or sand blasting machines and similar jet projecting machines (excl. compressed air operated and water cleaning appliances with built-in motor and appliances for cleaning special containers)

1.1.1.2 Existing categories from standards, Ecodesign or Energy labelling

For defining the scope, there are two relevant European standards covering HPCs. These standards primarily focus on safety, and performance considerations are largely limited to noise evaluation. However, the

[4] http://ec.europa.eu/eurostat/web/prodcom/data/database

terminology and parameters defined within the standards are still relevant for the work and have been used throughout this report.

The first standard covers high pressure cleaners with a rated pressure of no less than 2.5 MPa and not exceeding 35 MPa: EN 60335-2-79 "Household and similar electrical appliances - Safety - Part 2-79: Particular requirements for high pressure cleaners and steam cleaners" (2016). It does not define specific categories for HPCs; however, it covers HPCs without a traction drive, intended for household and commercial indoor or outdoor use, having a rated pressure of no less than 2.5 MPa and not exceeding 35 MPa. Hot water HPCs may incorporate a steam stage.

EN 60335-2-79 covers the following power systems of the drive for the pump in the HPCs:

- mains-powered motors up to a rated voltage of 250 V for single-phase machines and 480 V for other machines;
- battery-powered motors;
- internal combustion engines;
- hydraulic motors;
- pneumatic motors.

The above standard does not apply to:

- high pressure water jet machines having a rated pressure exceeding 35 MPa;
- steam cleaners intended for domestic use;
- handheld and transportable motor-operated electric tools;
- appliances for medical purposes;
- agricultural sprayers;
- non-liquid, solid abrasive cleaners;
- machines designed to be part of a production process;
- machines designed for use in corrosive or explosive environments (dust, vapour or gas); or
- machines designed for exclusive use in vehicles or on board ships or aircraft.

The second relevant European standard covers all HPCs with a water pressure above 35 MPa: EN 1829-1 High pressure water jet machines - Safety requirements - Part 1 (2010)

The standard contains safety-related requirements for high pressure water jet machines with drives of all kinds (e.g. electric motor, internal combustion engine, air and hydraulic) in which pumps are used to generate pressure. Standard EN 1829-1 deals with all significant hazards, hazardous situations and events arising during assembly, erection, operation and servicing relevant to high pressure water jet machines, when they are used as intended and under conditions of misuse which are reasonably foreseeable by the manufacturer. The standard includes machines for one or more of the following industrial applications:

- cleaning;
- surface preparation;
- material removal;
- readjustment of concrete;
- cutting.

In standard EN 1829-1 there is no formal definition of a minimum cutting pressure (and therefore a maximum cleaning pressure), since this depends upon the material to be cut.

The HPC product category is not covered by current EU Ecodesign criteria, nor is it covered by current EU Energy Labelling criteria. However, it should be noted that electric motors used as components in high pressure cleaners are already subject to Ecodesign measures (see further detail in Section 1.3 dealing with legislation).

1.1.2 Feedback from stakeholders with regard to the initial scope and definitions

The project team distributed a questionnaire in January 2018. Eight stakeholders submitted their feedback on ''Task 1: Scope'' via this questionnaire. These stakeholders comprise: two trade organisations for the sector, two consumer/environmental organisations and four manufacturers of HPC products.

From the responses received so far, most stakeholders agree that the scope of the Ecodesign / Energy Labelling preparatory study should be limited to the same scope and exclusions as defined in standard EN 60335-2-79

"Household and similar electrical appliances - Safety - Part 2-79: Particular requirements for high pressure cleaners and steam cleaners", i.e. HPCs with a maximum pressure of 35 MPa.

However, one stakeholder pointed out that there is a segment of HPCs with operating pressures higher than 35 MPa (products specially designed for heavy-duty industrial and agricultural applications). More specifically on that topic, one stakeholder suggested that the scope should only include units with a maximum water pressure of 15 MPa, whilst another respondent suggested a maximum pressure of 70 MPa. Regarding additional exclusions, with reference to EN 60335-2-79, one stakeholder proposed that HPC machines mounted on trucks or trailers should be excluded from the scope but without providing any reasoning for this exclusion. Another stakeholder proposed that handheld and transportable motor-operated electric tools (IEC 60745 series, IEC 61029 series, IEC 62841 series) be excluded.

Regarding the question of whether HPCs with internal combustion engines should be included or excluded from the scope, most respondents mentioned that this product type is a niche product, which is mostly used in the industrial or agricultural sectors. However, to have a complete picture, apart from the market share, other parameters should be taken into account, for example the energy and resource consumption, the environmental impact and use pattern of these HPCs. Two stakeholders are in favour of including HPCs with combustion engines in the scope. One respondent estimated that the market share of HPCs with internal combustion engines is relatively small without giving estimates. Meanwhile, two stakeholders state that the internal combustion engines' market share of the hot water commercial cleaners market is between 6% and 15%. Three stakeholders have no information on the market for HPCs with internal combustion engines.

Regarding the question of including battery-powered HPCs within the scope of the study, the responses received so far in general indicate that currently there are few battery-powered domestic HPCs on the EU market. Three respondents are of the opinion that battery-powered HPCs are not a significant product subgroup, and that they do not expect this to change in the foreseeable future as current battery capacities can only support high pressure cleaners with a low maximum pressure or short performance time. Large batteries with sufficient capacity would make the HPCs so heavy that they would not be considered mobile due to their weight. On the other hand, three stakeholders responded that they do expect more battery-powered HPCs in the future. Although nowadays battery-powered HPCs have no significant market share, and there may be few or no models available due to the aforementioned technical limitations, it is expected that battery-powered HPCs may emerge in the near future due to the rapid technological improvements in lithium ion batteries and their constant price drop per kWh during recent years. Thus, the project team suggests that they should be included in the product scope.

All but one stakeholder say that stationary high pressure units should not be included in the scope. Most stakeholders claim that the category is in the industrial sector (they are either used in an industrial environment or in an environment with an explosive atmosphere or in car wash facilities) and their use is very different from domestic and commercial applications. Furthermore, they argue that it is a niche market with very low sales (first estimations from stakeholders place these unit sales at the level of a few thousands units per year; however, more detailed information will be provided in Task 2). In contrast, one stakeholder states that the inclusion of the stationary units would give a complete overview of the HPC product group.

Seven out of eight stakeholders agree that steam cleaners are a different product and should not be included in the scope. One of these stakeholders mentions that commercial steam cleaners and those parts of hot water high pressure cleaners incorporating a steam stage which have a capacity not exceeding 100 l, a rated pressure not exceeding 2.5 MPa and a capacity and rated pressure not exceeding 5 MPa fall under EN 60335-2-79 and could be seen to be within the scope. One stakeholder does not answer directly this question but notes that the machine needs to be evaluated in all its functionalities following the current International Technical Standard.

1.1.3 Preliminary product scope

Based also on the initial round of feedback from stakeholders, summarised in the above section, together with initial findings from the HPC project team, a preliminary description of the product scope is given in this section. This was the basis of discussion for the first Technical Working Group meeting held on the 3 May 2018 in Brussels, Belgium.

The proposed primary performance parameter or 'functional unit' (i.e. related to the cleaning function), the description of the main components, and the energy and resource consumption during the use phase of the product are presented in this chapter.

1.1.3.1 Description of products

The European market has many designs of HPCs that are available to both European consumers and commercial operators. An HPC has been defined by one EU Directive as a: *machine with nozzles or other speed-increasing openings which allow water, also with admixtures, to emerge as a free jet. In general, high pressure jet machines consist of a drive, a pressure generator, hose lines, spraying devices, safety mechanisms, controls and measurement devices*[5].

An HPC has a motor that drives a water pump, which is provided with water from either a water tap, external water reservoirs (for HPCs with self-priming pumps) or, in rare cases, a built-in container. The water pump accelerates the water to high pressure and releases it through a hose. The hose can have various attachments that can be used for different cleaning purposes and applications. Some HPCs have a container for detergent which can be mixed into the water for optimising the cleaning.

The motor can be powered with electricity, fuel (diesel, petrol or gas) or hydraulic or pneumatic sources. There is also a very small volume of battery-powered units available on the EU market. Fuel-powered units are generally able to provide higher pressures. Units that deliver a water jet at pressures above 35 MPa are also available for commercial and industrial cleaning applications.

HPCs may work with hot or cold water. Hot water high pressure cleaners have an integrated burner or boiler, which enables them to convert cold water into hot. Warm or hot water can also be supplied to some HPCs directly from the water connection without the need for internal heating.

HPCs may be mobile or stationary. The Outdoor Noise Directive[6] defines these as follows:

- Mobile high pressure water jet machines are mobile, readily transportable machines which are designed to be used at various sites, and for this purpose are generally fitted with their own undergear or are vehicle-mounted. All necessary supply lines are flexible and readily disconnectable.
- Stationary high pressure water jet machines are designed to be used at one site for a length of time but capable of being moved to another site with suitable equipment. Generally skid- or frame-mounted with supply line capable of being disconnected.

In general, products meant for domestic and light use are not fitted with any form of traction drive. In all cases, the discharge line is considered to be handheld. Table 2 presents six typical types of HPCs. However, in the following Tasks more detailed information regarding HPC categorisation is presented as Base Cases.

Table 2. Typical high pressure cleaners

Domestic HPC	Compact units, suitable for general cleaning duties including garden tasks and furniture. Typically electric. Very few units on the market today are battery-powered. Typical power range 1 200-1 600 W. Typical pressure up to 11 MPa. Example product: Karcher K2	
Professional HP, electric (1-phase)	Compact units, often upright, suitable for general cleaning duties including garden tasks, furniture, patio and paths and car washing duties. Typically electric. Power range maximum 3.3 kW. Typical maximum pressure up to 18 MPa and/or with maximum flow rate below 900 l/h. Example product: Bosch AQT 37-13 Plus	

[5] Definition from the Outdoor Noise Directive; see description of the Directive in Section 1.3.
[6] Description of the Outdoor Noise Directive in Section 1.3.

Professional HPC, electric (3-pase)	More powerful units, often upright, suitable for a broad range of demanding cleaning duties. Typically electric. Typical power range: 2-15 kW. Typical maximum water pressure above 18 MPa and/or with maximum flow rate above 900 l/h. Example product: Karcher HD 20/15-4 Cage-plus	
HPC with combustion engine	Petrol or diesel combustion-engine-driven units. Units are typically mounted on larger wheels (but are still intended to be transported manually) with a frame similar to a manual lawnmower or in a trailer. Useful in remote applications where an electrical power source is not available. Used for cleaning purposes including large areas such as car parks or warehouse yards or large vehicle washing duties. Alternative sources of power may include biodiesel and gas. Power range: 5-15 hp; 3-15 kW. Pressure is typically 16 MPa and higher. Example product: SIP Tempest PPG680/210 207 Bar Petrol Pressure Washer	
Hot water HPC (1-3 phase)	Hot water HPCs exist in versions with electric motors and with combustion engines. Typically, the hot water is produced from fuels (diesel, heating oil) by a burner and heat exchanger for heating the pressurised water. It incorporates a fuel tank, fuel pump and ancillaries. Hot water HPCs with a combustion engine typically have separate fuel tanks for the burner and for the engine. For special purposes like indoor use, electric water heating is used. Units are typically 10-15 MPa, deliver hot water up to 90 °C (in rare cases up to 150 °C for steam output) and with an input power of the pump at 2-15 kW and input power of heater below 150 kW. Example product: V-Tuf – Rapid VSC Hot Water 230V	

Stationary cold or hot water HPC	Typically, this type of unit is installed in a cabinet or bench- or rack- or wall-mounted. Units may be hot or cold. Applications may include vehicle cleaning. Water pressure may be 10-20 MPa or higher. Motor ratings are typically 2-8 kW and the units incorporate a fuel tank with a low level warning. The mains supply may be 230 V single-phase supply for lower pressure units but above 15 MPa or 3.3 kW units will typically require a 400 V three-phase supply. Temperatures 0-100 °C. Example product: Mac International – Plantmaster	

1.1.3.2 Proposed product scope

The preliminary scope of this study covers:

- Cold water domestic high pressure cleaners.
- Cold water professional high pressure cleaners.
- Hot water professional high pressure cleaners.
- Cold water stationary high pressure cleaners.
- Hot water stationary high pressure cleaners.

The first, third and fourth subgroups above represent the three main categories which were preliminarily investigated in the Preparatory study to establish the Ecodesign Working Plan 2015-2017[7]. In addition, cold and hot water stationary high pressure cleaners are added as separate categories (excluding stationary HPC equipment installed as part of industrial/production processes). Figure 2 illustrates the proposed product scope which is further explained in the following sections.

[7] http://ec.europa.eu/DocsRoom/documents/20374

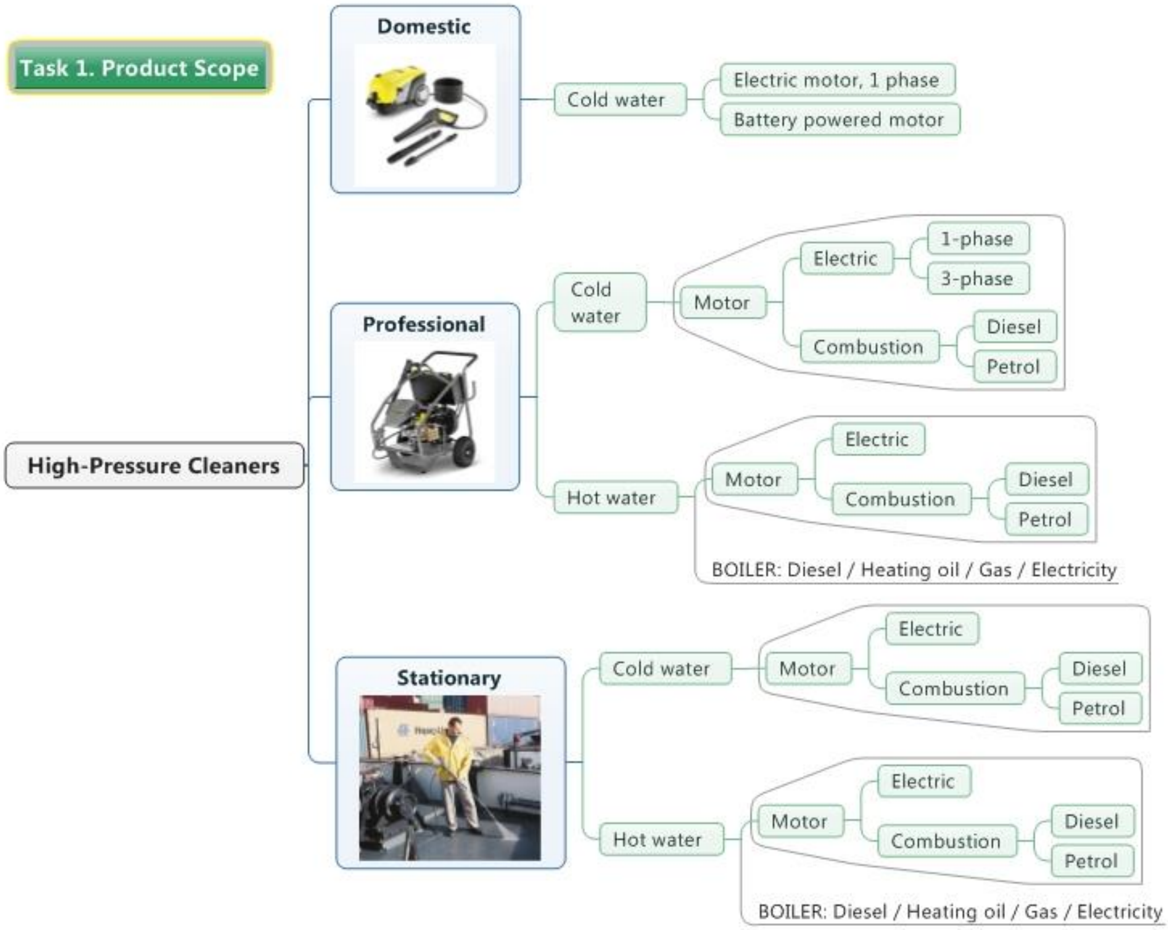


Figure 2. HPC product scope

Scope proposed

Based on the standard EN 60335-2-79 "Household and similar electrical appliances - Safety - Part 2-79: Particular requirements for high pressure cleaners and steam cleaners", i.e. HPCs with a maximum pressure of 35 MPa, the scope proposed covers high pressure cleaners without traction drive, intended for indoor or outdoor use, having a rated maximum water pressure of no less than 2.5 MPa and not exceeding 35 MPa. The high pressure cleaner may be fitted with a water heater (boiler or burner) for hot water production and can be mobile or stationary. Hot water high pressure cleaners may incorporate a steam stage.

The following power systems of the drive for the high pressure pump are covered:

- mains-powered motors up to a rated voltage of 250 V for single-phase machines and 480 V for other machines;
- battery-powered motors;
- battery- and electric-powered (hybrid);
- internal combustion engines;
- hydraulic or pneumatic motors.

According to standard EN 60335-2-79, the exclusions proposed are the following:

- high pressure water jet machines having a rated pressure exceeding 60 MPa;
- steam cleaners per se (i.e. steam cleaning technology only);
- appliances for medical purposes;
- agricultural sprayers;
- non-liquid, solid abrasive cleaners;

- machines designed to be part of a production process;
- machines designed for use in corrosive or explosive environments (dust, vapour or gas);
- machines designed for exclusive use in vehicles or on board ships or aircraft.

The definitions proposed are as follows:

- “High pressure cleaner” means a device that ejects water at high pressure (above 2.5 MPa and below 35 MPa) with the aim to remove dirt, dust, mould, etc. from a soiled surface or structure.
- "Hot water high pressure cleaner" means a high pressure cleaner that incorporates a water heater to raise the temperature of the input water.
- “Domestic high pressure cleaner” means a unit whose maximum power does not exceed 3.3 kW, single phase, and its intended use defined by the manufacturer is domestic.
- “Professional high pressure cleaner” means a unit (cold or hot water) whose power is equal to or above 2 kW, and its intended use defined by the manufacturer is professional or industrial. Units driven by internal combustion engines, single or three-phase electric and hydraulic or pneumatic motors are considered professional, and their intended use defined by the manufacturer is always professional or industrial.
- “Stationary high pressure cleaner” means a unit that is designed to be used at one site for a length of time, not intended to be moved while operation, but capable of being moved to another site with suitable equipment. Generally, they are skid- or frame-mounted with the supply line capable of being disconnected.
- “Steam cleaner” means a unit that is designed for steam cleaning only.
- “Agricultural sprayer” means a unit that is used to apply liquid fertilisers, pesticides, or other liquids to crops during their growth cycle.

Further proposed definitions of key parameters related to high pressure cleaners are available in Annex 1.

Rationale for the proposed scope

Stationary HPCs: Although the sales of stationary units can be much lower compared with the rest of the HPC subcategories, their environmental impact is likely to be disproportionally higher compared to the other HPC categories, as their use is more intense and frequent (e.g. stationary units for cars).

Water pressure limits (2.5 MPa to 35 MPa): Below 2.5 MPa the product cannot be considered a HPC. This minimum pressure limit was selected to be in line with the EN 60335-2-79 safety standard. The maximum water pressure limit was set at 35 MPa, to align it with the standard EN 60335-2-79. According to manufacturers, the products that provide higher pressures represent a marginal share of the market and due to their different characteristics and usage, they significantly differ from the products below 35 MPa.

Categorisation: Domestic (up to 3.3 kW) and professional categories were based on a preliminary analysis of 77 HPC models (hot and cold water, mobile and stationary) available on the market, presented in Figure 3. The electric power required by the appliance is a key feature, since domestic electricity supply (single-phase) cannot deliver more than approximately 3.3 kW, and therefore products above this limit are meant to be used for professional applications, where three-phase connections are more common. However, there is an overlap between domestic and professional appliances, as there are some HPCs below 3.3 kW that are intended for professional applications and therefore the power limit for professional HPCs is set at 2 kW. The manufacturers indicated that the intended application (domestic or professional) is crucial in the design and manufacture of the HPCs. The usage patterns are very different, and the intended use has therefore been included in the definitions of domestic and professional HPCs. Professional products are used much more frequently than domestic ones, so they are more robust in order to ensure sufficient endurance. They are also designed to enable high reparability, which is not the case for domestic products.

Battery-driven HPCs: Generally, wireless appliances (powered with batteries) are appreciated by consumers and widely increasingly found on the market. Battery-driven HPCs are already available on the market albeit in low numbers and for low-performance applications. Furthermore, battery technology has improved significantly over recent years (affected also by the fast development of electric cars) with new materials and technologies increasing their capacity and efficiency, and lowering their weight, which also results in a decreasing price trend.

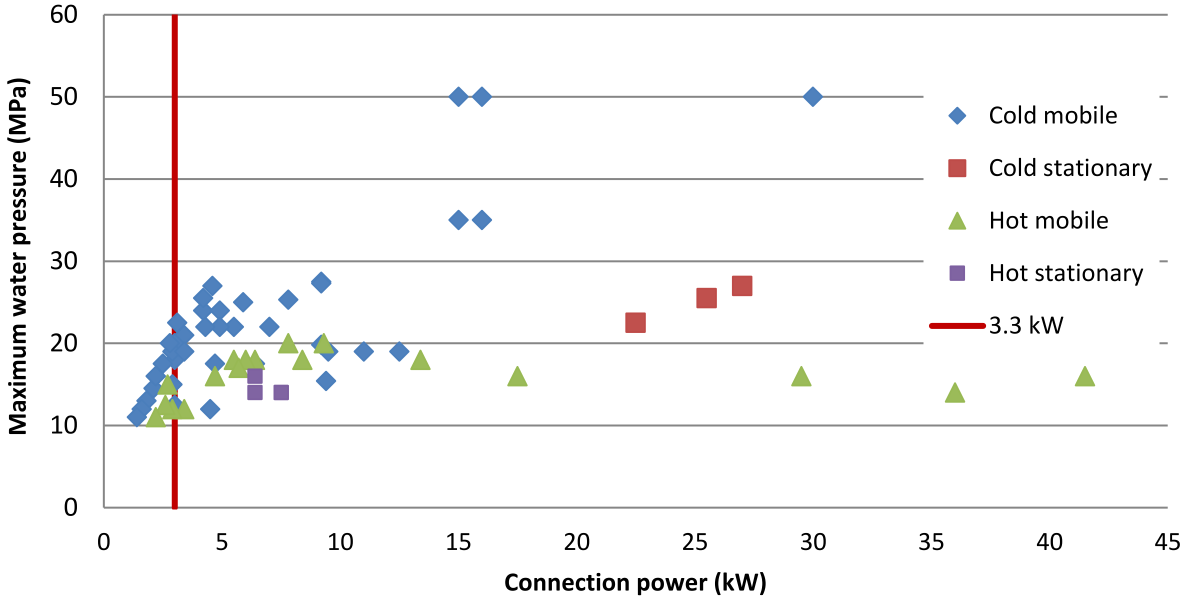


Figure 3. Maximum water pressure vs connection power of various HPC models

1.2 Test standards (EU, Member State and third country level)

The following tables collect and give details of the existing standards which are fully or partly relevant for Ecodesign or Energy labelling.

1.2.1 EN or ISO/IEC test standards

Table 3 presents the relevant test standards. They are divided into EN standard series on safety, EN standard series on electromagnetic compatibility and EN ISO standard series on acoustics. The table specifies the directive or regulation the standards relate to and a brief description of the content and scope.

Table 3. Overview of relevant EN and ISO standards

Standard	Title	Directive /Regulation	Content and scope
EN STANDARD ON PERFORMANCE			
EN IEC 62885-5	Surface cleaning appliances - Part 5: High pressure cleaners and steam cleaners for household and commercial use - Methods for measuring performance		EN IEC 62885-5:2018 lists the characteristic performance parameters for high pressure cleaners and steam cleaners in accordance with IEC 60335-2-79.
EN STANDARD SERIES ON SAFETY			
EN 60335-1:2012+A13:2017	Household and similar appliances – Safety: Part 1: General requirements	Harmonised under: Low Voltage Directive (2014/35/EU) Machinery Directive (2006/42/EC)	This European Standard deals with the safety of electrical appliances for household environment and commercial purposes, their rated voltage being no more than 250 V for single-phase and 480 V for others. This standard covers the reasonably foreseeable hazards presented by appliances and machines that are encountered by all persons. (The EN version is similar to the IEC version with Group Differences but excludes A1+A2 and adds amendment A13). Parameters and attributes covered: general, classification, marking and instructions, protection against access to live parts, power, heating, leakage current and electric strength, overvoltage, moisture resistance, endurance, abnormal operation, stability and mechanical hazards, mechanical strength, construction, external supply cords, earthing, insulation, resistance to heat and fire, resistance to rusting, radiation, toxicity and similar hazards.
EN 60335-2-79:2012	Household and similar appliances – Safety: Part 2-79: Particular requirements for high pressure cleaners and steam	Harmonised under: Machinery Directive (2006/42/EC) *Note 1	Part 2 standards supplement or modify the corresponding clauses in EN 60335-1, so as to convert that publication into the European Standard: Safety requirements for high pressure cleaners and steam cleaners. When a particular subclause of Part 1 is not mentioned in this Part 2, that subclause applies as far as is reasonable. When this standard states “addition”, “modification” or “replacement”, the relevant text in Part 1 is to be adapted accordingly. The scope covers the safety of high pressure cleaners without traction drive, intended for household and commercial indoor or outdoor

Standard	Title	Directive /Regulation	Content and scope
			use, having a rated pressure no less than 2.5 MPa and not exceeding 35 MPa. Parameters and attributes covered: • Rated pressure (MPa) • Flow rate (l/m) • Maximum flow rate (l/m) • Rated temperature • Sound pressure level (dBA) • Protection class (electric shock) • IP rating • Maximum power (water heater/if fitted) – (kW) • Cleaning agent, volume • Commercial use • Operator The standards also include: • Acoustic emissions • Vibration The standard IEC/EN 60335-2-79 requires that the product's vibration characteristic is documented and verified using the method defined in Annex DD of the standard.
EN 1829-1:2010	High pressure water jet machines — Safety requirements – Part 1: Machines	Harmonised under: Machinery Directive (2006/42/EC)	This standard is complimentary to EN 60335-2-79 and addresses HPCs above 35 MPa. It contains safety-related requirements for high pressure water jet machines with drives of all kinds (e.g. electric motor, internal combustion engine, air and hydraulic) in which pumps are used to generate pressure. The standard deals with all significant hazards.
EN 1829-2:2008	High pressure water jet machines — Safety requirements — Part 2: Hoses, hose lines and connectors	Harmonised under: Machinery Directive (2006/42/EC)	As above but relates to significant hazards associated with the hoses and lines of machines covered by EN 1829-1.
EN STANDARD SERIES ON ELECTROMAGNETIC COMPATIBILITY			
EN 55014-1:2017	Electromagnetic compatibility. Requirements for	Harmonised under:	This is a product-family-specific standard that covers all aspects of EM emission from products such as HPCs.

Standard	Title	Directive /Regulation	Content and scope
	household appliances, electric tools and similar apparatus. Emission	EMC Directive: (2014/30/EU)	
EN 55014-2:2015	Electromagnetic compatibility. Requirements for household appliances, electric tools and similar apparatus. Immunity	Harmonised under: EMC Directive: (2014/30/EU)	This is a product-family-specific standard that covers all aspects of EM immunity of products such as HPCs.
EN 61000-3-2:2014	Electromagnetic compatibility (EMC). Limits. Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)	Harmonised under: EMC Directive: (2014/30/EU)	This standard is listed separately in the Official Journal of the European Union (OJEU) and is mandatory for any product that is connected to the Public Low Voltage Supply.
EN 61000-3-3:2013	Electromagnetic compatibility (EMC). Limits. Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection	Harmonised under: EMC Directive: (2014/30/EU)	This standard is listed separately in the Official Journal of the European Union (OJEU) and is mandatory for any product that is connected to the Public Low Voltage Supply.
EN 61000-3-11:2000	Electromagnetic compatibility (EMC) - Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for Equipment with rated current <= 75 A and subject to conditional connection	Harmonised under: EMC Directive: (2014/30/EU)	This standard is listed separately in the Official Journal of the European Union (OJEU) and is mandatory for any product that is connected to the Public Low Voltage Supply.
EN 55012:2007	Electromagnetic Compatibility (EMC). Vehicles,	Harmonised under:	This standard applies to the emission of electromagnetic energy which may cause interference to radio reception emitted, among

Standard	Title	Directive /Regulation	Content and scope
	boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of off-board receivers	EMC Directive: (2014/30/EU)	others, from devices equipped with internal combustion engines.
EN ISO STANDARD SERIES ON ACOUSTICS			
EN ISO 4871:2009	Acoustics – Declaration and verification of noise emission values of machinery and equipment	-	This standard is referenced by EN 60335-2-79:2012 2017 as the means of declaring the noise emission Sound Pressure Level (SPL). Gives information on the declaration of noise emission values, describes acoustical information to be presented in technical documents and specifies a method for verifying the noise emission declaration.
EN ISO 11203:2009	Acoustics. Noise emitted by machinery and equipment. Determination of emission sound pressure levels at a workstation and at other specified positions from the sound power level	-	This standard is referenced by EN 60335-2-79:2012 as the method for determining airborne noise.
EN ISO 3744:2010	Acoustics. Determination of sound power levels and sound energy levels of noise sources using sound pressure. Engineering methods for an essentially free field over a reflecting plane	Annex III to Outdoor Noise Directive	This standard is referenced by EN 60335-2-79:2012 as one of two methods for determining the Sound Pressure Level (SPL). ISO 3744:2010 specifies methods for determining the sound power level or sound energy level of a noise source from sound pressure levels measured on a surface enveloping the noise source (machinery or equipment) in an environment that approximates to an acoustic free field near one or more reflecting planes. The sound power level (or, in the case of noise bursts or transient noise emission, the sound energy level) produced by the noise source, in frequency bands or with frequency A-weighting applied, is calculated using those measurements. The methods specified in ISO 3744:2010 are suitable for all types of noise (steady, non-steady, fluctuating, isolated bursts of sound energy, etc.) defined in ISO 12001.

Standard	Title	Directive /Regulation	Content and scope
			ISO 3744:2010 is applicable to all types and sizes of noise source (e.g. stationary or slowly moving plant, installation, machine, component or subassembly), provided the conditions for the measurements can be met. The test environments that are applicable for measurements taken in accordance with ISO 3744:2010 can be located indoors or outdoors, with one or more sound-reflecting planes present on or near where the noise source being tested is mounted. ISO 3743-1:2010 may be used as an alternative to this standard.
ISO 3746:2010	Acoustics - Determination of sound power levels of noise sources using sound pressure -- Survey method using an enveloping measurement surface over a reflecting plane	Annex III to Outdoor Noise Directive (refers to standard version from 1995)	ISO 3746:2010 specifies methods for determining the sound power level or sound energy level of a noise source from sound pressure levels measured on a surface enveloping a noise source (machinery or equipment) in a test environment for which requirements are given. The sound power level (or, in the case of noise bursts or transient noise emission, the sound energy level) produced by the noise source with frequency A-weighting applied is calculated using those measurements. The methods specified in ISO 3746:2010 are suitable for all types of noise (steady, non-steady, fluctuating, isolated bursts of sound energy, etc.) defined in ISO 12001. ISO 3746:2010 is applicable to all types and sizes of noise source (e.g. stationary or slowly moving plant, installation, machine, component or subassembly), provided the conditions for the measurements can be met. The test environments that are applicable for measurements taken in accordance with ISO 3746:2010 can be located indoors or outdoors, with one or more sound-reflecting planes present on or near where the noise source being tested is mounted. Information is given on the uncertainty of the sound power levels and sound energy levels determined in accordance with ISO 3746:2010, for measurements made with frequency A-weighting applied. The uncertainty conforms to that of ISO 12001:1996, accuracy grade 3 (survey grade).
EN ISO 3743-1:2010	Acoustics - Determination of sound power levels and sound energy	-	ISO 3743-1:2010 specifies methods for determining the sound power level or sound energy level of a noise source by comparing measured sound pressure levels emitted by this

Standard	Title	Directive /Regulation	Content and scope
	levels of noise sources using sound pressure -- Engineering methods for small movable sources in reverberant fields -- Part 1: Comparison method for a hard-walled test room		source (machinery or equipment) mounted in a hard-walled test room, the characteristics of which are specified, with those from a calibrated reference sound source. The sound power level (or, in the case of noise bursts or transient noise emission, the sound energy level) produced by the noise source, in frequency bands of width one octave, is calculated using those measurements. The sound power level or sound energy level with frequency A-weighting applied is calculated using the octave-band levels. The method specified in ISO 3743-1:2010 is suitable for all types of noise (steady, non-steady, fluctuating, isolated bursts of sound energy, etc.) defined in ISO 12001. The noise source being tested may be a device, machine, component or subassembly. The maximum size of the source depends upon the size of the room used for the acoustical measurements.

It should be noted that while the safety of HPCs is primarily addressed by the Household Appliance (and similar equipment) series of standards, an HPC is considered a tool or machine and therefore this standard is harmonised under the EU Machinery Directive.

The EN standards referenced in this subsection are also available as IEC variants and are therefore recognised under the International Electrotechnical Commission Electrical Engineering Certification Body (IECEE CB) scheme. This is an international system for mutual acceptance of test reports and certificates dealing with the safety of electrical and electronic components, equipment and products based on IEC standards. IEC standards form the basis for testing and evaluation under the IECEE CB Certification scheme. An IECEE CB Test Certificate and Report may be used as a 'passport' for gaining the certification marks of National Certification bodies and may aid market entry in certain countries. Retail and other sales channels may also accept an IEC Test Report (up to 3 years old) as evidence of compliance. The IEC variants are collected and explained in Table 4.

Table 4. Overview of relevant IEC standards

Standard	Title	Content and scope
IEC 62885-5:2018	Surface cleaning appliances - Part 5: High pressure cleaners and steam cleaners for household and commercial use - Methods for measuring performance	Same as EN IEC 62885-5.
IEC 60335-1:2010+A1:2013+A2:2016 (Ed. 5.2)	Household and similar appliances – Safety: Part 1: General requirements	The International IEC variant of the EN standard. It should be noted that there are some detailed differences between the IEC and EN variants (the EN version has not adopted A1+A2 but has amendment A14). The standard deals with the safety of electrical appliances for household environment and commercial purposes, their rated voltage being no more than 250 V for single-phase and 480 V for others. This standard covers the reasonably foreseeable hazards presented by

Standard	Title	Content and scope
		appliances and machines that are encountered by all persons. The following countries list National Differences against this standard: Austria, Canada, New Zealand, Denmark, Sweden, UAE.
IEC 60335-2-79 Ed. 4.0:2016	Household and similar electrical appliances – Safety – Part 2-79: Particular requirements for high pressure cleaners and steam cleaners *Note 2.	The International IEC variant of the EN standard.
IEC 61000-3-2:2014	Electromagnetic compatibility (EMC). Limits. Limits for harmonic current emissions (equipment input current ≤ 16 A per phase)	The International IEC variant of the EN standard.
IEC 61000-3-3:2013	Electromagnetic compatibility (EMC). Limits. Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤ 16 A per phase and not subject to conditional connection	The International IEC variant of the EN standard.
IEC 61000-3-11:2000	Electromagnetic compatibility (EMC) - Limits - Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems - Equipment with rated current <= 75 A and subject to conditional connection	The International IEC variant of the EN standard.
CISPR 14-1:2016	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 1: Emission	The international IEC variant of EN 55014-1.
CISPR 14-2:2015	Electromagnetic compatibility - Requirements for household appliances, electric tools and similar apparatus - Part 2: Immunity - Product family standard	The international IEC variant of EN 55014-2.
CISPR 12:2007	Vehicles, boats and internal combustion engines - Radio disturbance characteristics - Limits and methods of measurement for the protection of off-board receivers	The international IEC variant of EN 55012:2007.

1.2.1.1 Mandates issued by the European Commission to the European Standardisation Organisations (ESOs)

There are no specific standardisation mandates issued by the EC for this product category.

General mandates that apply include the Commission's standardisation requests:

- M/556 COMMISSION IMPLEMENTING DECISION C(2017) 7926 of 1.12.2017 on a standardisation request to the European Committee for Standardisation and to the European Committee for Electrotechnical Standardisation as regards compliance with maximum content criteria of Polycyclic Aromatic Hydrocarbons in rubber and plastic components of articles placed on the market for supply to the general public in support of Regulation (EC) No. 1907/2006 of the European Parliament and of the Council (REACH).

- M/552 COMMISSION IMPLEMENTING DECISION C(2016) 7641 final of 30.11.2016 on a standardisation request to the European Committee for Standardisation, to the European Committee for Electrotechnical Standardisation and to the European Telecommunications Standards Institute as regards harmonised standards in support of Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility.
- M/543 COMMISSION IMPLEMENTING DECISION C(2015)9096 of 17.12.2015 on a standardisation request to the European standardisation organisations as regards ecodesign requirements on material efficiency aspects for energy-related products in support of the implementation of Directive 2009/125/EC of the European Parliament and of the Council. Work carried out at the Joint Research Centre, Seville[8], provides input to the standardisation under this mandate.

The following regulation covers all standardisation requests. The latest Union work programme for standardisation was published in 2019.

- Regulation (EU) No 1025/2012 of the European Parliament and of the Council of 25 October 2012 on European standardisation, amending Council Directives 89/686/EEC and 93/15/EEC and Directives 94/9/EC, 94/25/EC, 95/16/EC, 97/23/EC, 98/34/EC, 2004/22/EC, 2007/23/EC, 2009/23/EC and 2009/105/EC of the European Parliament and of the Council and repealing Council Decision 87/95/EEC and Decision No 1673/2006/EC of the European Parliament and of the Council Text with EEA relevance.
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions The annual Union work programme for European standardisation for 2018 (COM/2017/0453 final) http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=COM:2017:453:FIN.
- Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions The annual Union work programme for European standardisation for 2019 (COM/2018/686 final) https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A52018DC068)

1.2.1.2 Member States

The Safety and Electromagnetic Compatibility (EMC) standards listed above are harmonised and are utilised as the basis for a Presumption of Conformity with the applicable directives by all Member States.

Annex ZB to EN 60335-1:2012+A13:2017 lists 'National Deviations'. Both the UK and Ireland list deviations related to statutory requirements for plugs fitted to this type of appliance.

1.2.1.3 Third country test standards

Table 5 presents third country test standards. Relevant standards have been found in the USA, Canada, Australia and New Zealand.

It should be noted that there are differences between IEC/EN standards and the North American standards. IEC and EN standards consider all reasonably foreseeable hazards but leave the means of achieving the essential requirements open to the creativity of the designer. IEC and EN standards define requirements and stimuli that must be applied to verify compliance. ANSI/UL (US) and CAN/CSA (Canada) standards, on the other hand, tend to be prescriptive in construction, methods and choice of wiring, components etc. The standards focus on construction and the performance sections cover how testing must be carried out to verify the construction. In this context 'performance' does not relate to the user experience of product performance or resources usage.

Table 5. Overview of relevant third country test standards

Standard	**Title**	**Content and scope**
US STANDARDS		
ANSI/UL 60335-1 (2016)	Household and similar appliances – Safety: Part 1: General requirements	This national standard is based on publication IEC 60335–1,

[8] http://susproc.jrc.ec.europa.eu/E4C/index.html

		Edition 5.1 (Edition 5:2010 including corrigendum 1:2010, corrigendum 2:2011, and amendment 1:2013) issued in April 2014. •
ANSI/UL 60335-2-79 (2016)	Household and similar appliances – Safety: Part 2-79: Particular requirements for high pressure cleaners and steam	This national standard is based on publication IEC 60335–2-79.
ANSI/UL 1776 (2013)	Standard for Safety High pressure Cleaning Machines	This standard covers electrically operated, high pressure cleaning machines in which the discharge line is hand-supported and manipulated, and that use water as the cleaning agent for household and commercial use. The products may use either hot or cold water, and they may be portable, stationary or fixed. A product listed by a Nationally Recognised Test Laboratory (NRTL) is deemed to meet the requirements for approval as defined in the National Electrical Code NFPA 70. Products which incorporate heating must be further evaluated to the UL 499 standard. Parameters and attributes covered: Construction (all products), Electrical Systems and Devices (including assembly, cord connections, access to live parts, insulation, etc.), Mechanical Systems and Devices (Fuel-Fired Products), Protection against injury, Performance – all products (includes normal operation tests, temperature, abnormal tests, materials, etc.), Performance – Fuel-fired (similar topics and tests to above), Manufacturing and production tests, Instructions and manuals. Use performance parameters are not covered.

ANSI/UL499	Standard for Electric Heating Appliances	These requirements cover heating appliances rated at 600 V or less for use in unclassified locations in accordance with the National Electrical Code (NEC), ANSI/NFPA 70.
FCC Part 15b (CFR 47)	Federal Communications Commission (FCC) requirements for 'unintentional' radiators	A household appliance using digital logic (an unintentional device or system that generates and uses timing signals or pulses at a rate in excess of 9 000 pulses or cycles per second, and uses digital techniques as defined in Section 15.3 (k)) is classified under Part 15b as a Class B digital device (as defined in Section 15 101) requiring an equipment authorisation under the Verification procedure (Section 2 902). The FCC rule part 15b focuses on "unintentional" radiation or noise generated by a digital device. This noise could potentially impact the operation of other devices in close proximity and therefore requires testing of the unintentional radiators.
CANADIAN STANDARDS		
CAN/CSA C22.2 NO. 60335-1:16	Safety of household and similar appliances - Part 1: General requirements (Tri-national standard, with NMX-J-521/1-ANCE and UL 60335-1)	Comments as per ANSI/UL 60335-1. There are national differences against the IEC version of the standard.
CAN/CSA E60335-2-79-09 (R2013) (Adopted IEC 60335-2-79:2002+A1:2004+A2:2007, edition 2.2, 2007-09)	Household and similar electrical appliances - Safety - Part 2-79: Particular requirements for high pressure cleaners and steam cleaners (Adopted IEC 60335-2-79:2002+A1:2004+A2:2007, edition 2.2, 2007-09)	Aligned with IEC standard.
CAN/CSA B140.11-M89 (R2014)	Oil/Gas-Fired Commercial/Industrial Pressure Washers and Steam Cleaners	Covers the performance, construction, testing, marking, installation, operation, and servicing of complete commercial and industrial pressure washers and steam cleaners that are either gas-fired or oil-fired. Hot water up to 100 °C.
AUSTRALIAN and NEW ZEALAND STANDARDS		

AS/NZS 60335.1:2011	Household and similar electrical appliances - Safety General requirements (IEC 60335-1 Ed 5, MOD)	Australian/New Zealand version based on IEC Edition 5 but with modifications. National differences apply for New Zealand.
AS/NZS 60335.2.79:2017	Household and similar electrical appliances - Safety Particular requirements for high pressure cleaners and steam cleaners	An adoption with national modifications of the fourth edition of IEC 60335-2-79, Household and similar electrical appliances – Safety – Part 2-79: Particular requirements for high pressure cleaners and steam cleaners. Takes into account Australian and New Zealand conditions.

Furthermore, two American voluntary industry standards are identified:

Test standard CETA Performance Certified Standard

The Cleaning Equipment Trade Association (CETA) in the USA has developed a test standard, CPC 100 (CPC: Cleaning Performance Program), in collaboration with Intertek US to provide a uniform method for testing and rating pressure washers. The tests calculate a maximum working pressure (MWP); the pressure at the pump cylinder head, and maximum working flow (MWF); the flow of water expressed as gallons per minute.

The definitions and scope are taken from American UL standard UL 1776 and the programme allows for third party verification and certification of the products' performance. Products must be listed to UL 1776 to be eligible.

The CETA CPC -100 does not prohibit manufacturers, retailers or users from advertising, marketing or using products if they have not conformed to the uniform testing method (it is not mandatory). The goal is to have a standard to evaluate pressure washer specifications used in advertising.

CETA Performance Certification is issued and controlled by a third party testing programme. The certification is issued by CETA based on test data provided by the third party laboratory. The authorisation to use 'CETA Performance Certified' is granted by CETA.

The programme and certification cover maximum pressure and maximum flow as the primary performance parameters but also verify additional specifications submitted by the manufacturer (e.g. horsepower, kW rating, rounds per minute or rpm etc.)

PW101 Standard for testing and rating performance of pressure washers

The Pressure Washers Association (PWMA) in the USA has published a performance standard PW101-2010: Standard for Testing and Rating Performance of Pressure Washers: Determination of Pressure and Water Flow. This standard is intended to provide a uniform method for testing and rating the performance of pressure washers with respect to maximum pressure and water flow rate, but not the in-use performance and efficiency of the cleaner. The PWMA also offers a voluntary certification programme which is managed by a third party (Intertek).

The standard applies to pressure washers intended for household, farm, consumer or commercial/industrial markets. Products are portable and may be powered by an engine or an electric motor.

The standard defines:

- test preparation requirements including initial running in of the machine for a set period (minimum 2h and maximum 5h);
- instrumentation and calibration requirements for pressure, flow, rpm (for engine driven) and voltage/current (for electric motors);
- conditions for the tests (e.g. operation at factory settings, or for user to set, at maximum settings);
- the positional requirements for pressure and flow instruments and measurement points;

- stability of supply voltage over measurement period;
- inlet water pressure range, water source temperature, ambient temperature range permitted;
- information required to be provided by the manufacturer;
- test reporting format;
- rounding methods for test data;
- rating and labelling requirements (based on average of at least three samples tested in accordance with the test method).

The test method includes:

- a test duration of 30 minutes of continuous operation;
- readings recorded at 5-minute intervals and average values calculated;
- average values used to assess performance and compliance with ratings;
- pressure and flow ratings no greater than the average of three samples divided by 0.9 (allows 10% tolerance)

1.2.2 Comparative analysis for overlapping test standards on performance, resources use and emissions

The standards described in Section 1.2 do not overlap on performance, resources use and/or emissions. All the standards listed in Section 1.2 are referenced in Annex CC of EN 60335-2-79. The two standards on acoustical methods (ISO 3743-1:2010 and ISO 3744-1:2010) are specified to allow manufacturers to choose a hard-walled room or free field environment to perform the tests. ISO 4871 describes how the Sound Pressure Level (SPL) should be declared.

1.2.3 Analysis of test standards on performance and resources use

As stated in Section 1.2.1, regarding test standard EN IEC 62885-5:2018 Surface cleaning appliances - Part 5: High pressure cleaners and steam cleaners - Methods of measuring the performance (IEC 62885-5:2018) was approved in 2018. Its intention is to serve the manufacturers in describing parameters that fit in their manuals. This includes the parameters listed in the standards definition document. When any of the parameters listed in the document are used, they shall be noted as being measurements taken in accordance with the document. The standard focuses on efficiency tests of oil-heated HPCs, based on the EUnited Voluntary burner efficiency label (see Section 1.3). The Technical Committee did not reach an agreement on test methods for cleaning efficiency, therefore this parameter will be 'under consideration' for future revisions of the standard. This means that for the time being, no existing standard covers the cleaning efficiency of HPCs.

Some manufacturers include specifications on performance in their technical data sheets, e.g. area performance (m^2/h) indicating in-house test protocols at their disposal. Various test laboratories have also carried out tests on behalf of consumer organisations. Measurement of energy and water consumption is essential, but, in order to generate comparative testing data, and enable the relative performance of HPCs to be compared, it is crucial to measure the speed and quality of removal of different kinds of soiling from different kinds of surfaces. There are two approaches that can be used, one on pre-soiled and aged surfaces and one on artificial test surfaces.

Pre-soiled and aged surfaces

Measurement of performance of HPCs can be performed using pre-soiled and aged surfaces, such as concrete walkways, car parks and block paving around a building. As these surfaces by nature tend to be rather variable, techniques such as randomisation of the test areas, using multiple test assessors and statistical analysis of the results need to be used to counter the effects of this variability. This may lead to the need for a large number of test samples and time- and labour-intensive test work.

Artificial test surfaces

Manufacturers and product testing industry occasionally devise artificial methods to test products that reproduce the practical usage as much as possible but permit more consistent homogeneous substrates to be used. This enables a far more empirical measurement of performance. In the case of HPCs, it is known that one leading manufacturer in particular has used this approach, and independently a similar method was established in order to test large numbers of products for European consumer magazines. The method involves moving the gun across the surface of pre-painted building insulation tiles. The removal of the paint approximates to the removal of the soiling on outdoor surfaces relatively well, but has the obvious advantage that these substrates can be controlled, largely eliminating any variability in the substrate.

Measurements

Defining a test protocol for assessment of HPCs requires a comparative performance element to be considered, which can be technical performance criteria such as power of the motor, maximum flow rate; and/or cleaning performance criteria.

Environmental performance indicators may include resource consumption per cleaned surface area for predefined soiled surfaces. This can then also be translated to environmental impact/m^2 (LCA, when including life cycle impact) and EUR/m^2 (LCC, when including life cycle costs).

Measured parameters for predefined surfaces may include:

- cleaning time;
- cleaning quality;
- water consumption;
- electricity consumption (for electric engines, and for electric hot water heating);
- fuel consumption for hot water and/or combustion engines;
- compressed gas/water consumption (for pneumatic/hydraulic motors respectively);
- detergent consumption.

Development of a test standard

Experience from developing test protocols and standards for other washing appliances including washing machines and dishwashers has been reviewed as part of this process. It is acknowledged that these are automated, pre-programmed washing cycles and that standards, loads, material types/deposits and reference machines and detergents are well established. In contrast, a major consideration is that HPC performance will in part include a 'user' element: how the HPC is used and the cleaning application (e.g. car washing, patio cleaning). Test protocols will need to consider standardised methods with performance related to a given reference or base machine. When evaluating the HPC performance, the 'user' variables such as the distance the lance is held from the target cleaning area and the speed at which the lance is moved across the surface has to be controlled, e.g. by fixing the position of the lance and head and moving the sample at a set rate.

Performance criteria will need to consider cleaning performance levels similar to 'wash performance' with cleaning performance assessed to a defined soiling level. Some examples of cleaning performance tests (not standards) are described in Task 3.

The Technical Committee responsible for the development of performance testing standards is IEC TC 59 'Performance of Household and Similar Appliances'. This TC handles all non-safety standard development. Details of current TC59 projects may be found on the IEC website[9].

1.2.4 Tolerances, reproducibility and real-life simulation

Many of the standards listed (including EN 60335-1 and EN 60335-2-79) reference ISO standards for tolerances which may include dimensional or other product characteristics. These standards also define the tolerance (or range) of operating conditions.

All measurements have a degree of uncertainty regardless of precision and accuracy. This is caused by three factors: the limitation of the measurement instrument (systematic error), the skill of the operator making the measurements and the environmental conditions in which the measurement is taken (random error).

The standard EN60335-2-79 includes an annex for noise emission measurements and this describes the requirements for taking measurement uncertainty into account for this particular parameter.

The measurement uncertainty is developed using statistical techniques and many methods adopt a Root Sum of Squares (RSS) approach to distribution. Laboratories have developed Measurement Uncertainty models as a requirement of accreditation by Accreditation Bodies such as UKAS. This knowledge will be applied during the development of any test protocols.

[9] http://www.iec.ch/dyn/www/f?p=103:23:31863158667620::::FSP_ORG_ID,FSP_LANG_ID:1275,25

A third element for consideration is sensitivity. The analysis of the repeatability or robustness of a given test protocol will be necessary in the case of tests for HPC performance due to the likely potential for variation. Statistical techniques will be employed to assess the validity and repeatability of results.

1.3 Legislation (EU, Member State and third country level)

1.3.1 European Union

EU Machinery Directive

The EU Machinery Directive[10] mainly sets safety requirements for machinery put on the market or put into service in all Member States and aims to ensure their freedom of movement within the European Union. The Directive embraces the Low Voltage Directive[11] requirements and its requirements must be met. However, any Declaration of Conformity for CE Marking purposes would be made in relation to the Machinery Directive only.

EU WEEE Directive

The WEEE Directive[12] sets selective treatment requirements for the Waste Electrical and Electronic Equipment and its components, and as such applies to all types of electrical HPCs. The Directive inter alia obligates Member States to establish and maintain a registry of producers of electronic and electrical products, and the producers to register in each individual EU country. Each year, producers are required to report the amount of EEE they put on the market, as well as pay an annual registration fee, which is intended to finance the handling of WEEE.

EU RoHS Directive

The RoHS Directive[13] restricts (with exceptions) the use of six hazardous materials in the manufacture of various types of electronic and electrical equipment. It is a sector-specific Directive that applies to Electrical and Electronic Equipment (EEE). The Directive covers electric HPCs.

EU Battery Directive

The Battery Directive[14] applies to all types of batteries and sets rules regarding the placing on the market of batteries, specifically prohibiting batteries containing hazardous substances such as lead, mercury and cadmium. This means that from 1 January 2017 it is no longer possible to place on the market battery-operated HPCs with nickel-cadmium batteries. Furthermore, it sets rules for collection, treatment, recycling and disposal of waste batteries.

EU Energy Labelling Regulation

The Energy Labelling Regulation[15] requires producers of energy-related products to label their products in terms of energy consumption on a scale of A to G, as well as informing consumers of a number of other parameters, so that consumers could compare the energy efficiency of one product with another.

HPCs fall within the scope of the Energy Labelling Regulation but are not currently covered by any measures.

EU Ecodesign Directive

The Ecodesign Directive[16] provides consistent EU-wide rules for improving the environmental performance of products placed on the EU market. This EU-wide approach ensures that Member States' national regulations are aligned so that potential barriers to internal EU trade are removed.

The Directive's main aim is to provide a framework for reducing the environmental impacts of products throughout their entire life cycle. As many of the environmental impacts associated with products are determined during the design phase, the Ecodesign Directive aims to bring about improvements in environmental performance through mandating changes at the product design stage.

[10] Directive 2006/42/EC on machinery, and amending Directive 95/16/EC (recast).
[11] Directive 2014/35/EC on the harmonisation of the laws of the Member States relating to the making available on the market of electrical equipment designed for use within certain voltage limits.
[12] Directive 2012/19/EU on waste electrical and electronic equipment (WEEE).
[13] Directive 2011/65/EU on the restriction of the use of certain hazardous substances in electrical and electronic equipment (recast).
[14] Directive 2006/66/EC on batteries and accumulators and waste batteries and accumulators.
[15] Regulation 2017/1369/EU on setting a framework for energy labelling and repealing Directive 2010/30/EU
[16] Directive 2009/125/EC on establishing a framework for the setting of ecodesign requirements for energy-related products.

The Ecodesign Directive is a framework directive, meaning that it does not directly set minimum requirements. Instead, the aims of the Directive are implemented through product-specific regulations, which are directly applicable in all EU Member States.

HPCs fall within the scope of the Ecodesign Directive but are not currently covered by any implementing measures.

Electric motors that may be used within HPCs are covered by the following implementing measure:

Regulation (EC) No 640/2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for electric motors with amendment (Commission Regulation (EU) No 4/2014 of 6 January 2014).

Commission Regulation on Ecodesign requirements for electric motors

Electric motors are subject to EU Ecodesign requirements[17] that establish minimum requirements for the products within its scope. The Regulation covers electric single speed, three-phase 50 Hz or 50/60 Hz, squirrel cage induction motors that:

- have 2 to 6 poles;
- have a rated voltage up to 1 000 V;
- have a rated power output between 0.75 kW and 375 kW;
- are rated on the basis of continuous duty operation.
- smaller motors between 120W and 750W
- larger motors between 375kW and 1000kW
- 60Hz motors, 8 poles motors and single phase motors (the latter only as of July 2023)

The Regulation does not cover motors completely integrated into a product (for example into a gear, pump, fan or compressor) and whose energy performance cannot be tested independently from the product. Therefore, HPC are not included in the scope of this regulation.

Outdoor Noise Directive

The Outdoor Noise Directive[18] regulates the noise emissions into the environment by outdoor equipment. 57 types of equipment are named in the Directive, one of which is high pressure water jet machines. It refers mainly to outdoor machinery, such as that used on construction sites or in parks and gardens.

This Directive is currently under review. An evaluation and impact assessment study for the Directive has been ongoing since May 2017. The results from this study (to be delivered by the first semester of 2018), as well as previously completed studies, will be used as the basis for the upcoming revision process. An online public consultation was launched on 23 January 2018 and ran until 18 April 2018. The study and document on the public consultation can be found on DG Growth's website[19].

Non-Road Mobile Machinery Regulation

The Non-Road Mobile Machinery Regulation (NRMM Regulation)[20] defines emission limits for non-road mobile machinery engines for different power ranges and applications. It also lays down the procedures engine manufacturers have to follow in order to obtain type-approval of their engines – which is a prerequisite for placing their engines on the EU market.

NRMM covers a very wide variety of machinery typically used off the road in many ways. It comprises, for example:

- small gardening and handheld equipment (lawn mowers, chainsaws, etc.);
- construction machinery (excavators, loaders, bulldozers, etc.);
- agricultural and farming machinery (harvesters, cultivators, etc.);

[17] Commission Regulation (EU) 2019/1781 of 1 October 2019 laying down ecodesign requirements for electric motors and variable speed drives pursuant to Directive 2009/125/EC.

[18] DIRECTIVE 2000/14/EC on the approximation of the laws of the Member States relating to the noise emission in the environment by equipment for use outdoors.

[19] http://ec.europa.eu/growth/sectors/mechanical-engineering/noise-emissions_en

[20] REGULATION (EU) 2016/1628 on requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery, amending Regulations (EU) No 1024/2012 and (EU) No 167/2013, and amending and repealing Directive 97/68/EC.

- railcars, locomotives and inland waterway vessels.
- cleaning equipment, including HPC driven by a combustion engine.

Stationary machinery is excluded from the scope.

Electromagnetic Compatibility (EMC) Directive

The Electromagnetic Compatibility (EMC) Directive[21] ensures that electrical and electronic equipment does not generate, or is not affected by, electromagnetic disturbance. It applies to electrical HPCs.

The EMC Directive limits electromagnetic emissions from equipment in order to ensure that, when used as intended, such equipment does not disturb radio and telecommunication, as well as other equipment. The Directive also governs the immunity of such equipment to interference and seeks to ensure that this equipment is not disturbed by radio emissions, when used as intended.

The main objectives of the Directive are to ensure:

- the compliance of equipment (apparatus and fixed installations) with EMC requirements when it is placed on the market and/or put into service;
- the application of good engineering practice for fixed installations, with the possibility that competent authorities of Member States may impose measures in instances of non-compliance.

Radio Equipment Directive

The Radio Equipment Directive[22] establishes a regulatory framework for placing radio equipment on the market. It sets essential requirements for safety and health, electromagnetic compatibility, and the efficient use of the radio spectrum. It also provides the basis for further regulation governing some additional aspects. These include technical features for the protection of privacy, personal data and against fraud. Furthermore, additional aspects cover interoperability, access to emergency services, and compliance regarding the combination of radio equipment and software. This Directive applies to remote controls and smart functions that some HPCs are equipped with.

Regulation on appliances burning gaseous fuels

The objective of the Regulation on appliances burning gaseous fuels[23] is to ensure that appliances burning gaseous fuels and their fittings on the Union market fulfil the requirements providing for a high level of protection of health and safety, while guaranteeing the functioning of the internal market. This regulation applies to hot water HPC, since they are equipped with a burner.

EU Packaging Directive

The Packaging Directive[24] provides a definition of the term 'packaging', sets targets for recovery and recycling of packaging waste and establishes essential requirements applicable to all packaging on the EU market. The Directive aims to provide a high level of environmental protection and ensure the functioning of the internal market by avoiding obstacles to trade and distortion and restriction of competition. It could apply to any packaging in which HPCs might be transported or sold (particularly domestic HPCs).

1.3.2 Third countries

1.3.2.1 USA

American appliances operating at 50 volts or more must be listed by an appropriate Nationally Recognised Test Laboratory (NRL), e.g. Intertek, UL (Underwriters Laboratories), Canadian Standards Association (CSA), in order to satisfy the requirements of the National Electrical Code NFPA-70 (2017).

[21] Directive 2014/30/EU of the European Parliament and of the Council of 26 February 2014 on the harmonisation of the laws of the Member States relating to electromagnetic compatibility (recast).
[22] Directive 2014/53/EU of the European Parliament and of the Council of 16 April 2014 on the harmonisation of the laws of the Member States relating to the making available on the market of radio equipment and repealing Directive 1999/5/EC.
[23] Regulation (EU) 2016/426 of the European Parliament and of the Council of 9 March 2016 on appliances burning gaseous fuels and repealing Directive 2009/142/EC.
[24] Directive 1994/62/EC on packaging and packaging waste.

The US Energy Star Program aims to promote the most energy-efficient products through verification and labelling of products that meet the Energy Star criteria. HPCs are currently not included in the Energy Star product categories[25].

1.3.2.2 Canada

Compliance in Canada is similar to the requirements for the USA. The Canadian Electrical Code is C22.1 (2015) and Rule 2-024 Use of approved equipment states: Rule 2-024 has two requirements: equipment must be "approved" and be "approved for the specific purpose".

Natural Resources Canada (NRCan) product categories align with the US Energy Star program.

1.3.2.3 Australia and New Zealand

On 1 October 2012, the Greenhouse and Energy Minimum Standards (GEMS) Act 2012 came into effect, creating a national framework for product energy efficiency in Australia.

Many categories of products are regulated under this Act and requirements include Minimum Energy Performance Standards (MEPS) and Mandatory Energy Performance Labelling (MEPL). Similar requirements apply for products sold in New Zealand.

At the present time HPCs are not covered by the scope of MEPS or MEPL.

1.4 Voluntary schemes

Voluntary burner efficiency label

EUnited Cleaning, the European Cleaning Machines Association, has set up a voluntary labelling scheme, 'EUnited Cleaning Burner Efficiency', which applies to oil-heated HPCs. The scheme sets requirements on thermal exhaust loss, burner efficiency, CO emission and dust emissions.

1.5 Other studies

High pressure cleaners were one of the five product types intensively analysed and to which improvements were sought in the now 20-year old Danish "EDIP" project (Environmental Design of Industrial Products)[26]. It was a 5-year collaboration between the Danish Industry association, several companies, the Danish EPA and DTU (Technical University of Denmark).

The method consists of six phases:

1. Goal definition - identifying the specific assessment task to be solved in product development and the potential environmental scenarios related to the decisions taken during that stage of product development.
2. Scope definition - identifying the methodological requirements for the assessment task in question and the scope of the systems to be studied.
3. Inventory analysis - compiling an inventory of the environmental exchanges from the systems studied.
4. Impact assessment - assessing the resource consumption and environmental impacts of the environmental exchanges identified in the inventory.
5. Sensitivity analysis - identifying which parameters are essential, their uncertainty and the significance of their variation.
6. Decision support - providing support for the different types of decisions to be taken during product development.

As a result of the project, a method was developed for Life Cycle Assessment of products - a tool for the environmental specialist and a PC tool. Furthermore, a database with environmental information on about 400

[25] https://www.energystar.gov/products
[26] http://orbit.dtu.dk/files/4646274/Wenzel.pdf

essential materials and processes covering the life cycle of electro-mechanical products as well as other product categories was established.

The Danish study on HPCs found that electricity consumption (of which 80% is in the use stage) and chemicals (being primarily the detergents in the use stage) stand for over 90% of the impact potential. The HPC manufacturer who participated in the study achieved a significant improvement by redesigning the nozzle, i.e. a combined hydraulic and mechanical shaping of the water jet, implying a large improvement of the pressure drop profile of the jet. As a result, and according to their own estimates, about 30% water and energy savings were achieved without a reduction in the cleaning effect.

2 Task 2: Markets

2.1 Generic economic data

This section presents an economic analysis based on official European statistics provided by Eurostat[27] concerning production and trade data, according to MEErP. There is not a specific category of 'high pressure cleaners' (HPCs) but HPCs are included in the PRODCOM category 28292230 - Steam or sand blasting machines and similar jet-projecting machines (excluding fire extinguishers, spray guns and similar appliances), corresponding to the HS code 842430.

Apart from being a category with a wide scope, the statistical data needs to be interpreted with care as there is data missing for some countries, particularly for production. However, it represents the official EU source and provides valuable qualitative information about the situation in each country in this sector. This is further detailed in the following sections.

2.1.1 EU-28 Production of steam or sand blasting machines and similar jet-projecting machines

2.1.1.1 Volume of EU production

Table 6 shows the estimated unit volume of steam or sand blasting machines and similar jet-projecting machines produced in EU Member States and EU-28 totals in the years 2009 to 2016 according to Eurostat.

The figures suggest that Italy and Denmark are the main producers of steam or sand blasting machines and similar jet-projecting machines. However, it is important to note that data is missing for some countries (NA), including Germany, where one of the main manufacturers is located. This leads to a data gap of around 2.6 million units in 2016 of the production listed in single Member States and the EU-28 totals production volume. This data gap corresponds to the production for which there is no data (NA).

[27] https://ec.europa.eu/eurostat/web/prodcom/data/database

Table 6. Volume (number of units) of steam or sand blasting machines and similar jet-projecting machines produced in the EU-28 between 2009 and 2016 (Eurostat)

Country	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Austria	0	0	0	0	0	0	0	0
Belgium	NA	NA	NA	NA	NA	NA	NA	NA
Bulgaria	NA	NA	0	0	NA	10	10	NA
Croatia	0	0	0	0	61	49	79	85
Cyprus	0	0	0	0	0	0	0	0
Czech Republic	NA	NA	302	1 062	978	NA	1 574	2 791
Denmark	83 651	90 363	185 263	154 093	92 693	75 053	32 857	12 531
Estonia	0	0	0	0	0	0	0	0
Finland	33	24	31	17	5	28	0	0
France	3 196	52 280	NA	NA	74 128	NA	NA	NA
Germany	NA	NA	NA	NA	NA	NA	NA	NA
Greece	0	0	0	0	NA	0	0	0
Hungary	NA	NA	NA	NA	294 300	314 951	310 129	29 347
Iceland	0	0	0	0	0	0	0	0
Ireland	NA	NA	NA	NA	NA	NA	NA	NA
Italy	686 533	784 608	906 212	87 237	112 034	145 562	201 161	146 620
Latvia	0	0	0	0	0	0	0	0
Lithuania	0	4 758	1 197	477	377	356	205	2 451
Luxemburg	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0
Netherlands	8 424	234	NA	1 641	809	NA	12 400	1 043
Norway	0	0	0	0	0	0	0	0
Poland	NA	438	518	769	800	2 200	2 056	1 948
Portugal	145	149	116	81	115	278	137	NA
Romania	0	0	0	0	0	0	NA	0
Slovakia	0	0	0	0	0	0	0	0
Slovenia	NA	NA	NA	NA	NA	85	107	99

Spain	4 805	4 224	4 179	1 619	1 745	2 176	2 488	2 474
Sweden	NA	NA	NA	NA	NA	NA	NA	NA
United Kingdom	3 597	4 713	7 345	9 395	8 397	5 356	6 831	6 794
EU-25 TOTALS	4 000 000	2 800 000	3 972 261	2 000 000	NA	NA	NA	NA
EU-27 TOTALS	4 000 000	2 800 000	3 972 261	2 000 000	NA	NA	NA	NA
EU-28 TOTALS	4 000 000	2 800 000	3 972 261	2 000 000	2 000 000	4 000 000	2 000 000	2 800 000

NB: "NA" means data is not available.
The sum of the individual Member States does not correspond to the EU-28 totals due to lack of data from some Member States.

2.1.1.2 Value of EU production

Table 7 provides an overview of the value corresponding to the number of units produced in Member States and EU-28 totals. The main producer seems to be Italy, however, data for Germany which is another main producer is not available.

The total value of produced household HPCs in the EU-28 increased from EUR 641 million in 2004 by 46% to EUR 938 million in 2012. This increment contradicts the production trend shown by the unit volumes, which is declining. It suggests that the unit price may be increasing at a pace that overcomes the effect of the lower production, or that the data may not be consistent.

Table 7. Value (in EUR) of steam or sand blasting machines and similar jet-projecting machines in the EU-28 between 2009 and 2016 (Eurostat)

Country	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Austria	0	0	0	0	0	0	0	0
Belgium	NA	NA	NA	NA	NA	NA	NA	NA
Bulgaria	NA	NA	0	0	NA	131 404	303 712	NA
Croatia	0	0	0	0	372 349	262 516	321 567	526 604
Cyprus	0	0	0	0	0	0	0	0
Czech Republic	1 250 047	NA	NA	NA	NA	NA	60 612 266	59 744 988
Denmark	36 212 431	21 992 400	20 840 872	23 387 160	24 538 543	20 238 236	19 449 502	19 859 775
Estonia	0	0	0	0	0	0	0	0
Finland	8 793 934	5 713 547	8 038 756	4 602 149	4 043 000	10 975 347	0	0
France	14 666 000	12 095 615	21 469 935	20 610 312	29 484 349	28 602 888	31 053 992	38 286 270
Germany	376 052 840	381 933 621	431 349 279	460 095 451	NA	459 810 988	NA	NA
Greece	0	0	0	0	NA	0	0	0

Hungary	NA	NA	NA	NA	34 400 717	37 172 411	33 943 600	33 331 855
Iceland	0	0	0	0	0	0	0	0
Ireland	NA	NA	NA	NA	NA	NA	NA	NA
Italy	255 759 000	226 631 000	328 266 000	247 685 000	203 889 000	355 345 000	493 636 000	285 327 000
Latvia	0	0	0	0	0	0	0	0
Lithuania	0	539 272	959 801	621 959	770 563	822 173	1 023 890	705 241
Luxemburg	0	0	0	0	0	0	0	0
Malta	0	0	0	0	0	0	0	0
Netherlands	NA	20 162 000	NA	23 096 000	18 090 000	18 707 000	19 647 000	21 021 000
Norway	0	0	0	0	0	0	0	0
Poland	5 937 795	10 258 017	14 721 545	19 350 611	26 316 617	22 374 328	30 089 195	28 288 481
Portugal	1 487 968	837 735	848 078	342 444	369 091	943 956	359 565	NA
Romania	0	0	0	0	0	0	NA	0
Slovakia	0	0	0	0	0	0	0	0
Slovenia	NA	NA	NA	NA	NA	11 269 338	15 663 075	12 665 575
Spain	4 231 291	3 659 575	4 196 896	3 337 620	2 928 365	4 669 424	6 173 934	6 076 468
Sweden	NA	NA	NA	NA	NA	NA	NA	NA
United Kingdom	28 831 347	25 796 186	33 248 836	35 755 423	31 128 276	37 250 037	46 143 778	28 654 757
EU-25 TOTALS	808 066 398	752 115 214	976 987 612	937 882 093	NA	NA	NA	NA
EU-27 TOTALS	808 276 398	752 515 214	976 987 612	937 882 093	NA	NA	NA	NA
EU-28 TOTALS	808 276 398	752 515 214	976 987 612	937 882 093	1 000 000 000	1 060 464 231	1 000 000 000	1 200 000 000

NB: "NA" means data is not available.

The sum of the individual Member States does not correspond to the EU-28 totals due to lack of data from some Member States.

As can be observed, there are many data gaps (shown by "NA") and also some remarkable figures: Finland shows meagre unit productions that yield values of millions, which may be due to the production of industrial and specialised equipment, or due to an inconsistency. There are some countries such as the Netherlands and Lithuania with high fluctuations in production, which suggests that data may not be fully reliable. The conclusion is that data production must be considered cautiously, and quantitative analysis discarded.

2.1.2 EU exports and imports of steam or sand blasting machines and similar jet-projecting machines

Table 8 provides an overview of exports and imports of steam or sand blasting machines and similar jet-projecting machines by Member State for the year 2016. The time series are presented in Annexes 2 and 3. While import values are consistent, export values show noteworthy figures for Cyprus, Malta and Luxembourg. Time series are omitted in this section to avoid data overloading, since no quantitative analysis is derived from them.

Germany and Italy are by far the largest exporters, followed by Denmark. Meanwhile, France, Germany and the UK are the main importers.

Table 8. Value (in EUR) of exports and imports of steam or sand blasting machines and similar jet-projecting machines in 2016 (Eurostat)

Country	Exports	Imports
Austria	36 032 630	55 249 540
Belgium	84 897 300	65 302 780
Bulgaria	2 149 270	6 283 540
Cyprus	741 410	7 418 000
Croatia	570 090	507 150
Czech Republic	39 621 160	24 425 450
Denmark	49 174 120	39 613 700
Estonia	1 485 840	2 952 750
Finland	2 723 500	14 651 410
France	31 875 470	178 653 730
Germany	629 105 080	190 281 430
Greece	2 134 730	6 170 520
Hungary	27 493 620	17 083 980
Iceland	NA	NA
Ireland	895 140	6 368 730
Italy	324 295 370	62 891 360
Latvia	2 122 860	3 218 010
Lithuania	5 697 530	6 387 950
Luxemburg	509 050	4 355 060
Malta	500	199 970
Netherlands	68 929 810	37 647 160
Norway	NA	NA
Poland	57 700 770	66 297 320
Portugal	1 578 410	14 689 300
Romania	1 707 810	15 128 680
Slovakia	1 204 110	9 980 920
Slovenia	17 592 790	16 820 290
Spain	32 954 560	55 693 060
Sweden	9 006 500	31 209 790

United Kingdom	41 713 390	144 806 240
EU-28 TOTALS	519 069 771	275 426 544

2.1.3 Apparent consumption of steam or sand blasting machines and similar jet-projecting machines

Apparent consumption of EU Member States as shown in Table 9 can be calculated as follows:

Equation 1: Apparent consumption = Production + Imports - Exports

Note that for several EU Member States import and export data have been reported in PRODCOM but production has been reported as zero or not available. These figures should thus be considered with caution, since the apparent consumption may result in negative data. For this reason, Eurostat[28] does not recommend this method to estimate consumption. Therefore, the consumption of high pressure cleaners is estimated by other means in this report (see Section 2.2).

In total, for the EU-28 the value of apparent consumption of steam or sand blasting machines and similar jet-projecting machines was around EUR 810 million in 2016.

[28] https://ec.europa.eu/eurostat/documents/120432/4433294/europroms-user-guide.pdf/e2a31644-e6a2-4357-8f78-5fa1d7a09556

Table 9. Calculation of apparent consumption (in EUR) of steam or sand blasting machines and similar jet-projecting machines between 2009 and 2016 (own calculations based on Eurostat)

Country	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Austria	622 160	155 862	563 971	-1 349 331	-905 357	-242 587	1 894 940	1 395 661
Belgium	11 606 130	10 150 380	5 898 610	3 769 780	NA	5 051 310	6 083 440	4 035 790
Bulgaria	22 324 661	15 094 325	14 372 896	8 337 200	11 265 495	20 067 174	29 271 644	28 814 968
Croatia	97 818 047	87 364 876	83 441 496	75 053 253	112 790 986	117 595 097	138 381 598	131 747 607
Cyprus	8 612 800	3 652 690	2 110 600	2 642 590	3 977 909	2 280 206	4 003 647	7 203 194
Czech Republic	12 082 458	9 946 865	8 850 828	3 442 204	4 460 231	7 390 946	14 288 525	NA
Denmark	1 545 380	557 940	880 080	1 474 840	1 286 630	1 129 000	1 730 990	1 466 910
Estonia	182 930	190 990	313 820	217 430	316 990	340 350	257 610	199 470
Finland	428 290	881 630	1 261 740	1 260 340	964 050	64 570	1 001 550	1 095 150
France	14 609 330	16 308 560	22 351 050	24 013 940	12 850 270	18 944 300	22 317 410	19 216 910
Germany	NA	NA	3 323 410	2 945 580	NA	3 312 404	4 553 532	NA
Greece	17 474 024	17 099 757	19 647 516	16 426 989	12 470 040	18 082 227	10 882 340	11 927 910
Hungary	5 289 830	5 888 590	4 095 930	4 754 720	9 608 050	14 248 730	9 522 530	8 776 810
Iceland	NA	NA	NA	NA	NA	NA	NA	NA
Ireland	20 960 491	6 800 490	6 500 672	5 526 240	4 107 093	-7 821 074	-8 152 658	10 299 355
Italy	8 612 800	3 652 690	2 110 600	2 642 590	3 977 909	2 280 206	4 003 647	7 203 194
Latvia	NA	334 910	NA	4 321 270	-6 656 170	5 876 600	121 200	-10 261 650
Lithuania	NA	NA	NA	NA	NA	NA	NA	NA
Luxemburg	NA	NA	NA	NA	12 979 477	14 808 911	16 850 260	22 922 215
Malta	2 452 120	2 104 170	2 367 060	3 029 130	-2 599 580	2 879 530	2 788 970	3 846 010
Netherlands	NA	NA	NA	NA	NA	NA	NA	NA
Norway	NA	NA	NA	NA	NA	NA	NA	NA
Poland	24 844 135	31 082 787	30 440 095	28 033 031	25 377 377	36 556 358	38 372 715	36 885 031
Portugal	111 488 480	118 964 505	134 922 685	153 094 392	153 161 309	153 403 208	162 456 602	185 064 530
Romania	NA	NA	NA	NA	NA	5 650 738	5 876 125	11 893 075
Slovakia	10 239 460	7 588 040	11 385 500	17 693 150	10 158 640	10 021 660	NA	13 420 870
Slovenia	NA	NA	NA	NA	NA	NA	NA	NA

Spain	63 516 600	38 317 901	-9 321 981	-25 203 309	NA	3 613 568	NA	NA
Sweden	6 869 150	-15 848 830	65 458 330	-45 939 790	-84 902 510	81 130 640	224 816 130	23 922 990
United Kingdom	-8 516 903	NA	NA	NA	NA	NA	43 223 826	44 549 278
EU-25 TOTALS	520 826 938	461 657 664	571 811 072	449 017 063	NA	NA	NA	NA
EU-27 TOTALS	536 493 868	475 299 604	587 038 052	467 979 083	NA	NA	NA	NA
EU-28 TOTALS	491 034 628	399 592 314	476 933 502	356 398 743	396 083 050	563 697 161	592 593 060	810 375 000

NB: “NA:” means data not derivable as input data (mostly production data) is not available.

2.1.4 EU sales and intra/extra-EU-28 trade of steam or sand blasting machines and similar jet-projecting machines

Table 10 shows the intra- and extra-EU trade of EU Member States in 2016 according to Eurostat statistics on international trade in goods. Time series are omitted since no quantitative analysis is derived from this data.

The trade data shows that the EU-28 is a net exporter of steam or sand blasting machines and similar jet-projecting machines. Germany and the UK are the main importers of from outside the EU-28, followed by Belgium and Italy, while Germany and Italy are the largest exporters. Germany and Italy also have the highest values of exports to other EU Member States (intra-EU exports), with France, Germany and the UK the main destinations of EU internal trade.

Table 10. Intra- and extra-EU-28 trade of Member States with steam or sand blasting machines and similar jet-projecting machines in 2016 (Eurostat)

	EXTRA-EU-28 (EUR)		**INTRA-EU-28 (EUR)**	
Country	**Imports**	**Exports**	**Imports**	**Exports**
Austria	3 761 161	3 911 085	51 488 384	32 121 547
Belgium	37 507 628	7 961 041	27 795 154	76 936 260
Bulgaria	813 652	233 979	5 469 894	1 915 301
Croatia	571 351	270 817	6 846 632	470 588
Cyprus	27 345	570 092	479 813	NA
Czech Republic	2 505 210	8 495 522	21 920 233	31 125 652
Denmark	18 673 711	21 847 536	20 939 973	27 326 583
Estonia	48 719	1 000 990	2 904 037	484 841
Finland	2 191 634	1 666 279	12 459 770	1 057 221
France	16 207 289	19 475 000	162 446 429	12 400 476
Germany	53 071 580	264 362 987	137 209 848	364 742 098
Greece	727 315	915 693	5 443 207	1 219 043
Hungary	1 248 946	232 203	15 835 030	27 261 401
Ireland	514 787	217 246	5 853 944	677 883
Italy	25 931 836	98 055 673	36 959 536	226 239 685
Latvia	52 950	1 212 765	3 165 049	910 080
Lithuania	197 666	4 353 278	6 190 267	1 344 256
Luxembourg	53 723	1 754	4 293 766	510 373
Malta	16 799	NA	183 175	497
Netherlands	19 270 114	20 517 836	18 377 039	48 411 968
Poland	8 175 461	20 110 803	59 945 286	38 733 802
Portugal	922 219	777 919	14 542 297	1 828 304
Romania	2 852 838	740 474	12 275 829	967 347
Slovakia	202 423	488 889	9 778 501	715 210
Slovenia	6 147 779	4 530 284	10 672 523	13 062 502
Spain	17 788 902	13 777 432	37 904 151	19 177 129
Sweden	6 810 639	5 452 934	24 399 150	3 553 571
UK	49 132 867	17 889 260	95 673 376	23 824 123

	EXTRA-EU-28 (EUR)		INTRA-EU-28 (EUR)	
Country	**Imports**	**Exports**	**Imports**	**Exports**
EU-28 Totals	275 426 544	519 069 771	-	-

2.1.4.1 Extra-EU-28 trade

Table 11 gathers the figures of extra-EU-28 trade with selected countries: Australia, Canada, China, Hong Kong (China), Indonesia, Japan, South Korea, Mexico, Norway, Russia, Saudi Arabia, Singapore, South Africa, Turkey and the United States. These countries represent 60% of extra-EU-28 exports and 96% of extra-EU-28 imports.

The main destinations of European exports are Russia, China and the United States. On the other hand, China is by far the largest exporter to the EU-28 (84% of extra-EU-28 imports). It is the only country of the group for which extra-EU-28 trade results in a negative balance.

Table 11: Value (in EUR) of extra-EU-28 trade with some countries in 2016 (Eurostat)

Country	Imports	Exports
Australia	33 961	13 957 231
Canada	1 771 048	5 872 510
China	222 554 836	57 873 522
Hong Kong (China)	462 471	3 023 856
Indonesia	235 434	2 140 757
Japan	5 470 299	17 121 812
South Korea	2 023 139	9 808 098
Mexico	1 008 901	13 172 198
Norway	2 525 871	28 651 581
Russia	220 899	61 304 333
Saudi Arabia	20 271	13 189 521
Singapore	322 082	4 287 440
South Africa	64 048	4 754 617
Turkey	2 914 102	19 833 352
United States	25 457 369	57 182 370

2.2 Market and stock data

2.2.1 Domestic HPCs

2.2.1.1 Historical sales and projections

Detailed market information regarding domestic and professional HPC sales in the EU has been purchased from GfK[29] (data gathered from retailers), as well as market information provided by stakeholders. This market data cover the following seven EU countries: Belgium, France, the Netherlands, the UK, Italy, Spain and Germany. In total, the above seven countries represent around 50% of EU-28 households and account for **2.5 million units sales**. Regarding professional HPCs, additional detailed market information has been provided by stakeholders, and together with the GfK dataset, has been double-checked and used as the main source of data for professional HPCs. For both domestic and professional HPCs (as defined in Task 1), this market information compilation has been considered a sufficiently representative sample to be extrapolated to the EU-28. More specifically, for scaling up the market data to the EU-28, the following parameters has been considered:

i) Number of households per country (from Eurostat).

ii) The volume index of GDP per capita in Purchasing Power Standards (PPS), expressed in relation to the European Union (EU-28) average set to 100. If the index of a country is higher than 100, this country's level of GDP per capita is higher than the EU average and vice versa (from Eurostat).

iii) Geographical pattern where the countries are divided into south and central-north Europe. For example, Spain was used as a proxy country to estimate the number of domestic HPC units for Portugal considering also the two parameters above.

Regarding the extrapolation, the HPC sales for each country for which data was lacking has been done by normalising the data gathered for the seven countries with the number of households of that particular country and its PPS which reflects the purchase consumers' ability. The aggregated sales of the seven countries, representing nearly half of the EU-28 households, were used as a proxy for all other EU-27 countries apart from the southern European countries where data from Spain were used as a proxy (to also capture geographical patterns).

Figure 4 presents the summation of HPC sales calculated for the EU-28 as well as the forward and backward projections, from the year 1987 to 2050. In 2017, the domestic HPC sales (in units) are calculated to be **3.5 million units**. Based on the historical data, forward and backward projections (curve fitting with regression analysis) were performed. Forward projection was made based on regression analysis up to the year 2025 and from 2026 to 2050 a minor decline in the growth trend was estimated assuming a minor decline in the growth of the EU market in the decade after 2040, as the market penetration rates gradually increase. By 2030 the domestic HPC sales are expected to increase to **4.9 million units per year** and by 2050 to **5.7 million units per year**.

[29] https://www.gfk.com/

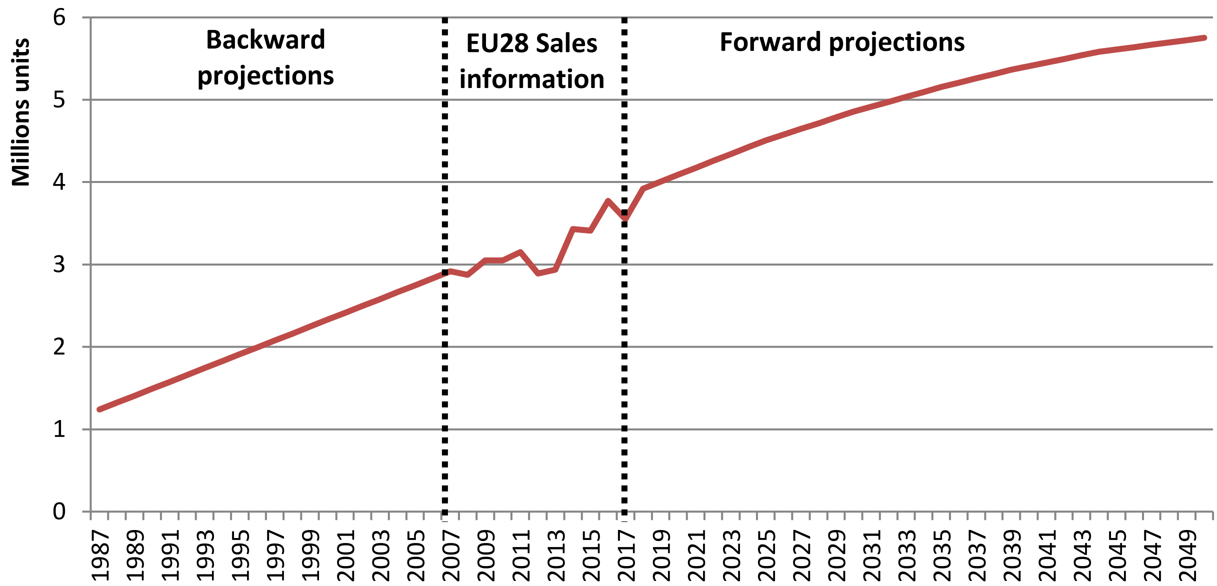


Figure 4. Estimated historical sales of domestic HPCs for the EU-28 for 2007-2017 along with forward and backward projections covering the period 1997-2050

2.2.1.2 Lifetime calculations

The lifetime of a product varies due to many factors such as the utilisation/user patterns, quality of manufacturing materials and components. The average lifetime of a product can be obtained using the Weibull distribution, which is a probability distribution widely used for survival analysis and expected product lifetime calculations, based on probability for a period of time. The Weibull distribution for different products has been studied by several authors such as Monier et al. (2013)[30], who presented the lifespan distribution of products put on the French market in 2005. The shape of the Weibull distribution depends on two factors: i) the shape parameter, and ii) the scale parameter.

For calculating the average lifetime [years], Equation 2 was used.

$$\text{Equation 2: Average Lifetime} = e^{\ln \Gamma(1+\frac{1}{\gamma})} * \lambda + \nu$$

where γ is the shape parameter; λ is the scale parameter; ν is the delay parameter.

'Retiring' is the probability of an HPC failing in a given year and 'surviving' the probability of it surviving a given year. The breakdown probability (or Probability Density Function), which corresponds to the probability of a product failing in a given year, is calculated for a period of 50 years as follows by Equation 3.

$$\text{Equation 3: \% retiring (t)} = \frac{\gamma}{\lambda} * \frac{t-\nu}{\lambda}^{\gamma-1} * e^{-\frac{t-\nu}{\lambda}^{\gamma}}$$

if $t < \nu$ then $\% \text{ retiring} = 0$

[30] Study on the quantification of waste of electrical and electronic equipment (WEEE) in France. Household and similar arising and destinations. December 2013. A study carried out on behalf of ADEME and OCAD3E by BIO Intelligence Service S.A.S.(V. Monier, M. Hestin, A. Chanoine, F. Witte, S. Guilcher) Contract n°1202C0048.

On the other hand, the survival probability or Cumulative Distribution Function, which corresponds to the probability of a product surviving in a given year, is calculated for a period of 50 years as follows by Equation 4.

$$\text{Equation 4: } \% \text{ surviving } (\mathrm{t}) = \mathrm{e}^{-\frac{\mathrm{t}-\nu^{\gamma}}{\lambda}}$$

if $\mathrm{t} < \nu$ then $\% \text{ surviving} = 100\%$

The survival for the next year is calculated based on the evolution of the survival probability as follows by Equation 5:

$$\text{Equation 5: } \% \text{ surviving to next year } (\mathrm{t}) = \frac{\% \text{ surviving } (\mathrm{t})}{\% \text{ surviving } (\mathrm{t}-1)}$$

if $\mathrm{t} < \nu$ then $\% \text{ surviving} = 100\%$

A delay period of 2 years was selected (v=2) for the analysis, as EU law requires manufacturers to give the consumer a minimum **2-year guarantee (legal guarantee)** as a protection against faulty goods, or goods that do not look or work as advertised. In some countries national law may require **longer guarantee periods**. Thus, for a period of 2 years the survivals are considered as 100% as the units that fail within this period are most probably returned by the consumers and repaired or replaced by the manufacturers at their own expense.

The Weibull stochastic approach was selected. Using this approach, the average lifetime is calculated with the same constant parameters for all years (shape parameter, scale parameter and delay parameter). This means that the average lifetime will be the same for all products manufactured in different periods. In addition, two parameters are included in the estimation of the survival probability of the product depending on its production year. The survivals calculation is done by tracking the survival probability of the sales per year for a certain number of years and modifying this estimate when the product reaches a certain age. The two parameters included are the adjustment period (in years) and the adjustment factor (in percentage of survivals). These correction factors avoid an overestimation of the stock as they further reduce the probability of an old product remaining in the stock. A Belgian study[31] found an average estimated life time of 12 years at End-of–Life for domestic high pressure cleaners. Sources amongst manufacturers and consumer organisations indicate that the expected lifetime is 10-12 years. To better define the lifetime Weibull distribution of HPC, information regarding the failure rate was considered.

More specifically, according to a survey performed by 'Which?[32]' among their members who owned a **domestic HPC** (sample size of 2 277), the faults in the first nine years were identified as follows:

- faults after the 1st year: 3% (covered by the legal guarantee);
- faults after the 3rd year: 9%.

  Feeding this information (average lifetime of around 10 years with faults in the first years) into the EcoModelling tool[33], a HPC-specific lifetime Weibull distribution is produced and presented in Figure 5. For domestic HPCs, the shape parameters of the Weibull distribution are: shape factor γ=1.15; scale factor λ=7.90; delay factor v=2 (associated with the guarantee). The average lifetime (Weibull) is calculated as **9.5 years**. Figure 5 also presents the percentage of retiring HPCs for a 50-year period by 5-year periods.

[31] Confidential.
[32] https://www.which.co.uk/reviews/pressure-washers/article/which-pressure-washer-brand/most-reliable-pressure-washer-brands

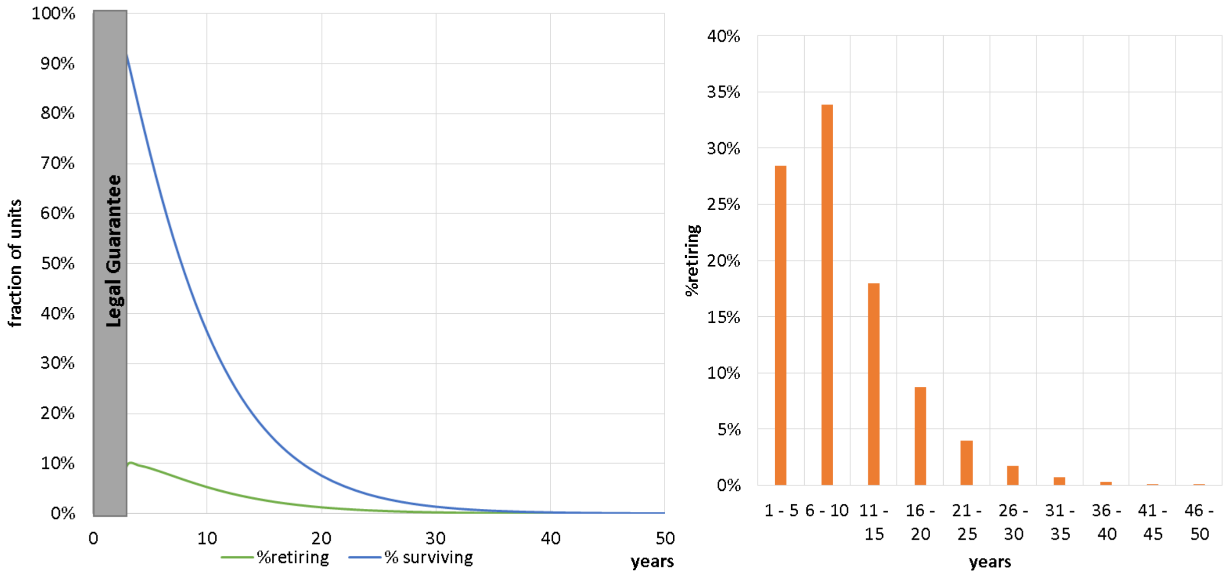


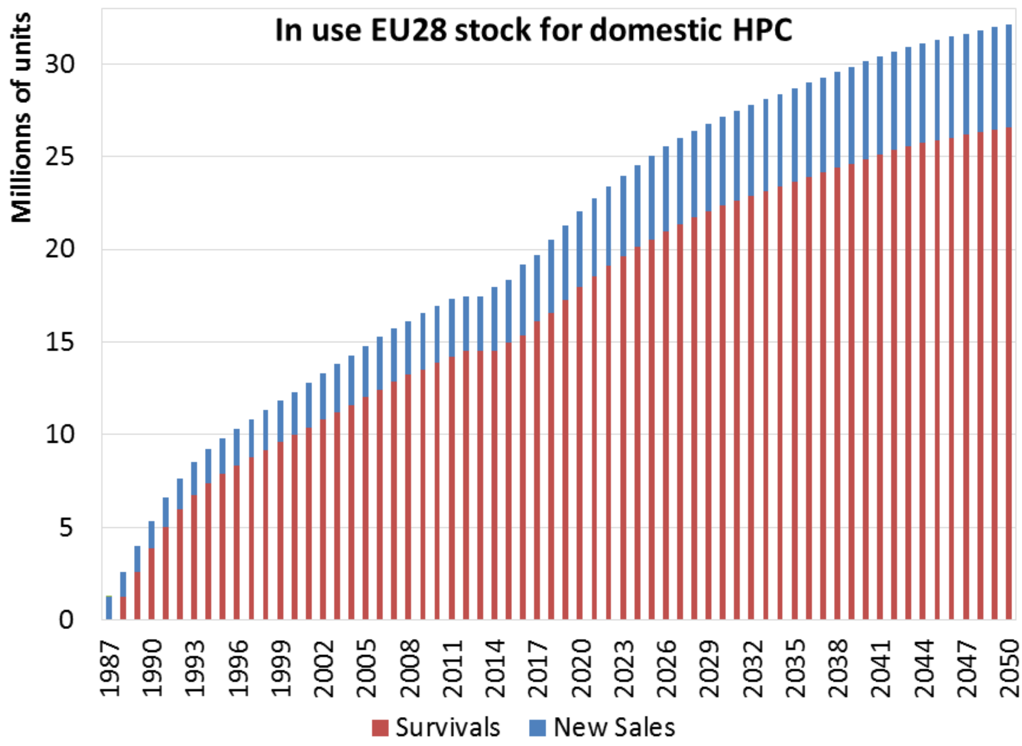
Figure 5. a) The domestic HPC Weibull lifetime distribution with information on the annual % of retiring products and the cumulative % of survivals and b) % of retiring products for a period of 50 years divided into 5-year periods

*2.2.1.3 In-use stocks at EU-28 level and WEEE generated**

Based on the estimated sales for the period 1997-2050 in combination with the lifetime Weibull distribution (presented in Figure 6) as defined for the case of domestic HPCs and described in the section above, the stock of domestic HPCs at EU-28 level was calculated for the same period.

Figure 6 presents the in-use stock of domestic HPCs in the EU-28 indicating the survival units (the units that survive each year) together with the new sales. For the year 2017 the overall stock is estimated to be around **20 million units**. The in-use stocks are expected to increase to around **27 million units** by 2030 and around **33 million units** in 2050.

The units for each year that fail (based on the Weibull lifetime) were considered as the Waste Electronic and Electrical Equipment (WEEE) stream. Figure 7 presents the estimated WEEE fraction per year at EU-28 level for the domestic HPCs. For 2017 this WEEE fraction is at the level of **3 million units per year** and it increases to **4.4 million units per year in 2030** and **5.4 million units per year** in 2050 (these calculations are not based on collection rates from Eurostat data).



*NB: The stock and WEEE estimations start from the year 1987. It has been assumed that before that year the domestic HPC sales were not significant. Nevertheless, this assumption does not influence the current and future in-use stocks (from 2018) as all units produced prior to 1987, based on the lifetime calculations, should have been retired by 2017 (see Figure 5b).

Figure 6. Estimated 'survival' and 'new sales' in-use stocks of domestic HPC units at EU-28 level

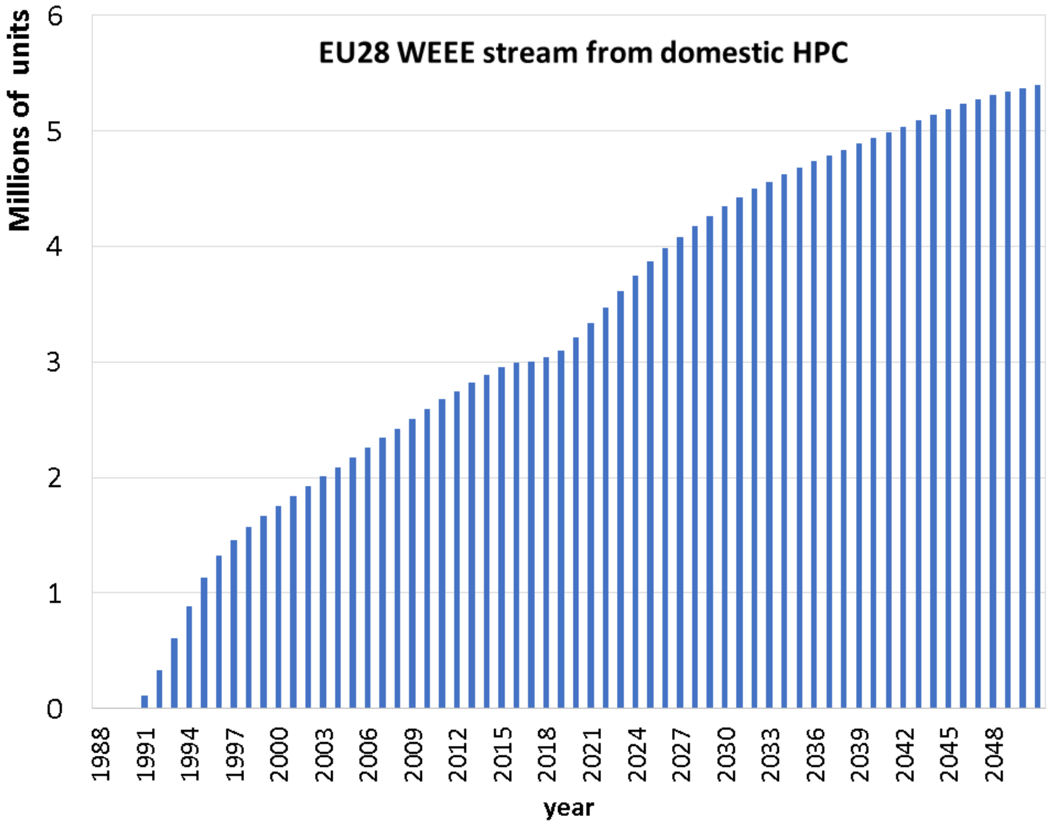


Figure 7. Estimated WEEE fraction generated by domestic HPCs at EU-28 level

2.2.1.4 *Market penetration of domestic HPC at EU-28 level*

Table 8 presents the market penetration rates (%) of domestic HPCs at EU-28 level. Market penetration per year was defined as the total number of in-use HPCs (new sales and survivals) per year divided by the overall number of EU-28 households. In 2017, 8.3% of EU-28 households had a domestic HPC in use. Within a 9-year period the market penetration increased 0.9%. The trend is steadily increasing. As the penetration rates are still low, provided that the lifetime of domestic HPCs is not extended, it is not expected that the EU market will become saturated until 2050. However, the estimated market penetration rate is an EU-28 average, and it is expected that there are significant variations among the EU-28 countries depending on the purchasing power, the number of households and the climatic conditions (impacting the need for a HPC). Countries like Belgium for example have much higher penetration rates according to a report from GfK.

Table 8. Estimated market penetration (%) at EU-28 level

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017
Market penetration (%)	7.4	7.6	7.7	7.6	7.6	7.7	7.8	8.1	8.3

2.2.2 Professional HPCs

2.2.2.1 *Historical sales, projections and market segmentation*

Professional HPCs are analysed as a separate market to domestic HPCs, based on their drive technology and delivery of hot or cold water. The analysis is based on detailed market information that has been provided by stakeholders, representing around 75% of the EU sales in economic terms according to their estimations. The extrapolation to 100% was performed based on this market share estimation. The extrapolated data was also confirmed and complimented by purchased market data from GfK. Figure 9 presents the market segmentation as it is for 2017 for professional HPCs.

Cold water professional HPCs had a 78% market share of the professional HPCs in 2017. More specifically for the year 2017, cold water electric single-phase HPCs had a 59% market share; three-phase HPCs had a 16% market share and combustion-engine-driven HPCs had only a 3% market share.

Hot water professional single-phase HPCs had a 12% share of the professional HPC market; three-phase (industrial) HPCs had a 10% market share. Less than 1% of the market (a few hundred units) is hot water combustion-engine-driven. In total, hot water HPCs have a significant market share, 22% of the professional market, and need to be analysed separately from cold water ones.

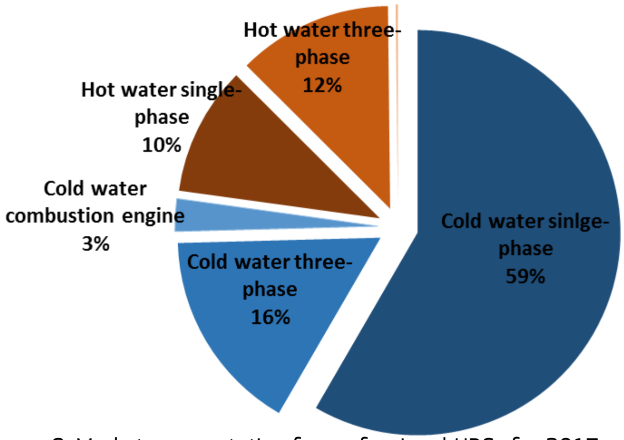


Figure 9. Market segmentation for professional HPCs for 2017

Figure 10 presents the aggregated sales of professional HPCs, cold and hot water, for the years 2011-2017; as well as the backward and forward projection/forecast of the market evolution performed with curve fitting regression analysis. Overall, cold and hot water professional HPC sales are around 200 000 units over recent years; with **203 000 units** sold in 2017 of which **155 000 units** were cold water professional HPCs and **48 000 units** were hot water. Hot water professional HPCs currently account for around 68 000 units sales per year. Cold water HPC projections show a steady increase for the following years while hot water HPCs show a slighter increase rate. Cold water professional HPC sales are expected to grow to **169 000 and 194 000** units in 2030 and 2050 respectively. Hot water professional HPC sales are expected to grow to 50 000 and 59 000 units in 2030 and 2050 respectively.

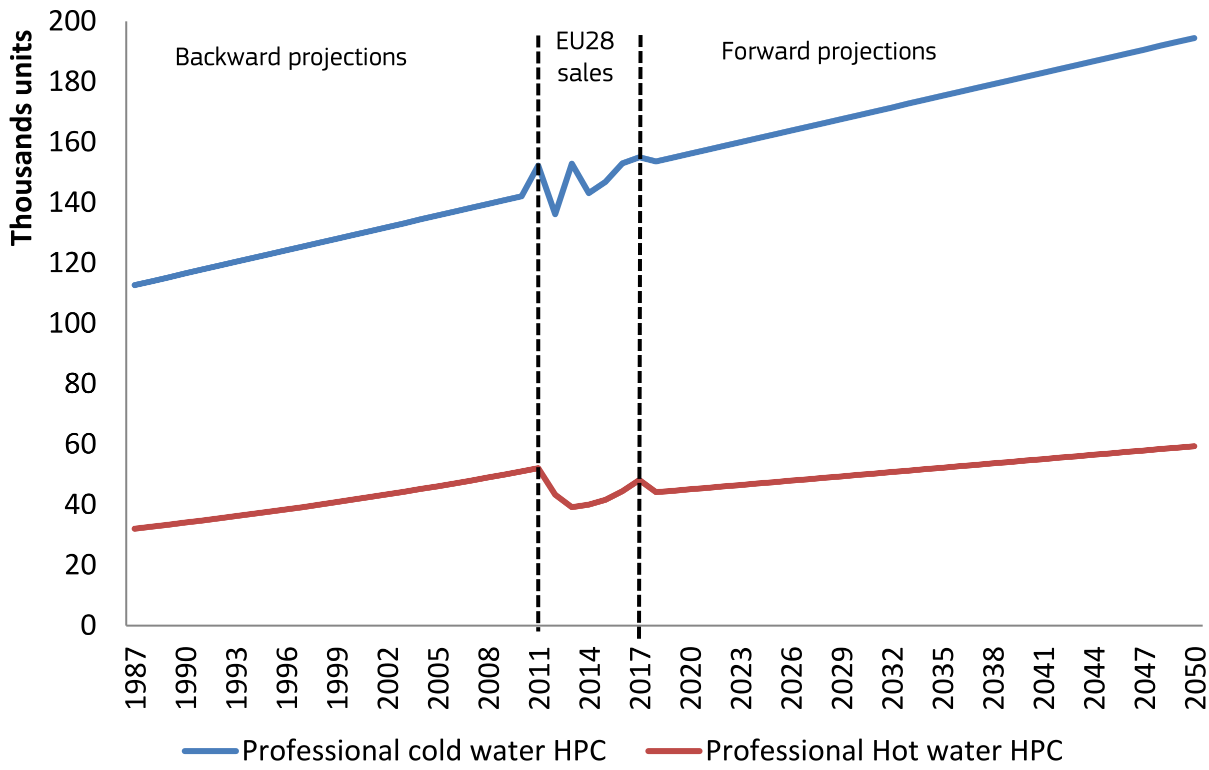


Figure 10. EU-28 estimated sales for cold and hot water professional HPCs for 2011-2017 along with forward and backward projections covering the period 1997-2050

2.2.2.2 Lifetime calculations

Input from stakeholders regarding the lifetime of professional HPCs indicates that it is 10 years (or 1 500 working hours). Most professional HPCs are easily repairable, since their components can be removed and repaired, in contrast with domestic HPCs which have a much lower reparability potential. In professional HPCs for example, the high pressure water pump is changed or refurbished every 500 hours, extending their lifetime. Based on this input, Figure 11 presents the Weibull distribution, tailored for professional HPCs. The shape parameters are: shape factor γ=3.00; scale factor λ=9.30; delay factor v=2 (associated with the minimum guarantee). The average lifetime (Weibull) is calculated as 10.30 years. Figure 11 also presents the percentage of retiring HPCs for a 50-year period by 5-year periods.

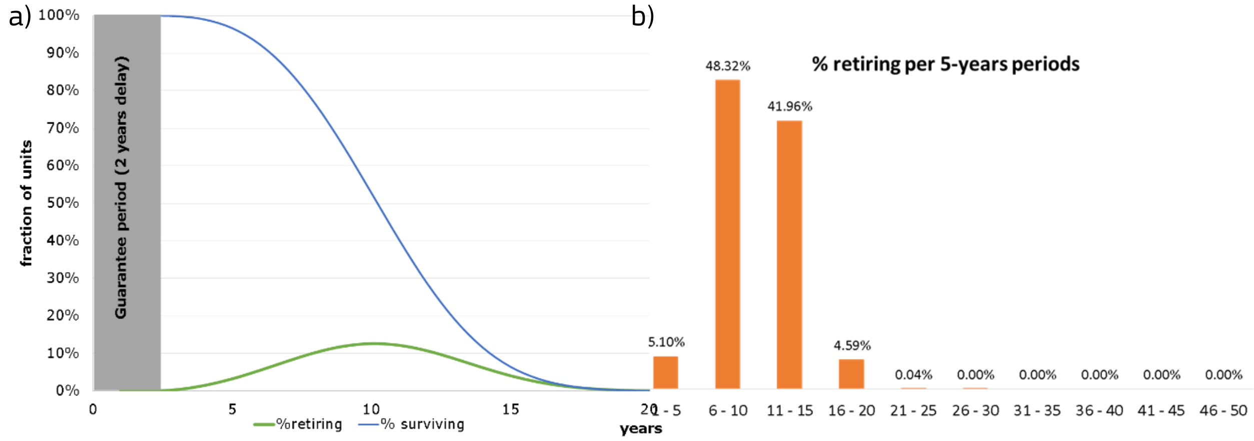


Figure 11. The professional HPC Weibull lifetime distribution with information on the annual % of retiring products and the cumulative % of survivals and b) % of retiring products for a period of 50 years divided into 5-year periods

2.2.2.3 In-use stock and WEEE calculations

The stock analysis has been done separately for professional cold water HPCs and for professional hot water HPCs using the Weibull lifetime distribution for professional HPCs (similarly to the domestic HPC stock analysis) as discussed in Section 2.2.2.2. Figure 12 presents the estimated in-use stock (composed each year by the 'survival' units and the 'new sales') for the period 1997-2050 at EU-28 level for cold and hot water HPCs respectively.

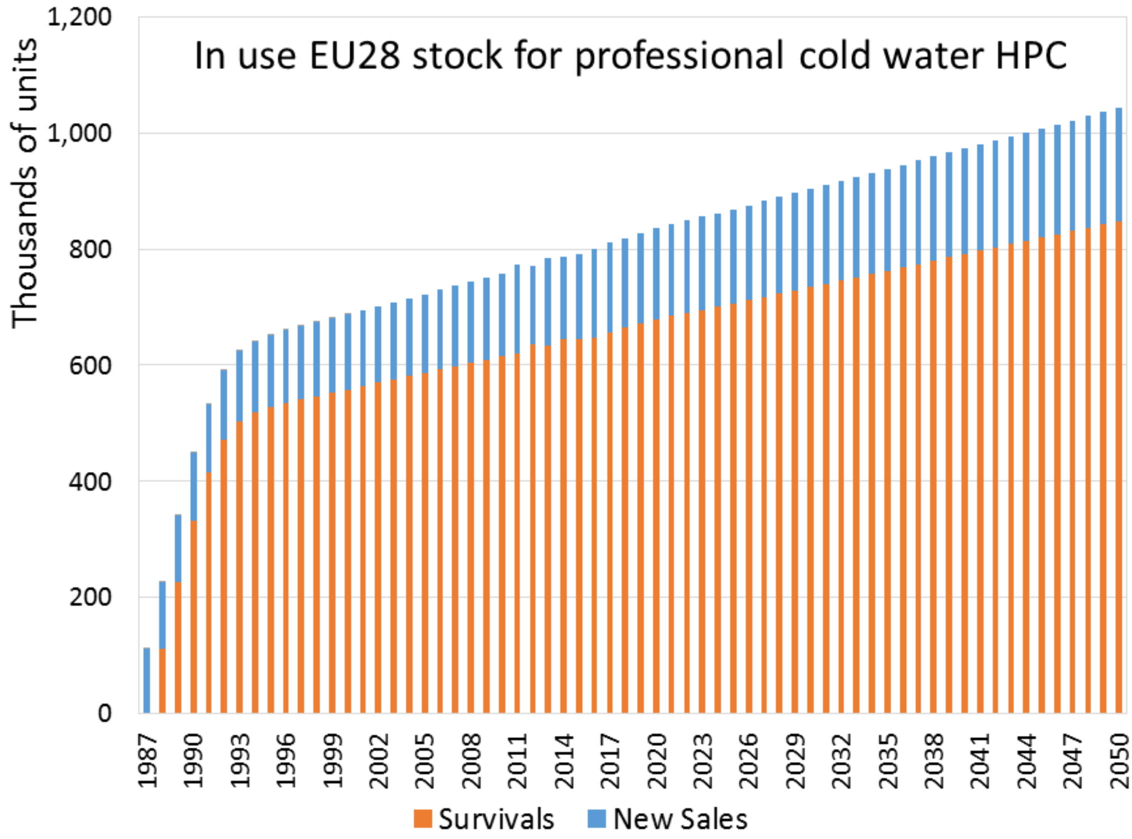


Figure 12. Estimated 'survival' and 'new sales' in-use stocks of cold water professional HPCs at EU-28 level

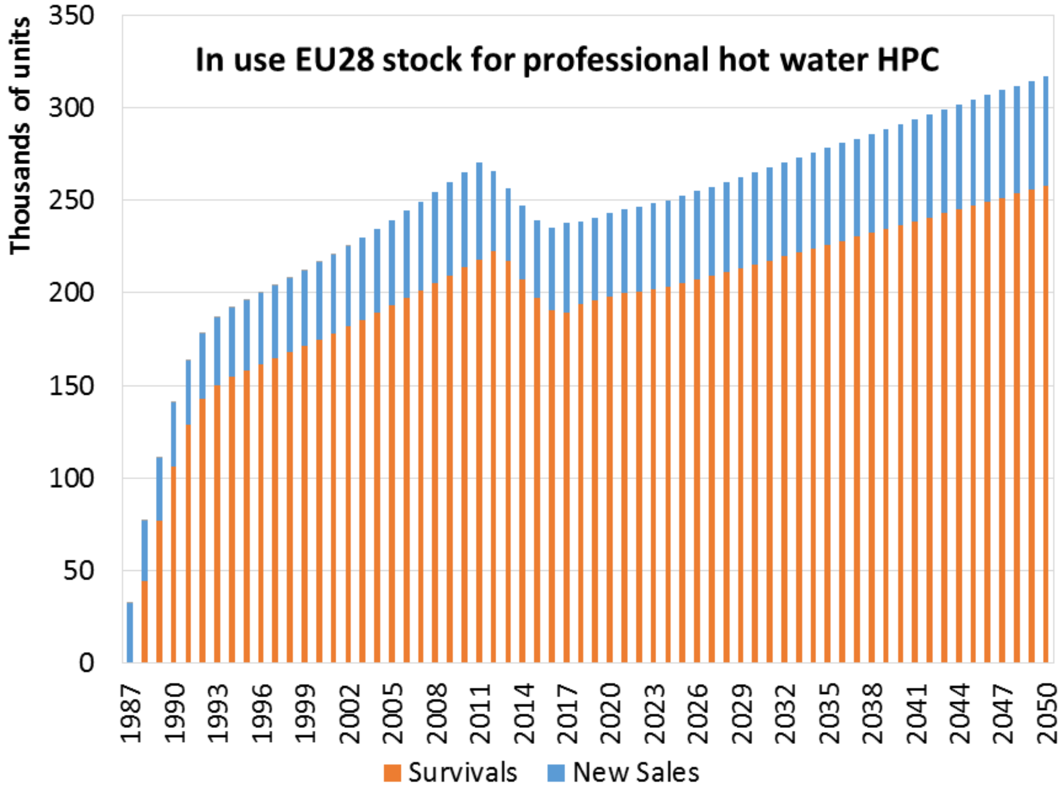


Figure 13. Estimated ‘survival’ and ‘new sales’ in-use stocks of hot water professional HPCs at EU-28 level

In 2017, cold water professional HPCs accounted for 656 000 units as ‘survivals’ and 155 000 units as new sales, in total **811 000 units** of in-use stock. The in-use stock is expected to increase to **904 000 and 1 042 000 units** in 2030 and 2050, respectively.

Hot water professional HPCs accounted in 2017 for around **234 000 units** of in-use stock, which is expected to rise to **265 000 units** and **317 000 units** in 2030 and 2050, respectively.

2.3 Market trends

This section presents the analysis of the main market trends and evolution of the main HPC characteristics, both domestic and professional, for a 10-year period (2007-2017) based on the market data gathered.

2.3.1 Input power (for domestic HPCs)

The input power is one of the main performance characteristics of HPC equipment as also described in Tasks 1 and 4. Figure 14 presents the evolution of the HPC input power of domestic HPC equipment based on sales numbers. The following conclusions can be drawn:

- A general trend is that the domestic HPC market slightly moves to more powerful units.
- The Main power category is the >1.3 kW and <=1.6 kW with a market share of 50% in 2017; followed by the >1.6 kW and <=1.9 kW with a market share of nearly 30% in 2017.
- The low power units (<= 1.3 kW) represent the smallest fraction, with a decrease in recent years. This market share was absorbed in the higher power categories.

- The upper input power for domestic HPCs is defined as 3.3 kW (3.3 kW is the typical limit for single-phase HPCs as described in Task 1). The input power categories above 1.9 kW up to 3 kW show an increase in their market shares in the last 3-4 years, confirming the first conclusion.

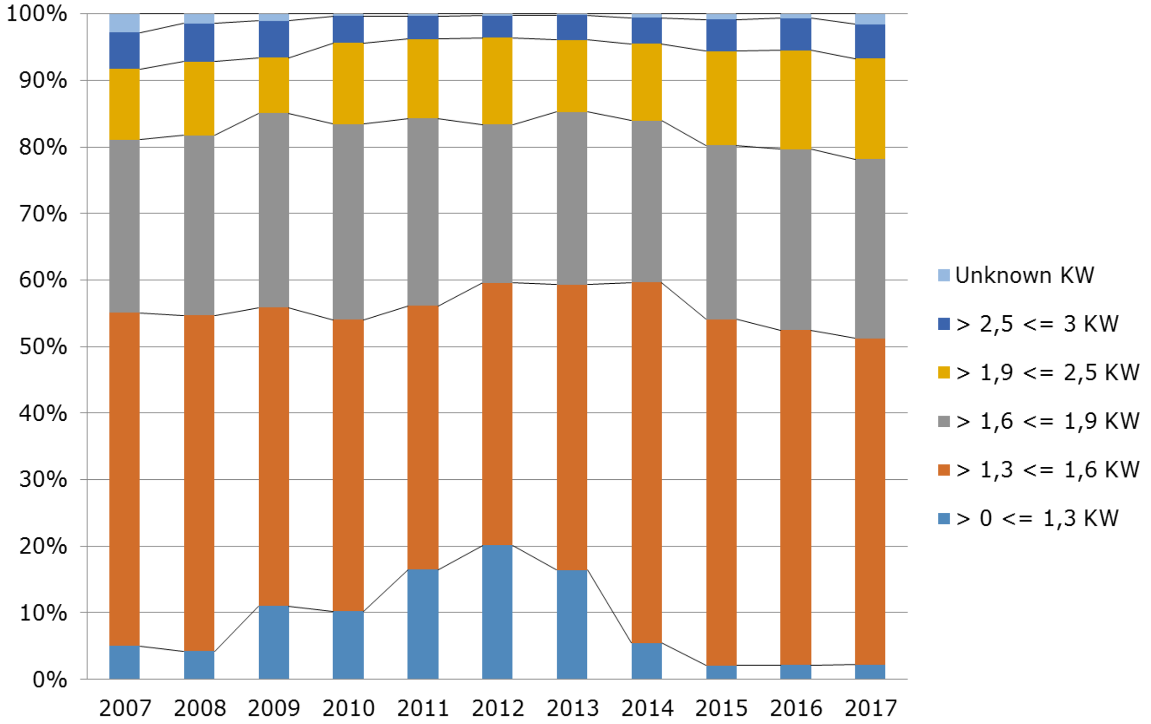


Figure 14. Market share (%) of input power categories for domestic HPCs for the years 2007-2017

2.3.2 Maximum water pressure

The maximum water pressure is the second main performance characteristic of HPCs. Figure 15 presents the evolution in maximum water pressure for the years 2007-2017.

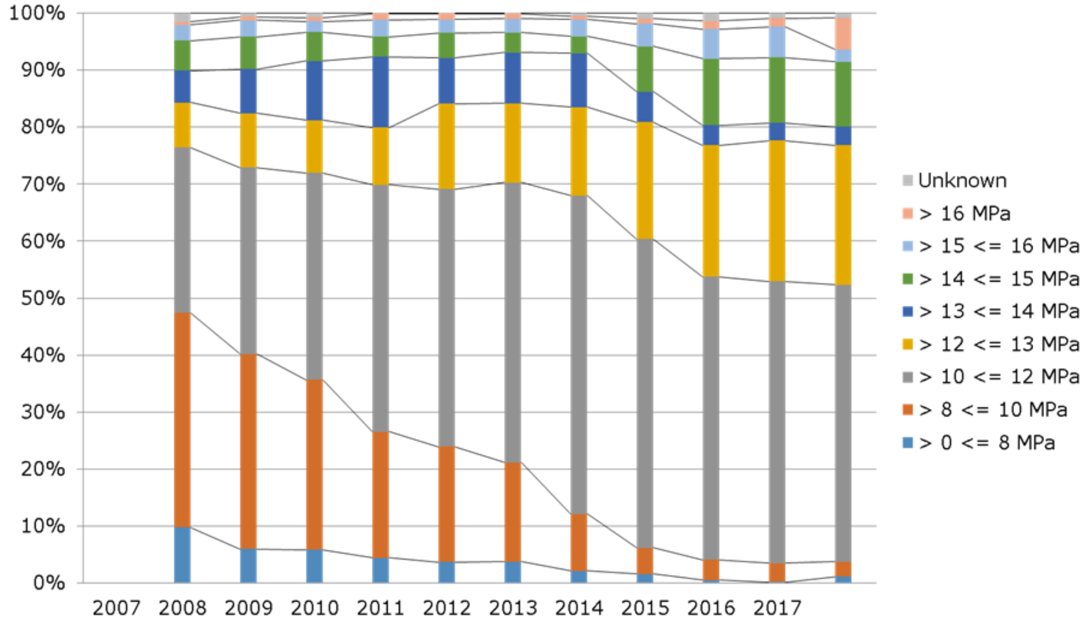


Figure 15 Market share (%) of input power categories for domestic HPCs for the years 2007-2017

The following conclusions can be drawn:

- The maximum pressure of HPC sold over recent years has generally increased.
- The category <=8 MPa represented nearly 50% of the market in 2007, but over the following years this share decreased and was absorbed in more powerful categories until 2017 when the market share dropped significantly, to less than 5%.
- The category >10 MPa and <= 12 MPa in 2017 has the largest market share (around 55%), representing the low-performance domestic HPCs. The category >12 MPa and <=13 MPa has had the second largest market share in recent years (around 25% in 2017) and the market share of the >14 MPa and <=15 MPa category is around 10%.
- The category > 16 MPa had around 8% of the market share in 2017. This category represents more powerful and high-performance professional HPC units. A separate analysis has been performed for this most powerful maximum water pressure category and is presented in the following section.

2.3.3 Above 16 MPa maximum pressure and cordless HPCs

As observed in the previous section, over the last 5 years HPCs with a maximum water pressure >16 MPa significantly increased their market share from 1-2% to 8% in 2017. Focusing more on this category (>16 MPa), this increase can be attributed to a cold water professional and domestic HPC sales increase, as can be seen at Figure 2.12. The information confirms that sales of HPCs capable of a maximum water pressure >16 MPa were at the level of 230 000 units in 2017. Sales of hot water HPCs with a maximum water pressure >16 MPa are stable over recent years at 7 000-9 000 units.

Another observation regarding the market trends is on cordless HPCs (Figure 16), sales of which were almost zero in previous years. In 2017, they accounted around 43 000 units. The expected wider use of batteries in domestic appliances in the years to come will lead to further growth of this market as also confirmed by stakeholders.

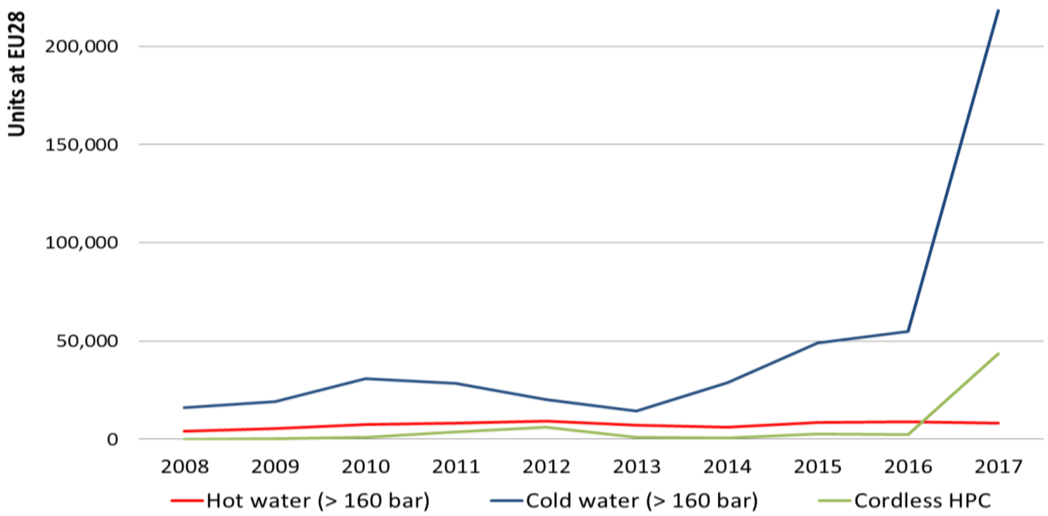


Figure 16. Unit sales of hot and cold water HPCs capable of a maximum water pressure above 16 MPa (160 bar) and unit sales of cordless HPCs with low water pressure for the period 2008-2017

2.4 Consumer expenditure base data

This section presents purchase prices, installation, repair and maintenance costs as well as applicable rates for running costs (e.g. electricity, water) and other financial parameters (e.g. taxes, rates of interest, inflation rates). This data will be input for later tasks where Life Cycle Costing (LCC) for new products will be calculated.

The average consumer prices and costs experienced by the end user throughout the product lifetime are determined by unit prices in the following categories:

- average price per HPC unit for each category;
- consumer prices of consumables (detergent and water);
- consumer prices of electricity and fuel;
- inflation and discount rate;
- installation costs;
- repair and maintenance costs;
- disposal tariffs and end-of-life cost.

The costs are shown as unit prices for domestic and professional products, litres of consumable, units of spare parts and components, kWh electricity and so on. The total life cycle costs, which also depend on use patterns and frequency of events, are assessed in Task 5.

2.4.1 Average unit values of HPCs produced in the EU-28

The average unit prices of HPCs vary greatly according to the product subgroup technology. Thus the average prices of HPC units are reported separately as also defined in the product scope (see Task 1) for:

- cold water single-phase (domestic use);
- cold water single-phase (professional use);
- cold water three-phase (professional use);
- cold water with combustion engine (professional use);
- hot water single-phase (professional use);
- hot water three-phase (industrial or semi-industrial use);
- hot water with combustion engine (professional use).

Figure 17 presents the price evolution for the years 2011-2017 based on stakeholders' inputs and commercial market reports for the above categories. Hot water HPCs with a combustion engine have a much higher average price compared to the other categories, at EUR 6 000 per unit. The year 2017 has been used as the reference year for the average prices; all prices are corrected for inflation to 2017 prices. To better illustrate the price evolution of the rest of the HPC categories, the average unit price of hot water HPCs with combustion engines is not included in the graph. The following conclusions can be drawn:

- The overall value of the domestic HPC EU market for 2017 has been estimated at EUR 600 million.
- The overall value of the professional HPC EU market for 2017 has been estimated at EUR 120-140 million.
- Combustion-engine-driven hot water HPCs are a niche product (with an average price of EUR 6 000 per unit).
- Single-phase professional cold water HPCs cost around double the average price of a domestic cold water HPC unit.
- The average prices have been relatively stable in recent years, with a small increasing trend for cold water HPCs with combustion engines, and the cold water three-phase professional HPCs.

- The average prices do not overlap, as they are discrete for each HPC category. The second and third most expensive HPC categories are the hot water HPC (three-phase) and the cold water combustion engine HPC, respectively.

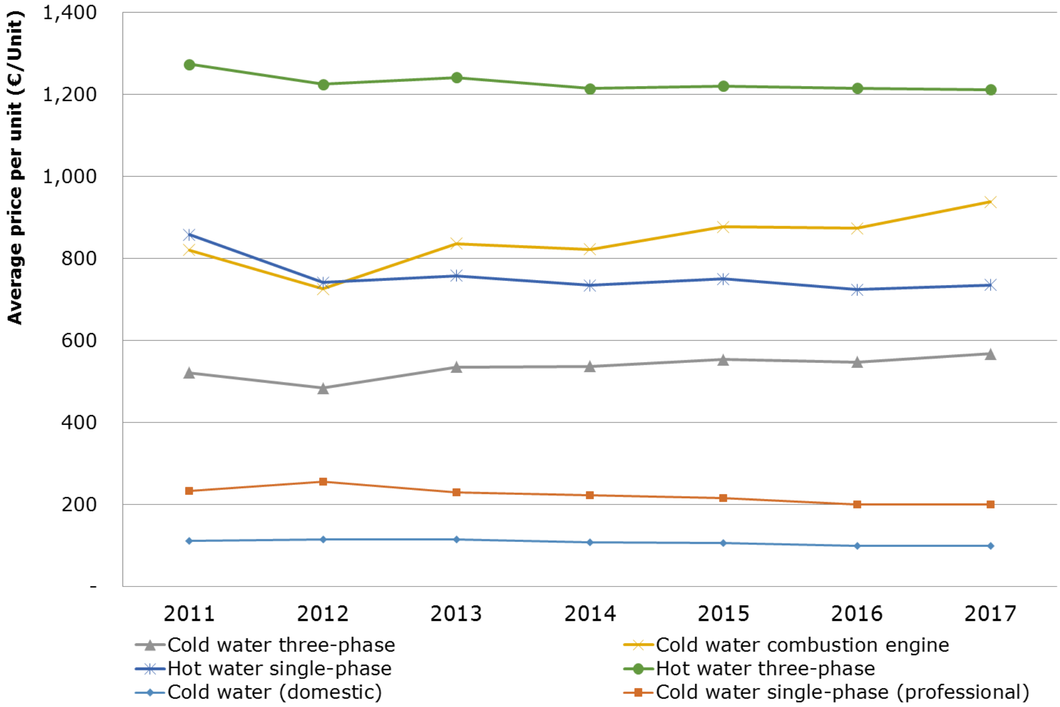


Figure 17. Average price per unit: historical evolution and forecasts per HPC subcategory

2.4.2 Consumer prices of consumables (detergent and water)

Domestic high pressure cleaners may use cleaning agents to improve the cleaning performance in some situations, for example to remove persistent dirt or grease or to clean specific surfaces such as wood, plastic, vehicle exterior, etc.

The consumer prices of detergents used in domestic HPCs have been gathered from a sample of retailers in Spain[34]. Table 12 displays this information for the different types and formats of detergents identified.

Table 12. Retail prices of detergents (incl. VAT) in Spain in 2018

Type of detergent and format	Av. price / price range (€/L)
Universal (2/5L)	2.5
Universal (1L)	6.3
Wooden surfaces (2-2.5L)	3 - 12
Wooden surfaces (1L)	13.5
Plastic surfaces (1L)	7.5 - 15
Exterior ceramic and concrete surfaces (2L)	3.5
Natural stone (1L)	8.3

[34] http://www.leroymerlin.es/productos/jardin/hidrolimpiadoras/detergentes_para_hidrolimpiadoras.html; https://www.amazon.es/detergente-hidrolimpiadora/s?ie=UTF8&page=1&rh=i%3Aaps%2Ck%3Adetergente%20hidrolimpiadora; https://www.manomano.es/detergentes-para-limpiadoras-de-alta-presion-2999; https://www.agrieuro.es/accesorios-para-hidrolimpiadoras/detergentes-arena-para-hidrolimpiadoras-c-67_669_1259.html accessed 22 August 2018

Roofs (5L)	4
Grease and oils (5L)	2.5
Ultra-foam cleaner for vehicle exterior (1L)	8
Ultra-foam cleaner for vehicle exterior (2.5L)	4
Rim cleaner (0.5L)	18
Bicycles / motorcycles cleaner (2.5L)	4
Ecological	9
Concentrated universal (0.5L)*	12 (*1.2)
Concentrated universal for professional uses (5L)*	5 (*0.5)

* To be diluted at 1:10.

The cost of water varies across the EU, at national and regional levels, and it is subject to very diverse taxation[35]. MEErP estimated the EU average price at € 3.70 / m^3 in 2011, with an annual nominal growth rate of 2.5% (more or less equal to inflation).

2.4.3 Consumer prices of electricity/fuel

The annual energy prices are taken from the PRIMES Model[36], which provides the prices referred to the year 2013. The 2017 prices have been calculated using the inflation rates mentioned in the next section. Both 2013 and 2017 prices are shown in Table 13.

Table 13. Annual prices of energy products

	2013 END USER PRICE (in € cents/kWh)					
Electricity	2005	2010	2015	2020	2025	2030
Average price	**11.7**	**13.6**	**14.4**	**15.3**	**15.7**	**16.1**
Industry	8.4	9.7	9.7	9.8	9.9	10.0
Households	15.6	17.2	19.0	20.3	20.9	21.2
Services	12.7	14.8	15.7	17.1	17.6	17.9
	2015 END USER PRICE (in € cents/kWh)					
Electricity	2005	2010	2015	2020	2025	2030
Average price	**12.0**	**14.0**	**14.8**	**15.7**	**16.1**	**16.5**
Industry	8.6	10.0	9.9	10.0	10.1	10.2
Households	16.0	17.6	19.5	20.8	21.4	21.8
Services	13.0	15.2	16.0	17.5	18.0	18.4
	2013 END USER PRICE (in € cents/kWh)					
	2005	2010	2015	2020	2025	2030
Diesel oil						
Industry	5.8	7.4	6.6	8.5	9.1	9.7
Households	6.6	7.4	6.6	9.0	9.8	10.7
Services	5.5	6.2	5.4	7.4	8.0	8.8

[35] https://www.eea.europa.eu/data-and-maps/indicators/water-prices
[36] https://ec.europa.eu/clima/policies/strategies/analysis/models_en#PRIMES

Fuel oil						
Industry	2.8	3.9	3.1	4.4	4.9	5.3
LPG						
Industry	7.4	7.8	5.6	8.3	9.0	9.5
Households	7.7	8.6	6.7	9.5	10.2	10.8
Services	6.6	7.1	5.5	7.6	8.1	8.7
	2015 END USER PRICE (in € cents/kWh)					
	2005	2010	2015	2020	2025	2030
Diesel oil						
Industry	5.9	7.6	6.8	8.8	9.3	9.9
Households	6.8	7.6	6.8	9.2	10.1	10.9
Services	5.6	6.4	5.6	7.5	8.2	9.0
Fuel oil						
Industry	2.8	4.0	3.1	4.5	5.0	5.5
LPG						
Industry	7.6	8.0	5.7	8.5	9.2	9.8
Households	7.9	8.8	6.8	9.7	10.4	11.0
Services	6.7	7.3	5.6	7.8	8.4	8.9

2.4.4 Inflation and discount rates

All economic calculations are made with 2015 as the base year. Inflation rates from Eurostat[37] (see Annex 4) are applied to scale purchase price, electricity prices, etc. to 2015 prices.

2.4.5 Installation costs

Installation of HPCs by a professional is only necessary for stationary fixed HPCs. All other types can be directly used by the end user. According to stakeholders' feedback, installation costs can be estimated by applying Equation 6.

Equation 6: Installation costs [EUR] = 20*Input power [kW] + 1500

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2.4.6 Repair and maintenance costs

Based on the results of endurance tests provided by the stakeholder, the most typical failures of domestic HPCs are:

- carbon brushes in the motor are worn and no longer make contact;
- bearings of the motor become defective;
- bearings of the pump become defective;
- leakages.

Retailers offer several spare parts for domestic HPCs, meaning that they may require replacement over the lifetime of the product. However, the failure rates of these parts have not been evaluated in the endurance

[37] https://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&language=en&pcode=tec00118&plugin=1

tests covered by this study. The user guides provided by manufacturers recommend the cleaning of the filter in the water connection and the nozzle. An internet search shows the retail prices of the spare parts, gathered in Table 14[38].

Table 14. Retail prices of spare parts of domestic high pressure cleaners in Spain in 2018

	Prices (€/unit) (VAT included)	
Spare part	**Min.**	**Max.**
Normal nozzles (including rotatory)	7	27
Special nozzles	40	65
Connections	3	12
Cylinder heads	23	54
Brushers	12	65
Elbows	5	24
Capacitors	7	23
Adaptors	3	40
Water filters	6	20
Switches and cables	23	40
O-rings	3	10
Hoses (per m)	4	6
Trigger guns	20	50
Wheels	7	9
Lances	5	60

In the case of professional high pressure cleaners, manufacturers indicated that the pump is the crucial component that requires the most maintenance. An internet search shows that there are specialised retailers offering pumps and repair kits with the spare parts that are needed the most frequently. The prices of the sample collected in this study[39] are displayed in Table 15.

Table 15. Prices of spare parts of professional high pressure cleaners in Spain in 2018

	Prices (€/unit) (VAT excluded)	
	Min.	**Max.**
Pumps	340	5160
Ceramic piston	19	124
Valves	5	74
Oil seals	2	11
Collars	6	33

[38] https://www.fiyo.es/hidrolimpiadora; https://www.erepuestos.es/hidrolimpiadora/catalogue.pl?path=984134
[39] https://www.accesoriosaltapresionagm.com/ accessed 27 August 2018.

If the repair or maintenance requires a professional service, the average EU labour cost in the category "Industry, construction and services (except public administration, defence, compulsory social security)" is to be used, as shown in Table 16. The labour cost levels are based on the latest Labour Cost Survey (currently 2012) and an extrapolation based on the quarterly Labour Cost Index (LCI). The data covered in the LCI collection relates to total average hourly labour costs[40].

Table 16. Average total labour costs for repair services

Year	2000	2004	2008	2012	2013	2014	2015	2016
EU-28 countries, (EUR/h)	16.7	19.8	21.5	23.9	24.2	24.5	25.0	25.4

2.4.7 Disposal tariffs/ taxes

Since HPCs are covered by the WEEE Directive and producers are responsible for paying an EPR fee or in some other way financing the EOL treatment, it is assumed that end users will not experience any further EOL costs. The EPR fee paid by manufacturers is assumed to be reflected in the sales prices of HPCs to end users. In the end user life cycle cost calculations, the EOL cost is therefore set to zero.

2.5 Recommendations

2.5.1 Refined product scope from the economic/commercial perspective

Hot water combustion engine HPCs are very expensive and niche products (the average price per unit is EUR 6 000), which is also reflected in the low sales volumes at the level of a few hundred units in the EU-28.

2.5.2 Barriers and opportunities for Ecodesign from the economic/ commercial perspective

Barriers:

- There seems to be a slight but apparent trend towards the increase of power and water pressure of entry-level domestic products. This means that the demand for more powerful products is increasing, while these products may be less water- and energy-efficient, depending on their cleaning performance and the usage pattern. This suggests that customers may be associating higher power with better performance, though that appraisal is not supported by any harmonised performance test. Consumers may even regard the environmental performance as detrimental to the cleaning performance of the product.
- There is no standard for cleaning performance/efficiency in order to differentiate the environmental performance of various products with different characteristics with a variety of cleaning activities.

Opportunities:

- Extending the lifetime and/or the reparability potential of domestic HPCs can have significant positive effects which will be examined in the following tasks.
- While this product is far from being as ubiquitous as for example washing machines, the penetration rate shows an increasing trend (around 1% yearly). Therefore, Ecodesign measures could lead to larger savings in the medium and long terms.
- As the EU exports these products to third countries, which in the future may adopt resource and energy efficiency measures similar to Ecodesign and Energy Labelling, this would also constitute a competitive advantage for EU manufacturers.

[40] http://ec.europa.eu/eurostat/cache/metadata/en/lc_lci_lev_esms.htm#unit_measure1475137997963

3 Task 3: Users

3.1 Introduction

3.1.1 Goal of the task

The scope of Task 3 is to analyse and report the consumer behaviour for use of high pressure cleaners (HPCs) and the related environmental impact in the use phase and the end-of-life phase.

This section in particular focuses on user behaviour and system aspects while product technologies are analysed in Task 4.

Task 3 comprises identification, analyses and reporting of:

- system aspects use phase, for ErP with direct energy consumption effects;
- system aspects use phase, for ErP with indirect energy consumption effects;
- end-of-life behaviour regarding life, repair, maintenance, disposal, recycling, reuse, etc.;
- local infrastructure regarding supply of energy, water, etc.;
- recommendations on refined product scope and barriers and opportunities.

3.1.2 Data collection

Data and information were requested from the manufacturers, consumer organisations and other stakeholders via two questionnaires (the first a broader request for data and information and the second focused on professional products) and via direct contacts. Technical data and data on user behaviour such as annual usage were received from some of the manufacturers and manufacturer associations. Furthermore, the study team received from a stakeholder data on laboratory tests of 43 domestic HPCs. Moreover, anonymised test data on 32 HPCs was provided by the team member Intertek and use was made of public data from the consumer organisation Which? (UK), who provides reviews, test results (mainly subjective testing of cleaning ability, ease of use, noise and water usage) and advice guides of HPCs.

To supplement this data, the study team collected technical specifications data of domestic and professional HPCs from public web sites of five major manufacturers (Kärcher, Nilfisk, Bosch, Stihl and IPC), in total on 160 models.

All this data is the main data source for the use phase analyses in Chapters 3 and 4.

3.2 System aspects of use phase, for ErP with direct energy consumption effects

High pressure cleaners have direct energy consumption effects because they use energy (electricity and/or fuels) for pumping - and for hot water HPCs also heating - the water. For a very limited amount of usage situations, indirect energy consumption effects are also relevant (see Section 3.3). In addition to energy, the HPCs also use water, cold or hot, for the cleaning, and in some cases also detergent to assist in the cleaning process.

The purpose of this subtask is to collect and analyse data that is relevant to environmental and resource impacts during the use phase and report these impacts.

The relevant user parameters that influence the environmental and resource impact during the use of the HPCs are:

- The cleaning tasks selected by the users according to their cleaning needs.
- The product usage in terms of selection of accessory (type of nozzle and cleaning attachment), cold or hot water (where relevant), possible detergent and dosage, and the actual usage (pressure, water flow, distance and angle to surface, speed of movement, etc.)
- Frequency of use, i.e. how often and how much are the various cleaning tasks needed, which results in a number of uses and time per use which can be summed up to the total annual use in hours. The time per use depends on the HPC cleaning performance and versatility. For example, if the HPC is suited to

car cleaning it would be used more often and if it cleans more efficiently the usage time would be decreased assuming the cleaning tasks are constant.

- Time in idle, standby and off modes (dependent on type of HPC), i.e. how long is the HPC plugged in without using it, how much is it on but idling and not cleaning?

  These user parameters combined with the product characteristics in terms of cleaning performance, versatility and product efficiency result in a certain level of consumption of electricity, fuels, water and detergent.

3.2.1 Cleaning tasks and cleaning performance

Domestic HPCs are used in households for a variety of domestic cleaning purposes such as cleaning patios, terraces, pavement, brickwork, swimming pools, cars, motorcycles, bikes and caravans. and general cleaning.

Professional HPCs are also used for several purposes but often acquired for specific cleaning tasks such as graffiti removal and cleaning stables, swimming pools, walls, monuments, communal park areas, vehicles (buses, tractors, trucks, etc.), machinery and engines.

Hot water HPCs are used for the same purposes as cold water HPCs, the difference being that the subjects to be cleaned may have more strongly attached dirt and especially oil, grease, etc.

For some cleaning tasks, special nozzles and attachments should be used. More information is gathered in Chapter 4.

The cleaning performance depends on several parameters, mainly the following:

- Preparation of the object or surface to be cleaned: Soaking with chemicals (e.g. for graffiti), detergent (for car wash) and water may ease the removal.
- Water volume: A volume is needed for transporting the dirt away from the area to be cleaned.
- Water pressure: A higher pressure is needed for dirt strongly attached to the subject; however, more porous areas may be damaged by the pressure.
- Water temperature (cold, hot): Hot water may be needed to remove grease, oil, fat, etc. and may for some purposes substitute the use of detergent. Very hot water can heat up the subject for quick drying afterwards, e.g. for avoiding corrosion.
- Detergent mixed in the water: Detergent can speed up and improve the cleaning process and can, as for hot water, be needed for removal of grease, oil, fat, etc. It may also provide disinfection of the subject.
- Characteristics of the fluid jet: The size and form of the jet – impacted by the type of nozzle, lance and other accessories – is relevant for cleaning performance and for the type of subject to be cleaned.

The basics of cleaning with an HPC can be seen in Figure 18.

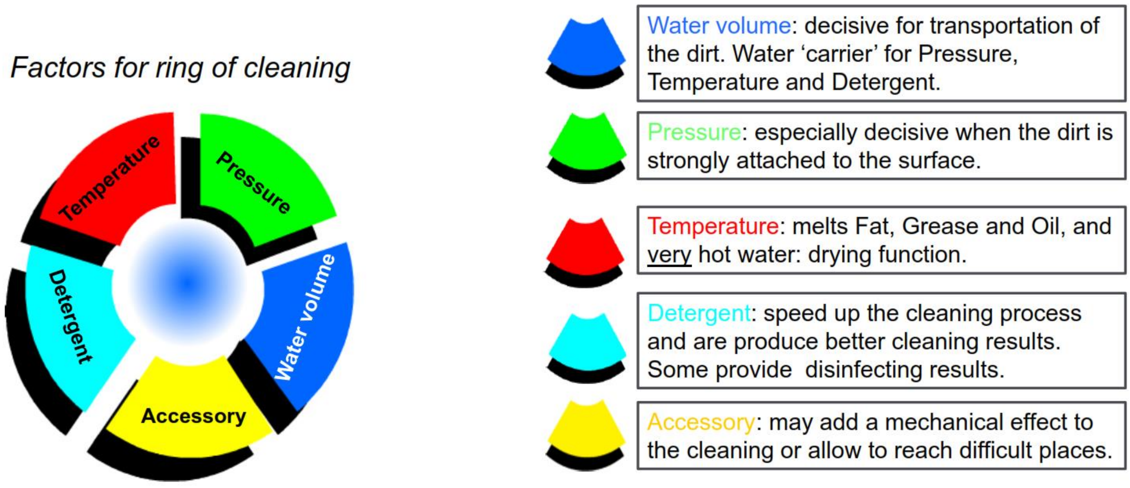


Figure 18. Cycle of the basic factors for cleaning (provided by the manufacturer Nilfisk)

The figure shows the parameters to be taken into account in the selection of the HPC for the specific cleaning purposes regarding water volume, pressure and ability to heat water, add detergent and use specialised accessories. Furthermore, after purchase, the specific cleaning task should determine the operator's choice of water volume, pressure, temperature (in case of a hot water HPC), detergent dosage and possible accessory.

3.2.2 Frequency and time of use

Through the questionnaire, the study team received estimates on frequency and the time of use is from an industry organisation, two manufactures and a consumer organisation, as shown in Table 17.

Table 17: Stakeholder information on usage patterns

Type of HPC	**Stakeholder 1**	**Stakeholder 2**	**Stakeholder 3**	**Stakeholder 4**	**Stakeholder 5**
Domestic HPC	12 uses/year, average duration of 10-30 minutes/use Totally: 2-6 hours/year	25 uses/year, average duration of 10-20 minutes/ time Totally: 4-8 hours/year	25 uses/year, average duration of 2 hours Totally: 50 hours/year	15 uses/year, average duration of 1 to 3 hours Totally: 15-45 hours/year	26 hours/year
Professional HPC	50-55 uses/year, average duration of 3 hours/use Totally: 150 hours/year	250 uses/year, average duration of 30 minutes/use Totally: 125 hours/year	100 uses/year, average duration of 2 hours/use Totally: 200 hours/year	No information	800/900 hours/year

As observed in the table, there is an apparent gap between the stakeholders' replies, ranging from 2 to 8 hours per year, and up to 50 hours per year. Large variations in replies regarding the usage pattern can also be observed for professional HPCs.

To better address the uncertainty in the usage patterns of domestic and professional HPCs, two scenarios were considered based on the stakeholders' input (see Table 18): i) a 'conservative' low usage scenario, and ii) a high usage scenario.

Based on the above figures, the study team established the assumptions of active annual use for domestic and professional HPCs presented in Table 48. Due to the uncertainty in the assumptions – which will considerably influence the following analyses – we provide a range of usage times and the average for both low and high usage scenarios, which will be used in all the analyses in this report.

Stationary cleaners are used for a variety of purposes in agriculture, industry, shipping and the food industry with very different usage patterns. No information or data was received on the usage. The study team has assumed the same usage pattern as for professional HPCs.

Table 18. Assumptions of annual hours of active use

Type of HPC	**Low usage scenario** **Annual usage in hours/year**	**High usage scenario** **Annual usage in hours/year**
Domestic HPC	2-8, average: 5	2-50, average: 26

Professional HPC	100-200, average: 150	100-900, average: 500
Stationary HPC	100-200, average: 150	100-900, average: 500

Due to the uncertainties on the annual usage, the following analyses on energy, water and detergent consumption are performed both with the 'low usage scenario' and the 'high usage scenario' to provide an uncertainty range.

3.2.3 Use of hot water

Most of the HPCs use cold water in the cleaning process, but for some cleaning tasks, especially for removing grease and oil from surfaces, hot water will enhance the cleaning process.

Typically, users needing hot water cleaning would acquire a hot water HPC, which heats the water internally using electricity or fuels. However, it is often also possible to connect a hot water supply to the HPC, which then is able to clean using externally heated hot water up to a certain temperature limit informed by the supplier.

These two usage situations are described below. The water heating technology is detailed in Chapter 4.

3.2.3.1 Use of internally heated hot water

When cleaning tasks require hot water, the solution is most often an HPC with a hot water heater built in. Based on the market research, this is only seen in the professional segment.

The maximum pressure delivered is typically lower for hot water machines due to the pressure requirements of the heating coils. This is further detailed in Task 4.

The data set with technical data collected from the manufacturers' web sites shows that the average pressure for hot water HPCs is about 20% lower than for cold water machines. This also means that when a user buys a hot water HPC, which delivers lower pressure and is more expensive (due to the hot water system) than a cold water HPC, it is because there is a real need for hot water for a substantial part of the use. The study team has assumed that half of the use of a hot water machine (both mobile and stationary professional machines) is with production of hot water.

3.2.3.2 Use of externally heated hot water

Many cold water HPCs including domestic types can be supplied with either cold or hot water up to a certain temperature. The maximum temperature is set by the manufacturer and determined by the materials, often the plastic components used in the low and high pressure water system. The temperature is stated in technical specifications and in the user manual.

The supply will typically be from the building's hot sanitary water system. In our data set of products on the market, 90% of all products (160 in total) allow supply of water at temperatures above cold water temperature, while 54% of them allow temperatures above 50 °C and 40% above 60 °C. Traditionally, a building's hot water system produces water between 50 °C and 60 °C. The energy consumption for heating the water is thus not part of the energy consumption of the HPC and it has an indirect energy consumption effect, which will be included in the analyses in Section 3.3.

A limitation of the use of a hot water supply is the availability of hot water taps outside, where HPCs often are used. Where outside water taps are available, most often they are cold water taps. Manufacturer input confirms that connection of hot water to the HPC does not usually take place. Apart from expert opinions, no data was available. The study team has estimated a relatively low share of use of externally heated hot water, namely 5%, and only for domestic cold water HPCs and professional cold water HPCs with electric motors.

3.2.3.3 Assumptions for use of hot water

Based on the above assessments, Table 19 presents the assumed proportion of hot water for the main categories of HPC. The proportion is related to the total annual usage time.

Table 19. Assumed proportion of hot water (%) used for main HPC categories

Type of HPC	Proportion of hot water (%)
Cold water HPC (externally heated hot water)	5
Hot water HPC (internally heated hot water)	50
Cold water stationary HPC	0
Hot water stationary HPC (internally heated hot water)	50

3.2.4 Use of detergents

3.2.4.1 Aim and precautions

Adding detergents to the water will increase the cleaning efficiency by reducing the surface tension. However, most dosage systems are simple and may add excessive detergent compared to the need. Furthermore, the rinse stage to remove the dirt requires extra water to remove the detergent.

3.2.4.2 Dispensing systems and size

Chapter 4 describes details of the detergent dispensing systems. A conclusion is that the dosage regulation systems are very imprecise, and it is not possible to select a specific required amount of detergent.

Of the 160 HPCs in the dataset of marketed HPCs, 40 informed about the maximum detergent dosage in litres/minute. With this figure, we calculated the maximum dosage as a percentage of the maximum water flow rate. The minimum, average and maximum percentage dosages are shown in Table 20.

Table 20. Minimum, average and maximum detergent dosage

Detergent dosage	Litres/minute	% of max flow
Minimum	0.30	2.6%
Average	0.66	5.5%
Maximum	1.33	8.0%

Only 4 of the 40 models stating dosage data are domestic HPCs and the average of their maximum dosages was 20% lower than for the professional HPCs, but with only 4 data points for domestic HPCs the sample is too small to use this figure for all domestic HPCs.

It is assumed that when using detergent, the dosage will in average be lower than the maximum dosage. Here it is assumed that the average dosage is approximately half of the maximum dosage, i.e. half of the average maximum dosage provided in the table (5.5%), totally about 2%. This figure is used in the calculations of the detergent consumption.

3.2.4.3 Types of detergents

There are a broad variety of detergents and other cleaning agents like soaps sold under HPC manufacturer brands and under other brands. They include detergents for universal types of cleaning and specialised detergents for cleaning specific materials such as wood or natural stone, vehicle exteriors, and for grease removal, paint removal (e.g. for graffiti) disinfection, etc. Biodegradable detergents also exist.

3.2.5 Use phase resource consumption

The use phase resource consumption includes energy (electricity and fuel), water and detergent consumption. The following analyses are based on both the ‘low usage scenario’ and the ‘high usage scenario’ (see Table 18).

3.2.5.1 Energy consumption

HPCs consume energy for the motor and control systems and in the case of hot water HPCs also for heating. The energy for the motor and the heating system can be either electricity or fuel (petrol, diesel) in these combinations:

- electric motor;
- electric motor and fuel heater;
- electric motor and electric heater; this is a special case and added as a subcategory in this section;
- fuel (combustion) motor;
- fuel (combustion) motor and fuel heater.

That is to say, for electric motor HPCs, the energy consumed may be both electricity and fuel, while for combustion motors only fuel is consumed.

Only consumption during active use is included, i.e. energy consumption in off and standby modes and in on-idle mode is not included. For domestic HPCs, laboratory test data that has been provided by a stakeholder do not include energy consumption data in low power modes (off and standby) and in on mode with the spray turned off. All have a 'deadman' trigger switch, i.e. when the handle is not pressed, the HPC does not spray and is not in use. The professional types also have such a function, though some machines are still active at a lower consumption level for a limited period of time. No further data was available, but the consumption impact is assumed to be marginal and has not been included in the analyses.

The technologies are described in Chapter 4.

Table 21 and Table 22 present the calculated annual use phase energy consumption for the low usage scenario for an average model in each category with an electric motor and a combustion motor, respectively. After the tables, the assumptions and the calculations are shown. The following Table 23 and Table 24 present the same calculations for the high usage scenario using the same assumptions apart from the annual usage figures.

Table 21. Calculated use phase annual energy consumption of the 'Low usage scenario', for the range of annual usage and average model in each category with electric motor

Type of HPC	**Average load motor (kW)**	**Annual usage** **Range and average (hours/year)**	**Annual electricity consumption** **Range and average (kWh/year)**	**Annual fuel consumption** **Range and average (kWh/year)**
Domestic cold water	1.8	2-8, average: 5	4-14, average: 9	
Professional cold water 1-phase	2.9	100-200, average: 150	294-587, average: 440	
Professional cold water 3-phase	7.7	100-200, average: 150	766-1533, average: 1150	
Professional hot water 1-phase	2.5	100-200, average: 150 (50% with hot water)	254-507, average: 380	1801-3603, average: 2702
Professional hot water 3-phase	6.7	100-200, average: 150 (50% with hot water)	674-1348, average: 1011	3545-7090, average: 5318
Professional hot water 3-phase, electric heater	5.0	100-200, average: 150 (50% with hot water)	1695-3390, average: 2543	

Stationary cold water	13.9	100-200, average: 150	1385-2770, average: 2078	
Stationary hot water	6.8	100-200, average: 150 (50% with hot water)	683-1366, average: 1024	3888-7776, average: 5832

Assumptions and calculations:

- Average load motor: The load is calculated from the maximum connected load (nameplate power, for HPCs with an electric heater, the heat load is subtracted) reduced by 10%. The maximum connected load is typically higher during start-up than continuous operation at maximum working pressure. The reduction, 10%, is approximate and based on an average reduction from the dataset, where the actual power load was measured at maximum working pressure.
- Annual hours of use: Assumptions presented in Table 48.
- Annual electricity consumption: Multiplication of average load and annual hours of use. For the electric heater HPC, the figure is corrected for 50% hot water use, see Table 19.
- Annual fuel consumption: This is calculated using the full load heating oil consumption (kg/h) from the dataset, multiplied by 50% hot water usage of annual hours of use and converted to kWh with the net calorific value (gas/diesel oil 43.38 MJ/kg[41]).

Table 22. Calculated use phase annual energy consumption of the 'Low usage scenario', for the range of annual usage and average model in each category with a combustion motor

Type of HPC	**Fuel consumption motor (kg/h)**	**Fuel consumption heating (kg/h)**	**Annual usage** **Range and average (hours/year)**	**Annual fuel consumption** **Range and average (kWh/year)**
Professional cold water combustion	2.87		100-200, average: 150	3457-6914, average: 5185
Professional hot water combustion	2.67	5.50	100-200, average: 150 (50% with hot water)	6537-13074, average: 9805

Assumptions and calculations:

- Fuel consumption motor: It is calculated based on data for a specific motor used for several combustion HPCs, Honda GW 270, which consumes 2.4 litres of petrol per hour to deliver 5.1 kW (continuous rated power) at max rpm corresponding to 0.3486 kg/h/kW. Only data for a petrol motor is used because 8 of 11 combustion motor HPCs are petrol ones.
- Fuel consumption heating: From the dataset of products on the market.
- Annual hours of use: Assumptions presented in Table 48.
- Annual fuel consumption: It is calculated with the sum of motor fuel consumption multiplied by annual hours of use plus fuel (gas oil) consumption heating (kg/h) from the dataset, multiplied by 50% hot water usage of annual hours of use and converted to kWh with the net calorific value (gas/diesel oil 43.38 MJ/kg[4]).

[41] "Energy Statistics MANUAL" OECD, IEA, Eurostat. http://ec.europa.eu/eurostat/ramon/statmanuals/files/Energy_statistics_manual_2004_EN.pdf

Table 23. Calculated use phase annual energy consumption of the 'High usage scenario', for the range of annual usage and average model in each category with electric motor

Type of HPC	Average load motor (kW)	Annual usage Range and average (hours/year)	Annual electricity consumption Range and average (kWh/year)	Annual fuel consumption Range and average (kWh/year)
Domestic cold water	1.8	2-50, average: 26	4-90, average: 47	
Professional cold water 1-phase	2.9	100-900, average: 500	294-2642, average: 1468	
Professional cold water 3-phase	7.7	100-900, average: 500	766-6898, average: 3832	
Professional hot water 1-phase	2.5	100-900, average: 500 (50% with hot water)	254-2282, average: 1268	1801-16213, average: 9007
Professional hot water 3-phase	6.7	100-900, average: 500 (50% with hot water)	674-6066, average: 3370	3545-31907, average: 17726
Professional hot water 3-phase, electric heater	5.0	100-900, average: 500 (50% with hot water)	1695-15255, average: 8475	
Stationary cold water	13.9	100-900, average: 500	1385-12465, average: 6925	
Stationary hot water	6.8	100-900, average: 500 (50% with hot water)	683-6146, average: 3414	3888-34993, average: 19441

Table 24. Calculated use phase annual energy consumption of the 'High usage scenario', for the range of annual usage and average model in each category with a combustion motor

Type of HPC	Fuel consumption motor (kg/h)	Fuel consumption heating (kg/h)	Annual usage Range and average (hours/year)	Annual fuel consumption Range and average (kWh/year)
Professional cold water combustion	2.87		100-900, average: 500	3457-31113, average: 17285

Professional hot water combustion	2.67	5.50	100-900, average: 500 (50% with hot water)	6537-58833, average: 32685

3.2.5.2 Water consumption

The calculated annual water consumption in the use phase for an average model in the low usage scenario in each category is shown in Table 25. After the table, the assumptions and the calculations are shown. The following Table 26 presents the same calculations for the high usage scenario using the same assumptions apart from the annual usage figures.

Table 25. Calculated use phase annual water consumption of the 'low usage scenario', for the range of annual usage and average model in each category

Type of HPC	**Average in-use water flow (l/h)**	**Annual usage** **Range and average (hours/year)**	**Annual water consumption** **Range and average (m^3/year)**
Domestic cold water	383	2-8, average: 5	1-3, average: 2
Professional cold water single-phase	540	100-200, average: 150	54-108, average: 81
Professional cold water three-phase	992	100-200, average: 150	99-198, average: 149
Professional cold water combustion engine	687	100-200, average: 150	69-137, average: 103
Professional hot water single -phase	463	100-200, average: 150	46-93, average: 69
Professional hot water three-phase	969	100-200, average: 150	97-194, average: 145
Professional hot water three-phase, electric heater	646	100-200, average: 150	65-129, average: 97
Professional hot water combustion engine	706	100-200, average: 150	71-141, average: 106
Stationary cold water	2528	100-200, average: 150	253-506, average: 379
Stationary hot water	889	100-200, average: 150	89-178, average: 133

Assumptions and calculations:

- Average in-use water flow: Based on the dataset of marketed HPCs combined with the dataset from laboratory tests of domestic HPCs. These tests show:

- average rated maximum flow (l/h) of all products: 429 l/h;
- average in-use maximum water flow with standard nozzle: 375 l/h.

- The in-use maximum water flow is 13% lower than the rated maximum flow. For the average in-use water consumption we assume a slightly higher reduction of the rated maximum flow, i.e. 15%, to account for situations where the maximum flow rate is not used. We use the same figure for all categories in the absence of specific data for the other categories. This figure is used to calculate the in-use water flow based on the average rated maximum flow (l/h) from the dataset of marketed HPCs.
- Annual hours of use: From Table 48.
- Annual water consumption: The water flow per hour is multiplied by the annual hours of use per year.

Table 26. Calculated use phase annual water consumption of the 'high usage scenario', for the range of annual usage and average model in each category

Type of HPC	Average in-use water flow (l/h)	Annual usage Range and average (hours/year)	Annual water consumption Range and average (m^3/year)
Domestic cold water	383	2-50, average: 26	1-19, average: 10
Professional cold water single-phase	540	100-900, average: 500	54-486, average: 270
Professional cold water three-phase	992	100-900, average: 500	99-892, average: 496
Professional cold water combustion engine	687	100-900, average: 500	69-619, average: 344
Professional hot water single-phase	463	100-900, average: 500	46-416, average: 231
Professional hot water three-phase	969	100-900, average: 500	97-872, average: 485
Professional hot water three-phase, electric heater	646	100-900, average: 500	65-581, average: 323
Professional hot water combustion engine	706	100-900, average: 500	71-635, average: 353
Stationary cold water	2528	100-900, average: 500	253-2275, average: 1264
Stationary hot water	889	100-900, average: 500	89-800, average: 444

3.2.5.3 Detergent consumption

We have found no data on specific uses of detergent; only general advice to consumers on detergent use. The consumer organisation *Which?* specifically recommends use of detergent for car washing but does not mention it for other purposes. Another consumer organisation advises in most cases not to use a detergent and only for grease removal. This organisation also states that a HPC in general uses more detergent than needed due to poor regulation of the amount added and that in many areas it is forbidden to clean cars with detergent.

The calculated annual detergent consumption in the use phase for the range of annual usage and for an average model in each category for the low usage scenario is shown in Table 27. After the table, the assumptions and the calculations are shown. The following Table 28 presents the same calculations for the high usage scenario using the same assumptions apart from the annual usage figures.

Table 27. Calculated use phase annual detergent consumption of the 'low usage scenario', for the range of annual usage and average model in each category

Type of HPC	**Annual water consumption** **Range and average (m^3/year)**	**Proportion using detergent (%)**	**Annual detergent consumption** **Range and average (l/year)**
Domestic cold water	1-3, average: 2	3	0-2, average: 1
Professional cold water single-phase	54-108, average: 81	3	32-65, average: 49
Professional cold water three-phase	99-198, average: 149	3	59-119, average: 89
Professional cold water combustion engine	69-137, average: 103	3	41-82, average: 62
Professional hot water single-phase	46-93, average: 69	3	28-56, average: 42
Professional hot water three-phase	97-194, average: 145	3	58-116, average: 87
Professional hot water three-phase, electric heater	65-129, average: 97	3	39-78, average: 58
Professional hot water combustion engine	71-141, average: 106	3	42-85, average: 63
Stationary cold water	253-506, average: 379	3	152-303, average: 228
Stationary hot water	89-178, average: 133	3	53-107, average: 80

Assumptions and calculations:

- Annual water consumption: From Table 25.
- Proportion using detergent: We have assumed that domestic users mainly use detergent for cleaning of cars, motorbikes and bikes and that professional users also use detergent for vehicles and for a variety of other specific cleaning tasks, such as disinfection in food processing and for graffiti removal. No information has been received on how much detergent is used. 2 % of all pressurised water use is assumed to be with added detergent.
- Annual detergent consumption: The annual water consumption is multiplied by the proportion using detergent and by the average dosage (2% as indicated in Section 3.2.4.2).

Table 28. Calculated use phase annual detergent consumption of the 'high usage scenario', for the range of annual usage and average model in each category

Type of HPC	**Annual water consumption** **Range and average (m^3/year)**	**Proportion using detergent** **(%)**	**Annual detergent consumption** **Range and average (l/year)**
Domestic cold water	1-19, average: 10	3	0-12, average: 6
Professional cold water single-phase	54-486, average: 270	3	32-292, average: 162
Professional cold water three-phase	99-892, average: 496	3	59-535, average: 297
Professional cold water combustion engine	69-619, average: 344	3	41-371, average: 206
Professional hot water single-phase	46-416, average: 231	3	28-250, average: 139
Professional hot water three-phase	97-872, average: 485	3	58-523, average: 291
Professional hot water three-phase, electric heater	65-581, average: 323	3	39-349, average: 194
Professional hot water combustion engine	71-635, average: 353	3	42-381, average: 212
Stationary cold water	253-2275, average: 1264	3	152-1365, average: 758
Stationary hot water	89-800, average: 444	3	53-480, average: 267

3.3 System aspects of the use phase, for ErP with indirect energy consumption effects

There are two indirect energy consumption effects described in the following sections.

3.3.1 Energy consumption effect of hot water externally heated

The first effect is - as described in Section 3.2.3 - due to a usage situation for cold water HPCs where they are connected to hot instead of cold water from a building's sanitary hot water system. In this usage situation, the HPC delivers hot water heated externally and the affected energy system is not only the HPC consuming energy but also the hot water heater consuming energy for heating the water. This energy consumption needs to be included in the analyses to reflect the full impact.

The extent of this usage situation is described in Section 3.2.3, where the energy consumption effect is calculated.

According to the preparatory study for eco-design of water heaters[42], an assumption for the energy calculations is a cold water supply temperature of 10 °C, which is heated to 60 °C. We use the same assumption here.

For the type of water heater and energy used to heat the water, we use the following approximate assumption based on the preparatory study for eco-design of water heaters[43]:

- 60 % natural gas water heaters and combi boilers;
- 40 % electric storage and instantaneous heaters.

The calculated annual energy consumption in the use phase for an average model in each relevant category is shown in Table 29. After the table, the assumptions and the calculations are shown. The following Table 30 presents the same calculations for the high usage scenario using the same assumptions apart from the annual usage figures.

Table 29. Calculated use phase annual energy consumption for externally heated hot water of the 'low usage scenario', for the range of annual usage and average model in each relevant category

Type of HPC	**Annual water consumption** **Range and average (m^3/year)**	**Proportion of hot water externally heated (%)**	**Annual heated water consumption** **Range and average (m^3/year)**	**Natural gas consumption** **Range and average (kWh/year)**	**Electricity consumption** **Range and average (kWh/year)**
Domestic cold water HPC	1-3, average: 2	5	0.04-0.15, average: 0.1	2-7, average: 4	1-4, average: 2
Professional cold water single-phase	54-108, average: 81	5	3-5, average: 4	118-236, average: 177	63-126, average: 94
Professional cold water three-phase	99-198, average: 149	5	5-10, average: 7	216-432, average: 324	115-231, average: 173

Assumptions and calculations:

- Annual water consumption: From Table 25.
- Proportion of externally heated hot water: From Table 19.
- Annual heated water consumption: Annual water consumption multiplied by proportion of externally heated hot water.
- Natural gas consumption: Calculated as heating the water to 50 °C with 80% (referred to net calorific values) boiler efficiency multiplied by 60% (proportion for natural gas, see above).
- Electricity consumption: Calculated as heating the water to 50 °C with 100% efficiency multiplied by 40% (proportion for electricity, see above).

Table 30. Calculated use phase annual energy consumption for externally heated hot water of the 'high usage scenario', for the range of annual usage and average model in each relevant category

Type of HPC	**Annual water consumption**	**Proportion of hot water externally heated (%)**	**Annual heated water consumption**	**Natural gas consumption**	**Electricity consumption**

[42] Preparatory Study on Eco-design of Water Heaters – Task 3 Report (Final). VHK. 2007.
[43] Preparatory Study on Eco-design of Water Heaters – Task 2 Report (Final). VHK. 2007.

	Range and average (m^3/year)		Range and average (m^3/year)	Range and average (kWh/year)	Range and average (kWh/year)
Domestic cold water HPC	1-19, average: 10	5	0.04-0.96, average: 0.5	2-42, average: 22	1-22, average: 12
Professional cold water single-phase	54-486, average: 270	5	3-24, average: 14	118-1060, average: 589	63-565, average: 314
Professional cold water three-phase	99-892, average: 496	5	5-45, average: 25	216-1946, average: 1081	115-1038, average: 576

3.3.2 Energy consumption effect of the water supply

The other indirect energy consumption effect is due to the energy consumption of the public water grid and the sewage system for supplying and disposing of water used by the HPC. The amount of water to be disposed of is less than the water supplied because not all water used will go into the sewage system; some will soak into the ground and soil.

For the purpose of this study, reduction of water consumption will be analysed and reported as the amount of water saved and not in terms of saved energy in the public water supply because it is small compared to the HPC energy consumption.[44].

3.4 Total use phase resource impacts

Table 31 shows the total resource impacts of the 'low usage scenario' in terms of consumption of electricity, fuel (diesel, petrol and natural gas), water and detergent covering both the direct and the indirect energy consumption effects. The following Table 32 presents the same calculations for the 'high usage scenario'. The figures are totals of the figures of the previous tables.

Table 31. Total use phase annual electricity, fuel, water and detergent consumption of the 'low usage scenario', for the range of annual usage and average model in each category summarising the figures in previous tables

Type of HPC	Annual electricity consumption Range and average (kWh/year)	Annual fuel consumption Range and average (kWh/year)	Annual water consumption Range and average (m^3/year)	Annual detergent consumption Range and average (l/year)
Domestic cold water	4-18, average: 11	2-7, average: 4	1-3, average: 2	0-2, average: 1
Professional cold water single-phase	356-713, average: 534	118-236, average: 177	54-108, average: 81	32-65, average: 49
Professional cold water three-phase	882-1764, average: 1323	216-432, average: 324	99-198, average: 149	59-119, average: 89

[44] Methodology for Ecodesign of Energy-related Products. MEErP 2011. Methodology Report. Part 1: Methods page 66, 3.4 Example shower head or water tap

Professional cold water combustion engine	0	3457-6914, average: 5185	69-137, average: 103	41-82, average: 62
Professional hot water single-phase	254-507, average: 380	1801-3603, average: 2702	46-93, average: 69	28-56, average: 42
Professional hot water three-phase	674-1348, average: 1011	3545-7090, average: 5318	97-194, average: 145	58-116, average: 87
Professional hot water three-phase electric heater	1695-3390, average: 2543	0	65-129, average: 97	39-78, average: 58
Professional hot water combustion engine	0	6537-13074, average: 9805	71-141, average: 106	42-85, average: 63
Stationary cold water	1385-2770, average: 2078	0	253-506, average: 379	152-303, average: 228
Stationary hot water	683-1366, average: 1024	3888-7776, average: 5832	89-178, average: 133	53-107, average: 80

Table 32. Total use phase annual electricity, fuel, water and detergent consumption of the 'high usage scenario', for the range of annual usage and average model in each category summarising the figures in previous tables

Type of HPC	**Annual electricity consumption** **Range and average (kWh/year)**	**Annual fuel consumption** **Range and average (kWh/year)**	**Annual water consumption** **Range and average (m^3/year)**	**Annual detergent consumption** **Range and average (l/year)**
Domestic cold water	4-112, average: 58	2-42, average: 22	1-19, average: 10	0-12, average: 6
Professional cold water single-phase	882-7936, average: 4409	216-1946, average: 1081	99-892, average: 496	59-535, average: 297
Professional cold water three-phase	0	3457-31113, average: 17285	69-619, average: 344	41-371, average: 206
Professional cold water combustion engine	254-2282, average: 1268	1801-16213, average: 9007	46-416, average: 231	28-250, average: 139

Professional hot water single-phase	674-6066, average: 3370	3545-31907, average: 17726	97-872, average: 485	58-523, average: 291
Professional hot water three-phase	1695-15255, average: 8475	0	65-581, average: 323	39-349, average: 194
Professional hot water three-phase electric heater	0	6537-58833, average: 32685	71-635, average: 353	42-381, average: 212
Professional hot water combustion engine	1385-12465, average: 6925	0	253-2275, average: 1264	152-1365, average: 758
Stationary cold water	683-6146, average: 3414	3888-34993, average: 19441	89-800, average: 444	53-480, average: 267
Stationary hot water	356-3207, average: 1782	118-1060, average: 589	54-486, average: 270	32-292, average: 162

3.5 Cleaning performance test methods reflecting typical usages

3.5.1 Opportunities for cleaning performance test methods

As described in Chapter 1, no commonly used cleaning performance test method in the industry exists. Some manufacturers use their own test method when designing new products; others just use different kinds of dirty surfaces. In the following subsections we describe briefly four different real-life test methods used in tests of HPCs.

3.5.2 Examples of test methods

3.5.2.1 Intertek US

Intertek US has developed a cleaning power index from a number of factors: System force (based on unit and nozzle), impact force (based on the actual force at the tip of the hose, pre-gun) and a spray pattern shape factor (based on an internally developed grid applied to each pattern). Each component is indexed against limits rather than against each other. These factors were weighted 40:20:40 resulting in one index figure for each product.

3.5.2.2 Intertek UK

Intertek UK uses defined test surfaces in the form of painted insulation panels with matte black paint (simulating soiling) applied in a standardised way so the soiling level is consistent. The HPC is fixed in a rig at a defined height to optimise the performance of the pressure washer. The soiled insulation tiles are run under the cleaning water jet at a set speed. The width of the soiled tile that is cleaned by the HPC is measured. This figure is translated into real-life performance. In other words, if a pressure washer was able to clean a large width, this would translate to cleaning a large area in a given period of time and in a practical situation it would clean a large external area. Consequently, the pressure washer would be relatively effective and rapid at the cleaning task. Conversely, if a pressure washer was only capable of cleaning a narrow strip, this would translate to cleaning only a small area in a given period of time. This pressure washer would be relatively ineffective and slow at the cleaning task.

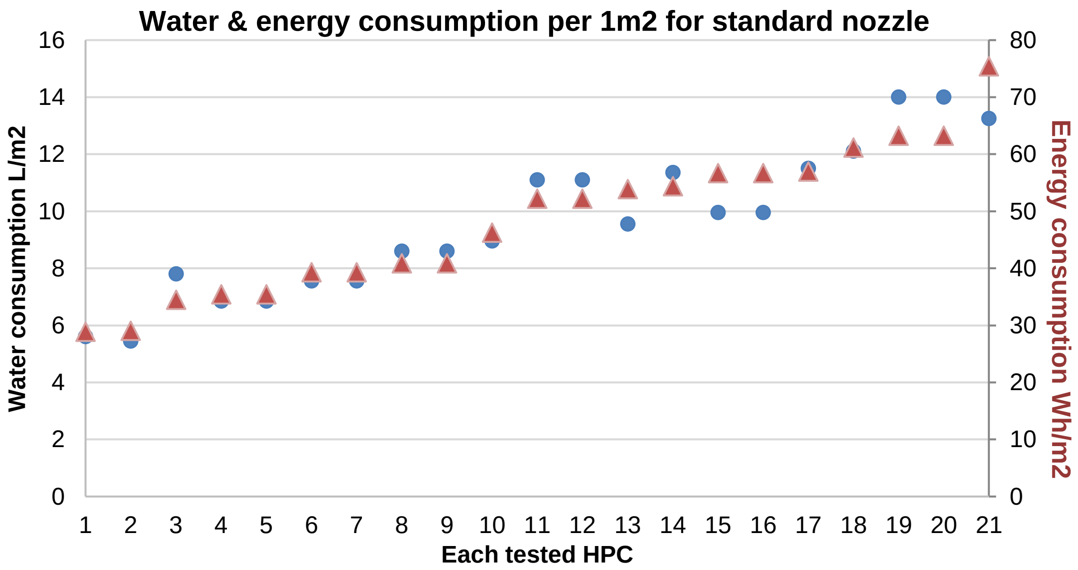
3.5.2.3 *Cleaning performance and durability laboratory tests for domestic HPCs*

A stakeholder has provided recent (2017) tests conducted in an external test laboratory for 43 domestic HPCs for a broad range of parameters including the performance. Their performance test consists of laboratory tests and real-life tests.

The laboratory test used foam panels soiled with water-based paint, where the spray nozzle moved at predefined speed over the panel. The width of the paint removed was quantified by two options: All paint removed and some paint removed. The uniformity of the cleaning was also measured. The test is done with a spray nozzle and with a rotating jet nozzle. The test reported that the width of the effective cleaning for the spray nozzle was 40-65 mm, mainly due to the construction of the nozzle. The rotating nozzle was reported to have a wider effective cleaning width, 45-135 mm.

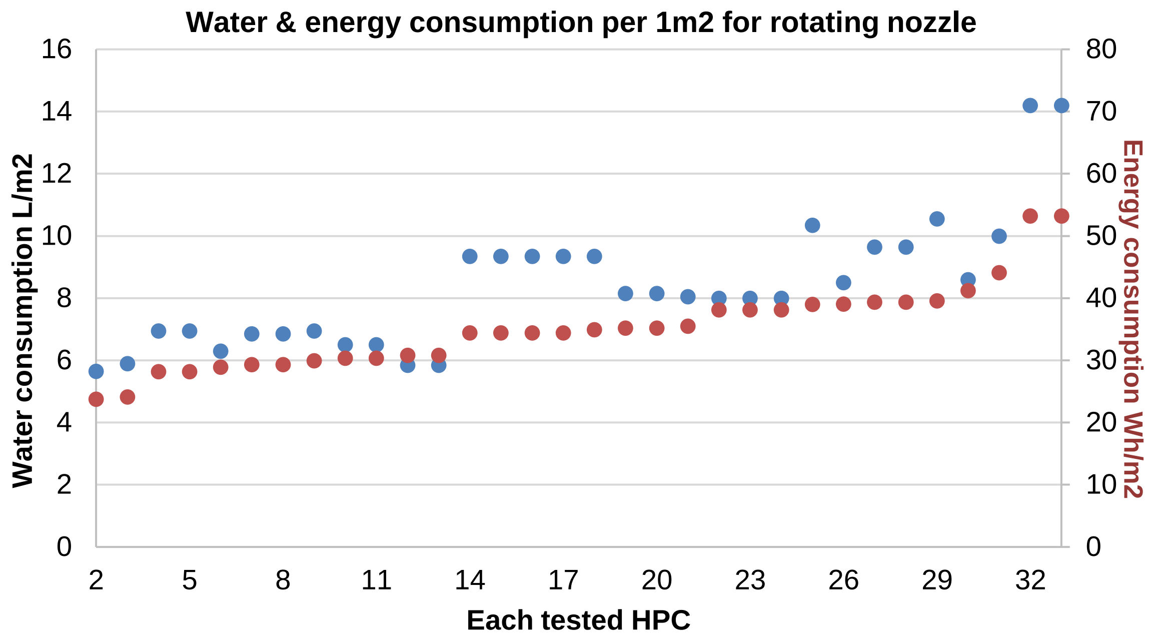
The real-life test consisted of cleaning of 1 m^2 of dirty pavement, recording and assessing the time for cleaning, quality of cleaning, water consumption, etc. Energy consumption can be calculated by the time for cleaning and a measured value for power at use. Tests were performed twice by different test experts to ensure uniformity. In the following figures, we show the results of the tests (average of the two tests) with a standard nozzle and a rotating nozzle for all tests with a sufficient and similar cleaning quality according to a qualitative assessment by two experts carrying out the tests. It has to be noted that manufacturers warn against the use of a rotating jet nozzle for cleaning vehicles or bicycles as it could cause damage to paint, tyres, tyre valves or ingress of water into bearings if used at too close a distance.

Figure 19 and Figure 20 show a large variation in water and energy consumption for the same cleaning task using the standard nozzle. The most consuming HPC consumes 2.6 times more water and energy than the least consuming HPC. More information about the results of these tests and the specifications of the models tested is available in Section 4.



NB: Average values are 10 l/m² and 48 Wh/m².

Figure 19. Water and energy consumption for cleaning 1 m^2 of pavement with a standard nozzle



NB: Averages are 8 l/m² and 35 Wh/m².

Figure 20. Water and energy consumption for cleaning 1 m² of pavement with a rotating nozzle

The figures show significant variations in water and energy consumption for the same cleaning task using the rotating nozzle. The most consuming HPC consumes 2.9 times more water and 2.5 times more energy than the least consuming HPC.

Laboratory tests were also performed with durability tests consisting of 300 cycles, each of them lasting 40 minutes: 15 minutes with highest pressure and maximum water flow, 3 minutes with a closed nozzle jet and the machine on, 12 minutes with the highest pressure and maximum water flow and 10 minutes pause. The durability tests are performed with a standard nozzle as well as with a rotating nozzle. As can be seen from Figure 21, not all HPCs survived the 300 cycles; 21.5% even failed prior to reaching 140 cycles. This indicates the large variation in durability performance of domestic HPCs.

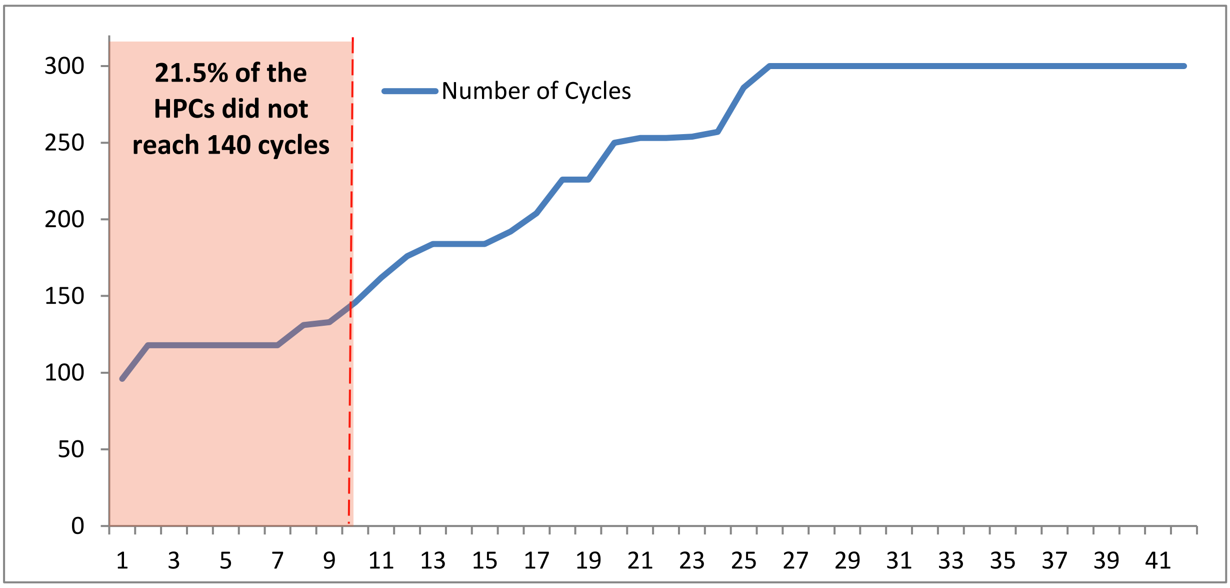


Figure 21. Durability tests of domestic HPCs for 300 cycles

3.5.2.4 Which?

Which? (independent UK consumer organisation) regularly tests domestic HPCs in relation to their consumer information[45]. Their performance test consists of manual testing by experienced testers. They wash a 1 m^2 patch of several different types of surface including concrete, block paving, paving slabs, and softwood decking. The surfaces are consistently and heavily soiled.

The surfaces are cleaned using the main lance and fan nozzle. They measure how long it takes and rate how clean the surfaces are. They also look for any signs that the pressure washer has damaged the surface or material between slabs and paving blocks during cleaning. In addition, they test what surface area of concrete can be cleaned in one minute. They also assess how well the pressure washer cleans the bodywork, windows and wheels of a heavily soiled car.[46]

3.6 End-of-life behaviour

The user end-of-life behaviour substantially influences the life-cycle environmental impact. If the real-life lifetime is short due to no maintenance or replacement before the HPC is worn out without giving the product a second life or if the user does not dispose of the HPC correctly as electrical waste, it will have a negative environmental impact. This is further described below.

In Task 2 the lifetime used for the modelling is described, while in Task 4 the technical lifetime is analysed.

3.6.1 Product life influenced by user behaviour

Longer-lasting products often have the potential to reduce their overall life cycle impacts. With a longer lifetime, the impact of consumption of raw materials is reduced since the impacts of mining, production, transportation, etc. are spread over a longer period of time and displace the need for new equipment[47]. The product lifetime can be interpreted in numerous ways. Different definitions exist (see Table 33) from other Ecodesign studies[48].

Table 33. Definitions of lifetime

The design lifetime	**The behavioural lifetime**	**Definition used in this study**
Intended lifetime regarding functioning time, the number of functioning cycles etc. foreseen by the manufacturer during design of the product, provided that it is used and maintained by the user as intended.	The number of years until the device is replaced for reasons other than technical failure, e.g. due to new features, upgrading to a more powerful model or just wanting a new model.	The term “lifetime” used in this study must be understood as the period (i.e. the number of years) during which the appliance is used and consumes electricity.

Very little information is available on the behavioural lifetime. A Belgian study[49] identified the HPC penetration in Belgian households to be 39% in 2015, where the households with HPCs each had 1.1 on average. This could indicate that some households had one or several older HPCs which were probably not in use. The study further found that defective HPCs were not always disposed of and might have been counted as in use.

3.6.2 Collection rates by fraction

Following the WEEE Directive[50], high pressure cleaners (falling under the category 'Electrical and electronic tools') must be collected at end-of-life and sent to suitable facilities for proper treatment incl. re-use, recovery or recycling. The directive requires that each Member State sets minimum annual collection rates expressed as a percentage of the average weight of electrical and electronic equipment placed on the market in the three preceding years in that Member State (45% from 2016 and 65% from 2019) with a few exemptions.

[45] https://www.which.co.uk/reviews/pressure-washers
[46] https://www.which.co.uk/reviews/pressure-washers/article/how-we-test-pressure-washers
[47] Deloitte (2016) Study on Socioeconomic impacts of increased reparability – Final Report. Prepared for the European Commission, DG ENV.
[48] https://www.eceee.org/ecodesign/products/airco-ventilation/
[49] GFK & Recupel Belgische huishoudens: 1-meting. Confidential.
[50] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0019&from=EN

Eurostat statistics report the Member State data[51]. No statistics are available specifically for high pressure cleaners but only for the overall category 'Electrical and electronic tools', which contains also many other tools. However, we have not received any evidence for assuming that the collection rates of high pressure cleaners should be different from other electrical and electronic tools.

Table 34 shows the collection rates for 'Electrical and electronic tools' for 2016.

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

Table 34. Calculated collection rate of 'Electrical and electronic tools' in EU, 2016. Data for Italy, Cyprus, Malta and Romania were not available for 2016; instead data for 2015 or 2014 were used.

Country	Average EEE put on the market 2013-2015 Tonnes/year	WEEE collected 2016 Tonnes/year	Collection rate
Austria	4 496	2 520	56%
Belgium	15 406	4 614	30%
Bulgaria	2 073	2 403	116%
Croatia	2 083	620	30%
Cyprus	392	47	12%
Czechia	14 148	2 598	18%
Denmark	8 898	1 485	17%
Estonia	945	319	34%
Finland	9 870	866	9%
France	100 595	17 029	17%
Germany	131 243	43 731	33%
Greece	3 721	117	3%
Hungary	5 354	683	13%
Ireland	3 961	1 229	31%
Italy	34 220	13 787	40%
Latvia	1 619	468	29%
Lithuania	2 248	1 059	47%
Luxembourg	514	301	59%
Malta	2 625	56	2%
Netherlands	13 623	2 743	20%
Poland	46 873	18 047	39%
Portugal	5 123	1 704	33%
Romania	7 598	815	11%
Slovakia	3 828	1 078	28%
Slovenia	1 603	212	13%
Spain	12 428	1 703	14%
Sweden	13 284	3 481	26%
United Kingdom	96 409	22 477	23%
Austria	4 496	2 520	56%
Belgium	15 406	4 614	30%
Bulgaria	2 073	2 403	116%
Total	545 178	146 192	27%

The table shows that the average collection rate for 'Electrical and electronic tools' at EU level was just below 30% in 2016 and only six Member States comply with the required level for 2016, 45%.

3.6.3 Reuse, second product life and remanufacturing

No data was available on second-hand use and second product life. However, a quick internet search showed many used HPCs for sale[52]. Furthermore, a Belgian study[53] discovered that 10% of the HPCs in people's homes are never used.

One manufacturer of professional HPCs indicated that the market for reused products is mostly focused on professional HPCs due to their higher price and more extensive use. Remanufacturing also focuses on more high-value products such as fuel-based hot water HPCs.

3.6.4 Best practice in sustainable product use

Sustainable product use can minimise the resource impact of HPCs. Important aspects include the following:

- Purchase:
    - Properly identifying the cleaning tasks to be carried out by a HPC. For domestic consumers new to the HPC area, this may require assistance from consumer organisations (magazines, websites, guidance, etc.), shops, neighbours, etc., while professionals would seek assistance from technical salespeople, suppliers, shops, etc.
    - Identifying the right size, features, technical parameters (e.g. pressure, water flow, cold/hot water, detergent use, weight, noise, independency of water and electricity supply system) and necessary accessories relevant to the cleaning tasks, repair and maintenance availability and consideration of total costs of ownership.
    - Considering alternatives to purchase such as neighbouring or community sharing, rental, leasing etc., if available.
- Use:
    - Proper training in using the HPC
    - Using the least environmental damaging cleaning setting, i.e. cold water with no detergent and accessories best suited for the cleaning purpose.
    - Proper preparation of surfaces to be cleaned.
    - Using the HPC only when other cleaning methods such as a water hose are not sufficient or would require larger amounts of water.
    - Proper handling of the HPC after use according to the manufacturer's instruction, e.g. by emptying the pump.
    - Frequent maintenance.
- End-of-use situation:
    - If the HPC is no longer needed, the owner should consider selling it.
- End-of-life situation:
    - If the HPC is defective and it is not possible to repair it, it should be disposed of through a public collection scheme complying with the WEEE Directive.

[52] https://www.ebay.com/bhp/used-pressure-washer https://www.machineseeker.com/High-pressure-cleaners/ci-286; https://www.gumtree.com/pressure-washers

[53] GFK & Recupel Belgische huishoudens: 1-meting. Confidential.

3.7 Local infrastructure

3.7.1 Energy: Reliability, availability and nature

3.7.1.1 Electricity

The power sector is in a state of transition, moving from fossil fuels to renewable energy. The origin of the electricity is a very important factor to consider regarding both the environmental impact of using a HPC and how it may affect consumer behaviour. Within the EU there are a number of renewable energy targets for 2020 set out in the EU's Renewable Energy Directive[54]. The overall target within the EU is for 20% of its final energy consumption to come from renewable sources. The final energy consumption is the total energy consumed directly by end users, such as households, industry and agriculture. It is the energy which reaches the final consumer's door and excludes that which is used by the energy sector itself[55]. To achieve this goal of 20% from renewable sources, the different EU countries have committed to set their own individual goals, ranging from 10% in Malta to 49% in Sweden. In 2015 the share of renewable energy use in the EU was almost 17%[56]. See also the EU Reference Scenario 2016[57].

The electricity consumption is a major part of the final energy consumption and the electricity mix is highly relevant for quantifying the environmental impacts of high pressure cleaners at EU level. The electricity mix in 2015 is presented in Figure 22.

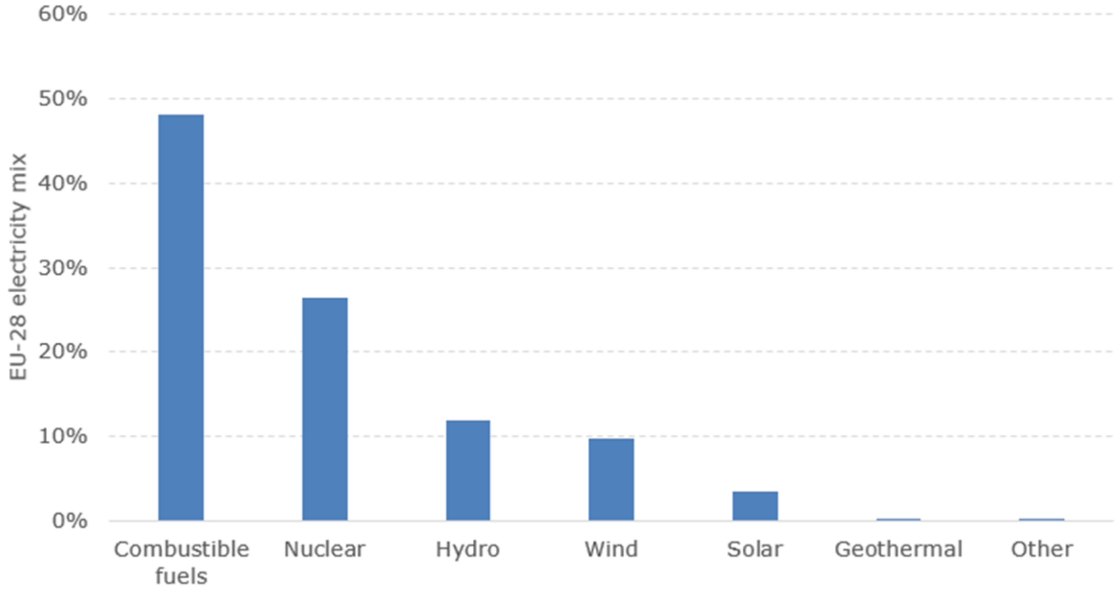


Figure 22. Net electricity generation, EU-28 in 2015 (% of total, based on GWh)[58]

Almost half of the electricity generation still originates from combustible fuels (such as natural gas, coal and oil) and renewable energy sources only constitute about 25% of the electricity generation in 2015.

The reliability of the electricity grid could, to some degree, be affected by the transition to a renewable energy system. With more renewable energy in the system new challenges occur, e.g. with excess production of wind energy and the two-directional transfer of energy (e.g. electric cars that can supply electricity to the grid when they are not in use). Renewable energy production can vary greatly from hour to hour and day to day.

[54] https://ec.europa.eu/energy/en/topics/renewable-energy
[55] http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Final_energy_consumption
[56] http://ec.europa.eu/eurostat/documents/2995521/7905983/8-14032017-BP-EN.pdf/af8b4671-fb2a-477b-b7cf-d9a28cb8beea
[57] https://ec.europa.eu/energy/sites/ener/files/documents/ref2016_report_final-web.pdf
[58] http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Net_electricity_generation,_EU-28,_2015_(%25_of_total,_based_on_GWh)_YB17.png

Due to technological developments, the reliability of the electricity supply in many EU countries is ensured via the expansion of the electricity grid to distribute renewable energy. The quality of the electricity grid in Europe is considered to be high and among the best in the world. Every year the World Economic Forum releases a Global Energy Architecture Performance Index report. The report ranks the different countries on their ability to deliver secure, affordable, sustainable energy. In recent years European countries have dominated the top spots (see Table 35[59]).

Table 35. Top spots of the global Energy Architecture Performance Index report

Country	2017 score	Economic growth and development	Environmental sustainability	Energy access and security
Switzerland	0.80	0.74	0.77	0.88
Norway	0.79	0.67	0.75	0.95
Sweden	0.78	0.63	0.80	0.90
Denmark	0.77	0.69	0.71	0.91
France	0.77	0.62	0.81	0.88
Austria	0.76	0.67	0.74	0.88
Spain	0.75	0.65	0.73	0.87
Colombia	0.75	0.73	0.68	0.83
New Zealand	0.75	0.59	0.75	0.90
Uruguay	0.74	0.69	0.71	0.82

3.7.1.2 Diesel, petrol and LPG

The reliability of diesel, petrol and LPG is high. These fuels can be bought at petrol stations or delivered directly to the user. Furthermore, there are many suppliers.

3.7.2 Water

Public water grids are available and reliable in most places. There are however differences in the water quality and in particular the calcium level, which may impact the maintenance and lifetime of the HPCs. This is very region-dependent and EU countries may have areas with very soft (less calcium) and with very hard (much calcium) water.

Many HPCs can use water from an alternative source to tap water, for example rainwater and water from ponds or lakes, if they are equipped with water filters.

Chapter 4 details the issue of water hardness and its influence on lifetime.

3.7.3 Installation and installers

None of the mobile units require installation, just the availability of the needed input of energy and water, i.e. for the HPCs supplied with electricity, a single- or three-phase mains connection with sufficient power capacity, and a water tap unless water from other sources is needed.

Some of the larger stationary HPCs do require installation. Most manufacturers have a supplier and installer network to take care of the installation.

[59] https://www.weforum.org/reports/global-energy-architecture-performance-index-report-2017

3.7.4 Rentals and sharing arrangements

Due to very low use frequency in households, domestic HPCs are very well suited for sharing with family members, neighbours, colleagues, etc. The product can also be rented from several suppliers[60]. This option may also be relevant for professional use, if the need is not on a daily or weekly basis.

However, no major schemes have been identified and we assume that only a marginal proportion of HPCs are rented out under such arrangements.

3.8 Recommendations

3.8.1 Refined product scope

The study team believes that the product scope is suitable with two observations:

- Additional subcategories may be added for battery-driven domestic HPCs and for professional electrically heated hot water HPCs.
- The stationary category is very broad, covering both smaller HPCs without wheels but which still can be moved and permanently installed HPCs. This may make it difficult to have one base case covering all the types and eventually to set requirements for this broad category.

3.8.2 Barriers and opportunities for ecodesign and energy labelling

The energy consumption level is low for domestic HPCs, but this should be seen together with water and detergent consumption which are strongly correlated. Furthermore, as described in the Task 1 report, there is no agreed common cleaning performance test method able to simulate average usages. However, there are individual test methods used by consumer organisations and test laboratories, which can be a starting point for developing an industry standard or a harmonised standard.

[60] https://www.ebay-kleinanzeigen.de/s-hochdruckreiniger-mieten/k0

4 Task 4: Technologies

4.1 Introduction

4.1.1 Scope of the task

Task 4 contains a general technical analysis of current products on the EU market and provides general inputs for the definition of the base cases for Task 5 as well as the identification of the improvement potential for Task 6. The task incorporates the full range of technical reporting, from a description of the existing products up to BAT (Best Available Technology) and BNAT (Best Not yet Available Technology).

Task 4 presents:

- technical product description of existing products, BAT products and BNAT products;
- production, distribution and end-of-life;
- barriers and opportunities for Ecodesign from a technical perspective including the typical design cycle and appropriate timing of measures.

4.2 Technical product description

This section provides technical descriptions and characteristics of existing HPC units, their individual components and technical analyses of energy and resource consumption (energy, water, fuel and detergents). Moreover, noise production and weight information of current products on the market are presented based on the product scope as defined in Task 1. The technical description includes Best Available Technologies (BAT) for reduced resource consumption and Best Not yet Available Technologies (BNAT).

4.2.1 Existing products

4.2.1.1 Technical description of the HPC categories

Domestic electricity-driven HPCs

HPCs aimed at domestic use are primarily segmented by power and pressure. Each manufacturer typically offers a range of models geared towards a variety of defined cleaning tasks, also differentiated via accessories delivered with the products for specific purposes. Some manufacturers aim to provide an indication of relative cleaning performance in the form of a cleaned area per hour. More details about the main parameters of domestic cold water HPCs are presented in Table 36.

Table 36. Typical main parameters for domestic cold water electricity-driven HPCs

Parameter	Parameter value range	Comments
Power	1200-3000 W	Rated power but usually just stated as unit 'power'
Pressure	9-18 MPa	Stated maximum or working pressure
Flow rate	4-9 l/min (240-540 l/h)	Stated maximum flow rate
Weight	2-18 kg	Can be stated with or without accessories
Fixed jet	Standard	Entry-level products often provide only one fixed nozzle as standard
Variable fan jet	Standard/optional	Approx. 70% of the models offer as standard
Rotating jet	Standard/optional	Approx. 70% of the models offer as standard

Professional HPCs - general description

Professional HPCs are also primarily segmented by power and pressure. For upright two-wheeled models, there is some overlap with the power and pressure range addressed by high-performance domestic models. However, construction and choice of materials and components reflect the high-duty usage and longer operating time, durability and lifetime of professional products together with reducing user fatigue, for example reduced kickback, anti-twist mechanisms and improved controls and for some models specialised applications, e.g. needing very high water pressure and flow rates.

Typical design changes compared to domestic models include the following:

- Pump design – this is generally of the Triplex design (see next section), crankshaft-driven and may incorporate higher quality and better wear-characteristic materials such as ceramic pistons. The cylinder head will typically be made of brass.
- Low-speed motors with improved cooling and more advanced controls (including improved pressure relief) to extend life and address increased duty requirements.
- Usability improvements including integral high-pressure hose reels and longer hoses for storage and to eliminate hose kinking. These may incorporate swivel joints to improve handling.
- Use of larger and stronger wheels on two-wheeled models or the provision of three or four wheels on horizontal models to improve manoeuvrability.
- More robust lances and cleaning tools with improvements including swivel joints and reduced pressure requirements on trigger for extended periods of use and reducing operator fatigue.
- Joints and connections for fittings and hoses are generally brass or mild steel, compared with the plastic fittings used on domestic models.
- Improvements to operating flow (reduced vibration) and reduced kickback when operating the trigger to reduce operator fatigue.

Professional cold water electricity single/three-phase HPCs

Single-phase professional cold water HPCs are similar to domestic models but with a longer operating time and higher weight due to being built for daily use. More details about the main parameters of professional cold water HPCs are gathered in Table 37.

Table 37. Typical main parameters for professional cold water electricity-driven single/three-phase HPCs

Parameter	Parameter value range	Comments
Power	1-phase: 2 800-3 000 W 3-phase: 7 000-10 000 W	Rated power but usually just stated as unit 'power'
Pressure	1-phase: 14-18 MPa 3-phase: 20 MPa	Stated maximum or working pressure
Flow rate	1-phase: 9-20 l/min (540-1 200 l/h) 3-phase: 15-20 l/min (900-1 200 l/h)	Stated maximum flow rate
Operating time	1-phase: 1-2 h/day 3-phase: 4+ h/day	Recommended maximum duration of use per day
Weight	20-80 kg	Can be stated with or without accessories
Variable fan jet	Standard/optional	Approx. 70% offer as standard
Rotating jet	Standard/optional	Approx. 70% offer as standard

Professional cold water combustion-engine-driven HPCs

This category is different to the previous category as these HPCs have a fuel-driven combustion engine (petrol or diesel) and a fuel tank instead of an electric motor, enabling cleaning without access to electricity and enabling higher maximum pressure. More details about the main parameters of these HPCs are gathered in Table 38.

Table 38. Typical main parameters for professional cold water combustion-engine-driven HPCs

Parameter	Parameter value range	Comment
Power (engine)	4 000-10 000 W (engine)	Rated power but usually just stated as unit 'power'
Pressure	16-24 MPa	Stated maximum or working pressure
Flow rate	10-15 l/min (600-900 l/h)	Stated maximum flow rate
Fuel source	Petrol or diesel	Depends on the specific motor
Fuel consumption	1-8 l/h	Petrol or diesel
Operating time	3-4 h/day	Recommended maximum duration of use per day
Weight	27–110 kg	Can be stated with or without accessories

Continuously variable flow and pressure	Standard	

Professional hot water single/three-phase HPCs with fuel heater

The category is based on the professional cold water machine, to which a fuel heater with a burner is added. Some HPCs may also deliver steam. Compact units are upright two-wheeled models, normally single-phase, with a separate fuel tank for fuel. The provision of hot water means that lower maximum pressures often are specified for this type of unit, though hot water models with high pressure are also available. For higher flow rate upright models, the power ratings increase above 3 kW and a three-phase 230 V supply is required. More details about the main parameters of these HPCs are gathered in Table 39.

Table 39. Typical main parameters for professional hot water single/three-phase HPCs with fuel heater

Parameter	Parameter value range	Comment
Power	1-phase: 2 000-3 600 W 3-phase: 3 800-15 000 W	Rated power but usually just stated as unit ‘power’
Pressure	1-phase: 11-18 MPa 3-phase: 20 MPa	Stated maximum or working pressure
Flow rate	1-phase: 9-20 l/m (540-1 200 l/h) 3-phase: 15-20 l/m (900-1 200 l/h)	Stated maximum flow rate
Temperature	60-150 °C	Of the water/steam leaving the nozzle
Heating fuel consumption	2-15 kg/h	Heating oil or gas
Operating time	3-4 h/day	Recommended maximum duration of use per day
Weight	60-200 kg	Can be stated with or without accessories
Variable fan jet	Standard/optional	Approx. 70% offer as standard
Rotating jet	Standard/optional	Approx. 70% offer as standard

Professional hot water three-phase HPCs with electric heater

The category is based on the professional cold water machine, to which an electric heater is added. The nameplate power is much higher and only three-phase connection is possible due to the higher electric load for the water heating. More details about the main parameters of these HPCs are gathered in Table 40.

Table 40. Typical main parameters for professional hot water three-phase HPCs with electric heater

Parameter	Parameter value range	Comment
Power	18 000-42 000 W	Rated power but usually just stated as unit ‘power’
Pressure	15-20 MPa	Stated maximum or working pressure
Flow rate	9-15 l/m (540-900 l/h)	Stated maximum flow rate

Temperature	60-98 °C	Of the water leaving the nozzle
Operating time	3-4 h/day	Recommended maximum duration of use per day
Weight	120 kg	Can be stated with or without accessories
Variable fan jet	Standard/optional	Approx. 70% offer as standard
Rotating jet	Standard/optional	Approx. 70% offer as standard

Professional hot water combustion-engine-driven HPCs with fuel heater

This model corresponds to the cold water combustion engine category, to which a fuel heater with a burner is added. There are typically two fuel tanks added, one for the engine and one for the burner. More details about the main parameters of these HPCs are gathered in Table 41.

Table 41. Typical main parameters for professional hot water combustion-engine-driven HPCs with fuel heater

Parameter	**Parameter value range**	**Comment**
Power	4 500-7 500 W	Rated power but usually just stated as unit 'power'
Pressure	14-17 MPa	Stated maximum or working pressure
Flow rate	10-15 l/m (600-900 l/h)	Stated maximum flow rate
Fuel source	Petrol or diesel	For the engine
Fuel consumption	1-8 l/h	Petrol or diesel
Heating fuel consumption	2.8-4.5 kg/h	Heating oil, diesel, bio-diesel
Temperature	60-98 °C	Of the water leaving the nozzle
Operating time	3-4 h/day	Recommended maximum duration of use per day
Weight	100-150 kg	Can be stated with or without accessories
Continuously variable flow and pressure	Standard	

Stationary cold water HPCs

The stationary HPC is a special category of professional units, which are typically larger and can operate more hours a day. More details about the main parameters of these HPCs are gathered in Table 42.

Table 42. Typical main parameters for stationary cold water HPCs

Parameter	Parameter value range	Comments
Power	1-phase: 3 000 W 3-phase: 4 000-55 000 W	Rated power but usually just stated as unit 'power'
Pressure	1-phase: 20-22 MPa 3-phase: 15-27 MPa	Stated maximum or working pressure
Flow rate	1-phase: 10 l/m (600 l/h) 3-phase: 10-150 l/m (720-9 000 l/h)	Stated maximum flow rate
Operating time	1-phase: 2-3 h/day 3-phase: 5-7 h/day	Recommended maximum duration of use per day
Weight	20-500 kg	Can be stated with or without accessories

Stationary hot water HPCs with fuel heater

This category is like the cold water stationary models just with a water heater added. The models are three-phase types. See Table 43.

Table 43. Typical main parameters for stationary hot water HPCs with fuel heater

Parameter	Parameter value range	Comments
Power	6 000-10 000 W	Rated power but usually just stated as unit 'power'
Pressure	14-18 MPa	Stated maximum or working pressure
Flow rate	10-20 l/m (600-1200 l/h)	Stated maximum flow rate
Heating fuel consumption	2.8-4.5 kg/h	Heating oil, diesel, bio-diesel
Operating time	5-7 h/day	Recommended maximum duration of use per day
Weight	140-400 kg	Can be stated with or without accessories

4.2.1.2 Main components

Overview

Figure 23 shows the main components of a HPC in a schematic way. The components are further detailed in the following paragraphs.

1: Detergent tank and hose

(if fitted)

2: Mains cold water supply

3: Electric motor or petrol/diesel engine to drive pump

4: High pressure pump

5: High pressure hose and spray head/lance

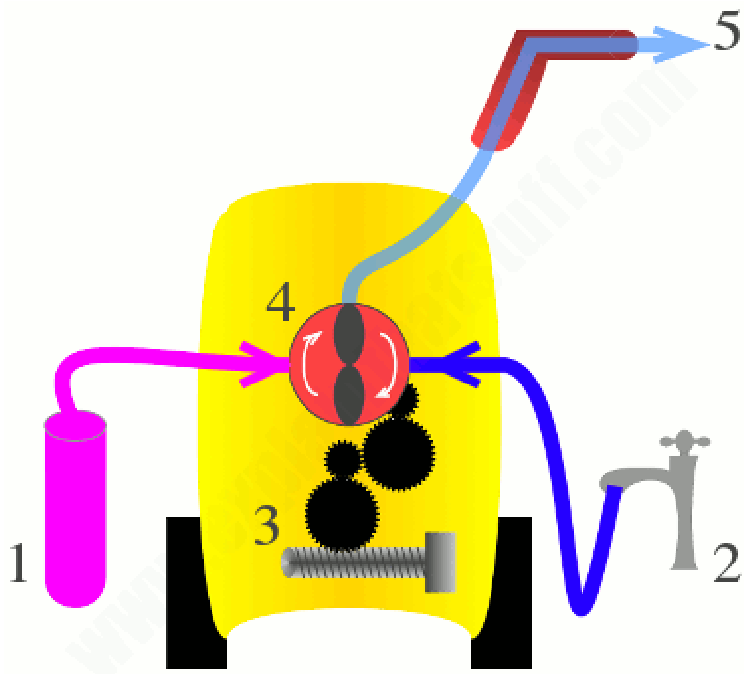


Figure 23. Main components of a high pressure cleaner[61]

On/off switch

The on/off switch is mounted on the main body of the HPC. The on/off switch switches the main motor and pump with associated electronics on/off. Special care is taken in the design and construction of the HPC to ensure the effective sealing and safety of this switch, both internally and externally, to prevent risks due to water ingress.

Many manufacturers incorporate a second pressure (or flow switch) in series with the on/off switch so that the pump will only run when the lance trigger is activated.

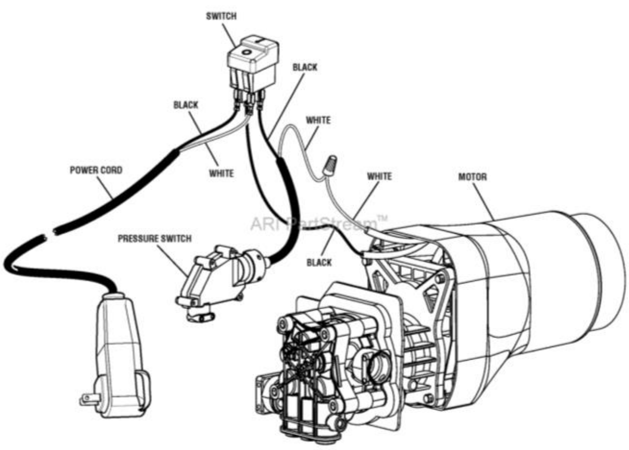


Figure 24. Example of a series connected pressure switch

[61] https://www.explainthatstuff.com/pressurewashers.html

Motor system

The motor or engine is designed to drive the water pump. The electric motor is often water-cooled but smaller motors may also be air-cooled by a fan housed at the end of the motor shaft. The fuel engine is most often air-cooled.

Electric motors are commonly universal motors in domestic HPCs and induction-based in professional HPCs. Induction motors are also known as asynchronous motors because the motor operates at a speed lower than the synchronous speed. The synchronous speed refers to the frequency of the rotating magnetic field in the stator. The stator is the fixed part of the motor and the rotor is the moving part. The AC supply to the motor creates a moving magnetic field (MMF). The number of poles and the frequency of the supply determine the synchronous speed by:

$$Ns = (120 \times f) / P$$

where,

f = frequency of the supply;

P = number of poles.

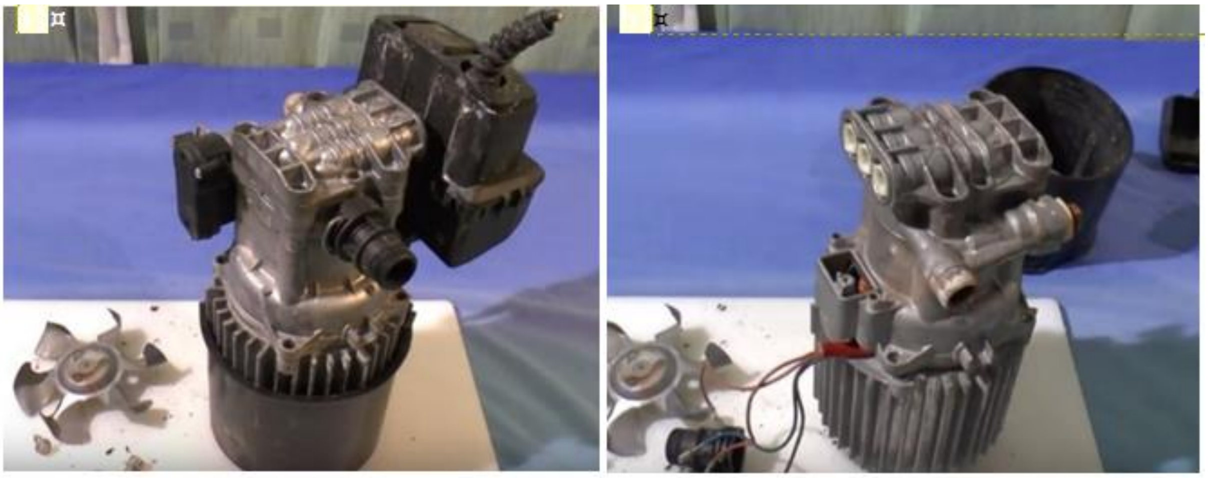
The conductors in the rotor are short-circuited and the current that flows in the rotor is produced as induced electromagnetic force (EMF) in accordance with Faraday's law of electromagnetic induction. The rotor will attempt to match the speed of the Motor Magnetic Field (MMF) and will operate at a lower speed than the synchronous speed described by a factor called slip:

$$\%\ \text{slip},\ s = ((Ns - N)/Ns) \times 100$$

Slip is typically 3-5% at full load.

The simplicity of the induction motor makes it a maintenance-free item as there are no brushes. Induction motors are not self-starting as there must be a difference in flux and a start or start-run capacitor is incorporated to achieve this. The capacitor is normally housed in the same special housing that protects the on/off switch from water ingress.

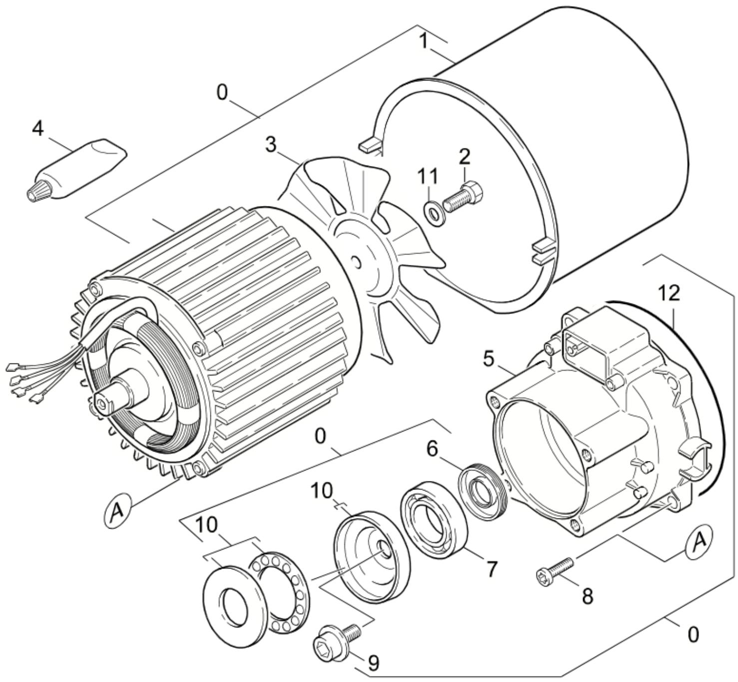
The motor/pump assembly is normally an integral unit with the pump being driven directly. The pump and motor are typically bolted together. See motor details in Figure 25.



NB: The bottom part of the unit is the motor; the cooling fan for the motor has been removed. The pump section sits directly on top of the motor.

Figure 25. (a) Electric motor/pump as an integral unit, and (b) another view with the motor case, switch, start capacitor, etc. removed

In the case of combustion-engine-driven machines, the engine may be two-stroke or four-stroke in the case of higher power or higher pressure professional units. HPC Original Equipment Manufacturers (OEMs) will often source industry standard diesel- or petrol-based engines from manufacturers such as Honda, Briggs and Stratton, Yanmar and others. Engines may be manual, pull-start or full electronic starting.



NB: The engine assembly comprises air filtration, choke, ignition, fuel tank and exhaust system. The pump is normally driven directly by the main shaft of the engine.

Figure 26. Details of a typical air-cooled electric motor

NB: An example of a combustion engine, where the pump is driven directly by the main shaft of the engine. In some configurations the pump may be driven indirectly via a belt.

Figure 27. Typical shaft-driven arrangement

Water pump

The water pump is the core component of the pressure cleaner. Driven by the motor, the pump draws in water from the supply side, pressurises the water and delivers water at the outlet at high pressure. The pump normally operates on a reciprocating basis; the motor rotates but the pump provides a reciprocating or back and forwards motion to both draw in supply water and pump out the high pressure water.

This may be achieved by a number of pistons located in the pump cylinder head, which are operated in sequence by an offset/eccentric (Swash Plate or Wobble Plate) plate that is driven by the motor shaft. The pistons operate in sequence to enable mains water to be drawn in via a suction valve and water that is already within the pump chamber(s) to be ejected via the pressure valve. The pistons are spring-loaded and pump efficiency is relatively low (about 70%) as the operation requires pushing against both the spring and the water. The pumps are self-priming and can run dry.

They have several moving parts and are generally not cheap to repair. They have the advantage of a relatively long life (200-800 hours, the professional ones at the higher end). For domestic products, replacement pumps often cost as much as a complete replacement HPC, while, for professional ones, pumps will be replaced approximately every 500 hours.

Water hardness also affects the life of a pump; mineral deposits in the water can lead to increased wear on moving parts. The water hardness is measured in terms of calcium carbonate per unit volume. There is no UK or EU formal standard for the hardness of drinking water, but the following scale is commonly used in the UK:

- soft water contains less than 100 mg of calcium carbonate per litre;
- moderately hard water contains between 100 mg and 200 mg of calcium carbonate per litre;
- hard water between 200 mg and 300 mg of calcium carbonate per litre;
- very hard water contains more than 300 mg of calcium carbonate per litre.

However, the American Society of Agricultural Engineers and the Water Quality Association[62] sets the following classification:

[62] https://www.wqa.org/learn-about-water/perceptible-issues/scale-deposits

- Soft: <17.0 mg of calcium carbonate per litre.
- Slightly Hard: 17.1-60 mg of calcium carbonate per litre.
- Moderately Hard: 60-120 mg of calcium carbonate per litre.
- Hard: 120-180 mg of calcium carbonate per litre.
- Very Hard: >180 mg of calcium carbonate per litre.

Whilst the effect of hard water is greater when the water is directly heated, limescale build-up will affect pump valves and chambers, leading to wear and potential loss of pressure over time. Water passing through the pump is subject to heating through friction and other losses and this results in the build-up of limescale deposits. HPCs used in hard water areas may require regular descaling or the use of water-softening products in the supply water to the HPC.

The whole pump may be referred to as the 'cylinder head' in some products, reflecting the pump design and the use of pistons. See illustration in Figure 28

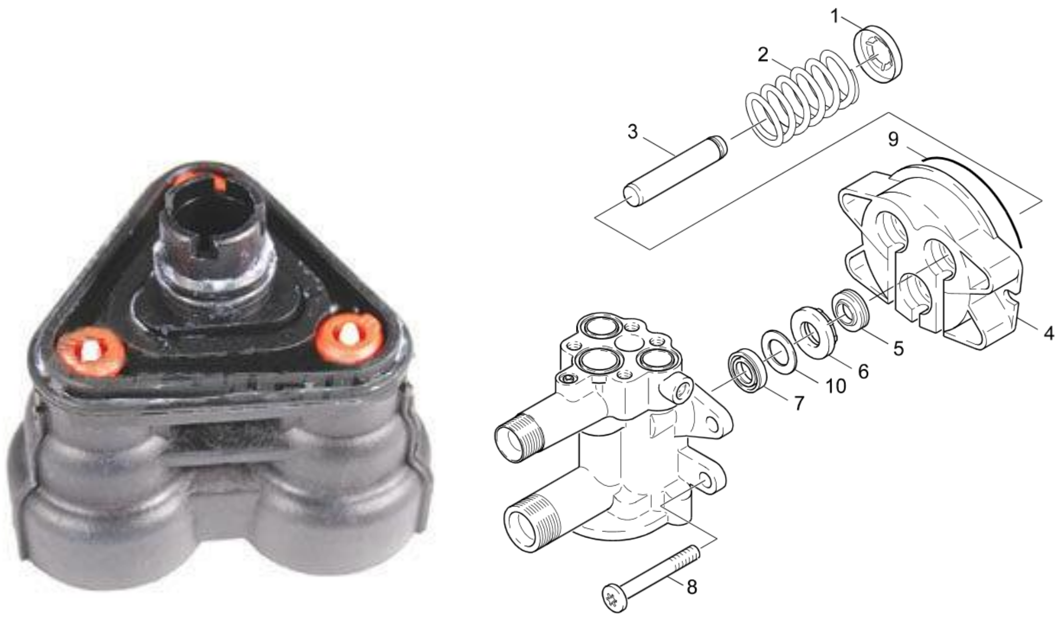


Figure 28. Water pump with a manifold assembly that houses the chemical injector, a pressure check valve (unloader valve) and the inlet and outlet tubes

The rate at which the pump can deliver the high-pressure water jet is a key performance factor determining the design of the pump. In addition to drawing in the supply water, the pump may also draw in detergent from an internal or external supply bottle and mix this with the water prior to delivery at high pressure. In some products, the inlet water flows around a water jacket that surrounds the motor. This provides cooling for the motor and reduces noise.

Three types of pump technology are employed as presented in Figure 29, Figure 30 and Figure 31. All are displacement types and operate on a reciprocating basis.

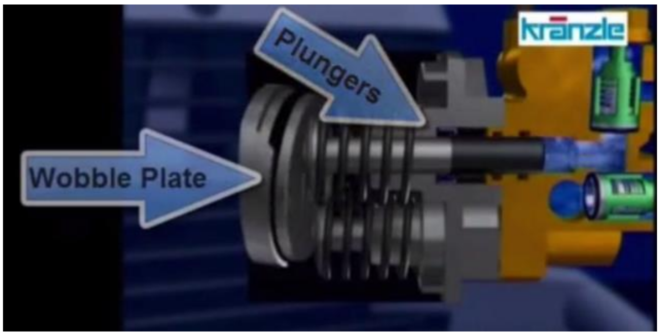


Figure 29. The Wobble-type pump

The Wobble (or moving Swash plate) type is most commonly used in domestic HPC products. In this type of pump, the rotary action of the input shaft, which is driven by the motor, is converted into a reciprocating action. Spring-loaded pistons mounted on fixed cylinders are activated by the wobble plate on every rotation. This type of pump is simple and has few components.

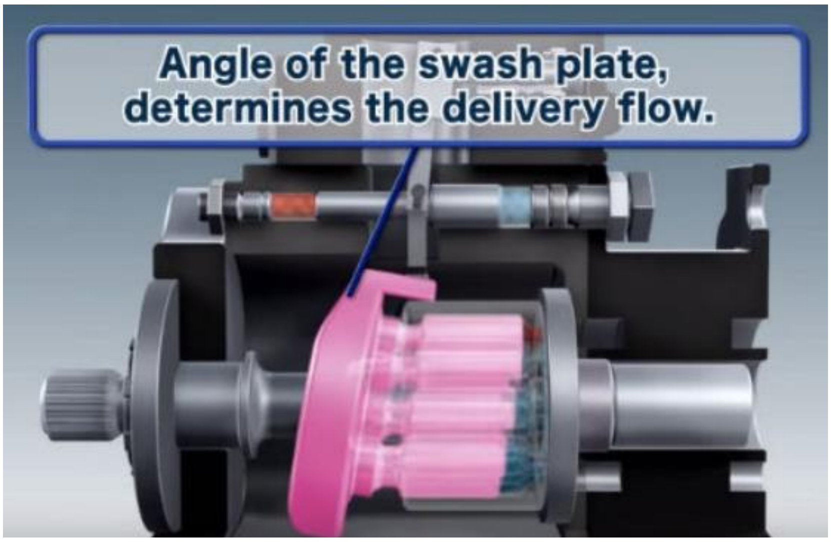


Figure 30. The axial-type pump

The axial pump is driven directly from the rotating shaft of the motor and the angle of the swash plate may be adjusted to set the flow rate. This is a more complex pump construction and the cylinder seal is on the piston head, causing wear on each operation. Axial pumps are typically used in professional HPCs, where a higher usage pattern is expected. Serviceability and operational life are important considerations and enhancements such as the use of ceramic pistons in pumps are common. The lifetime is typically 500-800 hours (the cost of such a pump starts from EUR 80 [63], at 2017 prices).

[63] https://bepressure.co.uk/replacement-pumps

Figure 31: Typical Triplex pump

The Triplex pump is typically used in professional HPC applications and utilises three crankshaft-operated pistons to draw in and pump out water on each stroke. It offers much higher efficiency (typically 90%) and has a lifetime of thousands of hours. This type of pump is also maintainable – it typically runs cooler than axial types due to the larger area and improved cooling. The pump can be used for very high pressure applications. The Triplex pump typically includes the drive housing to the motor. It is generally driven directly by the motor or engine but belt-driven arrangements are also deployed. The typical cost of a triplex pump[64] starts from EUR 200 in 2017 prices.

Built-in hot water heater

Cleaning using hot water is generally considered to improve cleaning efficiency by 30-35%[65] and for greasy or oil cleaning applications, including automotive, hot water is essential for a satisfactory performance. A heated surface will also dry more quickly. Hot water HPCs – supplied with cold mains water - contain a fuel oil burner or electric heater and a hot water tank for storing hot water or use instantaneous water heaters. These are generally included in industrial or professional HPCs. Figure 32 presents typical examples of hot water HPCs with a diesel burner and electric boiler.

[64] https://bepressure.co.uk/replacement-pumps

[65] https://www.kaercher.com/uk/professional/pressure-washers/benefits-of-hot-water-high-pressure-cleaners.html

NB: Both have an electrically driven motor-pump assembly.

Figure 32. Hot water HPCs with diesel burner (left) and with electric boiler (right)

Electrically heated hot water HPCs are for use in applications where exhaust emissions would be unacceptable (indoor areas, food processing, hospitals, etc.) This type of unit includes a high-power instantaneous water heater. Power ratings for the heater assembly are typically in the range 12-36 kW, requiring a three-phase connection. The electric boiler offers the potential for better temperature control and low thermal losses with units typically offering reduced or eco-mode settings for operation at fixed 60 °C operation or, for intense cleaning tasks, up to 85 °C.

A range of controls including for flow sensing and water level are included to prevent damage in the case of a low flow or a low water level in the boiler and temperature control settings that match the outlet temperature to the cleaning task. Figure 33 shows a typical heating coil and burner assembly.

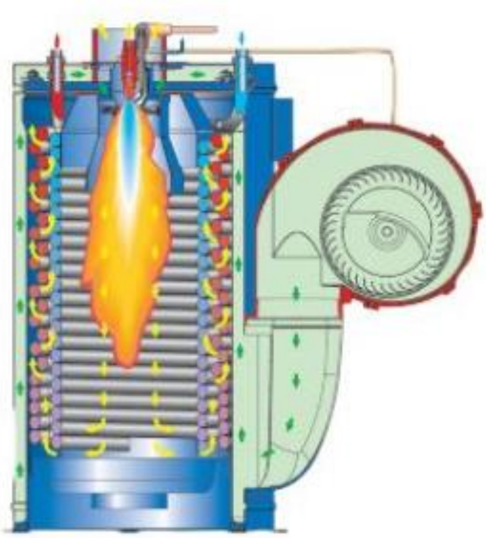


Figure 33. Typical heating coil (left) and burner assembly (right) for a hot water HPC[66]

In all cases, regardless of the heating source, high-pressure water is pumped through the coil prior to heating. Given that the water is heated on the high-pressure side, there are important considerations for operating heated high pressure cleaners in terms of start-up, bypass and shutdown sequences. For a professional hot water HPC, it is normal practice to start the unit up delivering cold water before activating the burner. This ensures that water is flowing continuously through the coil prior to heating and the maximum operating temperature is then progressively increased to the operating temperature as the coil is heated. During bypass

[66] www.nilfisk.com/en-gb/features/Pages/EcoPower-Boilers.aspx

(when the trigger gun is deactivated), water is recirculated via the pump to the low-pressure side of the pump via the unloader valve. Since the hot water raises the temperature of the pump there are restrictions on how long the HPC should operate in this mode. This time should be minimised by the operator and some machines have auto-shutdown to prevent damage.

Similarly, on completion of the cleaning task, the heating coil should be cooled by passing water through the system with the heating source off. This maximises the lifetime of the heating coil and seals and reduces the risk of thermal shock.

By heating the delivery water in the coil (via either the burner or in the case of an electrically heated unit via a heater and heating water tank), the assembly operates as an instantaneous water heater. Where a burner is used as the heating source, the flame from the burner passes through the centre of the coil to heat the high pressure water contained within the coil. With electrical heating, the coil may be mounted in a water tank in which the hot water is electrically heated. Heat is transferred from the hot water tank to the high-pressure water in the coil.

Common burner control and protection mechanisms are incorporated and include a flame sensor (to ensure that fuel is only injected when there is a flame present), flow sensing (to ensure that the burner can only be operated when water is in the coil), low fuel controls and exit/exhaust temperature monitoring to prevent excess coil temperature.

Hot water pressure cleaners may suffer from a build-up of limescale mineral deposits on hot water boiler coils. The main part of this deposit is calcium carbonate and magnesium. Hard water contains calcium particles that are more readily soluble in hot water than cold. The effect of hard water is greater when the water is directly heated. Limescale builds up in the heater and scale is a poor heat conductor, resulting in the water being insulated from the heating coil's heat source. This affects water heating efficiency, maintaining hot water production, and can restrict water flow or pressure, resulting in a heavier strain on other HPC components, blockage of jets or similar failures.

Limescale prevention is a major consideration for extending the life of a heating coil. Limescale can reduce the efficiency of a heating coil by up to 50% (depending on the thickness of limescale deposit) and has a similar reduction effect on the lifetime. Hot water HPCs may therefore include dosing systems for hard water reduction and limescale control.

Some machines are fitted with water softener systems. This is a dosing system that operates when the machine is used in hot mode by means of a dosing pump controlled by a timer circuit. The water softener is poured into a holding tank - a typical capacity is 5 l. This drips the softener into the machine's header tank, and mixes in the water that is fed into the pump, additionally extending the life of the pump by helping to prevent valves from sticking. There are professional HPC units with a built in limescale remover available in the market. Manufacturers offer limescale reduction chemicals and details including Safety Data Sheets are available via the manufacturer's website.

In order to inform consumers and professionals of the burner efficiency improvements/environmental performance, the cleaning machines association EUnited has created a High Pressure Cleaner burner efficiency label[67]. This is a visual endorsement that the oil-heated burner fitted to the high pressure cleaner meets the scheme's requirements for thermal exhaust loss and CO and dust emissions.

The acceptable limits of thermal losses per net power of the heater, CO emissions and smoke number are as follows:

- Net power of heater (kW) ≥ 4 and ≤ 25: max. thermal loss qA = 11%.
- Net power of heater (kW) > 25 and ≤ 50: max. thermal loss qA = 10%.
- Net power of heater (kW) > 50: max. thermal loss qA = 9%.
- CO emission: max. 75 ppm.
- Smoke number: max. 1 (Bacharach scale).

[67] https://www.eu-nited.net/cleaning/labels/hpc-label/index.html

These numbers can be compared with German emission criteria in the occupational regulations[68], e.g. the maximum CO emission from diesel exhaust is 30 ppm. In this specific criterion, the German emissions criteria is much stricter than the EUnited label criteria.

Water inlet and high-pressure hose

The water inlet is through a hose that connects the pressure washer to the main water supply. This is normally a mains-fed water supply but other sources including a water butt, tank or lake may be possible for certain models. The minimum inlet pressure specification for the HPC specifies the requirement, and models constructed using a self-priming water pump or special adaptor hoses are required for non-mains-fed applications.

The hose connects the HPC to the cleaning attachment or nozzle. The high-pressure hose is reinforced with wire mesh and normally has two or more layers of high-density plastic. This is a safety-critical component and the hose is rated with a significant safety margin over the maximum pressure rating of the HPC. Hoses are typically rated with a safety factor of 3. The inlet includes a simple filter to stop dirt and debris entering the washer; debris within the water supply could cause damage or excess wear to the pump impellor or be ejected under high pressure.

On domestic HPCs, the tap connection fitting is a standard push-fit hose-type connector. There is generally a requirement to ensure that back-siphoning of water into the drinking water supply cannot occur and a separator or non-return valve may be specified as a requirement for this connection.

The manufacturer specifies the inlet pressure and temperature requirements, the minimum length and diameter or hose required and, for non-mains-fed applications, the special adaptor hose. The adaptor hose normally comprises an integral filter and one-way valve at one end and a standard hose connection at the other. The attachment end of the hose has an auto-stop valve and a twist-lock or bayonet-type fitting into which various cleaning attachments may be fitted.

Nozzle and cleaning attachment

The nozzle creates the spray jet. Cheaper pressure washers usually come with just one nozzle whilst more expensive models may come with more nozzles that provide different strengths and shapes of jet spray. The nozzle types can be divided into the following three main types:

- Fixed jet: The shape and pressure of this jet cannot be adjusted.
- Variable fan jet: The nozzle has different positions that allow the user to vary the angle and pressure of the spray.
- Rotating jet: A powerful, focused jet spins as it leaves the nozzle, providing very strong cleaning power.

Dependent on the type of cleaning task, the HPC may be fitted with a simple trigger gun; this is essentially just a manually operated valve that only lets water through when the handle is squeezed. Different manually operated lances are available with straight and angled heads and with adjustments to control the mix of detergent and water.

Powered accessories include attachments intended for cleaning surfaces such as wooden decks and patios or rotating brushes. Powered attachments are driven by the force of the water flowing through them.

The trigger on the gun normally operates a pressure switch that forms part of the motor/pump assembly that activates the pump when the trigger is squeezed. While the trigger is in the off position, the pressure builds up in the pump and the switch activates to disable the pump.

Detergent hose and tank

Appliances may include a means of adding detergent to the high-pressure water supply. The mix of detergent with the water may be controlled in the tank or via the attachment.

Detergent dosage requirements depend on the specific detergent to be used and are usually indicated in the use instructions. There are different ways that the detergent can be added to the water:

- A container integrated in the HPC main body, where the detergent is sucked through a tube and injected into the water.

[68] https://www.dieselnet.com/standards/de/ohs.php

- A separate container placed beside the HPC, where the detergent is sucked and injected into the water.
- A dedicated spraying nozzle with a small detergent container attached underneath; it is to be used only when detergent should be added.

  Professional HPCs typically have integrated detergent containers, while domestic HPCs may typically have integrated or separate containers, or a dedicated spraying nozzle with a container attached. Domestic HPCs often have a simple dosage system where regulation is not possible or which does not even allow the possibility to stop adding detergent except by removing the detergent tube or emptying the container.

The dispensing control on most machines is very limited and detergent may be added either upstream or downstream of the pump. The most common is upstream and operates on a simple siphon injector basis. The detergent is applied in a low-pressure mode.

The control is typically by means of a simple flow restriction at the tank end and the nozzle then has a detergent position which ensures that detergent is supplied. Some detergents are intended to be used in an 'as supplied' form via a pick-up tube on the HPC, some require that the undiluted detergent is added to the integrated tank and others require dilution before use. Detergent usage or dosage is infrequently specified and rarely for domestic appliances.

Certain products with electronic controls offer a more precise 'visual' control of key parameters including detergent use – these normally allow the setting to be adjusted up or down (+/-) but do not allow the dose to be set by value. Data provided by a stakeholder shows a typical detergent 'mix ratio with cleaning agent' of 0.3 l/min for a range of machines with maximum flow rates of 7-8.3 l/min. This gives a typical dosage ratio of >20:1.

Water hardness may limit the effectiveness of detergents. Soap and detergents have an ionic nature and, when they dissolve in hard water, soap molecules react with the suspended calcium ions. This limits the formation of lather and may result in poor foaming or scum which renders the detergent ineffective. Consequently, cleaning performance is adversely affected, and more detergent is required.

Safety components

These form an integral part of the HPC design and are included to ensure safe operation of the appliance and to protect the appliance in the case of misuse or a fault.
The safety components include the following:

- Unloader valve: A device which allows the water to circulate within the appliance whilst the motor is still running but the outlet of the appliance is closed, e.g. the lance trigger is not operated. Circulating water will heat up over time and a pressure vent or temperature vent may release the heat to the atmosphere (normally at ground level), allowing cooler water to be drawn in and recirculated. The unloader valve is an in-line valve used in higher pressure models (generally 17 MPa up). This valve is often spring-adjustable to set the maximum pressure and the valve has a dual function – it regulates the outlet pressure and also acts as a pressure relief.
- Flow switches*:* These sense and protect in the event of no flow (e.g. to prevent the pump running dry).
- Pressure relief: They prevent the appliance from excess pressure.
- Temperature sensors: An appliance that provides water heating will include sensors to both control the temperature and provide protection. It is typically a thermal switch and takes the form of a limiter that would activate a contact to isolate the heater.
- Motor protection switch: Electric motors include protection devices. They may be fuses, self-resetting thermal switches or temperature sensors (thermistors, thermocouples or PT100) embedded in the windings which are monitored by a control system.
- Operator Presence Control (OPC): As a safety feature, most HPCs have an OPC, which ensures that water is not pressurised when the lance is not operated. It does not mean that the machine is fully shut off.

Mains cable

Mains-operated electric motor products are supplied with a fixed mains cable secured by a suitable cable entry gland to prevent water ingress and to provide tension relief on the cable during movement. Smaller products are typically supplied with a 5-metre cable while larger products can be supplied with a 10-metre cable.

Casing and wheels

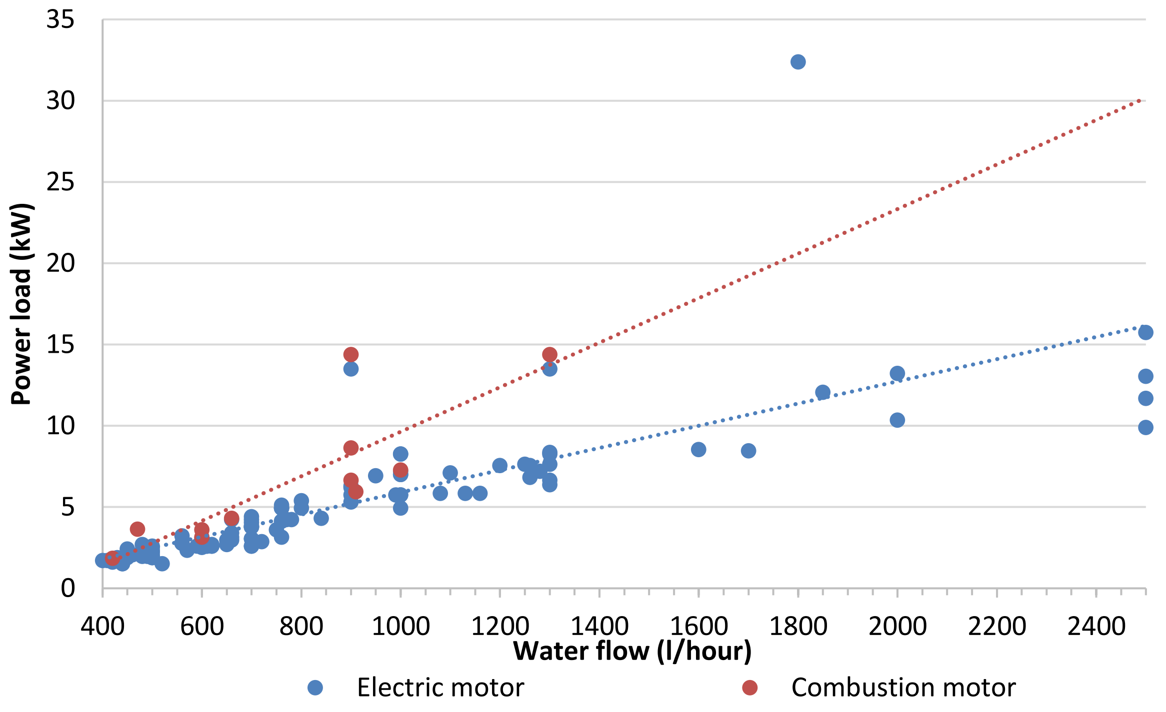
The casing of products used on domestic HPCs is normally plastic and provides a balance between durability and weight. Wheels are provided on heavier units. These are normally solid wheels, but combustion-based units feature pneumatic tyres.

4.2.1.3 Analysis of main performance parameters

The study team has collected a number of analyses of the main performance parameters, aiming at assessing the resource consumption for the products on the market and reporting the efficiency figures.

Power load versus maximum water flow rate

Figure 34 presents the power drawn versus the water flow for domestic (excluding battery-driven models) and professional HPCs, including both electric motors and combustion engines, but excluding stationary units which have different characteristics.



NB: HPCs with an electric motor and with a combustion motor are shown separately. Trend lines are added for each type of motor.

Figure 34. Power load vs. maximum water flow (l/hour) for professional HPCs (excluding stationary HPCs and deducting power for electrically heated hot water HPCs) based on the technical specifications

The power load is calculated from the nameplate power reduced by 10% because the maximum connected load (nameplate power) is typically higher during start-up than continuous operation. The reduction, 10%, is approximate and based on an average reduction from a test study conducted by a stakeholder. An average value of 3.9 Wh/l is calculated for domestic HPCs; 5.8 Wh/l for professional electric HPCs; and 8.6 Wh/l for professional combustion-engine-driven HPCs.

However, Figure 34 does not take the pressure level and possible other features into account.

Combined working pressure, water flow and rated power

In the previous sections, the water flow correlation with input power has been analysed. Both water flow and pressure are important for a good cleaning result: The water pressure loosens the dirt from the surface, while the water flow removes the dirt after it has been loosened. Therefore, a single performance parameter which includes both of them is proposed. Several internet resources[69,70,71,72] report a simple combination by multiplying water pressure and water flow – by sources called "cleaning units". In this report we define this index as the Cleaning Power Index (CPI) as it reflects the performance of its units in terms of maximum water pressure and maximum water flow and can be calculated as follows:

CPI = maximum water flow x maximum flow pressure (litres*MPa*minute^{-1})

Figure 35 presents the relationship between CPI and the input power of a HPC unit (domestic and professional).

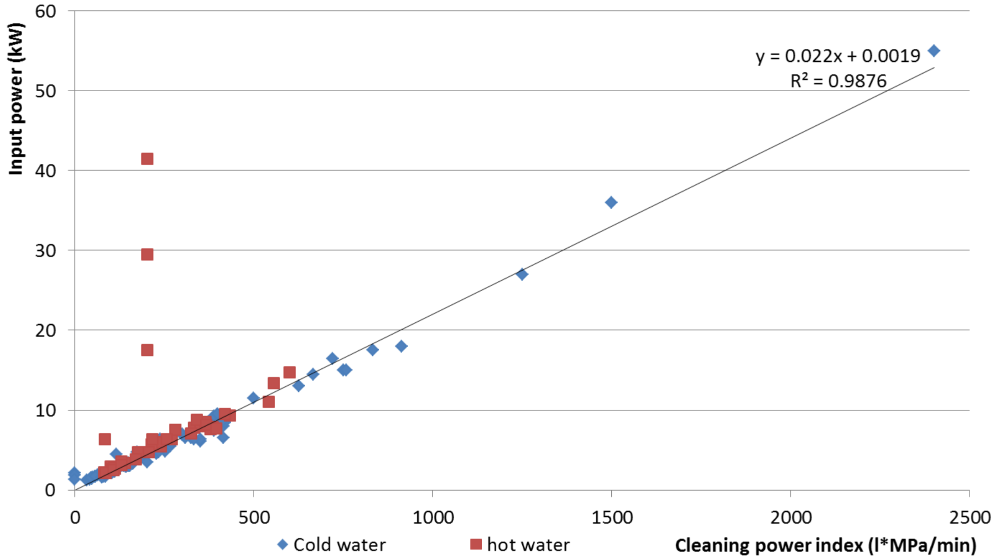


Figure 35. Input power versus CPI (maximum water flow x maximum water pressure) for domestic and professional HPCs based on the technical specifications

The following conclusions can be drawn:

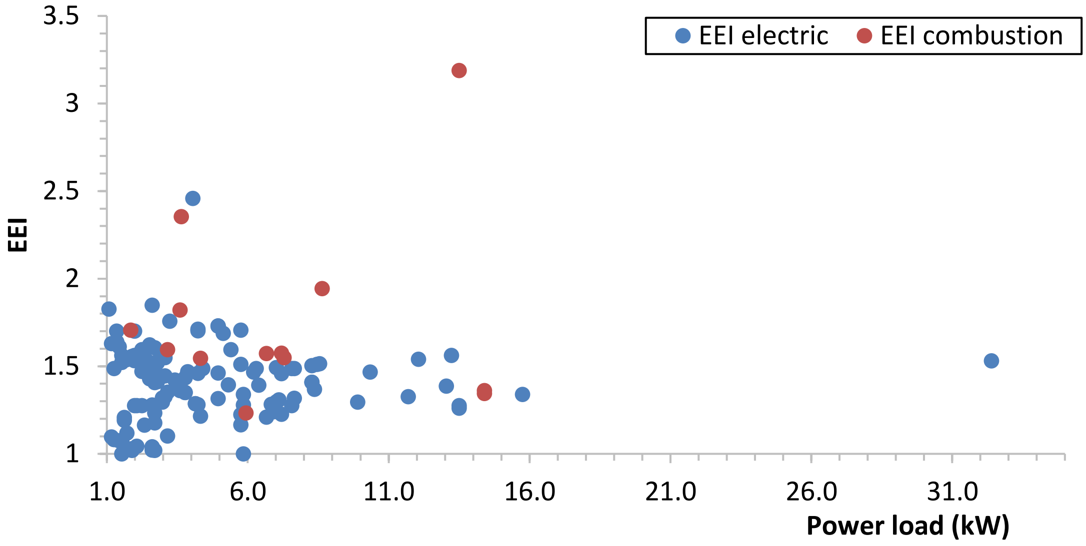
- There is a clear correlation between CPI and input power; they correlate very well ($R^{2=}$0.988). The relation is:

  Input power = 0.022 x CPI +0.0019

- The red markers that deviate too much from the trend, regards hot water HPC units with an electric heating boiler, and thus a large fraction of the input power is intended for heating water.

The study team has analysed the data further by calculating an energy efficiency number as the power load divided by flow multiplied by pressure and normalising it, resulting in an EEI, Energy Efficiency Index for domestic and professional HPCs. The normalisation takes place by dividing each energy efficiency number by the lowest number for each category. The lower the index, the less power is needed to be delivered to the cleaning unit (pressure x flow). The resulting EEI vs power loads are shown in Figure 36 for domestic and professional HPCs.

69 https://www.goodway.com/hvac-blog/2011/03/flow-rate-is-key-when-choosing-a-pressure-washer/
70 http://www.rentalmanagementmag.com/Art/tabid/232/ArticleId/17838
71 https://www.thoroughclean.com.au/factors-influence-high-pressure-cleaning-constitutes-cleaning-power/
72 https://simpsoncleaning.com/tips/2016/psi-vs-gpm-what-matters-most/



NB: HPCs with electric motor and with combustion motor are shown separately.

Figure 36. EEI (Energy Efficiency Index) vs. power load for professional HPCs (excluding stationary HPCs and deducting power for electric heated hot water HPCs) based on the technical specifications

The figures show only limited correlation with power loads, and mainly for the electric motors, with a down-sloping tendency in EEI with increasing power loads. For combustion motors, there are only 13 data points and therefore much more uncertainty so no conclusion is drawn here.

Main parameters and real water and energy consumption

The study team has assessed the test results of real water and energy consumption of the domestic HPCs. In order to allow for a fair comparison, the HPCs selected performed to a minimum cleaning quality according to the in-house test designed by the laboratory. This filter resulted in a subset of 22 HPCs out of 43. The test results are provided for standard (fixed) and rotating nozzles. Only the results for standard (fixed) nozzles have been included. Figure 37 shows the energy and water consumption of the HPCs expressed as a percentage of deviation from the average. Negative values mean that the unit consumes less water or energy than the average. The order of the results is based on the energy performance, from less (left) to more (right) energy consumption than the average.

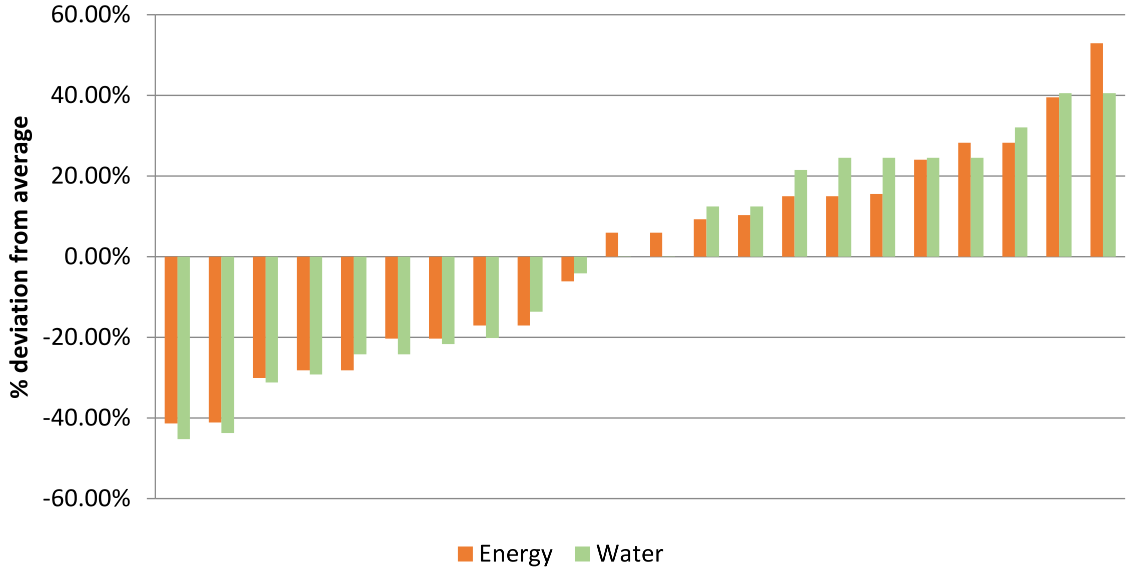


Figure 37. Energy and water consumption of 22 HPCs, expressed as % deviation from the average

As can be observed, in general, water and energy consumption are correlated, meaning that in most cases the units perform better or worse in both energy and water, and just the two HPCs that are closer to the average behave slightly differently. Of the group on the left, 7 out of 10 consume at least 20% less water and energy, and 2 reach the best performance (more than 40% less energy and water consumption). Of the group on the right, 8 out of 12 consume at least 20% more water, while the number of units that consume a minimum of 20% more energy is 5. However, the worst performing unit consumes above 50% more energy and 40% more water.

Figure 38 gathers the values of energy and water consumption with the rated input power (as a percentage of deviation from the average). Of the group of HPCs that consume less than 20%, all but one have larger input power (7% larger). The HPCs water consumption does not appear to be correlated to the input power.

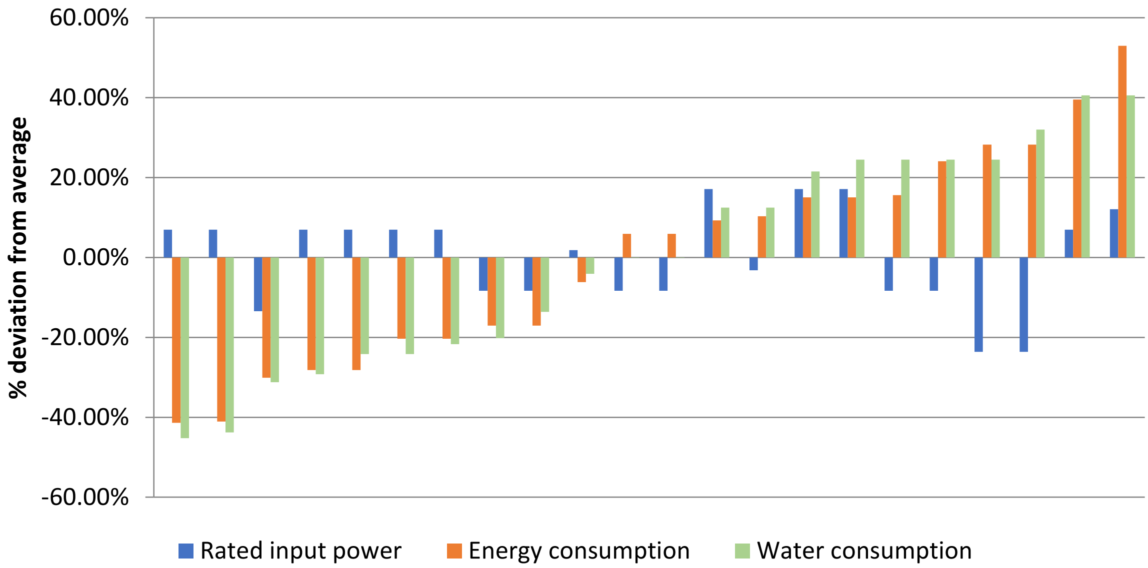


Figure 38. Energy and water consumption and rated input power of 22 HPCs, expressed as % deviation from the average

Figure 39 shows the values of energy and water consumption with the rated pump pressure (as a percentage of deviation from the average). The profile is very similar to input power, except that the variations are larger. This is the result of the different pump efficiencies of the units.

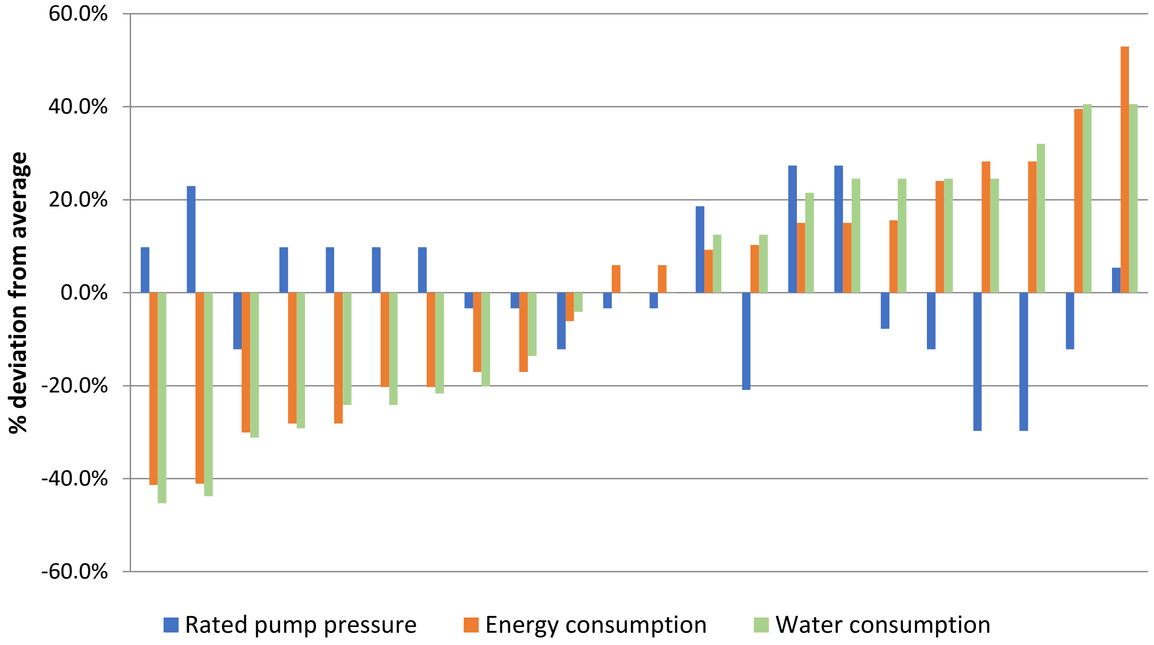


Figure 39. Energy, water consumption and rated pump pressure of 22 HPCs, expressed as % deviation from the average

Figure 40 shows the values of energy and water consumption with the rated maximum flow (as a percentage of deviation from the average). The profile is very similar to input power, except that the variations are larger. All the units that consume 20% less energy and water show a rated maximum flow at least 8% higher. On the opposite side, 5 out of 8 units that consume 20% more water achieve lower flows, though the rated flows of the worst ones are very close to the average.

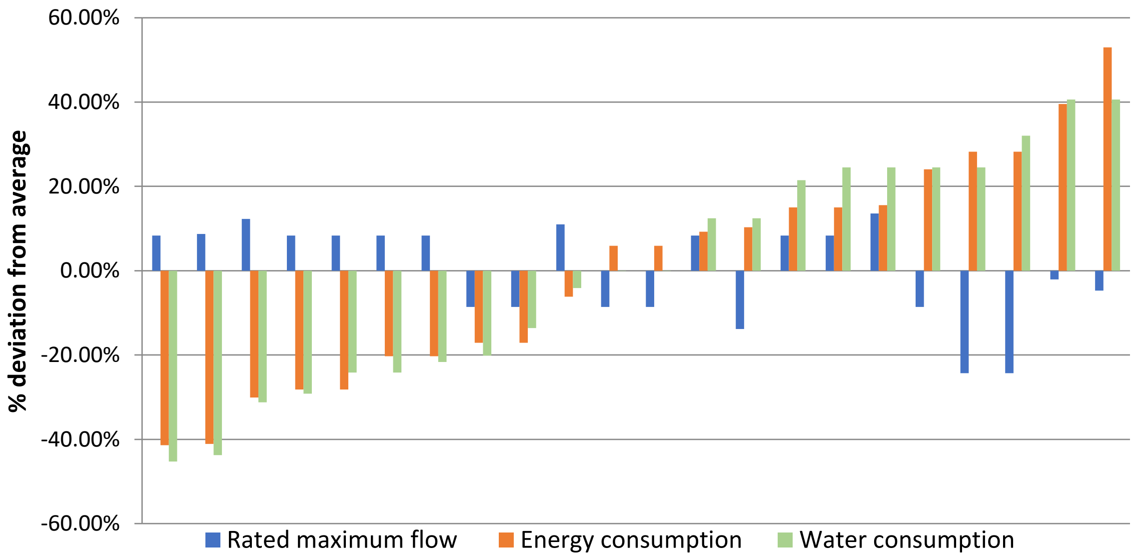


Figure 40. Energy, water consumption and rated maximum flow of 22 HPCs, expressed as % deviation from the average

Figure 41 shows the capability of units to vary their power at maximum and minimum spray. Of the 10 best performing HPCs, 7 are able to vary their power up to 50%, while among the worst performers there are units both capable and not capable of power variation.

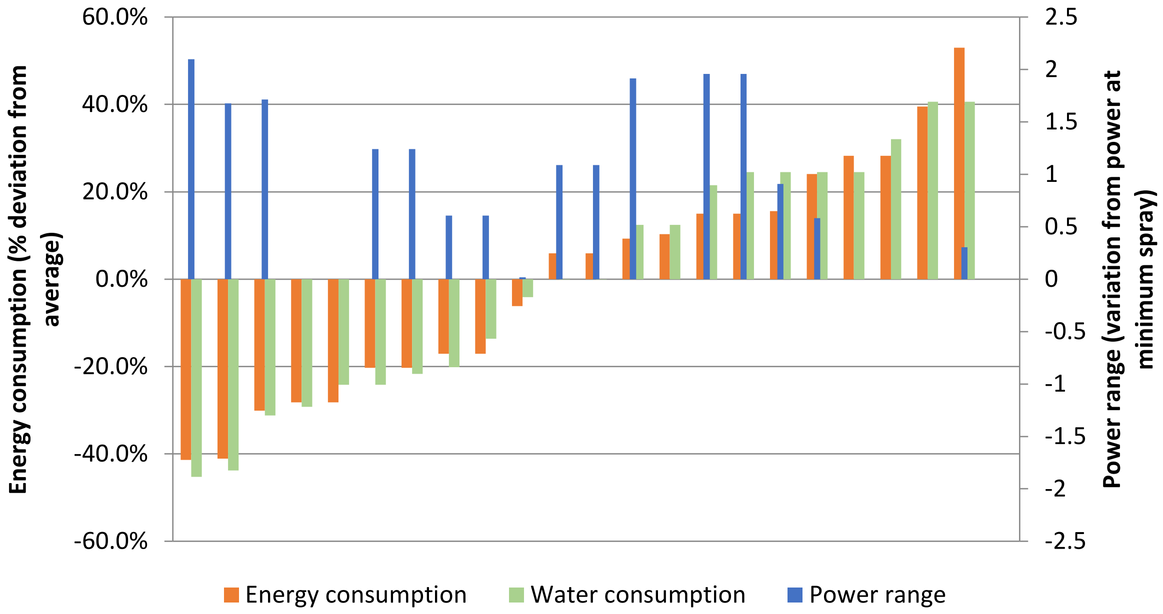


Figure 41. Energy and water consumption of 22 HPCs, expressed as % deviation from the average, and power range as variation of power at minimum spray

The energy and water consumption have been evaluated in relation to the EEI as defined above. For this purpose, the following indexes have been defined:

- EEI nominal: This corresponds to the EEI shown in Figure 14.
- EEI measured: This is a normalised index based on the measured power load divided by the measured water flow and measured force.
- Water consumption normalised: This is a normalised index of water consumption for cleaning 1 m^2 of pavement including only test points with sufficiently high quality (at least 4 on a scale of 0.5-5.5).
- Energy consumption normalised: This is a normalised index of energy consumption for cleaning 1 m^2 pavement including only test points with sufficiently high quality (at least 4 on a scale of 0.5-5.5).

Figure 42 shows a certain correlation between the EEI measured and the water consumption. Due to it being a real-life test for the measured indices, there are uncertainties involved even though the tests were performed by experts and done twice for the water and energy consumption (results averaged).

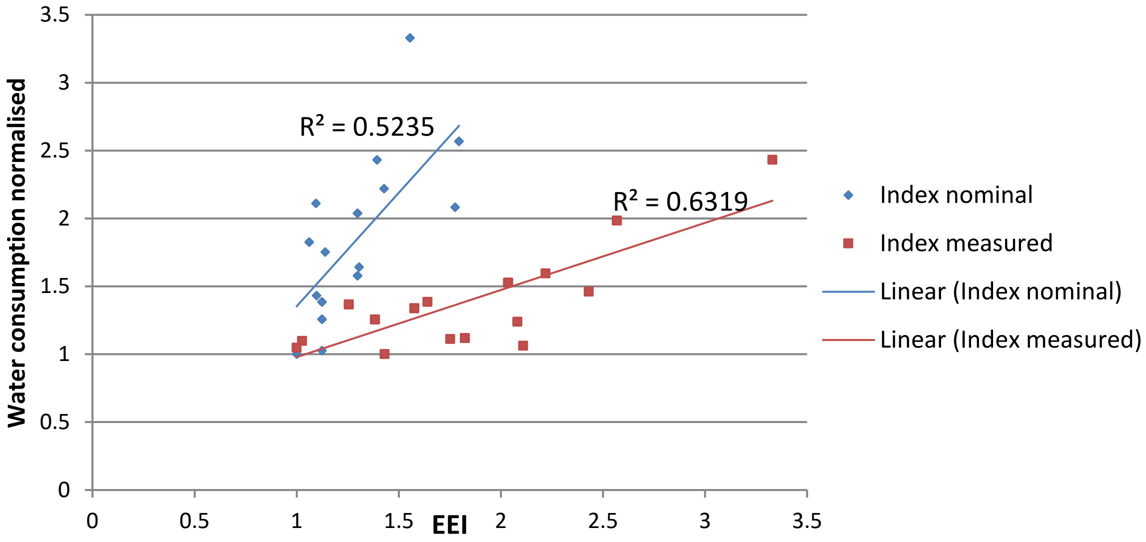


Figure 42. Water consumption versus EEI nominal and measured

As can be observed in Figure 43, the correlation between EEI and energy consumption is much weaker. Apart from the uncertainties related to real-life tests mentioned above, the energy consumption is calculated by multiplying the time by the measured power at maximum spray.

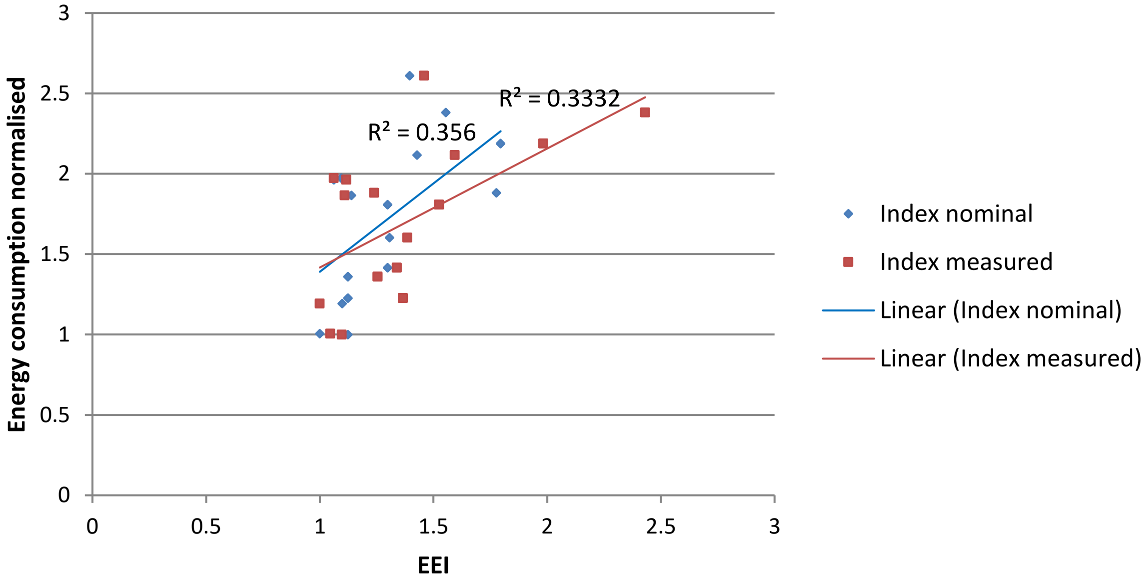


Figure 43. Energy consumption versus EEI nominal and measured

The correlation between cleaning time and EEI is better as Figure 44 shows, which suggests that the variation of power over the test cycle plays a role.

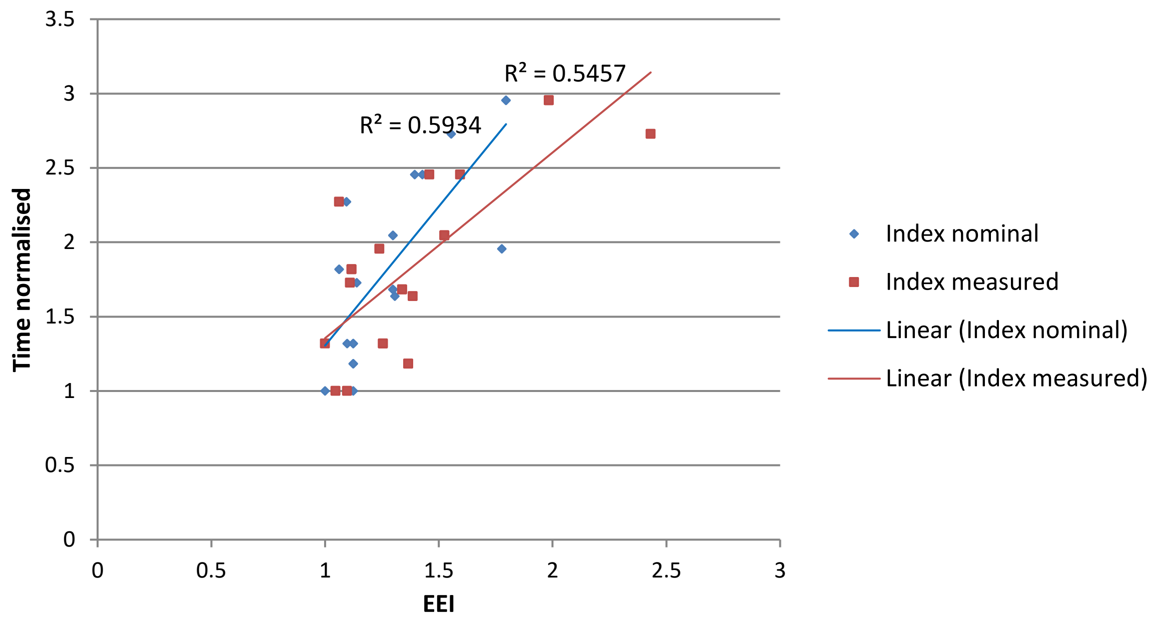


Figure 44. Cleaning time versus EEI nominal and measured

Finally, the results of cleaning units and water and energy consumption normalised are displayed in Figure 45 for standard nozzles and rotating nozzles. The size of the bubbles is related to the cleaning units.

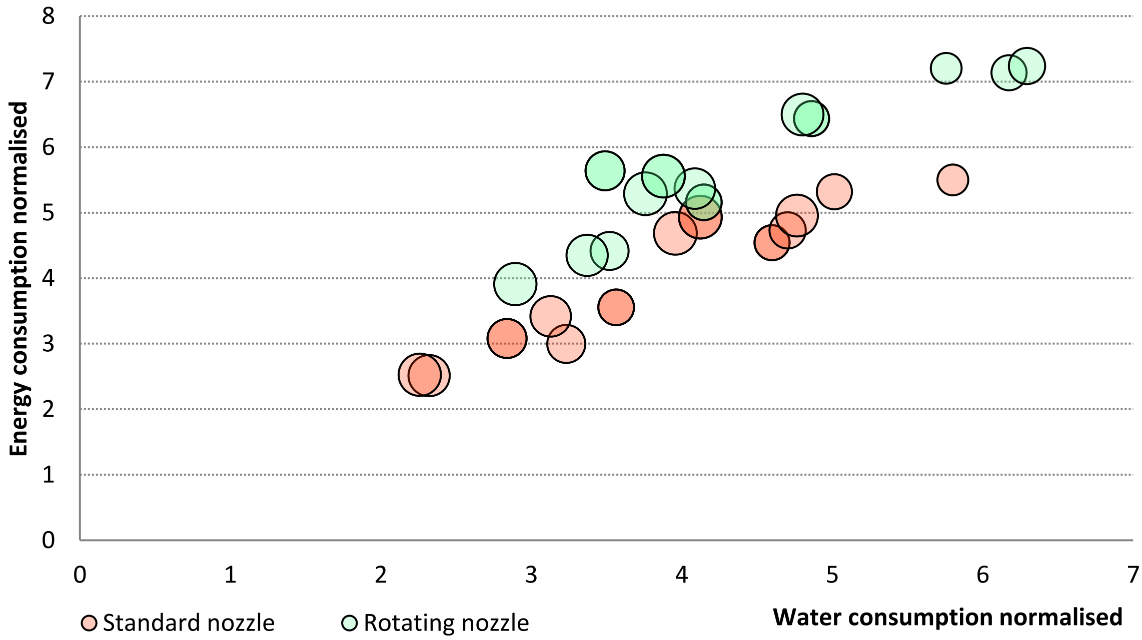


Figure 45. Energy versus water consumption normalised for standard nozzles and rotating nozzles

As can be observed, the rotating nozzle setting consumes less energy and water per m^2 compared to the standard nozzle setting. There is significant variation in both water and energy consumption for similar cleaning quality for different units. This indicates that there is potential for energy and water savings improvements. There is no clear correlation between the cleaning effect and the energy and water consumption per surface area.

4.2.1.4 Analysis of ability to reduce power consumption with reduced force

Based on laboratory tests of 43 domestic HPCs, the study team has analysed the ability of HPCs to reduce the energy consumption when reducing the spray force. If a product has a good ability to reduce power consumption when using the HPC at lower pressure and flow rates – assuming no increase in cleaning time - this may provide energy savings for the user.

Figure 46 shows for each of the 43 HPCs tested the rated power and power draw at minimum and maximum spray force and with a rotating nozzle. Where the red dots (minimum spray force) are low compared to the blue and green dots, the HPC has a good ability to reduce the power draw and thereby the energy consumption.

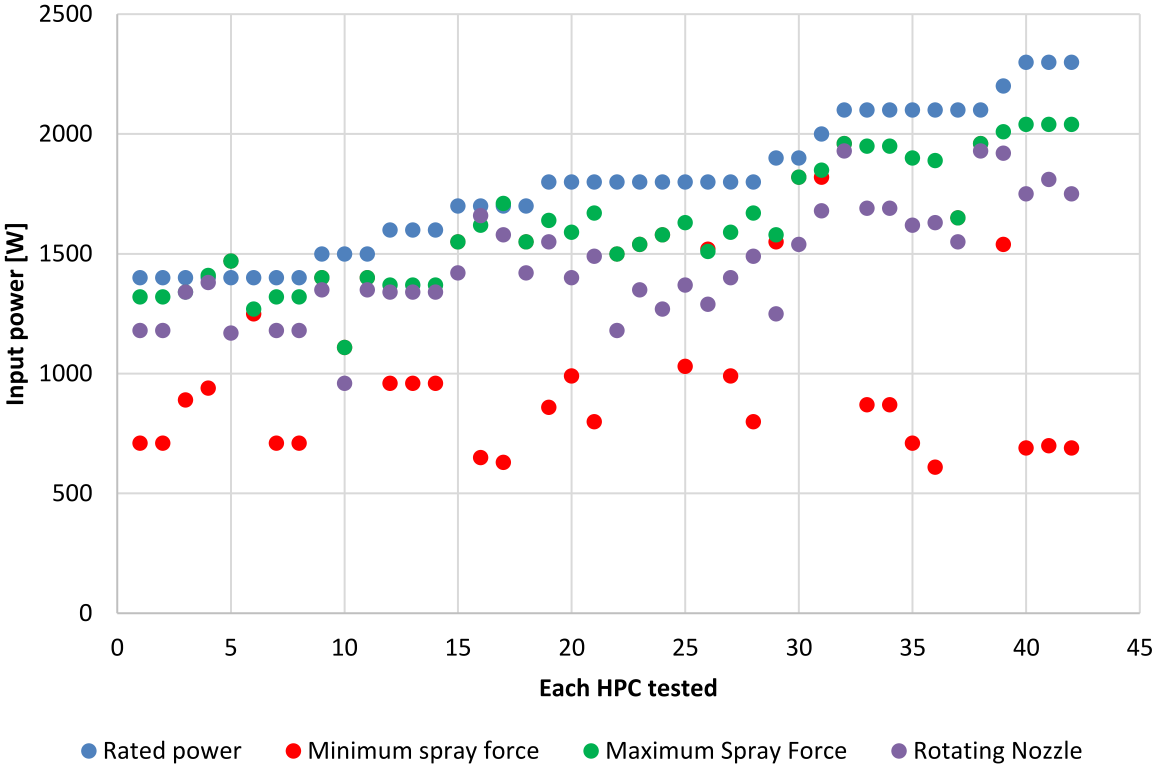


Figure 46. Rated power and power draw at minimum and maximum spray force and with a rotating nozzle for a test sample of 43 domestic HPCs

On average, the HPCs reduced the power draw 35% at minimum spray force compared with the rated power, while the best reduced it by 70% and the worst by 4%. This clearly indicates a large market spread of power reduction ability.

4.2.1.5 Analysis of weight of domestic products

The weight of the HPCs is dependent on the individual components, features such as hot water and sturdiness. Professional types are often heavier than domestic types because they are built for many operating hours and to be used in variety of usage situations perhaps with different operators. Professional HPCs also have more types of form factors such as with two or four wheels, caged to be moved with a fork-lift, wall-mounted and stationary.

Domestic HPCs are usually equipped with two wheels though they often exist in three basic series: An entry-level line, a sturdier and higher quality line and a compact line. The study team has analysed the weight of domestic products based on the technical data collected from websites. Professional products have not been included due to their many different applications which make it difficult to compare the products on equal terms. The weight of domestic products has been divided into seven ranges in steps of 5 kg. The distribution can be seen in Figure 47. The distribution of the weight of domestic HPC products is fairly spread out. The heaviest domestic HPC weighs 47 kg while the lightest only weighs 2.9 kg.

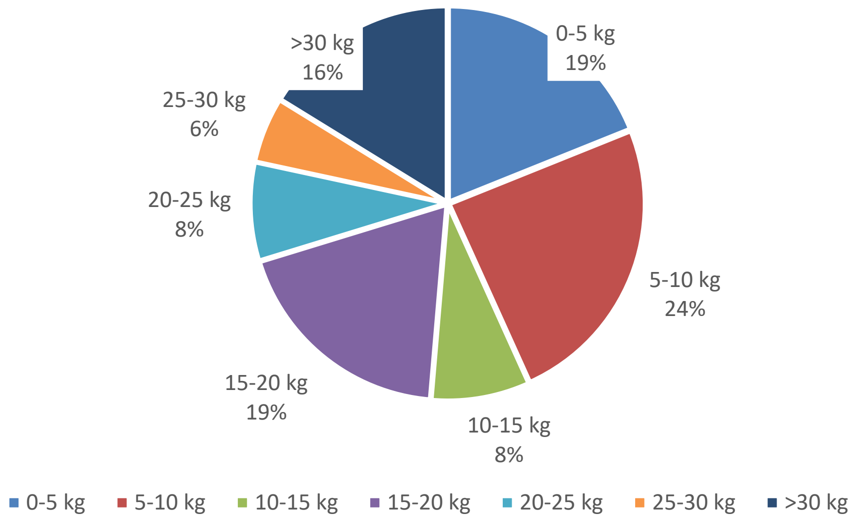


Figure 47. Weight distribution of the sample included in the analysis

4.2.1.6 *Analysis of detergent use*

The amount of detergent that the HPC uses in operation is stated for some of the HPCs (approximately 25%). Of the remaining 75%, most of them can use detergent but it is considered an add-on accessory and the minimum or maximum detergent dosage is not specifically stated. Many of both the domestic and professional models also have a built-in function which allows the amount of detergent to be manually adjusted. In the operation and maintenance manual, a manufacturer states that foam detergents can be adjusted to between 1% and 5% of the water consumption and low-foaming detergents can be adjusted to between 1% and 8% of the water consumption. The detergent use for those HPCs where the amount of detergent use is specified is shown versus the maximum flow rate in Figure 48.

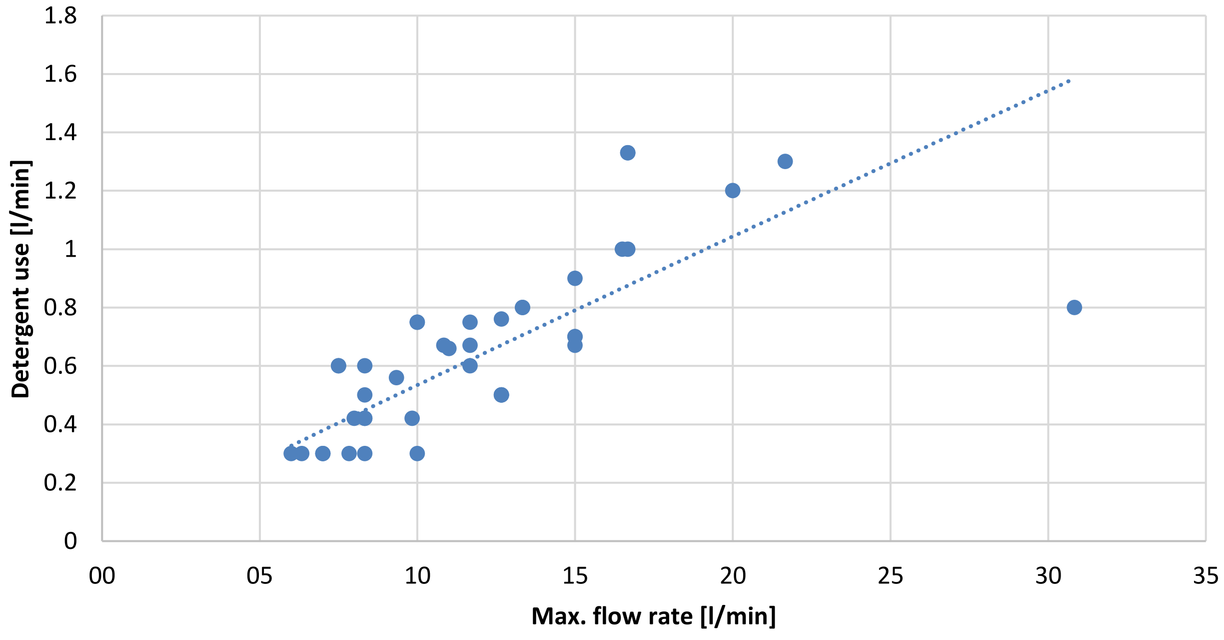


Figure 48. Detergent use vs. maximum flow rate

The use of detergent compared to the maximum flow rate shows a good correlation and approximately follows a linear trend. A calculation of the ratio shows that all, except one, have a detergent use between 4% and 8% of the maximum flow rate which is in line with what one of the manufacturers stated in the operation and maintenance manual.

4.2.1.7 Analysis of noise

This section analyses the sound power (L_{wa}) and the sound pressure (L_{pA}) based on the technical specifications. The sound power and pressure figures are presented for HPCs in each of the seven categories (see Figure 49). There is a large variation of sound power and sound pressure levels within each category and also between the categories. Combustion motors slightly increase the levels.

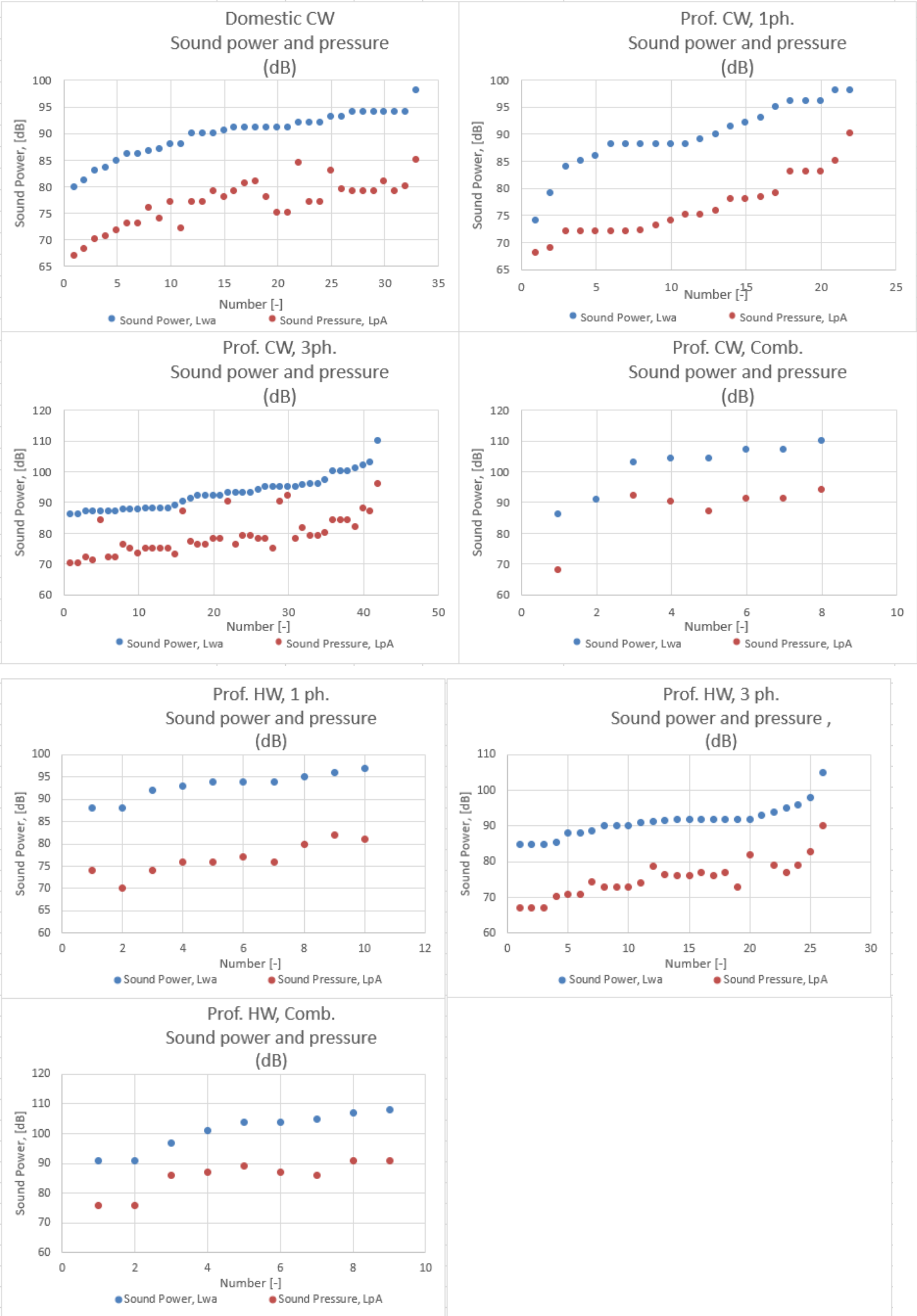


Figure 49. Sound power and pressure for each of the 7 categories

4.2.2 Products with standard improvement options, BAT and BNAT

The following sections describe different areas of technological progress and product design, which have an influence on product lifetime, energy, water and/or other resource consumption (e.g. materials, detergents) and noise emissions. For each technology area, it is stated if the improvement options are standard, BAT (Best Available Technology) or BNAT (Best Not yet Available Technology).

4.2.2.1 Energy efficiency in pumps and motors

Motor-pump automatic shutdown (standard)

Most HPCs automatically shut down when the spray lance is not operated. For combustion engine HPCs, there would be a short time period before the engine shuts down to avoid many stop-starts.

Hydrostatic drives (BAT)

The pump commonly employed with HPCs is a form of a hydrostatic pump, the swash plate and axial piston pumps described previously. They are compact in design and also allow through-drive via a simple in-line motor (electric or combustion). The pumps are easier and more economical to manufacture. The variable displacement type of these pumps can continuously alter fluid discharge per revolution and system pressure based on load requirements, maximum pressure cut-off settings, or horsepower/ratio control. This offers power savings compared to other constant flow pumps in systems where prime mover/diesel/electric motor rotational speed is constant and the required fluid flow is non-constant. However, alternative pump arrangements include rotary vane, radial piston and Archimedes screw.

Energy-efficient water pumps (BAT)

Clean water pumps are generally very similar in terms of design options. With clean water there is little risk of clogging or blockage. As such, there is no differentiation between most of the standard designs of displacement water pumps between manufacturers. However, BAT improvements in design are seen as product ranges move from domestic through to commercial product application achieved with minor design modifications. Many of these design improvements are aimed at improving operational life, running time and/or maintainability of pumps and include improvements such as better seals, the use of ceramic pistons (achieving a five times better operating life), better surface finishes and reduced frictional losses.

Deployment of better and more efficient pumps such as the Triplex type in consumer products would increase costs and weight but can show benefits in terms of longer lifetime and lower energy consumption. A typical Triplex-type pump (see Figure 50) may incorporate:

- stainless steel hardened piston guides;
- stainless steel check valve;
- forged brass (or stainless steel option) head with corrosion-proof ceramic plungers;
- double sealing gaskets (for high and low pressure);
- forged brass connecting rods for long durability;
- oversized bearings.

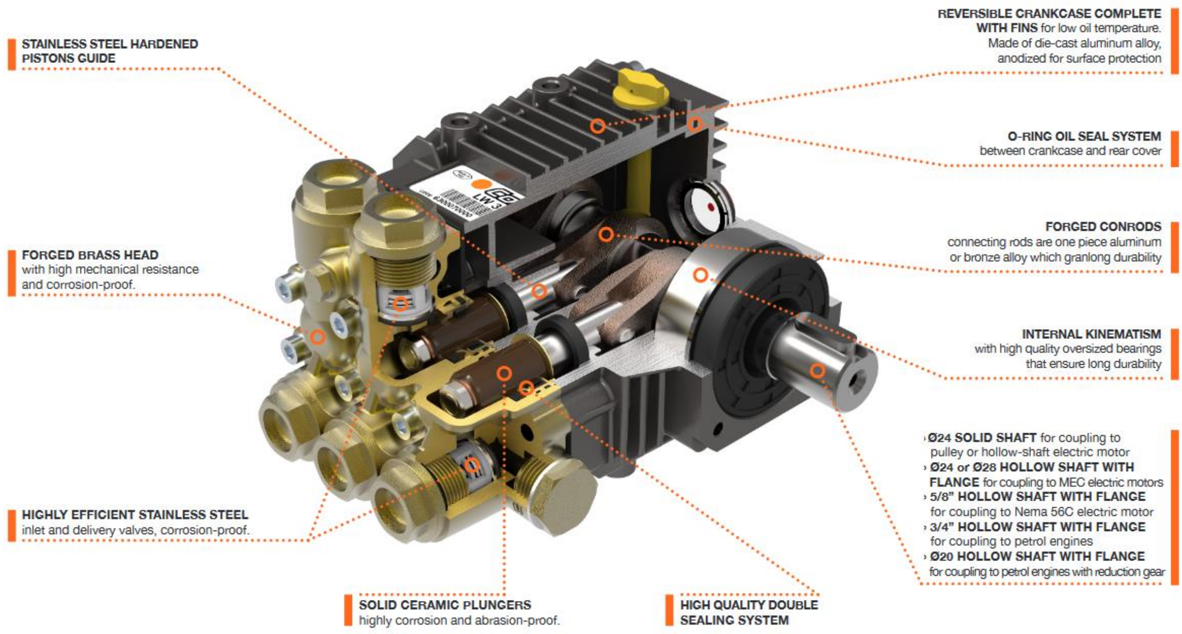


Figure 50. An example of a Triplex pump (LW Series Triplex Pump – Comet Industrial Pumps, Italy)

In order to arrive at even higher energy efficiencies, the surface roughness of the pumps has to be improved. The surface roughness of the pump depends on the casting method and if the surface is polished or coated. User behaviour regarding prevention of limescale build-up and drain-down procedures following cleaning task completion may also yield longer term advantages.

Standard pumps are often produced by sand casting of metal (cast iron, bronze, steel, etc.), which is a cost-efficient production method and therefore widely used in pump production. Sand casting does, however, result in rougher products than products made using other types of casting. A reduced roughness of the impeller and the volute can decrease losses and thereby increase the energy efficiency. However, most manufacturers find that the increased cost of investment required for casting does not outweigh the benefits.

Delivering high pressure alone is not enough for certain cleaning tasks. The maximum flow rate that a given machine can achieve has a significant effect on cleaning performance when it concerns the removal of dirt after it has been loosened from the surface. A machine with a lower maximum pressure but higher flow rate may outperform a product with higher pressure. This is especially the case where the amount of dirt requires more water for removing it.

High-efficiency motors (BNAT)

Brushless DC motor (BLDC) technology is widely deployed in a range of different sectors including HVAC, general air movement, refrigeration, vacuum cleaners and small portable garden equipment. At the time of writing, this technology has not yet been deployed in the HPC application and is thus a BNAT. In particular, increased demand for cordless, battery-operated products such as vacuum cleaners has resulted in significant developments within this sector. Additionally, Ecodesign measures in categories such as ventilation fans have driven deployment of BLDC motors.

BLDC motors offer high efficiency but are generally deployed in continuous applications such as cleaning, ventilating or blowing applications due to the higher energy efficiency gains there. A very high power to size ratio can be achieved which may be useful for smaller, more compact products.

It may be argued that the less frequent use of HPCs, a generally low price point expectation from consumers and the perception of 'lower technology' may limit the potential for BLDC application in these products. HPCs are high-power devices and the power levels demanded for effective cleaning do not ideally suit BLDC motors although the technology might be deployed in portable, battery-operated units. Control of BLDC motors is more complex and inverter controls would be required.

Electric motor with variable speed drive (BNAT)

The motor supplies the mechanical energy for the pump in order to release the water at a desired flow and/or pressure out of the high-pressure cleaners. This is done by controlling the rotational speed of the motor which drives the shaft and controls the specific speed of the pistons in the displacement water pump.

The majority of domestic and light professional HPCs utilise single-phase induction motors (SPIM). These are normally used in fixed speed applications and full load efficiencies (output shaft power/electrical input power) may be up to 85% in a well-designed motor. However, motor efficiencies may vary from 30% to 85% in practice with losses caused by copper losses in the stators and rotor windings (resistance effects), iron losses (due to eddy current effects) and frictional losses. The efficiency of single-phase induction motors is not addressed by existing ecodesign measures such as Regulation (EC) No 640/2009 – this is only applicable to three-phase motors.

Using variable speed drives (VSDs) with motors can help to better control the rotational speed, adapting the flow and/or pressure of water to user specific needs. The use of VSDs with motors and (rotodynamic) water pumps can reach a level of energy savings of 20-50% considering the whole pump unit (motor, pump and VSD). For example, reducing the motor speed to 80% of the maximum can save up to 50% energy. However, the reduction depends on the use profile, i.e. the annual operational time and the flow pressure the HPC needs from the pump to supply water and pressure compared to the full load flow pressure.

Variable speed drives are widely employed in fan and pump applications in industrial applications. VSDs are commonly employed with AC induction motors and may be used to control both the speed and the torque delivered by the motor. This technology lends itself to closed loop control applications in which the control of a given process parameter (e.g. flow or pressure) can be regulated by suitable measurement transducers and controlled via the VSD. Packaged off-the-shelf VSDs typically range from 0.25 kW up to 1 000 kW, with smaller units being aimed specifically at pump and fan control. VSDs offer 95-98% efficiency.

For HPC applications, the use of packaged VSDs is unlikely to be economic and the trade-off between energy savings through closed loop control and increased costs and complexity requires consideration and therefore it is mostly a BNAT.

Technologies for combustion-engine-powered HPCs (BNAT)

All current products utilise readily available small garden machinery four-stroke, single-cylinder petrol or diesel engines. Advantages include ease of maintenance, no requirement for specialist tools, and commonality of parts across a range of different garden or commercial equipment. This is an established technology with little development or improvement.

The decision to use a petrol or diesel HPC is primarily based upon the following:

- Petrol engines are powerful, reliable and generally involve a lower acquisition cost compared to diesel machines.
- Diesel running costs are lower and better durability means a longer lifetime.
- Availability of fuel on site and other portable equipment (e.g. is equipment used mostly petrol or diesel?) For smaller commercial machines, the choice of petrol will be the obvious one because petrol will be used in other machinery (two-stroke) with two-stroke oil in garden machinery etc. For site-based use where a supply of diesel may already be present for vehicles etc., the choice of diesel or biodiesel may be more appropriate. Diesel fuel consumption appears similar across a range of machines reviewed.
- Increased noise of diesel engines.

Commercial petrol four-stroke engines have a typical efficiency of 20-30%, while commercial diesel engines have a typical efficiency of 45%. Diesel has a longer durability than petrol, typically double the lifetime. Diesel oil assists cylinder bore and piston ring lubrication, reducing wear. Furthermore, diesel engines weigh more, though this is offset by improved reliability, have simplified controls (direct fuel injection, no electronic ignition), potentially high pollutant (NOx, PM) emission rates and offer biodiesel options, which improves lubrication and offers reduced environmental risk in the case of spillage.

Developments in small machinery combustion engines include the High-Efficiency Hybrid Cycle (HEHC) Rotary engine[73]. This utilises a modification of the Otto cycle formerly deployed in automotive applications (Wankel

[73] http://news.mit.edu/2014/liquidpiston-small-efficient-rotary-engine-1205

engine) and claims a 20% reduction in fuel consumption and 30% reduction in material compared to conventional petrol combustion engines.

The HEHC engine combines constant volume combustion and overexpansion for increased efficiency compared with conventional combustion engines. At the time of writing, only one manufacturer of engines is exploring this technology.[74] Though this is BNAT for small machinery, it is not expected to have any importance for developments in the energy efficiency of HPCs in the near future.

4.2.2.2 Energy efficiency in water heating

High-efficiency burner boilers (standard)

Hot water high pressure cleaners can be equipped with a burner that has an improved boiler/burner efficiency which reduces oil usage for heating water. EUnited Cleaning, the European Cleaning Machines Association, has set up a voluntary labelling scheme EUnited Cleaning Burner efficiency that applies to oil-heated high pressure cleaners. The scheme sets requirements on thermal exhaust loss, burner efficiency, CO emission and dust emissions.

Direct hot water feed (standard)

When a more resource-efficient and lower-cost hot water supply is available at the place for cleaning, a standard option is to use a cold water HPC that allows hot water inlet.

Improved heat exchanger (BAT)

The pressurised water is heated by circulating in a coil inside the burner chamber. Better coil design may improve the heat transfer to the water and increase the energy efficiency.

Improved thermal insulation of heated parts (BAT)

If the HPC contains a built-in water tank, the tank can be insulated which reduces standby losses from the tank and saves energy. All tanks are insulated but a further improvement in insulation could typically yield 80% savings in losses for a 50% increase in insulation.

Temperature control of the water tank also reduces energy consumption. Many professional HPCs incorporate an eco-mode, holding the water at a lower temperature (typically 60 °C) whilst maintaining the maximum flow rate.

Use of waste heat from motor (BAT)

Waste heat from the combustion motor can be used to preheat water before entering the water heater. A coil is built into the motor being heated by the combustion process. It is not a standard option, but BAT used by some models on the market.

4.2.2.3 Spraying technology

Improved nozzle designs (standard / BAT)

Improved nozzle design improves the cleaning performance and may also yield water savings. The nozzle design includes a small high-pressure nozzle as a concentrated jet, spraying systems, spray patterns and rotary nozzles. These can be designed to provide high pressure and low water flow. However, some cleaning tasks need a high water flow to remove loosened dirt and low water flow attachments cannot be used for these tasks.

Some brands design their own improved-design nozzles, while others brands normally purchase them from suppliers.

Furthermore, the user selection of attachments and the way the user cleans the subject will greatly influence the water consumption.

4.2.2.4 Water and consumables efficiency

Use of water-saving attachments (BAT)

See above under improved nozzle designs.

[74] http://liquidpiston.com/

Use of alternative water resources (standard)

Some HPCs have self-priming pumps and can use water sources other than tap water, e.g. water from ponds and lakes. This naturally requires available water sources close to the locations where HPCs are used.

Water recycling for stationary HPCs (standard/BAT)

Stationary HPCs may use recycled water from the use of the HPCs. It is the standard option for commercial car wash machines.

Precise detergent regulation (BAT)

Detergent consumption can be improved by better regulation of the amounts of detergent added to the water and providing users with better instructions.

4.2.2.5 Sensors and automatic controls

Advanced control (BAT)

Some of the latest HPCs incorporate advanced controls that make the selection of the correct pressure, flow and detergent easy to match with the cleaning task. As an example, excess pressure for a car cleaning task could result in damage to paintwork or trim or water ingress to the vehicle together with excess water and detergent usage. By making it easy and simple for the user to match the product's performance to the cleaning task, resources can be optimised. This kind of control is mainly for domestic users, because they may have less knowledge and experience of optimised settings.

Other controls – also suitable for professional users - include:

- automatic eco-modes;
- leakage detection;
- temperature of hot water.

  Examples of advanced control can be seen in Figure 51.

NB: The example to the left is an advanced regulation via a display, while the example to the right is a manually settable pressure regulation.

Figure 51. Two examples of pressure control

User selection and visual confirmation via a display on the trigger handle means that users are more likely to operate the equipment correctly compared with controls located on the chassis. The majority of HPCs incorporate some form of manually settable pressure regulation.

Benefits of controls include:

- water saving and waste reduction;
- detergent reduction;
- reduction of run time;
- maintenance period reduction and lifetime extension.

Other controls (standard/BAT)

Especially for professional HPCs, electronic controls can be installed to supervise the machine's main functions, for example combustion, control of losses from the hydraulic circuit, maintenance time, temperature control.

An example of the best controls may be seen in HPCs that include mode selection and match the pressure/flow to the cleaning task by controls on the lance head rather than at the HPC panel.

Optimisation is more likely when the controls are within easy reach of the operator and the means of selection is simple.

4.2.2.6 Resource efficiency

Design improvements (standard/BAT)

There are several design improvements available for lifetime extension and use of materials for reduced environmental impact such as the following:

- Use of materials which increase the lifetime of components (e.g. ceramic and stainless steel components for increased resistance to wear, weather, corrosion, soap, acids, chlorine, etc.)
- Optimisation of material content for components.
- Critical components identification regarding breakdown and easy repair or replacement of those (e.g. piston seals).
- Modular build-up providing easy access to all components for repair and recycling.
- Improved water seals.
- Design of components to reduce build-up of limescale.
- Use of recycled plastic.

Furthermore, dedicated user information regarding use, maintenance and storage when not in use may increase the lifetime.

4.3 Production, distribution and End-of-Life

This section provides an overview of the components and materials used in high pressure cleaners, their production, distribution and end-of-life. The composition of high pressure cleaners has been established based on the typical products placed on the EU market. The inputs will be used to model the environmental footprint in a later task.

4.3.1 Product weight and Bills-of-Materials (BOMs)

The list of the main components of the typical products has been compiled according to different data sources[75,76,77,78,79,80], expert judgment and stakeholder input. In Table 44 this list is provided for each typical

[75] Caspersen, N.I. & Sørensen, A. Improvements of products by means of life cycle assessment; high pressure cleaners. Journal of Cleaner Production 6 (1998). 371-380.

[76] EUP Lot 11 Motors. Final report. 2008. University of Coimbra (Task 4).

[77] Pressure washers description. Accessed June 2018: https://www.explainthatstuff.com/pressurewashers.html

[78] Ecodesign Pump Review. Study of Commission Regulation (EU) No.547/2012 incorporating preparatory studies on 'Lot 28' and 'Lot 29' (Pumps). Final report. Viegand Maagøe and VHK. July 2017 (not publicly available).

[79] Review study on vacuum cleaners – Draft interim report. Viegand Maagøe and VHK. January 2018. Available at: https://www.review-vacuumcleaners.eu/documents

[80] Kärcher website: How does a pressure washer work? Accessed July 2018: https://www.kaercher.com/int/inside-kaercher/difference-kaercher-magazine/kaercher-stories/how-does-a-pressure-washer-work.html

product, as well as the main materials (in MEErP nomenclature) for each component. The specific reference used to establish the BOM is shown for each component.

A website[81] comparing larger high pressure cleaners that suit the definition of professional in this report was used to cross-check that the total weight of the BOM was appropriate according to the declared product weight of typical professional products. For domestic high pressure cleaners, a cross-check was also done with several products offered on the market.

Generally, it is noticed that high pressure cleaners are getting heavier compared to the figures shown in a LCA study done in 1998[75], which gave the weight of the product assessed as 6.135 kg including packaging. However, the study does not show the performance parameters of the product assessed.

Table 44. List of components and materials for typical domestic and professional HPCs

Component	**Materials**
Motor[76]	Steel, aluminium sheet/extrusion, copper winding wire, plastics types
Water pump & piston chamber[78]	Stainless steel, brass, aluminium, different types of plastic
Housing[75,80]	ABS, other types of plastic
Water inlet[82]	PP, brass, other types of plastic
High-pressure hose[75,77,80]	HDPE, stainless steel, brass, PVC, different types of plastic and rubber
Cleaning attachment (i.e. lance) [75,77]	Brass, stainless steel, different types of plastic
Detergent hose and tank[75,77,80]	HDPE, PVC, PP, LDPE
Fuel tank	HDPE
Burner	Steel, aluminium, brass, ceramic, copper, different types of refractory materials
Electric cable & plug[79]	PVC, copper winding wire
Casing[75,79]	ABS, HI-PS, steel sheet, other types of plastic
Wheels[79]	PP, other types of plastic and rubber
Safety components[75]	Brass, stainless steel, different types of plastic, aluminium
Integrated circuit board[79]	avg., 5% Si, Au
Packaging[83]	LDPE, cardboard, wooden pallet

[81] http://www.ultimatewasher.com/electric-pressure-washer/index.htm

[82] Assessed to be made of polypropylene as a robust plastic without any special need concerning handling requirements, e.g. corrosive chemicals, very hot water temperatures.

[83] Expert judgment.

Table 45. Estimated material composition for each typical high-pressure cleaner in Eco-Modelling Framework Tool format

Material group	**Domestic high pressure cleaners – cold water**	**Professional high pressure cleaners - cold water**
Bulk plastics (kg)	5.26	8.02
Ferrous (kg)	3.88	14.94
Non-ferrous (kg)	4.01	8.13
Electronics (kg)	0.03	0.05
Misc. (kg)	1.5	2.25
Total weight incl. Packaging (kg)	**14.68**	**33.69**
Bulk plastics (%)	35.8	24.0
Ferrous (%)	26.4	44.8
Non-ferrous (%)	27.3	24.4
Electronics (%)	0.2	0.1
Misc. (%)	10.2	6.7
Total weight incl. Packaging (%)	**100**	**100**

Overall, a dominance of bulk plastics and metals (ferrous and non-ferrous) can be seen in high pressure cleaners. This is typical of a product like this, which has a similar material composition to vacuum cleaners, electric motors and water pumps with some additional components adding pressure and safety.

For domestic high pressure cleaners, bulk plastics are the dominant component in comparison to other material groups, whilst for professional high pressure cleaners it is ferrous metals. According to a study[84], this is because professional cleaners typically use larger and heavier motors as they provide more power compared to the smaller motors in domestic cleaners. The BOMs for the motors and pumps were thus adjusted accordingly, considering the sanity check performed on the total product weight.

4.3.2 Assessment of primary scrap production during sheet metal manufacturing

The primary scrap production during sheet metal manufacturing is considered to be negligible. It is assumed that cuttings and residues are mostly reused in new materials either at the production site or at a recycling site off site.

4.3.3 Packaging materials

Cardboard and low-density plastic are used to protect the products during transportation. They are then sorted by the end user and sent for disposal. Cardboard is generally well sorted, collected and recycled both in households and businesses. Low-density plastic is likely to be incinerated with different percentages of energy recovery throughout the EU.

[84] https://pressurewashr.com/induction-vs-universal-motor-pros-cons/

4.3.4 Volume and weight of the packaged product

The volume of the packaged product is assumed to be same as the dimensions of typical high-pressure cleaners plus five additional centimetres due to packaging. This means that the volume of the packaged product (full-size high pressure cleaner) is 13.1 kg and 31.0 kg for domestic and professional high pressure cleaners, respectively, excluding packaging, and 15 kg and 34 kg including packaging.

4.3.5 Actual means of transport employed in shipment of components, subassemblies and finished products

For distribution, it is assumed that 70% of packaged high pressure cleaners will be transported by ship and truck and 30% only by truck considering most of the cleaners are produced outside Europe (i.e. transported by ship and truck) and the rest produced within Europe and therefore transported by truck. For cleaners transported by ship and truck, a transport distance of 10 000 km by ship and 3 000 km by truck is assumed and for cleaners transported only by truck, a transport distance of about 3 400 km is assumed (conservative assumptions considering the many transport scenarios). However, transport by ship and by truck is often negligible in life cycle assessments since the impact is often small compared to the environmental impact of the rest of the product.

4.3.6 Material flow and collection effort at end-of-life (secondary waste), to landfill/ incineration/ recycling/reuse (industry perspective)

Caspersen and Sørensen[75] established an end-of life materials distribution for packaging, plastic and metal materials as is shown in Table 46.

Table 46. End-of-life scenarios according to Caspersen and Sørensen[75]

End-of-life route	Metals in product	Plastics in product	Packaging materials
Reuse (%)	15	0	0
Incineration (%)	0	25	70
Landfill (%)	85	75	30
Recycling (%)	0	0	0

Although this seems to be the only Life Cycle Assessment study done for HPCs that is publicly available, it is already 20 years old and the end-of-life routes for these material fractions are very different today. For example, the default values for the relevant material groups shown in Table 44 in the Eco-Modelling Framework Tool are shown in Table 47, and have been adapted slightly to reflect the scenario routes for the vacuum cleaners review study[79] and those used for the water pumps review study[78]. Both studies were considered due to the technological similarities and differences of high-pressure cleaners with both product groups, and the fact that both are recent studies (2018 and 2017 respectively). As can be seen from both tables, the share of relevant materials sent to landfill has been greatly reduced since the 1998 study, while fractions sent for reuse/recycling are quite different (probably because in the 1998 study reuse accounted for material recycling).

End-of-life routes shown in Table 47 are those to be considered as input. Differences may exist between domestic and professional products which will be consulted with stakeholders.

Table 47. Default end-of-life routes for relevant material groups in EcoReport tool (version 3.06)

End-of-life route	**Bulk & Tech plastics**	**Ferrous & Non-ferrous**	**Electronics**	**Misc. (packaging)**
EoL mass fraction to reuse	1%	5%	1%	1%
EoL mass fraction to recycling	29%	80%	50%	64%
EoL mass fraction to (heat) recovery	30%	5%	0%	1%
EoL mass fraction to non-recov. incineration	10%	5%	30%	5%
EoL mass fraction to landfill/missing/fugitive	30%	5%	19%	29%

4.3.7 Time-to-failure of critical parts

In an endurance test of 42 domestic HPCs performed by a stakeholder, it was observed that the failures are mostly in the following parts:

- the carbon brushes in the electric motor are worn and no longer make contact, resulting in a defective motor;
- the bearings of the motor become defective;
- the bearings of the pump become defective;
- water leakages.

  Consumer surveys carried out by Which?[85] revealed that common problems were:

- water leaks from the HPC body **22%**;
- lance failures **12%**;
- Pressure losses **11%**.

Which? stated that some of the problems were caused by improper use. For example, water leaks frequently appear after a pressure washer has been left idle over the winter and are often caused by water in the pressure washer freezing, expanding and then splitting the plastic components inside the pump.

Since domestic products generally have a low annual use problems might also be related to the low use, for example, of valves and seals in motors and pumps. Blockages of the inlet filter and of the lance/accessories are also commonly seen.

Professional HPCs are more expensive and repairs and regular maintenance are typically carried out. A stakeholder informs that it is common to have service checks after each 500 hours of use and when the pump needs to be refurbished or replaced (pumps with longer lifetimes like triplex may not need such a service). Leaving water in the pump can result in mineral build-up and corrosion; this means that high pressure cleaners that are not in use on a daily or very regular basis should be emptied of water. The product should also be protected against freeze damage.

Lifetime analyses are further provided in Task 2 and Task 3.

The requirements for endurance as specified in the applicable European Product Safety standards are as follows. Part 2 of the product standard details the requirements; EN 60335-2-79 Clause 18: Endurance specifies:

[85] https://www.which.co.uk/reviews/pressure-washers/article/which-pressure-washer-brand/most-reliable-pressure-washer-brands

- 18.101 'The insulation, contacts and connections shall not be damaged and shall not work loose, as a result of heating, vibration etc.'
- Motor-operated devices – compliance is checked by tests 18.102 AND 18.106 with additional tests as applicable.
- For 18.102 the machine is operated under normal operation and at a rated voltage for 96 hours**.**
- Machines are started (Clause 18.103) under *normal operation,* 50 times at 1.1 x rated voltage and 50 times at 0.85 x rated voltage with the duration not being less than 10 s and at least 10 x the period required from start to full speed.
- Tests are interspersed with other safety tests (e.g. dielectric strength and leakage current tests) during the endurance tests to ensure that safety has not been compromised by the Clause 18 tests.
- 'Connections, handles, guards, brush-caps and other fittings or components shall not have worked loose, and there shall be no deterioration impairing safety in normal use'.

It can be seen that the endurance tests specified are to ensure that safety is assured rather than considering the 'life' of the product in practical use.

4.4 Recommendations

4.4.1 Refined product scope from the technical perspective

There are no further recommendations for a refined product scope.

4.4.2 Barriers and opportunities for Ecodesign from a technical perspective

Barriers

- Some of the technologies identified for reducing in-use consumption of energy, water and detergent require design changes or different components, which may be too expensive compared to the marginal gains due to the infrequent usage pattern for domestic products, and even for some of the professional products. However, this will be further investigated in Task 6.

Opportunities

- Existing Ecodesign measure for electric motors and pumps do not apply to single-phase motors and pumps used in domestic HPCs and some of the professional HPCs. Therefore, there is an opportunity to develop measures for those components.
- Differences in water and energy consumption between the products indicate a market spread, which may provide an opportunity for promoting the BAT products.
- Selected technical measures for in-use resource consumption for mainly professional products may be cost-efficient such as detergent dosage systems.
- Provision of cleaning mode selection (simple, at point of use, e.g. on the head) to optimise pressure/flow and detergent (and/or heat) for a given cleaning task.
- Extension of lifetime through use of better material, facility repairs and improved user information on use, maintenance and storage.
- Assessment and characterisation for the full operating envelope is needed.

5 Environment and economics of base cases

5.1 Introduction

5.1.1 Aim of Task 5

In accordance with the MEErP methodology, Task 5 defines the base cases and quantifies and presents per base case the results of the environmental impact assessment and the Life Cycle Costs (LCC) per consumer per unit and at EU level; as well as the overall energy and water consumption during the use phase and greenhouse gas (GHG) emissions at EU level.

The calculations are made with the an excel tool for estimation of sales and stocks and modelling impacts and the EcoReport Tool 2014 Version 3.0[86]. All calculations are made for the defined six base cases (BC) as presented in Task 1 and Task 3. The excel tool is used for the sales and stock estimations (as presented in Task 2), for the definition and quantification Business As Usual (BAU) scenario presented in this task (Task 5) and for the design option and policy measures scenarios presented in Tasks 6 and 7, respectively. The EcoReport Tool calculates the life cycle environmental impact for a reference year, i.e. for the production, distribution, use and end-of-life treatment considering the bill of materials (BOM) assessed in Task 4 and the direct and indirect energy and resource consumption assessed in Task 3.

5.2 Product-specific inputs

5.2.1 Definition of base cases

The base cases have been defined using the conclusion and analysis of the scope and the various product categories identified in Task 1, combined with the market analysis of Task 2.

The following base cases have been selected in agreement with stakeholders:

- BC1: Domestic cold water electric motor HPC;
- BC2: Professional cold water electric motor single-phase HPC;
- BC3: Professional cold water electric motor three-phase HPC;
- BC4: Professional cold water combustion motor HPC;
- BC5: Professional hot water (fuel burner) electric motor single-phase HPC;
- BC6: Professional hot water (fuel burner) electric motor three-phase HPC.

The selected base cases represent nearly 100% of the domestic and the professional HPC markets and allow a thorough analysis as professional HPCs are split into five different BCs. For each base case, data from average models within each base case already defined in the previous tasks are used as input for the calculations as presented in Task 3. The average model data are based on technical data collected from the manufacturers' specifications on their web sites and from the instruction manuals.

5.2.2 Market data

The market data that were used are presented in Task 2 and are based on the sales data and calculated stocks using the excel tool mentioned above. A Weibull distribution has been assumed for the lifetime of domestic and professional HPCs.

Additional market data are defined and/or calculated in Task 5:

- Purchase prices are based on current purchase prices in Task 2 and adjusted over the period by use of a learning curve in the model for the manufacturer production price.
- Energy prices (electricity, natural gas and gas oil) are from PRIMES 2016[87] from 2005 to 2050 in 5-year intervals and interpolated in each interval to have annual prices. Before 2005, prices are de-escalated by approximately 2% per year.

[86] https://ec.europa.eu/docsroom/documents/5309/attachments/1/translations
[87] These are based on the PRIMES model and delivered by DG Energy.

- Water prices are extracted from the Preparatory study for Ecodesign and Energy Label for Household Washing machines and washer dryers[88] (EUR 4.08/m^3 including VAT for 2015 with an escalation rate of 2.5% in accordance MEErP.
- The average detergent price is set at EUR 2.5/litre for the domestic base case and EUR 0.4/litre for the professional base cases.
- Repair and maintenance costs over the lifetime for all professional products are assumed to sum up to approximately the same level as the purchase price of one unit in 2017. This would include change of water pump, seals, minor components, and some maintenance. No repair and maintenance costs are assumed for the domestic types because, as described in Task 2, domestic HPCs have very low reparability potential.

5.2.3 Annual resources consumption and emissions

The annual resource consumption data for both low and high usage scenarios come from Task 3 and are based on the assumptions established in Task 3. Emissions and the environmental impact at EU level are calculated using the MEErP EcoReport Tool 2014 and the excel tool to model stocks, respectively.

To better address the uncertainty in the usage patterns of domestic and professional HPCs (see Task 3), two scenarios are considered based on the stakeholders' input (see Table 48):

- a low usage scenario, which is the average of the low values provided by stakeholders, and
- a high usage scenario, which is an average of all the range of values provided by stakeholders.

Table 48. Assumptions of annual hours of active use

Type of HPC	Low usage scenario Annual usage in hours/year	High usage scenario Annual usage in hours/year
Domestic HPC	2-8, average: 5	2-50, average: 26
Professional HPC	100-200, average: 150	100-900, average: 500
Stationary HPC	100-200, average: 150	100-900, average: 500

Due to the uncertainties on the annual usage, the following analyses are performed both with the 'low usage scenario' and the 'high usage scenario' to provide an uncertainty range.

5.2.4 Bill of material and end-of-life

The data for the production, distribution and end-of-life including the product weight and bill of material (BOM) come from Task 4. The BOMs are based on total product weight and an assumed distribution of materials used in the production of HPCs.

Professional units are used with a high frequency and are designed to optimise durability and reparability. This results in a small contribution of the production phase (see section 5.3.2-7), and therefore there is little room for improvement in that area and no design options are envisaged. For this reason and in order to simplify the modelling of the five professional bases cases, the BOM for the professional BCs is based on the average of BC2 and BC3 (professional cold water units), i.e. not including BOMs for the heating unit, for the combustion motor and for heavier HPCs. The environmental impact for each professional base case is therefore based on the production material content for BC2/BC3 and on the consumption of energy, water and detergent for the specific base case.

[88] JRC, 2017. Ecodesign and Energy Label for Household Washing machines and washer dryer .https://publications.jrc.ec.europa.eu/repository/handle/JRC109033

5.3 Base case environmental impact assessment

The environmental impacts have been calculated using the MEErP EcoReport Tool and the data inputs presented in the previous section. This section shows the results of these calculations in the MEErP format for:

- raw materials use and manufacturing,
- distribution,
- use phase,
- end-of-life phase.

5.3.1 Domestic cold water high pressure cleaner (BC1)

Table 49 and Table 50 show the material consumption of a domestic high pressure cleaner over the whole life cycle of 9.5 years in low and high usage scenarios. The material consumption during production is equivalent to the input values of the bill of materials. The materials consumed during the use phase correspond to the materials consumed for replacement with spare parts, and the sum of detergents (i.e. auxiliaries) used over the life cycle. The material consumption during the end-of-life phase is split into disposal, recycling and the stock. Stock is meant to maintain the mass balance, since the mass discarded seldom equals the mass of new products sold.

Table 49. Life cycle material consumption of a domestic high pressure cleaner in a low usage scenario

Life Cycle phases		**Production**	**Use**	**End-of-Life**		
Materials	Unit	Total		Disposal	Recycl.	Stock
Bulk Plastics	g	5 257	53	2 382	1 949	978
Ferro	g	3 880	39	160	3 037	722
Non-ferro	g	4 012	40	165	3 141	747
Electronics	g	30	0	12	13	6
Misc.	g	1 500	15	420	816	279
Auxiliaries	g	0	10 946	10 946	0	0
Total weight	g	14 680	11 093	14 086	8 955	2 73 1

Table 50. Life cycle material consumption of a domestic high pressure cleaner in a high usage scenario

Life Cycle phases		**Production**	**Use**	**End-of-Life**		
Materials	Unit	Total		Disposal	Recycl.	Stock
Bulk Plastics	g	5 257	53	2 382	1 949	978
Ferro	g	3 880	39	160	3 037	722
Non-ferro	g	4 012	40	165	3 141	747
Electronics	g	30	0	12	13	6
Misc.	g	1 500	15	420	816	279
Auxiliaries	g	0	56 930	56 930	0	0
Total weight	g	14 680	57 077	60 070	8 955	2 73 1

Table 51 and Table 52 show the environmental impacts of a domestic high pressure cleaner over the whole life cycle of 9.5 years in low and high usage scenarios, and according to the assumptions made on user behaviour described in Task 3. The share of total energy at the use phase that is not electricity refers to the assumption of use of hot water from the tap, heated by means of the domestic heating systems of dwellings.

Table 51. Life cycle environmental impacts of a domestic high pressure cleaner in a low usage scenario

Life Cycle phases	Unit	PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE		TOTAL
Resources Use and Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	
Other Resources & Waste							debit	credit	
Total Energy (GER)	MJ	1 486	295	1 782	230	1 595	55	-310	**3 352**
of which, electricity (in primary MJ)	MJ	285	176	461	0	1 081	0	-45	**1 496**
Water (process)	l	41	3	44	0	25 333	0	-3	**25 375**
Water (cooling)	l	736	84	819	0	55	0	-48	**827**
Waste, non-haz./ landfill	g	6 578	917	7 495	166	1 027	194	-1 924	**6 959**
Waste, hazardous/ incinerated	g	45	0	45	3	26	0	-4	**70**
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	74	16	91	16	70	0	-17	**160**
Acidification, emissions	g SO_2 eq.	854	71	925	48	305	2	-235	**1 046**
Volatile Organic Compounds (VOCs)	g	3	0	3	2	24	0	-1	**29**
Persistent Organic Pollutants (POP)	ng i-Teq	99	0	99	1	6	0	-31	**75**
Heavy Metals	mg Ni eq.	136	0	136	8	12	0	-40	**116**
PAHs	mg Ni eq.	286	0	286	7	6	0	-73	**227**
Particulate Matter (PM, dust)	g	79	11	91	342	7	1	-22	**419**
Emissions (Water)									
Heavy Metals	mg Hg/20	344	0	344	0	10	0	-90	**265**
Eutrophication	g PO_4	3	0	4	0	587	191	0	**781**

Table 52. Life cycle environmental impacts of a domestic high pressure cleaner in a high usage scenario

Life Cycle phases	Unit	PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE		TOTAL
Resources Use and Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	
Other Resources & Waste							debit	credit	

Total Energy (GER)	MJ	1 486	295	1 782	230	8 231	189	-310	**10 122**
of which, electricity (in primary MJ)	MJ	285	176	461	0	5 608	0	-45	**6 024**
Water (process)	l	41	3	44	0	131 739	0	-3	**131 780**
Water (cooling)	l	736	84	819	0	256	0	-48	**1 028**
Waste, non-haz./ landfill	g	6 578	917	7 495	166	5 067	636	-1 924	**11 440**
Waste, hazardous/ incinerated	g	45	0	45	3	131	0	-4	**175**
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	74	16	91	16	363	1	-17	**453**
Acidification, emissions	g SO_2 eq.	854	71	925	48	1 549	7	-235	**2 295**
Volatile Organic Compounds (VOCs)	g	3	0	3	2	126	0	-1	**131**
Persistent Organic Pollutants (POP)	ng i-Teq	99	0	99	1	26	0	-31	**96**
Heavy Metals	mg Ni eq.	136	0	136	8	58	0	-40	**162**
PAHs	mg Ni eq.	286	0	286	7	20	0	-73	**240**
Particulate Matter (PM, dust)	g	79	11	91	342	33	2	-22	**447**
Emissions (Water)									
Heavy Metals	mg Hg/20	344	0	344	0	39	0	-90	**294**
Eutrophication	g PO4	3	0	4	0	3 053	991	0	**4 047**

The results for the low usage scenario are shown in Figure 52 and Figure 53 in terms of relative contributions (%) of each life cycle phase (i.e. manufacturing, distribution, use and end-of-life) to the overall results. The results are presented for each impact category as the sum of the contributions (%) of all the phases in absolute value summing up to 100%. Negative values in the end-of-life phase represent credits, i.e. avoided impacts.

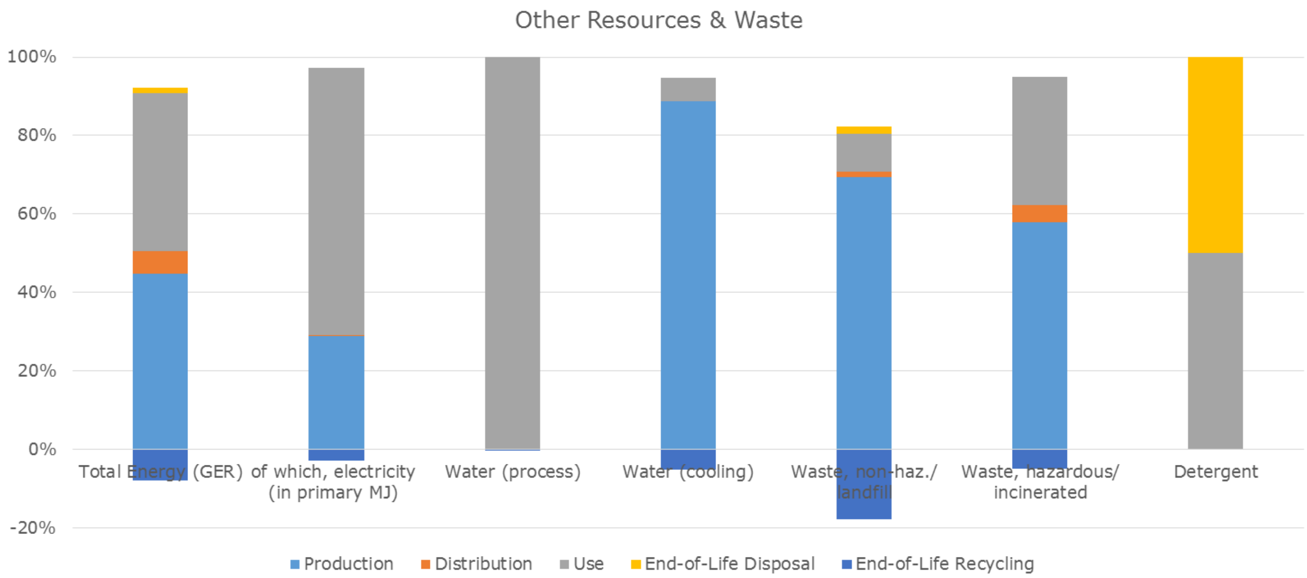


Figure 52. Contribution of different life cycle phases to other resources and waste of a domestic high pressure cleaner in a low usage scenario

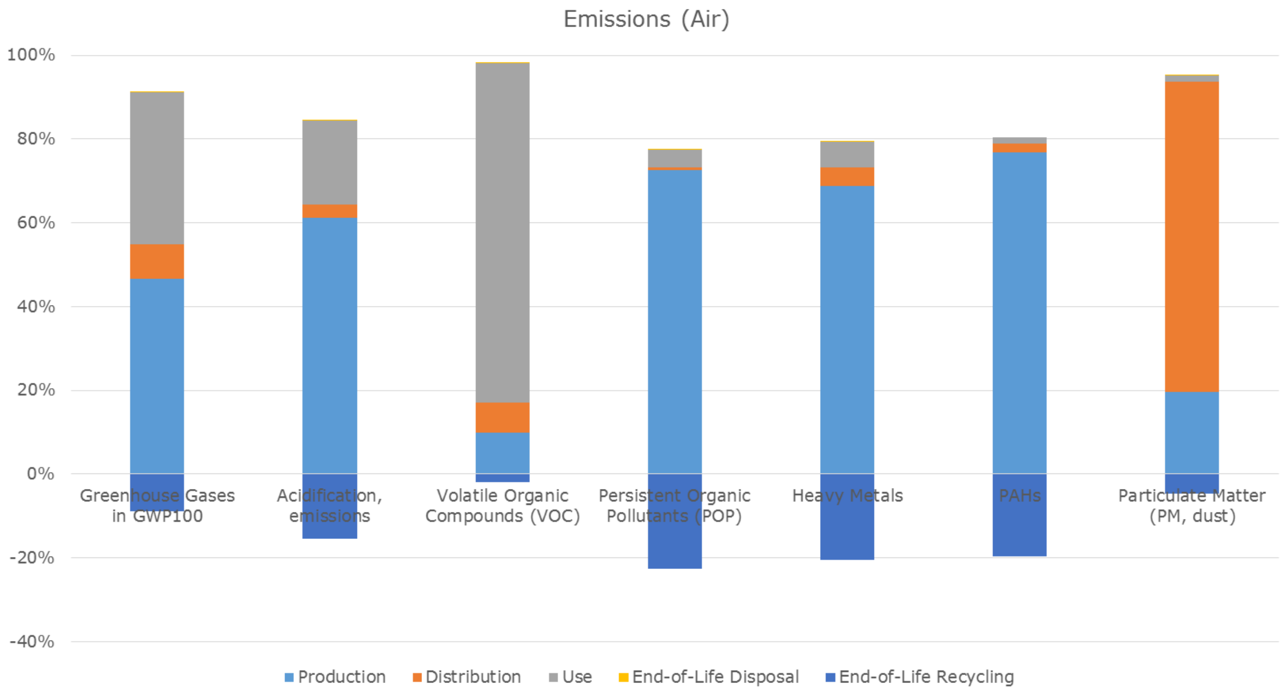


Figure 53. Contribution of different life cycle phases to emissions to air of a domestic high pressure cleaner in a low usage scenario

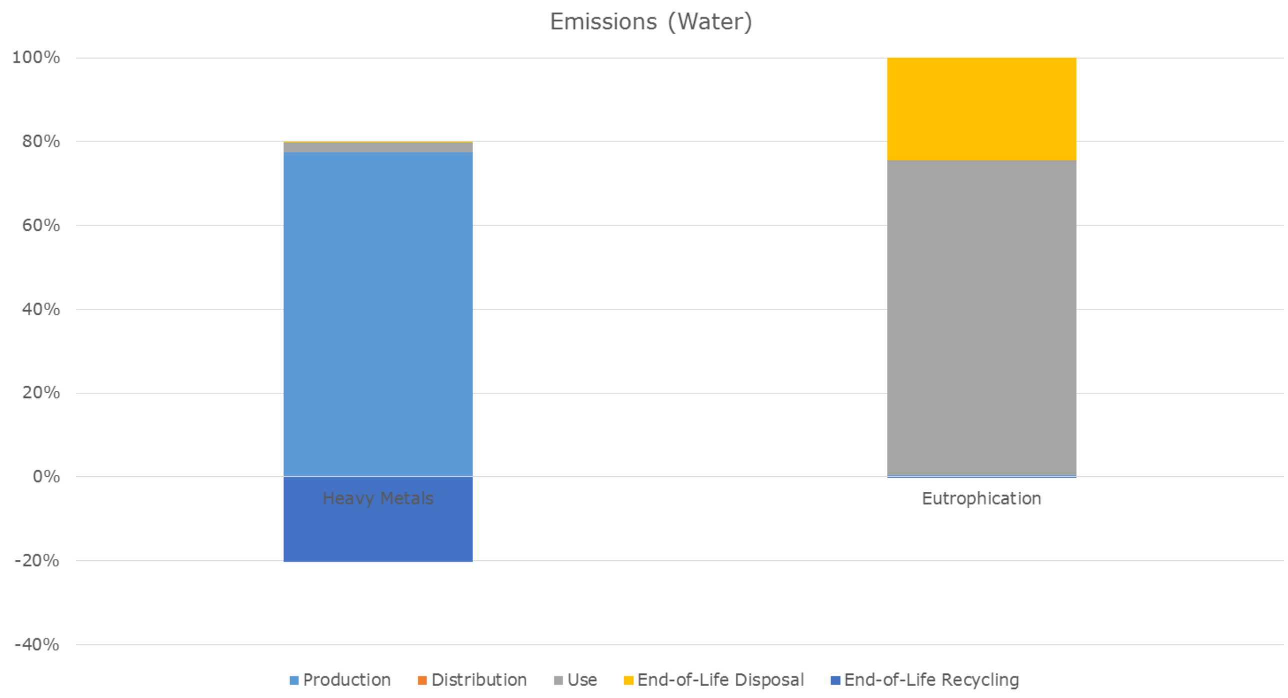


Figure 54. Contribution of different life cycle phases to emissions to water of a domestic high pressure cleaner in a low usage scenario

Figure 52 and Figure 53 show that the use and production phases have similar shares in the consumption of energy and global warming potential (≈40% each). Process water is due to the consumption of water by use of the machine for cleaning, and it is one of the main resources, together with the consumption of electricity.

As can be observed in Figure 53 and Figure 54, the use phase is dominant for volatile organic compounds (VOCs) (≈ 90%) and eutrophication potential (EP) (≈80%). This is mainly caused by the consumption of electricity and detergent, respectively. Global warming potential is split between use and production phase, similar to energy consumption.

The contribution of the production phase scores significantly in the following impact categories: acidification (≈ 60%), POP (≈ 75%), HM air (≈ 75%), PAHs (≈ 80%). The extraction of raw materials such as minerals and the further manufacturing to steel or processing of raw materials to get the different types of plastics is the main contributor to these impact categories.

The distribution phase is relevant only for PM (≈ 80%) due to the transport of the packaged products.

The EoL presents significant negative impacts in some categories, as a result of the credits (avoided impacts) that the EcoReport Tool assigns to the recycling of materials.

The same results for the high usage scenario are shown in Figure 55 and Figure 56.

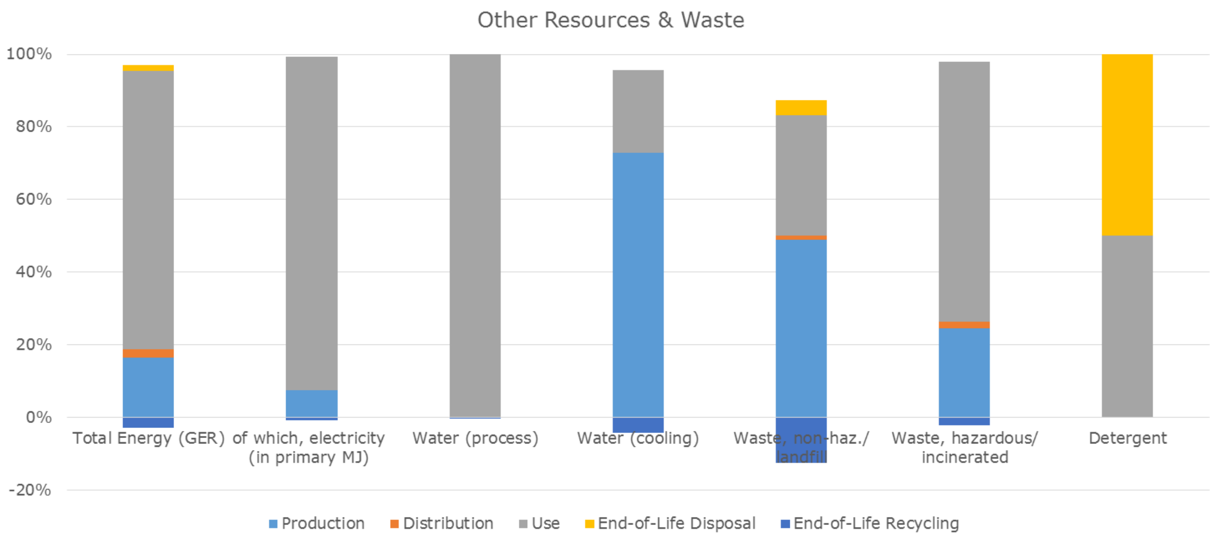


Figure 55. Contribution of different life cycle phases to other resources and waste of a domestic high pressure cleaner in a high usage scenario

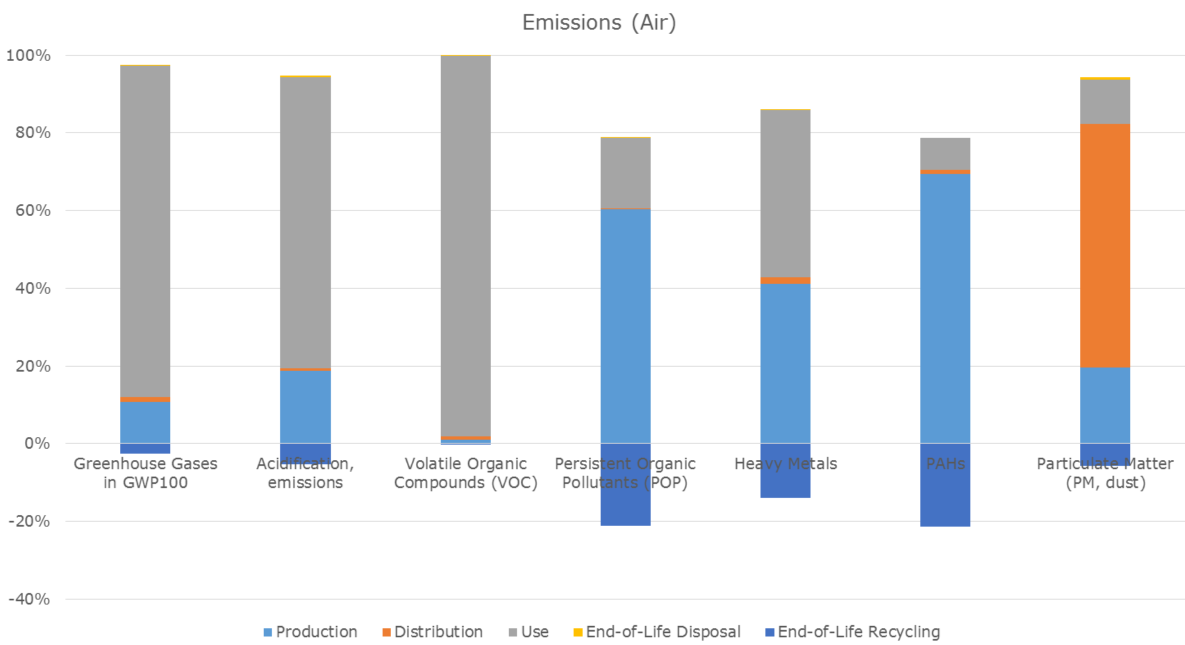


Figure 56. Contribution of different life cycle phases to emissions to air of a domestic high pressure cleaner in a high usage scenario

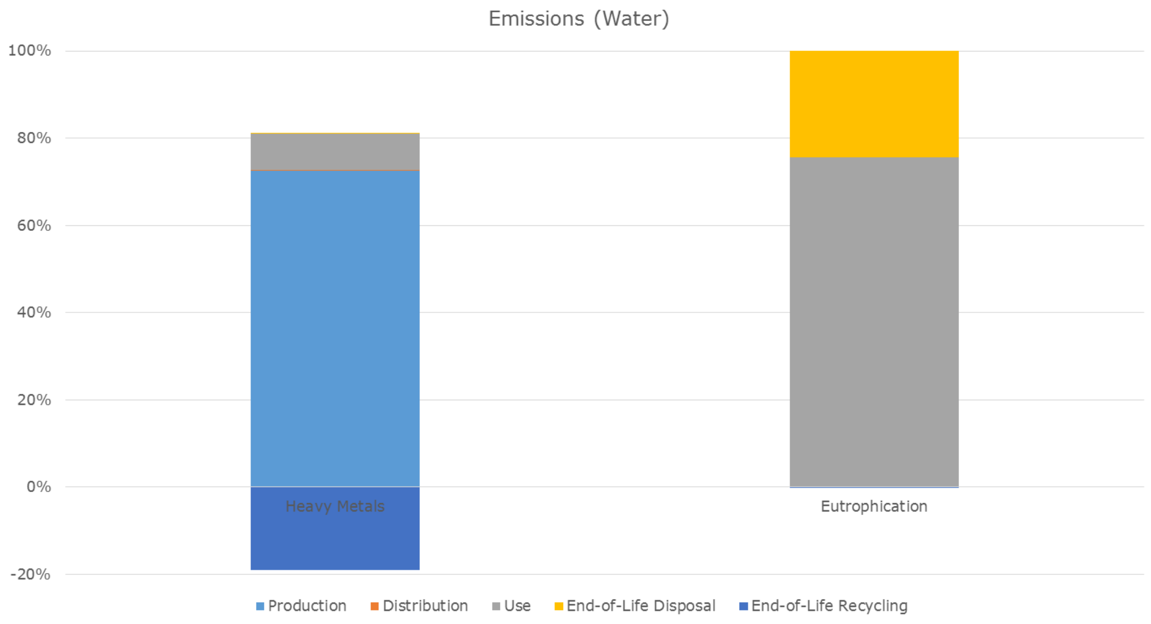


Figure 57. Contribution of different life cycle phases to emissions to water of a domestic high pressure cleaner in a low usage scenario

Figure 55 shows that the use phase clearly dominates the consumption of energy (>70%) and water (100% of water used in the process) and the generation of waste (especially hazardous/incinerated waste) along the life cycle.

As can be observed in Figure 56, the use phase is also dominant for the four impact categories: global warming potential (GWP100) (≈ 80%), acidification potential (AP) (≈ 70%), volatile organic compounds (VOCs) (≈ 90%) and eutrophication potential (EP) (≈80%).

This is the result of a higher frequency of use, which turns the use phase into a more relevant phase compared to the low usage scenario.

5.3.2 Professional high pressure cleaners (BC2 to BC6)

Table 53 and Table 54 show the material consumption of a professional HPC cold water electric motor single-phase high pressure cleaner over the whole life cycle of 10.3 years in low and high usage scenarios. The material consumption during the production is equivalent to the input values of the bill of materials. As explained before, the same bill of materials has been applied to model all the professional base cases.

Table 53. Life cycle material consumption of a professional high pressure cleaner (BC2) in a low usage scenario

Life Cycle phases		Production	Use	End-of-life		
Resources Use		**Total**		Disposal	Recycl.	Stock
Materials	Unit					
Bulk Plastics	g	18 502	185	9 423	7 710	1 554
TecPlastics	g	0	0	0	0	0
Ferro	g	34 476	345	1 596	30 329	2 896
Non-ferro	g	18 764	188	869	16 506	1 576
Electronics	g	104	1	47	49	9
Misc.	g	5 191	52	1 634	3 172	436
Auxiliaries	g	0	501 015	501 015	0	0
Total weight	g	77 037	501 785	514 585	57 766	6 471

Table 54. Life cycle material consumption of a professional high pressure cleaner (BC2) in a high usage scenario

Life Cycle phases		Production	Use	End-of-life		
Resources Use		**Total**		Disposal	Recycl.	Stock
Materials	Unit					
Bulk Plastics	g	18 502	185	9 423	7 710	1 554
TecPlastics	g	0	0	0	0	0
Ferro	g	34 476	345	1 596	30 329	2 896
Non-ferro	g	18 764	188	869	16 506	1 576
Electronics	g	104	1	47	49	9
Misc.	g	5 191	52	1 634	3 172	436
Auxiliaries	g	0	1 670 053	1 670 053	0	0
Total weight	g	77 037	1 670 824	1 683 623	57 766	6 471

5.3.2.1 BC 2 and BC 5: Professional single-phase high pressure cleaners

Table 55 and Table 56 show the environmental impacts of a professional high pressure cleaner over the whole life cycle of 10.3 years in low and high usage scenarios, and according to the assumptions made on user behaviour described in Task 3. The results clearly show that the main difference between domestic and professional products is frequency of use.

As for the domestic base case, the results are also shown in Figure 58 and Figure 59 in terms of the relative contributions (%) of each life cycle phase (i.e. manufacturing, distribution, use and end-of-life) to the overall results. These relative contributions are very similar among the different professional base cases and therefore they will only be analysed in this section.

Table 55. Life cycle environmental impacts of a professional high pressure cleaner (BC2) in a low usage scenario

Life Cycle phases	Unit	PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE		TOTAL
Resources Use & Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	
Other Resources & Waste							debit	credit	
Total Energy (GER)	MJ	6 713	1 358	8 071	710	77 872	1 552	-1 750	**86 456**
of which, electricity (in primary MJ)	MJ	1 024	810	1 834	1	54 839	0	-189	**56 486**
Water (process)	l	153	13	167	0	1 159 295	0	-15	**1 159 447**
Water (cooling)	l	2 618	386	3 003	0	2 463	0	-198	**5 268**
Waste, non-haz./ landfill	g	52 754	4 225	56 980	406	47 372	5 472	-18 021	**92 208**
Waste, hazardous/ incinerated	g	159	0	159	8	1 236	0	-15	**1 388**
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	359	76	435	47	3 428	5	-102	**3 812**
Acidification, emissions	g SO_2 eq.	3 334	327	3 661	142	14 630	54	-1 044	**17 442**
Volatile Organic Compounds (VOCs)	g	13	0	13	10	1 236	0	-3	**1 256**
Persistent Organic Pollutants (POP)	ng i-Teq	800	0	800	2	241	1	-280	**764**
Heavy Metals	mg Ni eq.	532	0	532	21	560	2	-180	**935**
PAHs	mg Ni eq.	1 498	1	1 499	25	175	0	-462	**1 237**
Particulate Matter (dust)	g	486	51	537	1 710	314	14	-158	**2 417**
Emissions (Water)									
Heavy Metals	mg Hg/20	1 398	0	1 398	1	353	2	-423	**1 331**
Eutrophication	g PO_4	13	1	14	0	26 865	8 719	-2	**35 596**

Table 56. Life cycle environmental impacts of a professional high pressure cleaner (BC2) in a high usage scenario

Life Cycle phases l	**Unit**	**PRODUCTION**			**DISTRIBUTION**	**USE**	**END-OF-LIFE**		**TOTAL**
Resources Use & Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	
Other Resources & Waste							debit	credit	
Total Energy (GER)	MJ	6 713	1 358	8 071	710	259 417	4 947	-1 750	**271 395**
of which, electricity (in primary MJ)	MJ	1 024	810	1 834	1	182 774	0	-189	**184 420**
Water (process)	l	153	13	167	0	3 864 327	0	-15	**3 864 480**
Water (cooling)	l	2 618	386	3 003	0	8 149	0	-198	**10 954**
Waste, non-haz./ landfill	g	52 754	4 225	56 980	406	156 674	16 701	-18 021	**212 740**
Waste, hazardous/ incinerated	g	159	0	159	8	4 117	0	-15	**4 269**
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	359	76	435	47	11 417	16	-102	**11 812**
Acidification, emissions	g SO_2 eq.	3 334	327	3 661	142	48 689	169	-1 044	**51 617**
Volatile Organic Compounds (VOCs)	g	13	0	13	10	4 119	0	-3	**4 139**
Persistent Organic Pollutants (POP)	ng i-Teq	800	0	800	2	785	4	-280	**1 310**
Heavy Metals	mg Ni eq.	532	0	532	21	1 853	4	-180	**2 231**
PAHs	mg Ni eq.	1 498	1	1 499	25	547	0	-462	**1 609**
Particulate Matter (dust)	g	486	51	537	1 710	1 036	36	-158	**3 162**
Emissions (Water)									
Heavy Metals	mg Hg/20	1 398	0	1 398	1	1 145	4	-423	**2 125**
Eutrophication	g PO_4	13	1	14	0	89 551	29,058	-2	**118 621**

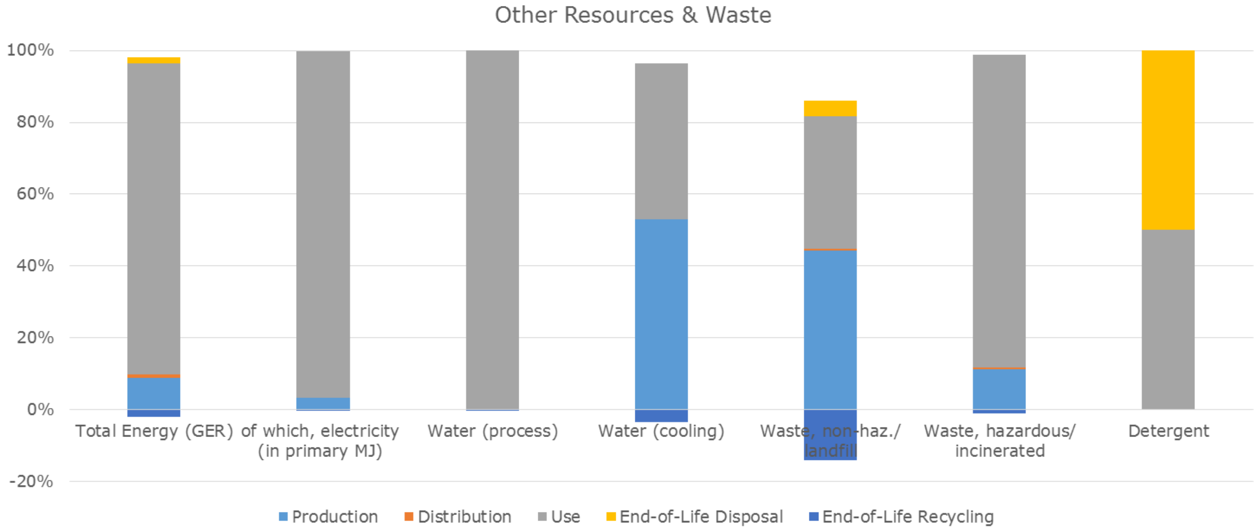


Figure 58. Contribution of different life cycle phases to other resources and waste of a professional high pressure cleaner in a low usage scenario

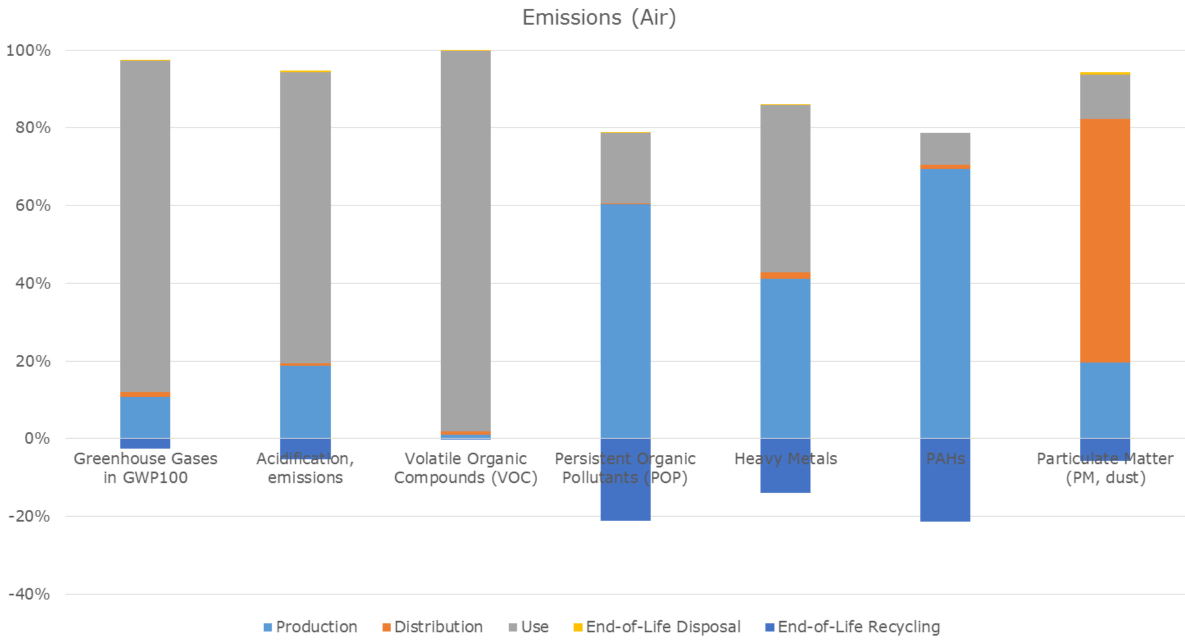


Figure 59. Contribution of different life cycle phases to emissions to air of a professional high pressure cleaner in a low usage scenario

Figure 58 shows that the use phase is the main contributor to the consumption of energy (>85%) and water used in the process l and the generation of waste (especially hazardous/incinerated waste) along the life cycle. Regarding the emissions to air and water, the use phase is also dominant for the four impact categories: global warming potential (GWP100) (≈ 80%), acidification potential (AP) (≈ 80%) and VOCs (> 95%). The percentages are higher than for domestic units, due to the longer lifetime and more intensive use which reduce the impact of production.

The contribution of the production phase scores significantly in the following impact categories: water for cooling (≈ 50%), non-hazardous waste (≈ 40%), POP (≈ 60%), HM air (≈ 40%), PAHs (≈ 70%).

The same results for the high usage scenario are shown in Figure 60 and Figure 61. As expected, the use phase is more significant, reaching around 95% for GWP and acidification, while the production phase reduces its weight in POP, HM air and PAHs.

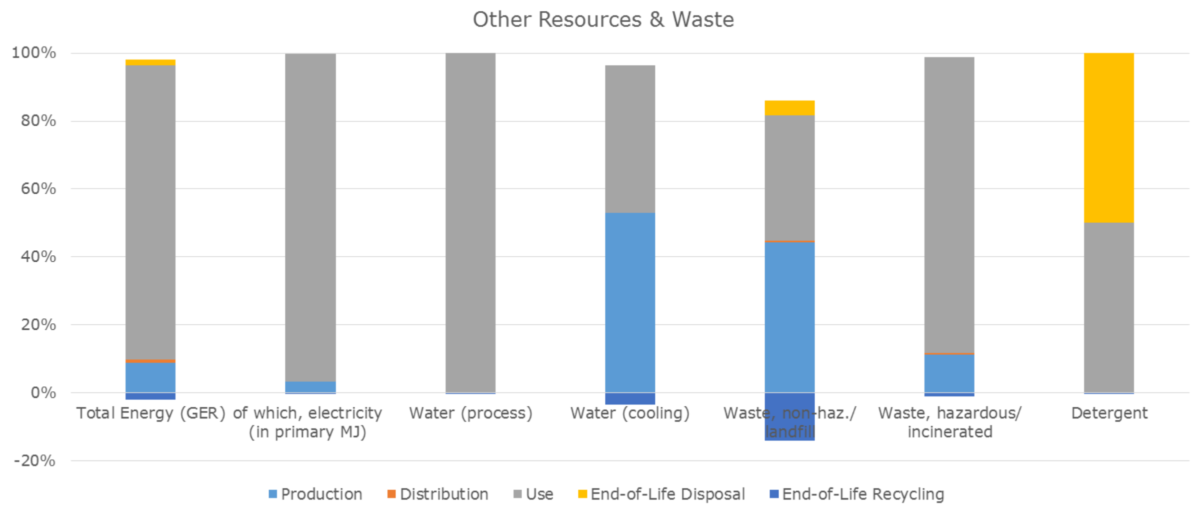


Figure 60. Contribution of different life cycle phases to other resources and waste of a professional high pressure cleaner in a high usage scenario

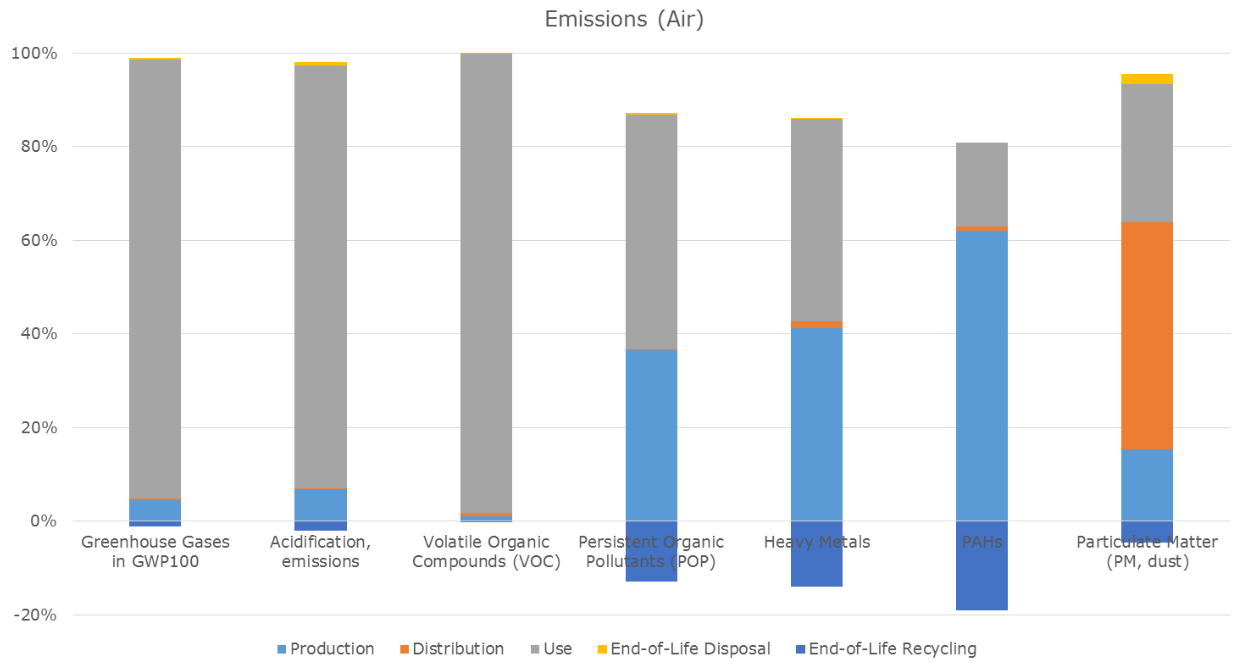


Figure 61. Contribution of different life cycle phases to emissions to air of a professional high pressure cleaner in a high usage scenario

Table 57 and Table 58 show the environmental impacts of a professional hot water high pressure cleaner over the whole life cycle of 10 years, and according to the assumptions made on user behaviour described in Task 3. The main difference is due to the heating oil consumed by the boiler, which increases the total energy consumption in the use phase and reduces the share of electricity compared to the cold water unit (from 65% to 23%).

Table 57. Life cycle environmental impacts of a professional high pressure cleaner (BC5) in a low usage scenario

Life Cycle phases	**Unit**	**PRODUCTION**			**DISTRIBUTION**	**USE**	**END-OF-LIFE**		**TOTAL**
Resources Use & Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	
Other Resources & Waste							debit	credit	
Total Energy (GER)	MJ	6 713	1 358	8 071	710	169 636	1 343	-1 750	**178 010**
of which, electricity (in primary MJ)	MJ	1 024	810	1 834	1	39 780	0	-189	**41 426**
Water (process)	l	153	13	167	0	991 137	0	-15	**991 289**
Water (cooling)	l	2 618	386	3 003	0	1 794	0	-198	**4 599**
Waste, non-haz./ landfill	g	52 754	4 225	56 980	406	36 938	4 780	-18 021	**81 082**
Waste, hazardous/ incinerated	g	159	0	159	8	945	0	-15	**1 097**
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	359	76	435	47	10 959	4	-102	**11 342**
Acidification, emissions	g SO_2 eq.	3 334	327	3 661	142	21 926	46	-1 044	**24 731**
Volatile Organic Compounds (VOCs)	g	13	0	13	10	1 043	0	-3	**1 064**
Persistent Organic Pollutants (POP)	ng i-Teq	800	0	800	2	191	1	-280	**714**
Heavy Metals	mg Ni eq.	532	0	532	21	407	2	-180	**783**
PAHs	mg Ni eq.	1 498	1	1 499	25	141	0	-462	**1 203**
Particulate Matter (dust)	g	486	51	537	1 710	423	12	-158	**2 524**
Emissions (Water)									
Heavy Metals	mg Hg/20	1 398	0	1 398	1	274	2	-423	**1 252**
Eutrophication	g PO_4	13	1	14	0	23 001	7 465	-2	**30 478**

Table 58. Life cycle environmental impacts of a professional high pressure cleaner (BC5) in a high usage scenario

Life Cycle phases l	Unit	PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE		TOTAL
Resources Use & Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	
Other Resources & Waste							debit	credit	
Total Energy (GER)	MJ	6 713	1 358	8 071	710	565 295	4 250	-1 750	**576 577**
of which, electricity (in primary MJ)	MJ	1 024	810	1 834	1	132 575	0	-189	**134 222**
Water (process)	l	153	13	167	0	3 303 800	0	-15	**3 303 952**
Water (cooling)	l	2 618	386	3 003	0	5 918	0	-198	**8 723**
Waste, non-haz./ landfill	g	52 754	4 225	56 980	406	121 896	14 394	-18 021	**175 654**
Waste, hazardous/ incinerated	g	159	0	159	8	3 148	0	-15	**3 300**
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	359	76	435	47	36 521	14	-102	**36 914**
Acidification, emissions	g SO_2 eq.	3 334	327	3 661	142	73 010	145	-1 044	**75 914**
Volatile Organic Compounds (VOCs)	g	13	0	13	10	3 478	0	-3	**3 498**
Persistent Organic Pollutants (POP)	ng i-Teq	800	0	800	2	617	3	-280	**1 142**
Heavy Metals	mg Ni eq.	532	0	532	21	1 346	4	-180	**1 723**
PAHs	mg Ni eq.	1 498	1	1 499	25	434	0	-462	**1 496**
Particulate Matter (dust)	g	486	51	537	1 710	1 398	32	-158	**3 519**
Emissions (Water)									
Heavy Metals	mg Hg/20	1 398	0	1 398	1	880	3	-423	**1 859**
Eutrophication	g PO_4	13	1	14	0	76 670	24 880	-2	**101 561**

5.3.2.2 BC 3 and BC 6: Professional three-phase high pressure cleaners

Table 59 and Table 60 show the environmental impacts of professional high pressure cleaner (BC3) over the whole life cycle of 10.3 years in low and high usage scenarios, and according to the assumptions made on user behaviour described in Task 3. The main difference is due to the higher power and flow, which results in an increase of energy and water consumption at the use phase.

Table 59. Life cycle environmental impacts of a professional high pressure cleaner (BC3) in a low usage scenario

Life Cycle phases l	Unit	PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE		TOTAL
Resources Use & Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	
Other Resources & Waste							debit	credit	
Total Energy (GER)	MJ	6 713	1 358	8 071	710	174 555	2 768	-1 750	**184 355**
of which, electricity (in primary MJ)	MJ	1 024	810	1 834	1	132 329	0	-189	**133 975**
Water (process)	l	153	13	167	0	2 127 755	0	-15	**2 127 907**
Water (cooling)	l	2 618	386	3 003	0	5 907	0	-198	**8 712**
Waste, non-haz./ landfill	g	52 754	4 225	56 980	406	102 833	9 492	-18 021	**151 690**
Waste, hazardous/ incinerated	g	159	0	159	8	2 767	0	-15	**2 919**
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	359	76	435	47	7 641	9	-102	**8 028**
Acidification, emissions	g SO_2 eq.	3 334	327	3 661	142	32 809	95	-1 044	**35 663**
Volatile Organic Compounds (VOCs)	g	13	0	13	10	2 976	0	-3	**2 996**
Persistent Organic Pollutants (POP)	ng i-Teq	800	0	800	2	510	2	-280	**1 034**
Heavy Metals	mg Ni eq.	532	0	532	21	1 343	3	-180	**1 719**
PAHs	mg Ni eq.	1 498	1	1 499	25	382	0	-462	**1 444**
Particulate Matter (dust)	g	486	51	537	1 710	700	22	-158	**2 811**
Emissions (Water)									
Heavy Metals	mg Hg/20	1 398	0	1 398	1	773	3	-423	**1 752**
Eutrophication	g PO_4	13	1	14	0	49 314	16 000	-2	**65 326**

Table 60. Life cycle environmental impacts of a professional high pressure cleaner (BC3) in a high usage scenario

Life Cycle phases -	Unit	PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE		TOTAL
Resources Use & Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	
Other Resources & Waste							debit	credit	
Total Energy (GER)	MJ	6 713	1 358	8 071	710	581 694	8 998	-1 750	**597 724**
of which, electricity (in primary MJ)	MJ	1 024	810	1 834	1	441 073	0	-189	**442 720**
Water (process)	l	153	13	167	0	7 092 517	0	-15	**7 092 670**
Water (cooling)	l	2 618	386	3 003	0	19 629	0	-198	**22 434**
Waste, non-haz./ landfill	g	52 754	4 225	56 980	406	341 547	30 102	-18 021	**411 013**
Waste, hazardous/ incinerated	g	159	0	159	8	9 221	0	-15	**9 373**
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	359	76	435	47	25 460	29	-102	**25 868**
Acidification, emissions	g SO_2 eq.	3 334	327	3 661	142	109 286	307	-1 044	**112 352**
Volatile Organic Compounds (VOCs)	g	13	0	13	10	9 918	0	-3	**9 939**
Persistent Organic Pollutants (POP)	ng i-Teq	800	0	800	2	1 680	6	-280	**2 208**
Heavy Metals	mg Ni eq.	532	0	532	21	4 465	7	-180	**4 846**
PAHs	mg Ni eq.	1 498	1	1 499	25	1 239	0	-462	**2 301**
Particulate Matter (dust)	g	486	51	537	1 710	2 320	63	-158	**4 473**
Emissions (Water)									
Heavy Metals	mg Hg/20	1 398	0	1 398	1	2 545	6	-423	**3 527**
Eutrophication	g PO_4	13	1	14	0	164 380	53 331	-2	**217 723**

Table 61 and Table 62 show the environmental impacts of a professional high pressure cleaner (BC6) over the whole life cycle of 10.3 years in low and high usage scenarios, and according to the assumptions made on user behaviour described in Task 3. The main difference is due to the heating oil consumed by the boiler, which increases the total energy consumption in the use phase and reduces the share of electricity compared to the cold water unit (from 70% to 30%).

Table 61. Life cycle environmental impacts of a professional high pressure cleaner (BC6) in a low usage scenario

Life Cycle phases	Unit	PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE		TOTAL
Resources Use & Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	
Other Resources & Waste							debit	credit	
Total Energy (GER)	MJ	6 713	1 358	8 071	710	360 465	2 708	-1 750	**370 205**
of which, electricity (in primary MJ)	MJ	1 024	810	1 834	1	103 213	0	-189	**104 859**
Water (process)	l	153	13	167	0	2 077 496	0	-15	**2 077 648**
Water (cooling)	l	2 618	386	3 003	0	4 613	0	-198	**7 418**
Waste, non-haz./ landfill	g	52 754	4 225	56 980	406	87 069	9 295	-18 021	**135 728**
Waste, hazardous/ incinerated	g	159	0	159	8	2 293	0	-15	**2 445**
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	359	76	435	47	22 704	9	-102	**23 092**
Acidification, emissions	g SO_2 eq.	3 334	327	3 661	142	48 280	93	-1 044	**51 132**
Volatile Organic Compounds (VOCs)	g	13	0	13	10	2 611	0	-3	**2 632**
Persistent Organic Pollutants (POP)	ng i-Teq	800	0	800	2	437	2	-280	**961**
Heavy Metals	mg Ni eq.	532	0	532	21	1 049	3	-180	**1 425**
PAHs	mg Ni eq.	1 498	1	1 499	25	324	0	-462	**1 386**
Particulate Matter (dust)	g	486	51	537	1 710	937	21	-158	**3 047**
Emissions (Water)									
Heavy Metals	mg Hg/20	1 398	0	1 398	1	644	3	-423	**1 622**
Eutrophication	g PO_4	13	1	14	0	48 210	15 644	-2	**63 866**

Table 62. Life cycle environmental impacts of a professional high pressure cleaner (BC6) in a high usage scenario

Life Cycle phases	Unit	PRODUCTION			DISTRIBUTION	USE	END-OF-LIFE		TOTAL
Resources Use & Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	
Other Resources & Waste							debit	credit	
Total Energy (GER)	MJ	6 713	1 358	8 071	710	1 201 394	8 800	-1 750	**1 217 226**
of which, electricity (in primary MJ)	MJ	1 024	810	1 834	1	344 019	0	-189	**345 666**
Water (process)	l	153	13	167	0	6 924 977	0	-15	**6 925 130**
Water (cooling)	l	2 618	386	3 003	0	15 315	0	-198	**18 120**
Waste, non-haz./ landfill	g	52 754	4 225	56 980	406	288 998	29 446	-18 021	**357 809**
Waste, hazardous/ incinerated	g	159	0	159	8	7 639	0	-15	**7 791**
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	359	76	435	47	75 673	29	-102	**76 080**
Acidification, emissions	g SO_2 eq.	3 334	327	3 661	142	160 856	301	-1 044	**163 916**
Volatile Organic Compounds (VOCs)	g	13	0	13	10	8 703	0	-3	**8 724**
Persistent Organic Pollutants (POP)	ng i-Teq	800	0	800	2	1 439	6	-280	**1 967**
Heavy Metals	mg Ni eq.	532	0	532	21	3 484	7	-180	**3 864**
PAHs	mg Ni eq.	1 498	1	1 499	25	1 046	0	-462	**2 108**
Particulate Matter (dust)	g	486	51	537	1 710	3 111	62	-158	**5 262**
Emissions (Water)									
Heavy Metals	mg Hg/20	1 398	0	1 398	1	2 113	6	-423	**3 095**
Eutrophication	g PO_4	13	1	14	0	160 702	52 143	-2	**212 857**

5.3.2.3 Base Case 4: professional high pressure cleaners combustion engine driven

Table 63 and Table 64 show the environmental impacts of a professional high pressure cleaner (BC4) over the whole life cycle of 10.3 years in low and high usage scenarios, and according to the assumptions made on user behaviour described in Task 3. The main difference is due to the fuel consumed by the combustion engine that substitutes the power consumed by the electrically driven units. The energy consumption in the use phase is greater than for the cold water three-phase unit, although the electrical unit is more powerful. This means that the energy transformation (heat into mechanical energy) carried out by the internal combustion engine is less efficient than the electricity production together with the electric motor.

Table 63. Life cycle environmental impacts of a professional high pressure cleaner (BC4) in a low usage scenario

Life Cycle phases	**Unit**	**PRODUCTION**			**DISTRIBUTION**	**USE**	**END-OF-LIFE**		**TOTAL**
Resources Use & Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	
Other Resources & Waste							debit	credit	
Total Energy (GER)	MJ	6 713	1 358	8 071	710	249 894	1 948	-1 750	**258 874**
of which, electricity (in primary MJ)	MJ	1 024	810	1 834	1	6 703	0	-189	**8 349**
Water (process)	l	153	13	167	0	1 472 057	0	-15	**1 472 210**
Water (cooling)	l	2 618	386	3 003	0	324	0	-198	**3 129**
Waste, non-haz./ landfill	g	52 754	4 225	56 980	406	27 626	6 782	-18 021	**73 772**
Waste, hazardous/ incinerated	g	159	0	159	8	577	0	-15	**729**
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	359	76	435	47	17 795	6	-102	**18 180**
Acidification, emissions	g SO_2 eq.	3 334	327	3 661	142	27 363	67	-1 044	**30 189**
Volatile Organic Compounds (VOCs)	g	13	0	13	10	445	0	-3	**466**
Persistent Organic Pollutants (POP)	ng i-Teq	800	0	800	2	157	2	-280	**681**
Heavy Metals	mg Ni eq.	532	0	532	21	73	2	-180	**449**
PAHs	mg Ni eq.	1 498	1	1 499	25	82	0	-462	**1 144**
Particulate Matter (dust)	g	486	51	537	1 710	495	16	-158	**2 601**
Emissions (Water)									
Heavy Metals	mg Hg/20	1 398	0	1 398	1	174	2	-423	**1 153**
Eutrophication	g PO_4	13	1	14	0	34 167	11 092	-2	**45 270**

Table 64. Life cycle environmental impacts of a professional high pressure cleaner (BC4) in a high usage scenario

Life Cycle phases -->	**Unit**	**PRODUCTION**			**DISTRIBUTION**	**USE**	**END-OF-LIFE**		**TOTAL**
Resources Use & Emissions		Material	Manuf.	**Total**			Disposal	Recycl.	
Other Resources & Waste							debet	credit	
Total Energy (GER)	MJ	6 713	1 358	8 071	710	565 295	4 250	-1 750	**576 577**
of which, electricity (in primary MJ)	MJ	1 024	810	1 834	1	132 575	0	-189	**134 222**
Water (process)	l	153	13	167	0	3 303 800	0	-15	**3 303 952**
Water (cooling)	l	2 618	386	3 003	0	5 918	0	-198	**8 723**
Waste, non-haz./ landfill	g	52 754	4 225	56 980	406	121 896	14 394	-18 021	**175 654**
Waste, hazardous/ incinerated	g	159	0	159	8	3 148	0	-15	**3 300**
Emissions (Air)									
Greenhouse Gases in GWP100	kg CO_2 eq.	359	76	435	47	36 521	14	-102	**36 914**
Acidification, emissions	g SO_2 eq.	3 334	327	3 661	142	73 010	145	-1 044	**75 914**
Volatile Organic Compounds (VOCs)	g	13	0	13	10	3 478	0	-3	**3 498**
Persistent Organic Pollutants (POP)	ng i-Teq	800	0	800	2	617	3	-280	**1 142**
Heavy Metals	mg Ni eq.	532	0	532	21	1 346	4	-180	**1 723**
PAHs	mg Ni eq.	1 498	1	1 499	25	434	0	-462	**1 496**
Particulate Matter (dust)	g	486	51	537	1 710	1 398	32	-158	**3 519**
Emissions (Water)									
Heavy Metals	mg Hg/20	1 398	0	1 398	1	880	3	-423	**1 859**
Eutrophication	g PO_4	13	1	14	0	76 670	24 880	-2	**101 561**

5.4 Base case life cycle costs per consumer per unit and at EU level

The base case life cycle costs (LCC) per consumer is the total price of ownership, i.e. the sum of all costs for acquiring the HPC plus the annual costs over the lifetime. The annual cost includes energy (electricity for the direct consumption + electricity and natural gas for the small part of indirect consumption via the externally heated water + fuel for hot water machines), water and detergent. For domestic HPCs the repair and maintenance costs are assumed to be null, due to the higher cost of repairs compared to purchase price. For the professional HPCs these costs over the lifetime of the machine are assumed to be equal to the initial purchase price.

The annual energy, water and detergent consumption is constant over the lifetime; however, the utility prices vary from year to year. In the model, the energy prices are based on PRIMES 2016[89], and the water prices are extracted from the dishwasher and washing machines and the detergent price has been considered constant (see previous description). Utility prices for all years are expressed in euro at 2015 values (i.e. taking 2015 as the reference year).

For calculation of the LCC at EU level, the unit LCC is scaled up to EU-28 level based on the sales and stock model.

The following sections present two charts for each base case: one showing the LCC for an HPCs purchased in the particular year from 1987 to 2050 shown on the Y-axis and the other one showing the LCC scaled up to EU level. All prices are in constant 2015 prices. The graphs represent the low usage scenario detailed in the different cost categories, while the high usage scenario is represented as total LCC.

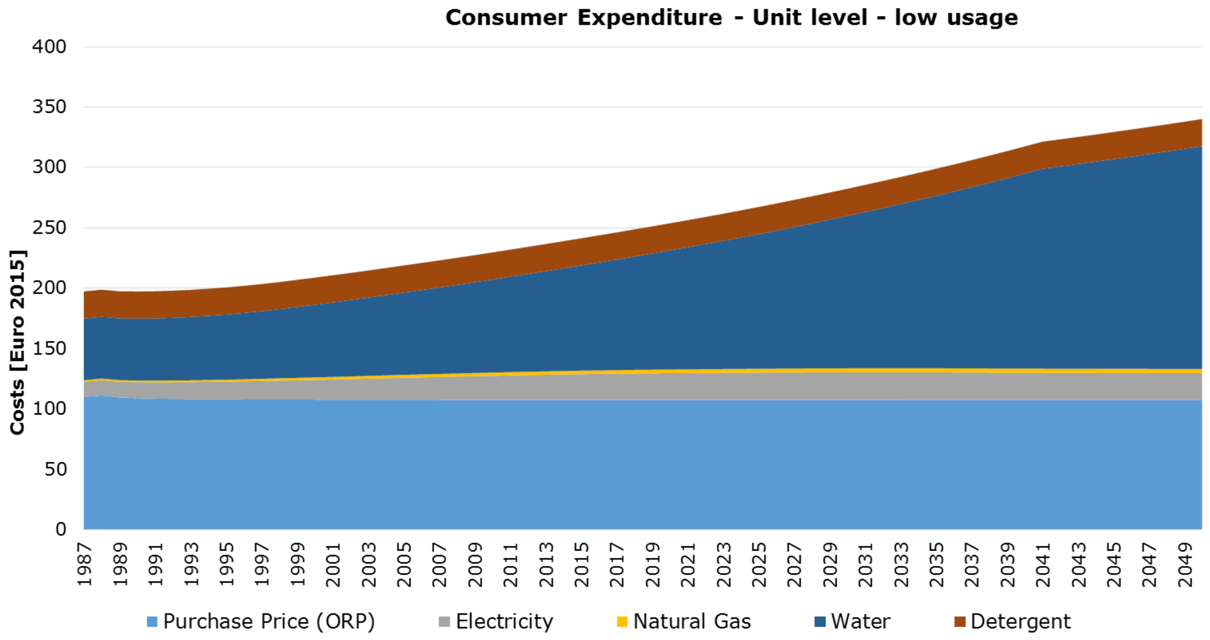
5.4.1 BC1: Domestic cold water HPC

Figure 62 shows the evolution of life cycle costs (at unit level) of a domestic high pressure cleaner for the examined period, 1987 till 2050, in low and high usage scenarios. In the low usage scenario, water and purchase price are the main cost contributor areas. The overall LCC increase from nearly EUR 200 in 2017 to EUR 340 in 2050, mainly due to the increase over time of the water price. In the high usage scenario, water becomes dominant and the detergent cost also increases. This means that any measure aiming at reducing the water consumption could positively impact the LCC and particularly the user expenditure. This impact would be more significant in the high usage scenario.

The cost of electricity also steadily grows, but remains stable within the range of EUR 20-22 at low usage and EUR 90-95 at high usage, for the 2019-2050 period. Water and electricity are correlated in this product group, meaning that measures to save water will most probably lead to electricity savings. Detergent consumption is proportional to water use; therefore, water savings may also lead to a reduction in the detergent cost.

Regarding purchase price, domestic high pressure cleaners require a balance between durability and purchase price, in order to achieve equilibrium between the additional costs of manufacturing and therefore price increase, and the turnover due to the extension of the lifetime. This will be further investigated in Task 6.

[89] These are based on the PRIMES model and delivered by DG Energy.



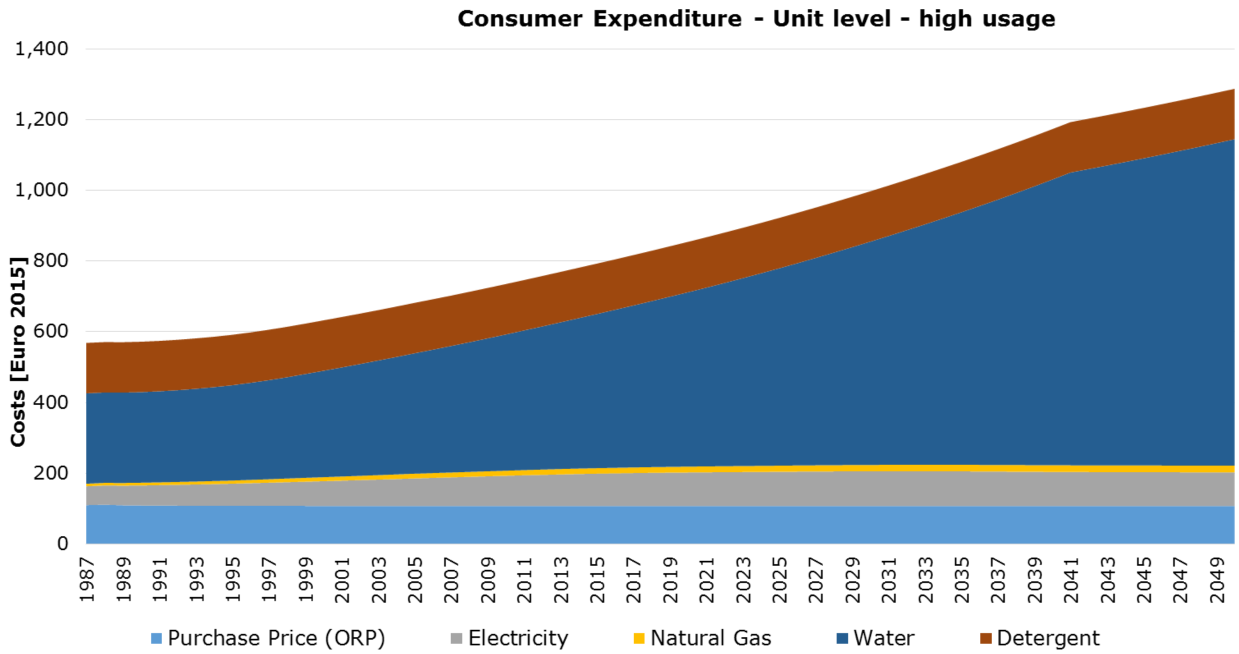


Figure 62. Life cycle costs per unit for BC1 (in 2015 EUR equivalent) under low usage (top graph) and high usage (bottom graph)

Figure 63 shows an increase in the overall consumer expenditure over the period due to the increased sales and increased LCC at unit level. In 2050, the total EU life cycle costs in the low usage scenario are about EUR 1.2 billion (2015), which means an increment of 140% compared to 2019 which is EUR 0.5 billion (2015). In the high usage scenario, EU life cycle costs could reach more than EUR 4 billion (2015) in 2050.

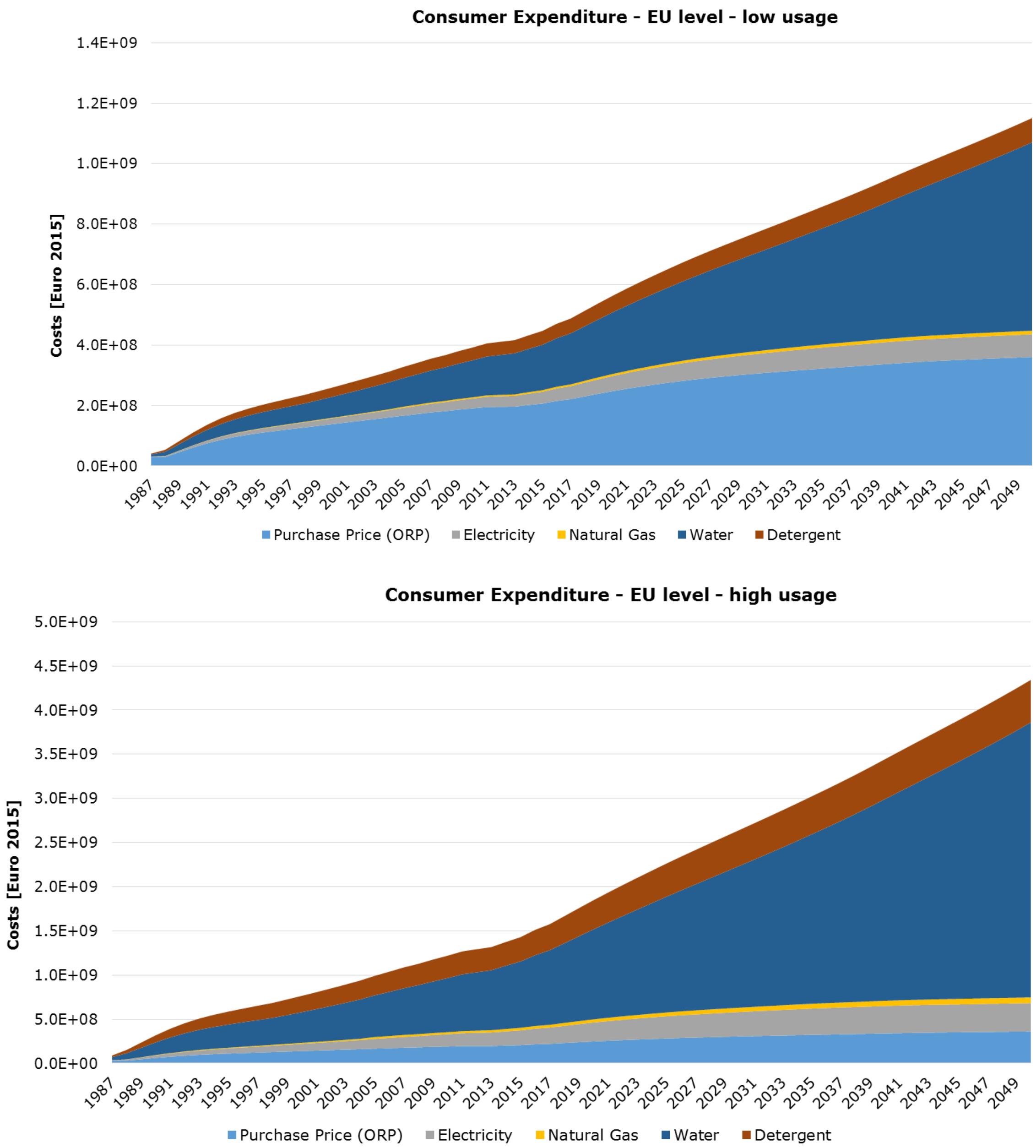


Figure 63. Life cycle costs at EU level for BC1 (in 2015 EUR equivalent)

5.4.2 BC2: Professional cold water electric motor single-phase HPC

Compared to BC1, Figure 64 shows the lesser importance of the purchase price for professional cold water machines (it was considered to be EUR 500/unit based on stakeholder input). This is due to the resource consumption linked to a higher frequency and duration of use. The share of the purchase price is also reduced due to the longer lifetime and higher use frequency of professional products. Similarly to BC1, in the low usage scenario, the LCC increases from about EUR 6 000 in 2019 to EUR 10 000 in 2050, mainly due to the water price increment. In the high usage scenario, these values would be trebled. Water consumption is the main part of the LCC during the whole period, followed but not closely by detergents and electricity consumption cost. Compared to BC1, the costs are one order of magnitude higher, meaning that measures to reduce water and electricity would have a much larger impact.

This professional base case includes a cost for repair and maintenance, though it is not significant compared to other costs. The total cost of repair and maintenance was assumed to be 70% of the purchase price for all professional HPCs.

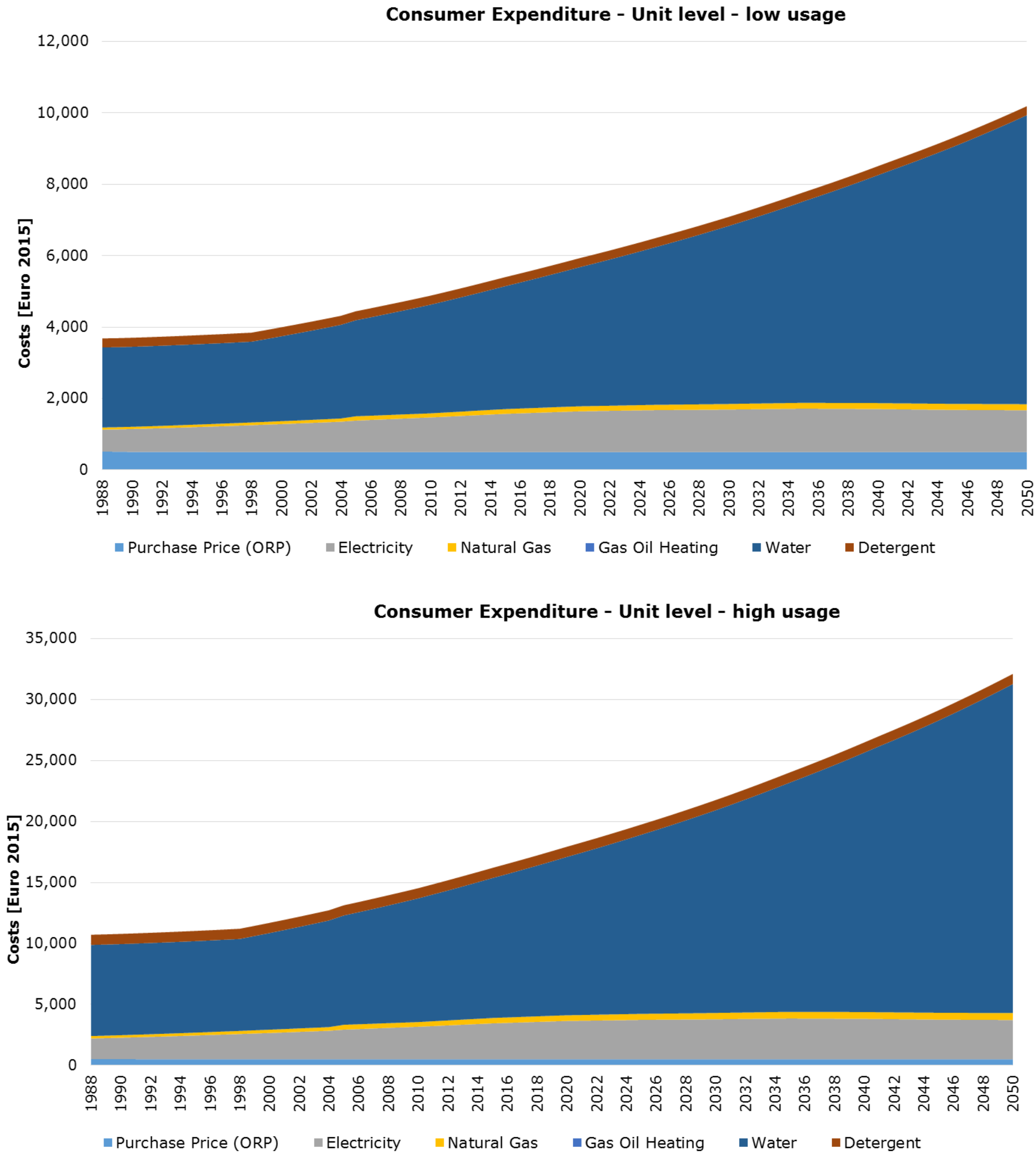


Figure 64. Life cycle costs per unit for BC2 (in 2015 EUR equivalent)

Figure 65 shows an increase in the overall consumer expenditure over the period due to the increased sales and increased LCC at unit level. In 2019 the total EU life cycle costs in the low usage scenario are about EUR 0.6 billion while in 2050 they are estimated to more than double to EUR 1.3 billion, to the same levels as BC1. As can be observed, the LCC at EU level of BC1 and BC2 are similar, which means that the lower market volume of professional units is compensated by more intensive use. In the high usage scenario LCC at EU level could reach EUR 4 billion.

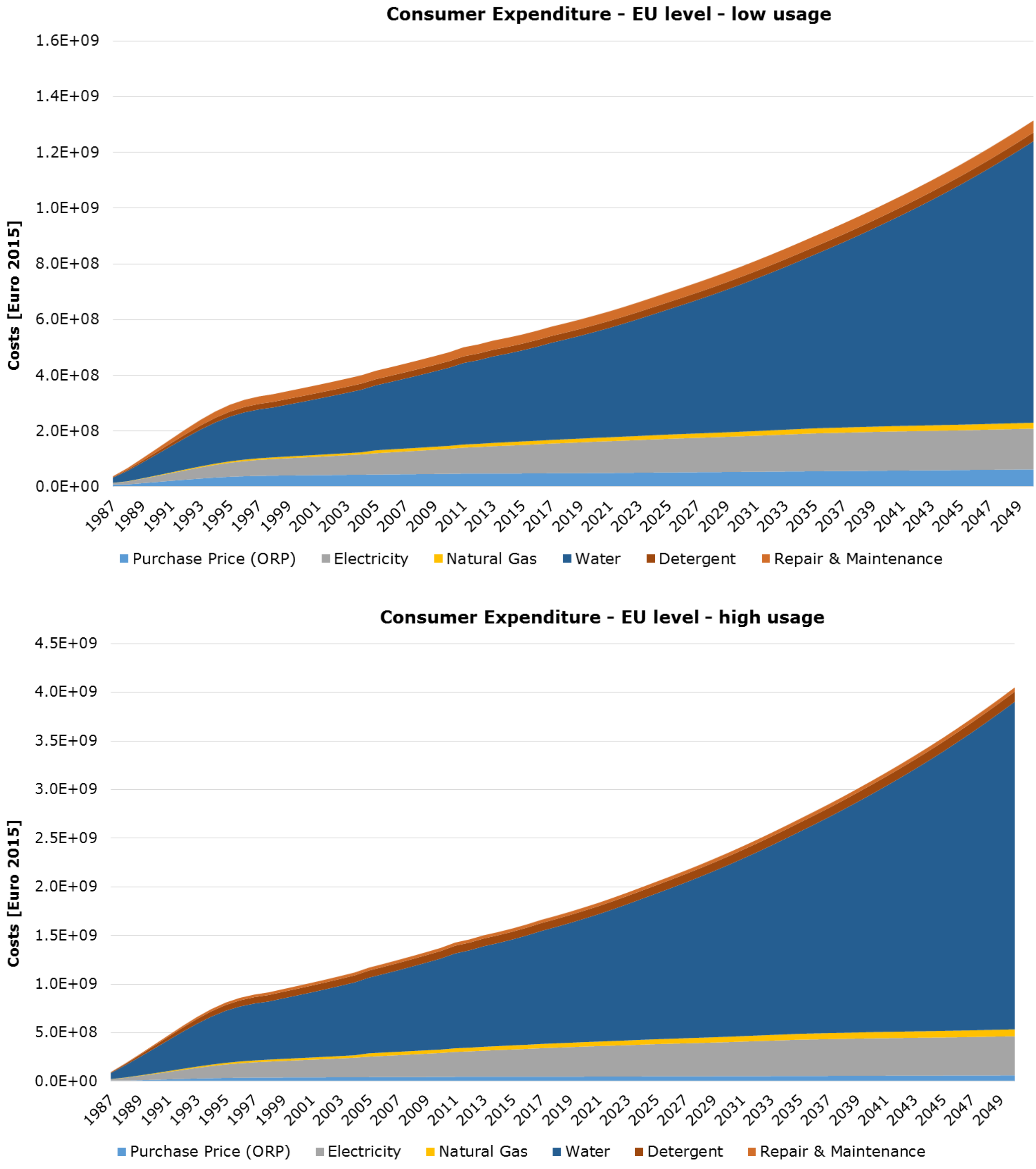


Figure 65. Life cycle costs at EU level for BC2 (in 2015 EUR equivalent)

5.4.3 BC3: Professional cold water electric motor three-phase HPC

Figure 66 shows the LCC evolution for BC3 (professional cold water three-phase) at unit level for the 1987-2050 period. Similarly to the other professional HPC base cases, the importance of the purchase price for professional HPCs is lower due to the higher resource consumption. The average purchase price for BC3 was estimated to be EUR 1 800/unit based on stakeholder input. In the low usage scenario, the LCC increase from about EUR 13 000 in 2019 to around EUR 20 000 in 2050 which again is due to the water price increase. Water consumption is the main part of the LCC during the whole period. In the high usage scenario, the LCC could reach almost EUR 60 000 in 2050, and the shares of purchase price and repair and maintenance costs become less relevant.

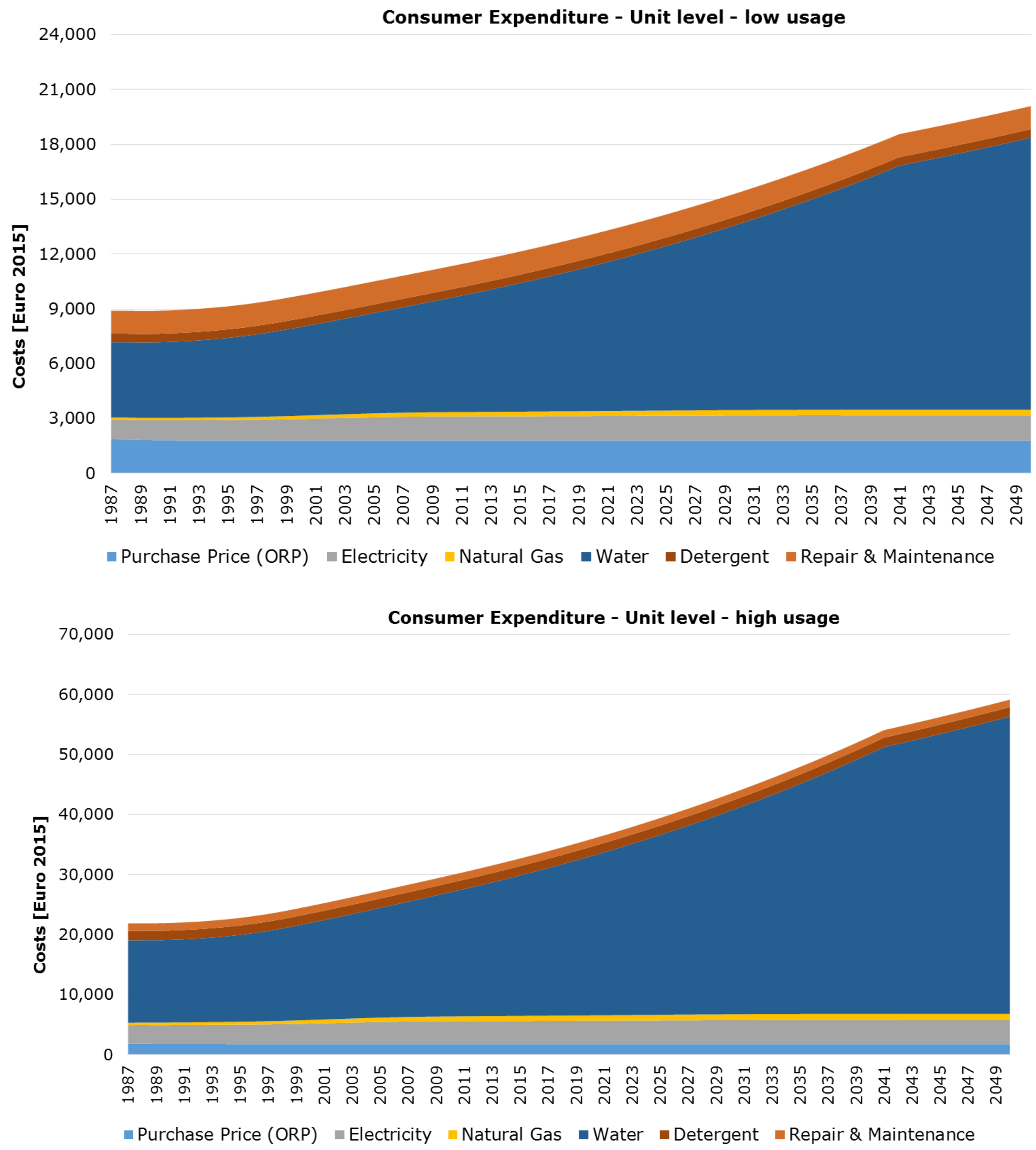
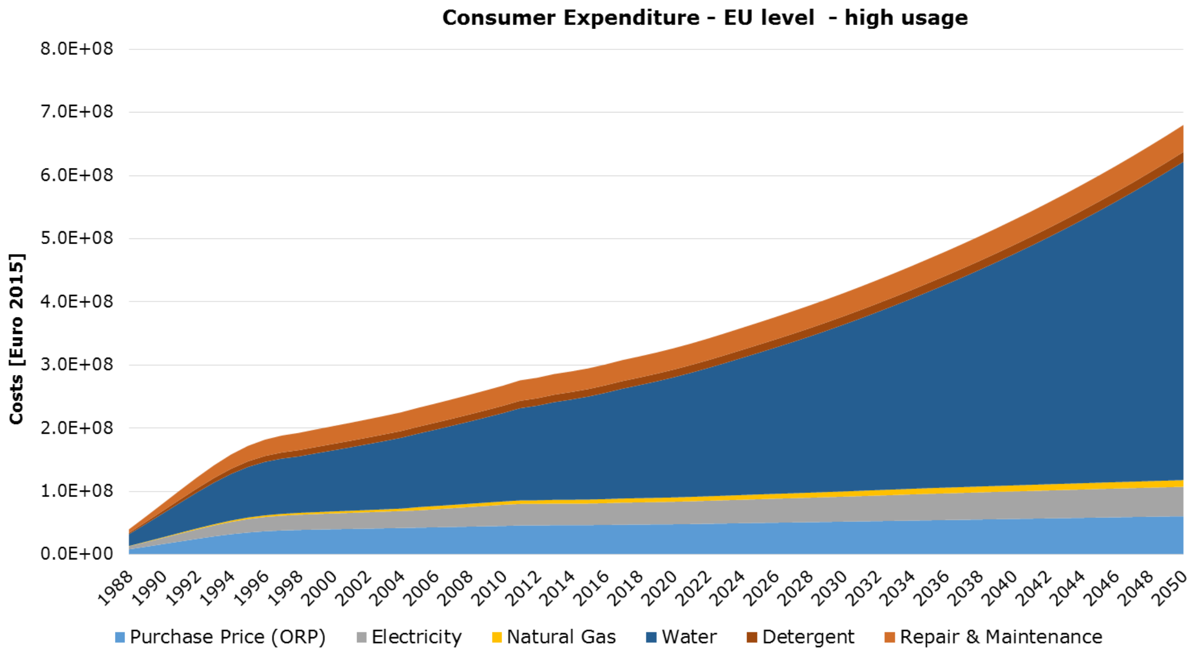


Figure 66. Life cycle costs per unit for BC3 (in 2015 EUR equivalent)

Figure 67 shows an increase in the overall consumer expenditure over the period due to the increased sales and increased LCC at unit level. In 2050, the total EU life cycle costs in the low usage scenario are estimated about EUR 0.7 billion. In the high usage scenario, they could reach EUR 2 billion.



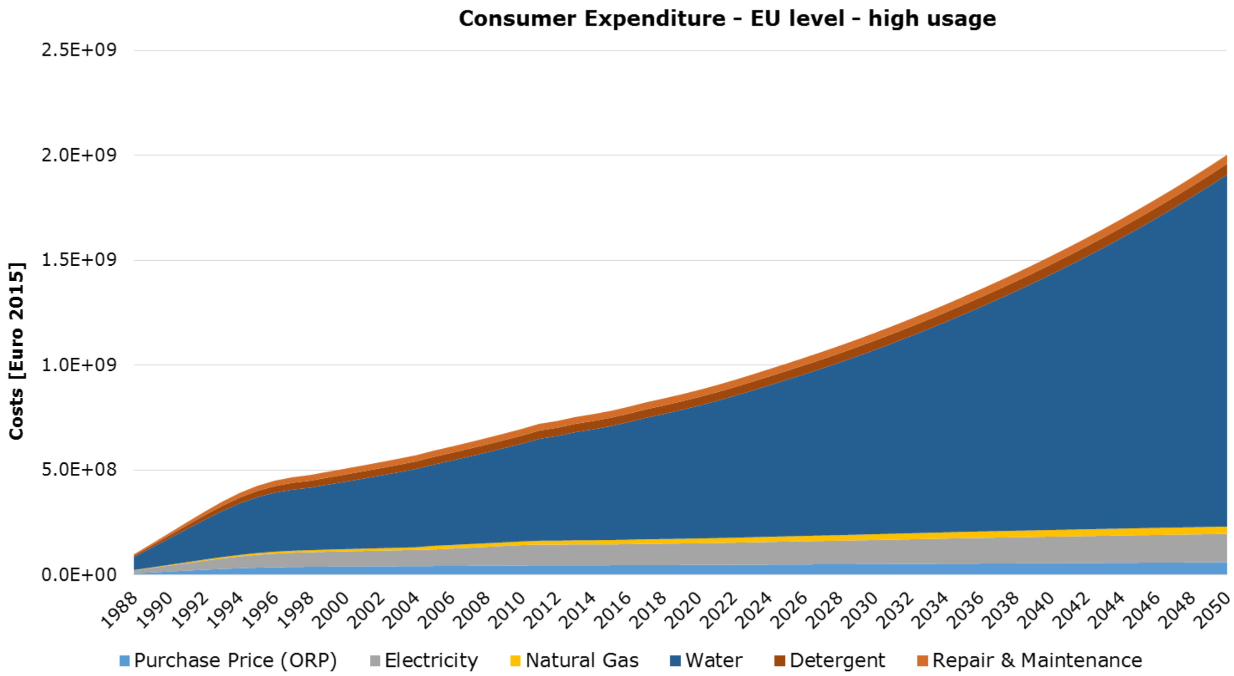
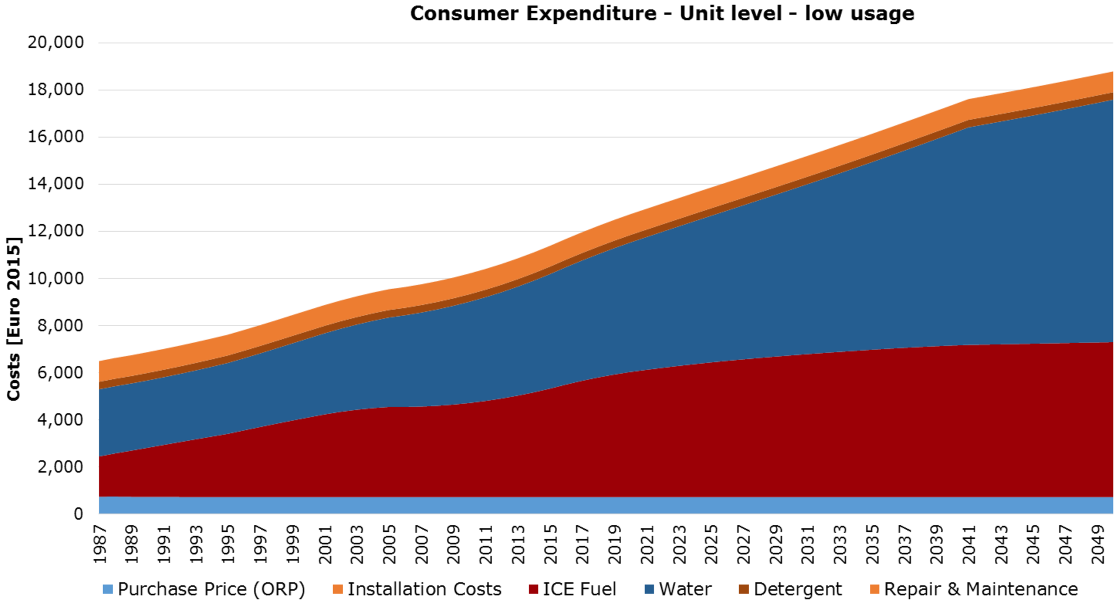


Figure 67. Life cycle costs at EU level for BC3 (in 2015 EUR equivalent)

5.4.4 BC4: Professional cold water combustion motor HPC

Figure 68 presents the LCC consumer expenditure at unit level for BC4. The LCC at low usage scenario increases from about EUR 13 000 in 2019 to about EUR 19 000 in 2050 which is mainly due to the water and fuel (important cost contribution areas) price increase over the years. In the high usage scenario, the LCC could reach almost EUR 60 000 in 2050, and the shares of purchase price and repair and maintenance costs become less relevant. Water consumption is the main part of the LCC during the whole period and the fuel consumption of the internal combustion engine is also a significant cost, higher than the electricity cost of their electric counterparts.

Figure 68. Life cycle costs per unit for BC4 (in 2015 EUR equivalent)



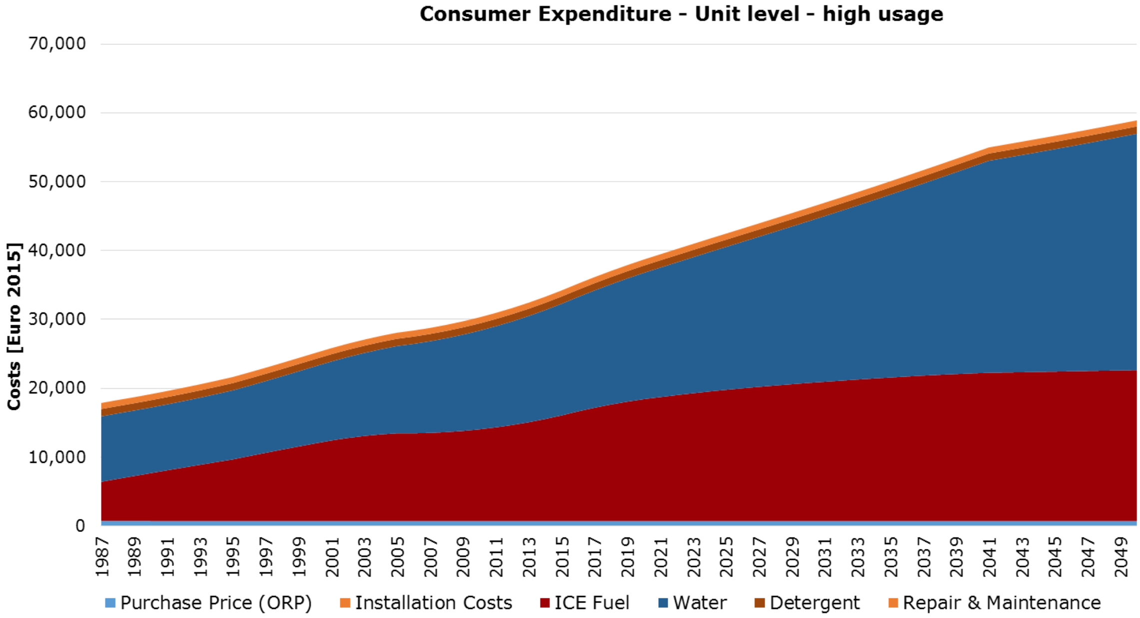
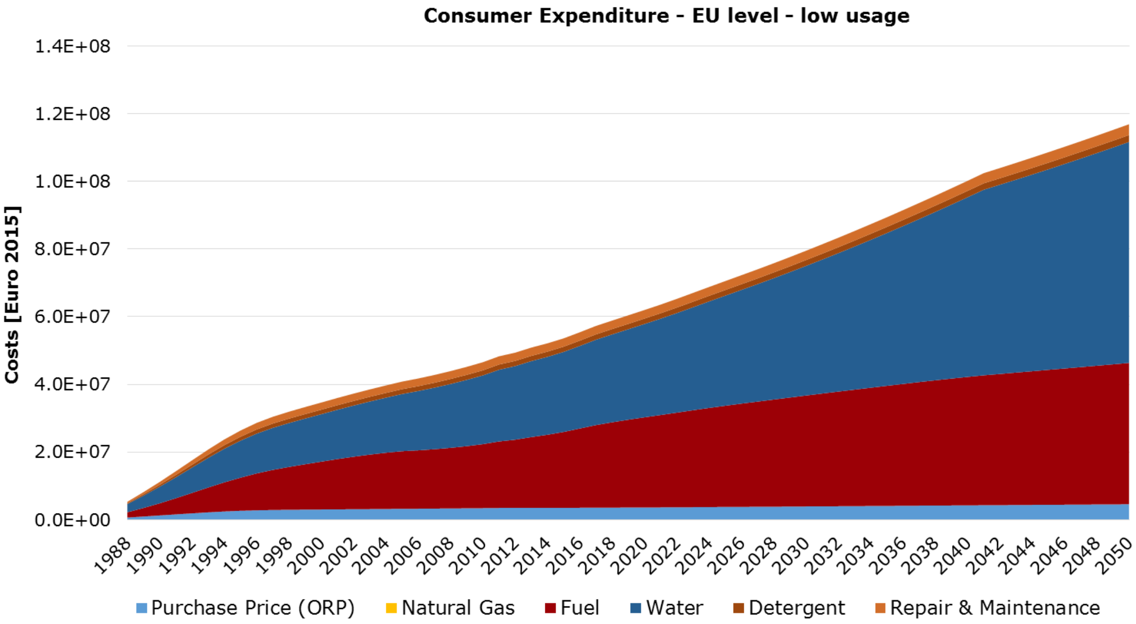
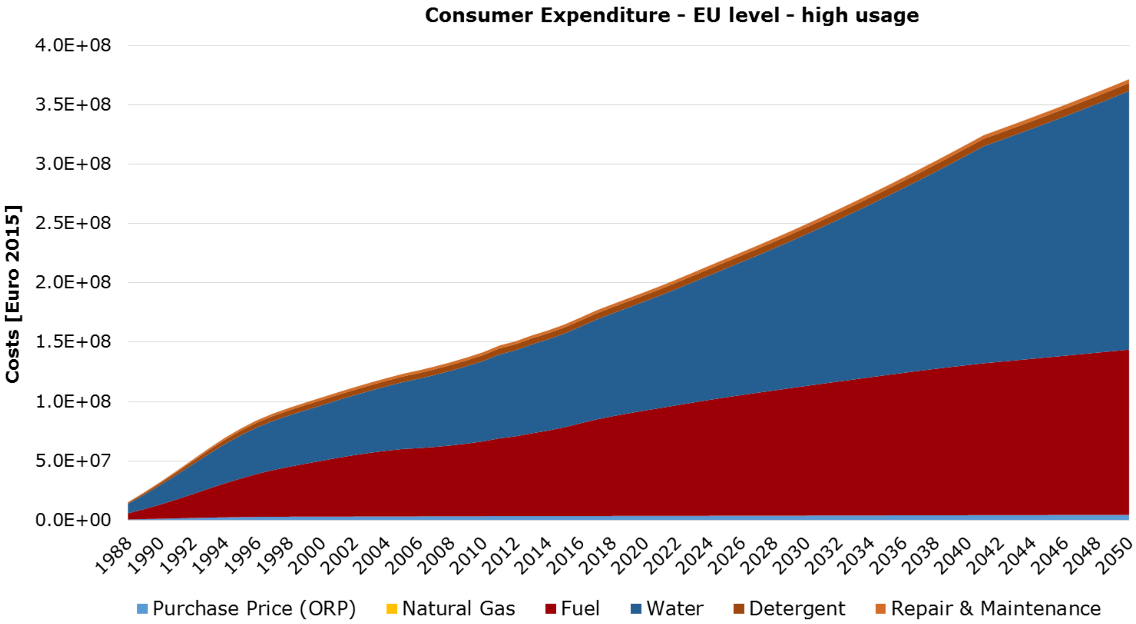


Figure 69 shows an increase in the overall consumer expenditure over the period due to the increased sales and increased LCC at unit level. In 2050, the total EU life cycle costs are about EUR 0.12 billion and EUR 0.37 billion, in the low and high usage scenarios respectively.

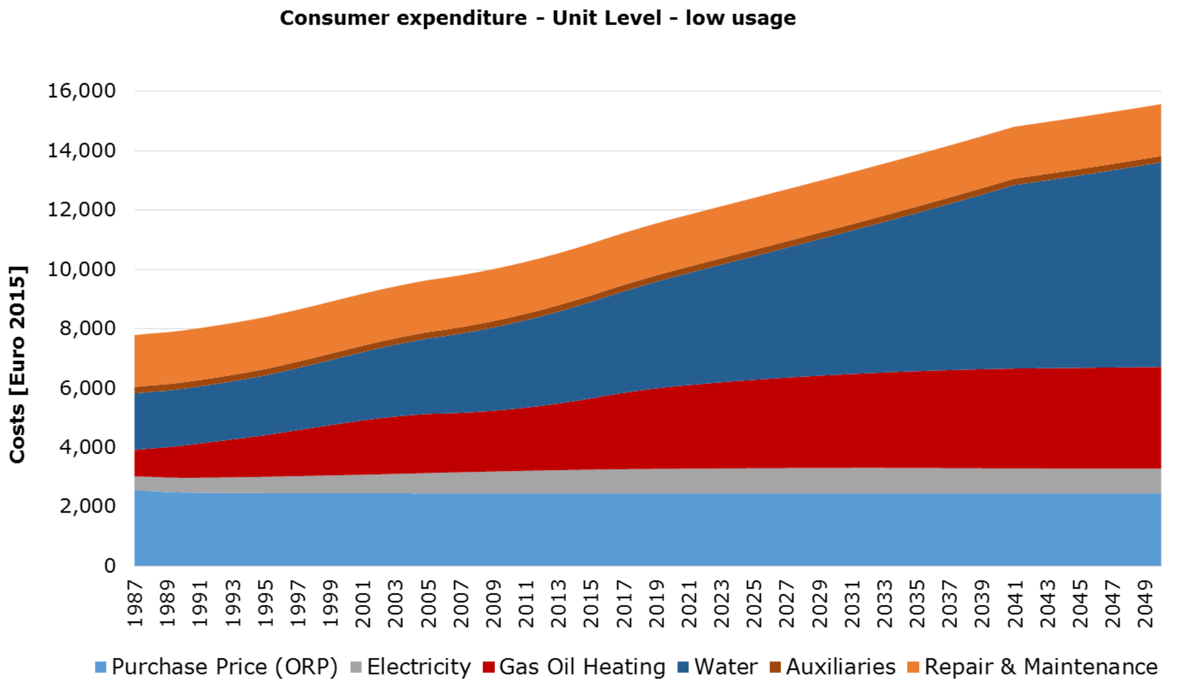
Figure 69. Life cycle costs at EU level for BC4 (in 2015 EUR equivalent)





5.4.5 BC5: Professional hot water (fuel burner) electric motor single-phase HPC

Figure 70 presents the consumer expenditure for BC5 at unit level. The LCC increases in the low usage scenario from almost EUR 10 800 in 2019 to about EUR 15 500 in 2050 which is mainly due to the water and gas oil price increase. Water consumption is the main part of the LCC during the whole period. However, energy consumption (both fuel for the water heater and electricity for driving the HPC motor) is equally important from a cost perspective. The average purchase price for BC5 was estimated at EUR 2 500/unit based on stakeholder input. In the high usage scenario, the LCC at unit level would reach EUR 43 000 and the shares of purchase price and repair and maintenance would be diminished.



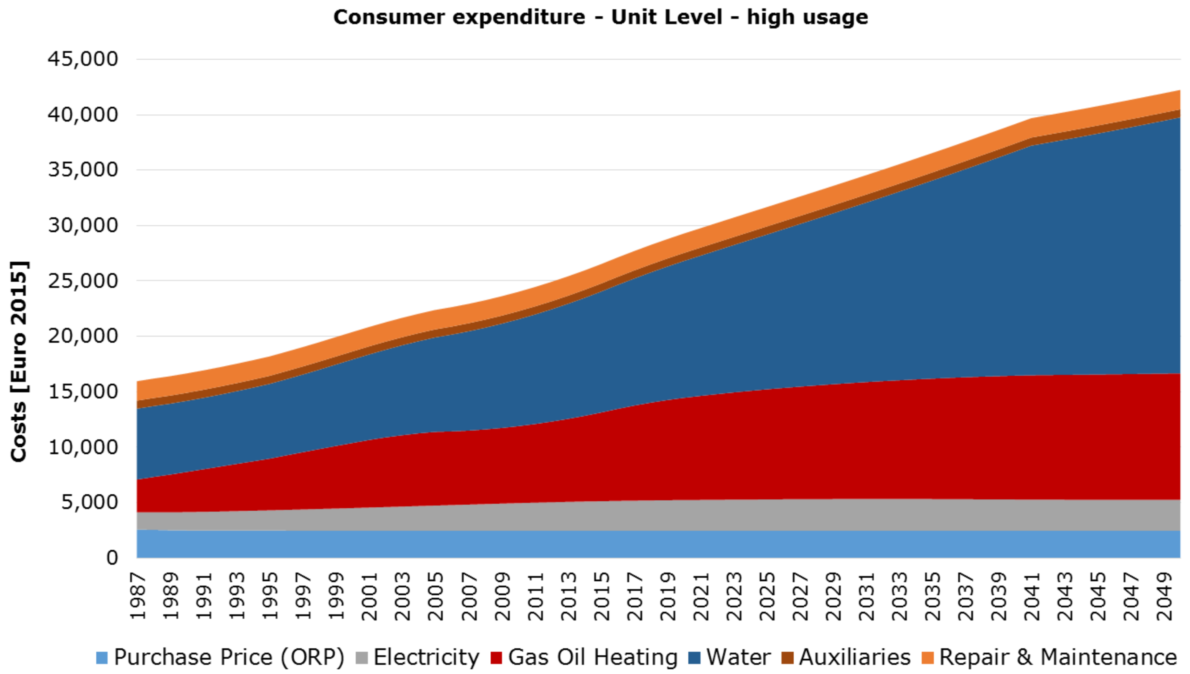
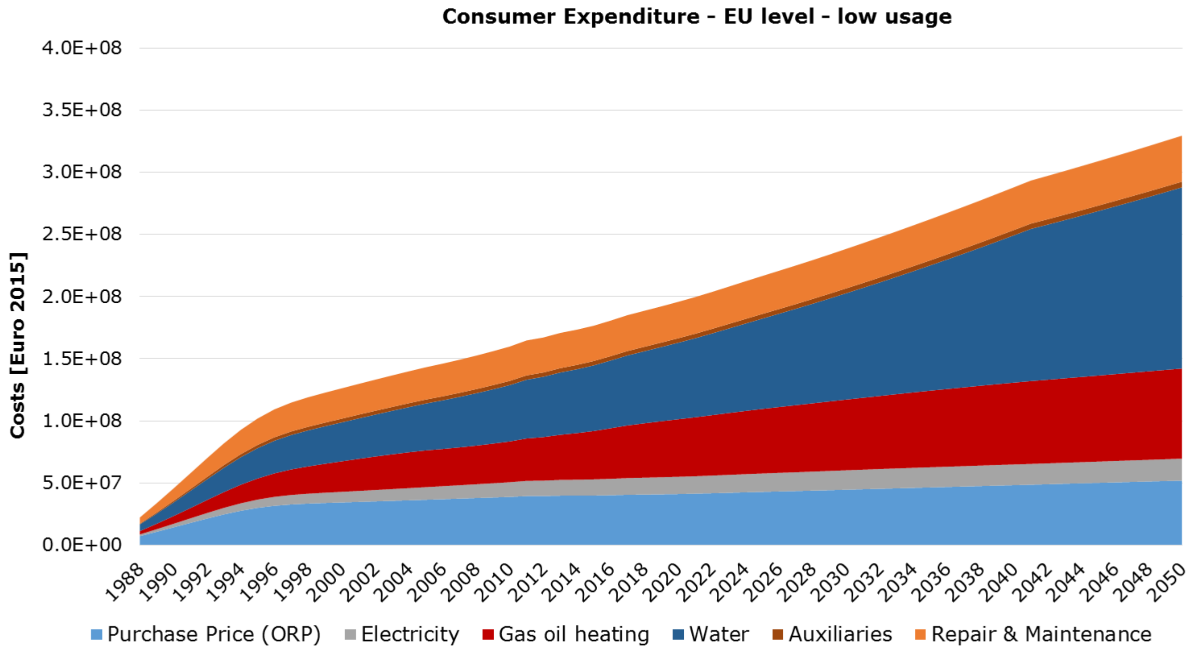


Figure 70. Life cycle costs per unit for BC5 (in 2015 EUR equivalent)

Figure 71 shows an increase in the overall consumer expenditure at EU level over the period due to the increased sales and increased LCC at unit level. In 2050, the total EU consumer expenditure will be at the level of EUR 0.34 billion and EUR 0.9 billion in the low and high usage scenarios respectively.



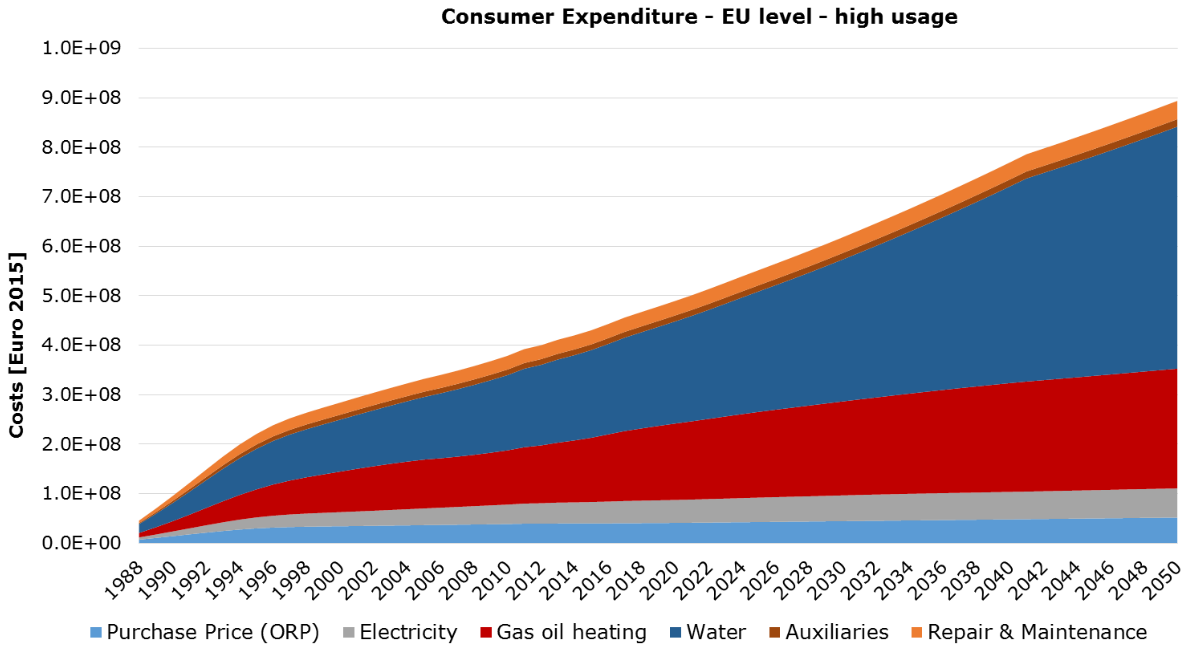


Figure 71. Life cycle costs at EU level for BC5 (in 2015 EUR equivalent)

5.4.6 BC6: Professional hot water (burner) electric motor three-phase HPC

Figure 72 presents the LCC results of BC6 at unit level. The consumer expenditure in the low usage scenario increases from about EUR 18 000 in 2019 to about EUR 27 600 in 2050, mainly due to the price increase in water and gas oil. The average purchase price for BC5 was estimated at EUR 3 000/unit based on stakeholder input. In the high usage scenario, LCC could reach EUR 80 000.

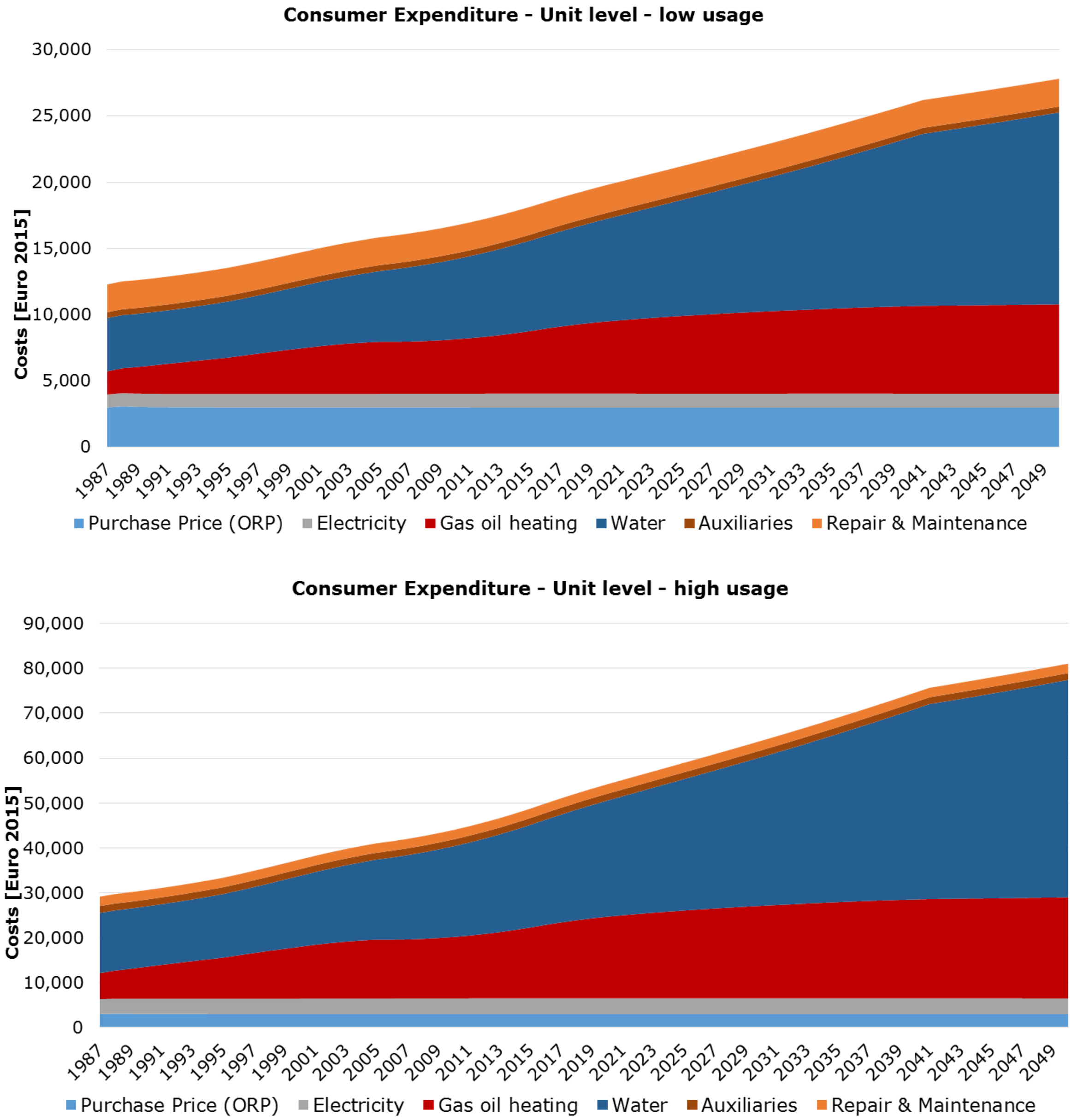
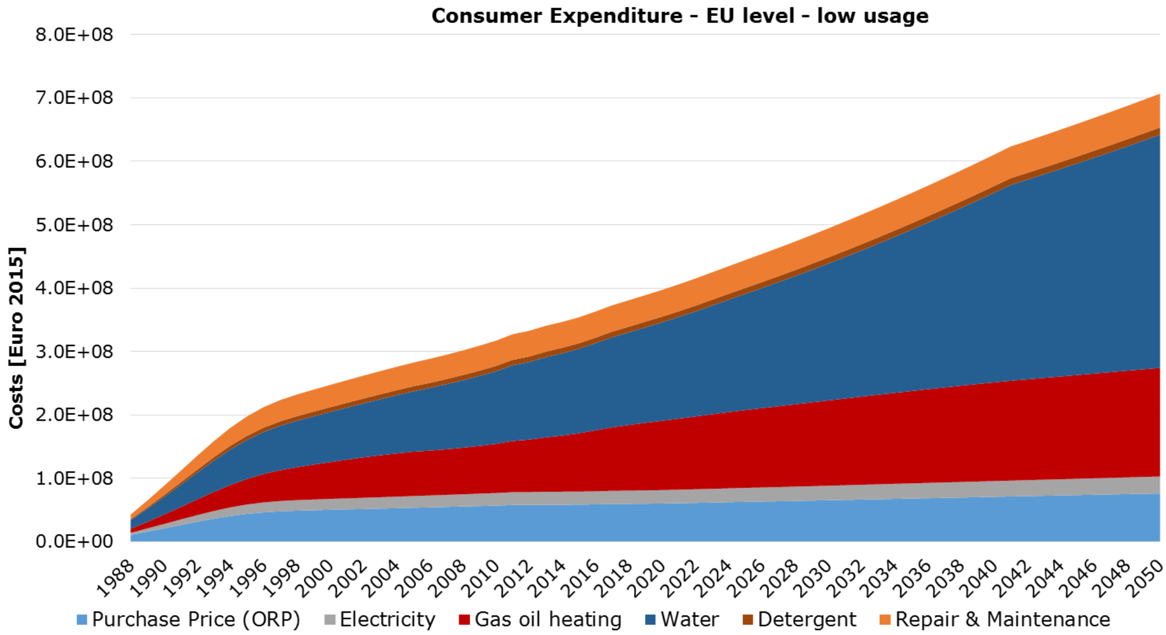


Figure 72. Life cycle costs per unit for BC6 (in 2015 EUR equivalent)

Figure 73 shows an increase in the consumer expenditure at EU level over the period due to the increased sales and increased LCC at unit level. In 2050, the total EU life cycle costs are estimated at the level of EUR 0.70 billion and EUR 2 billion in the low and high usage scenarios respectively.



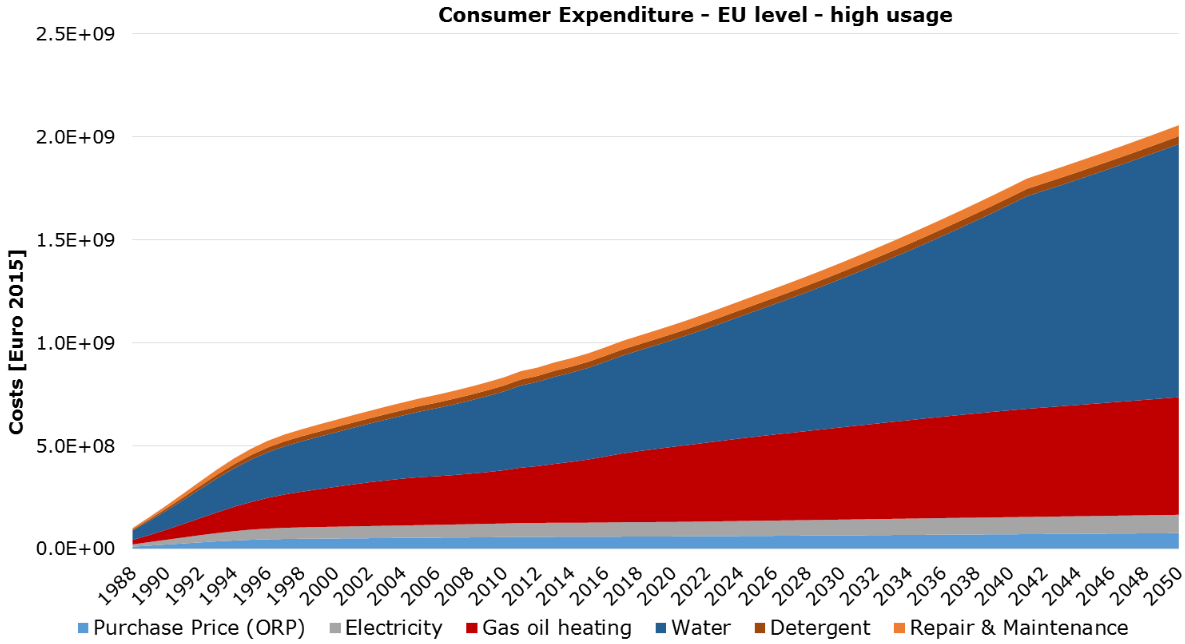


Figure 73. Life cycle costs at EU level for BC6 (in 2015 EUR equivalent)

5.5 EU Totals

5.5.1 Total direct energy consumption at EU level (low usage scenario)

The direct energy consumption includes the energy consumption during the use phase of the HPC for the EU-28 and excludes the indirect heat consumption, which is when the HPC is connected to a hot water tap with the water heated externally by the building's sanitary hot water systems. This is further described in Task 3. Figure 74 presents the results of HPC energy (electricity as well as heat energy from liquid fuels) consumption during use for all BCs.

BC1 to BC3 are cold water electric BCs, so consume only electric energy, while BC5 and BC6 are hot water machines consuming both electric energy for the electric motors as well as liquid fuels consumed in the built-in water heater of the hot water HPC, thus heat energy is presented separately in the chart. BC4 represents a combustion-engine-driven HPC that consumes only gasoline.

The main conclusions from the energy chart of Figure 74 are as follows:

- The total energy consumption of all HPCs in 2050 is estimated at the level of 3.9 TWh (final energy at use phase), which is about one third of the estimated value in the working plan study (11.2 TWh in 2030 for the EU-27)[90]. The overall HPC direct energy consumption is estimated at 3.0 TWh and 3.3 TWh for the years 2019 and 2030, respectively. Energy consumption for hot water HPCs is presented separately for electric and heat energy.
- The heat energy from liquid fuel used for the hot water HPC (BC5-6) and the combustion engine HPC (BC4) represents nearly half (52%) of the total energy consumption.
- For the hot water HPC, the energy for heating the water is more important than the electricity consumption even when taking the primary energy factor into account.
- The base case with the highest electricity consumption is BC2 (professional cold water single-phase), which represents nearly 38.3% of the overall electricity consumption; followed by BC3 with a 25.7% share, BC1 with a 16.6% share, BC6 with a 14.7% share and BC5 with a 4.6% share.
- The professional combustion engine HPC (BC4) does not have significant energy consumption at EU level; it represents nearly 0.8% of the overall energy consumption as its market share is very low (see Task 2).

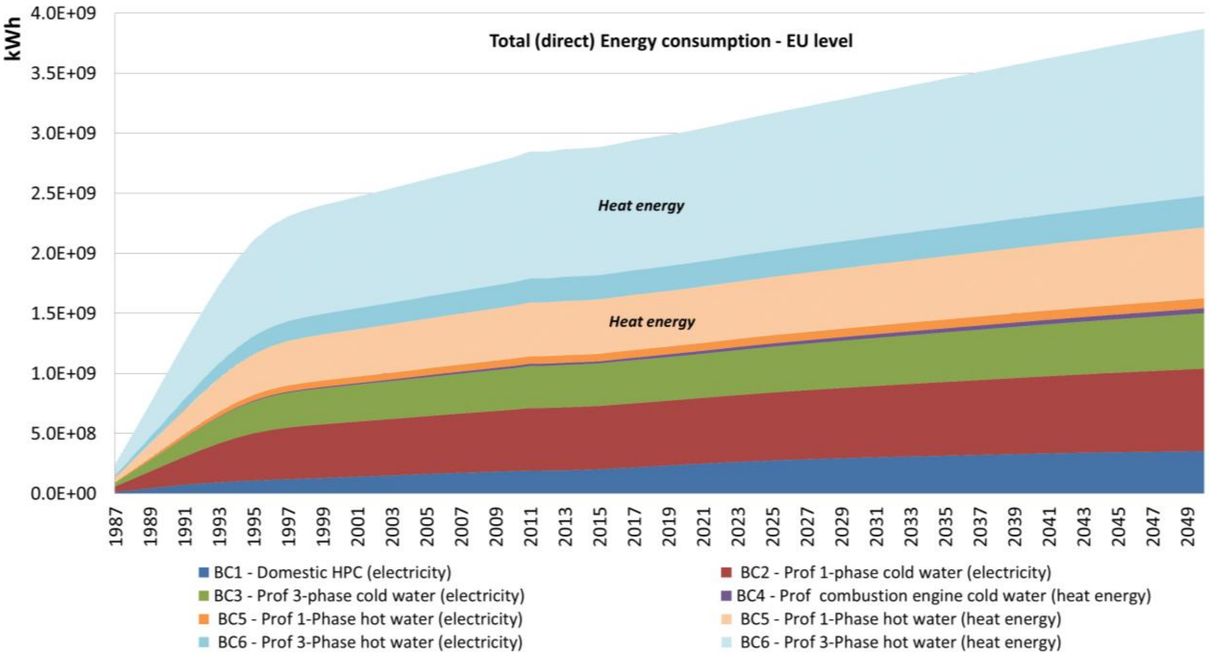


Figure 74. Total direct energy consumption for each base case for the EU-28 (low usage scenario).

5.5.2 Total water consumption during use at EU level (low usage scenario)

Figure 75 presents the water consumption during the use phase for all base cases for the EU-28. Below the main conclusions are summarised:

[90] Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC. Task 3 Final Report.

- The total water consumption of all HPCs for 2019 is estimated at 212 million m^3, for 2030 it is 239 million m^3, and for 2050 it is estimated to be 280 million m^3 which is less than half of the estimated figure in the working plan study (about 634 million m^3 in 2012 for the EU-27)[91].
- Each base case's share of the total water consumption correlates with the energy consumption presented in the previous section.
- The base case with the highest water consumption is BC2 (professional HPC with single-phase connection and use of cold water) with a 38.4% share. BC1 has a a 20.5% share of the aggregated HPC water consumption, followed by BC3 with 19.1%, BC6 with 14% and BC5 with a 5.5% share.
- The professional combustion engine (BC4) does not have significant water consumption at EU level compared to the other HCP types; it has only a 2.5% share.

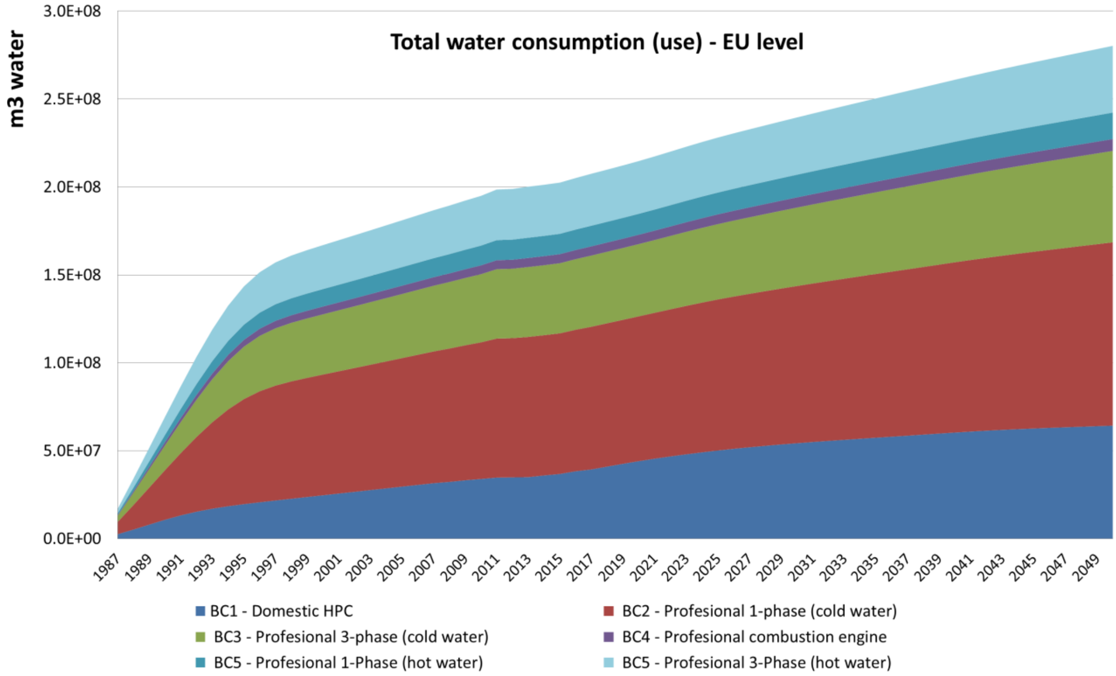


Figure 75. Total water consumption for each base case for the EU-28 (low usage scenario)

5.5.3 GHG emissions at EU level (low usage scenario)

The greenhouse gas (GHG) emissions, expressed in million tonnes of CO_2 eq., are estimated for the 2017-2050 period for all life cycle stages and for each BC. Figure 76 presents the overall GHG emissions generated during HPC life cycle stages (production, use, end-of-life treatment) aggregated per base case. The main conclusions are as follows:

- The total GHG emissions of all HPCs are estimated to be currently (2019) 4.7 million tonnes of CO_2 eq., increasing to 5.3 million tonnes, 5.8 million tonnes and 6.2 million tonnes of CO_2 eq. in 2030, 2040 and 2050, respectively, due to the increase of the stock.
- The base case with the largest share of GHG emissions is BC1 (domestic HPC), which represents nearly 36.2% of the total GHG emissions. The main reason is the large volumes of domestic HPCs produced and sold per year (see Task 2), thus this BC has a higher production impact at EU level (sales multiplied by the production phase impact) compared with the rest of the BCs. On the other hand, professional

[91] Preparatory Study to establish the Ecodesign Working Plan 2015-2017 implementing Directive 2009/125/EC.

HPCs have much lower sales per year compared to BC1 but a much higher impact in the use phase as they are more frequently used (150 hours instead of 5 hours of average use per year).

- The professional combustion engine (BC4) has the lowest GHG emissions at EU level compared to the other HPC types. BC2 has a 23.9% share of the total GHG emissions, while BC6 has 17.1%, BC3 12.6%, BC 5 6.9% and BC4 the lowest share with 3.2%.

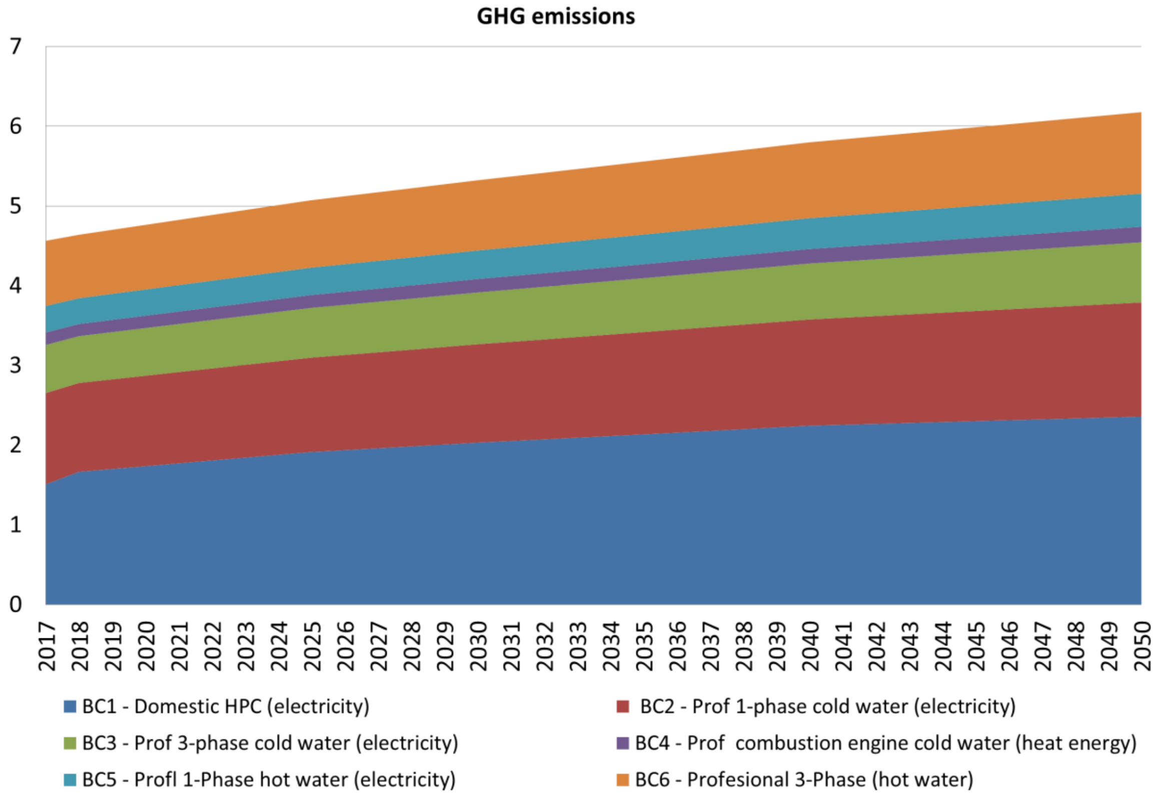


Figure 76. Total GHG emissions for each base case for the EU-28 (low usage scenario)

5.5.4 Low usage vs high usage scenario

Figure 77 and Figure 78 provide the range of low versus high usage scenarios of the direct energy and water consumption of HPCs at EU level, and for the 2020-2050 period.

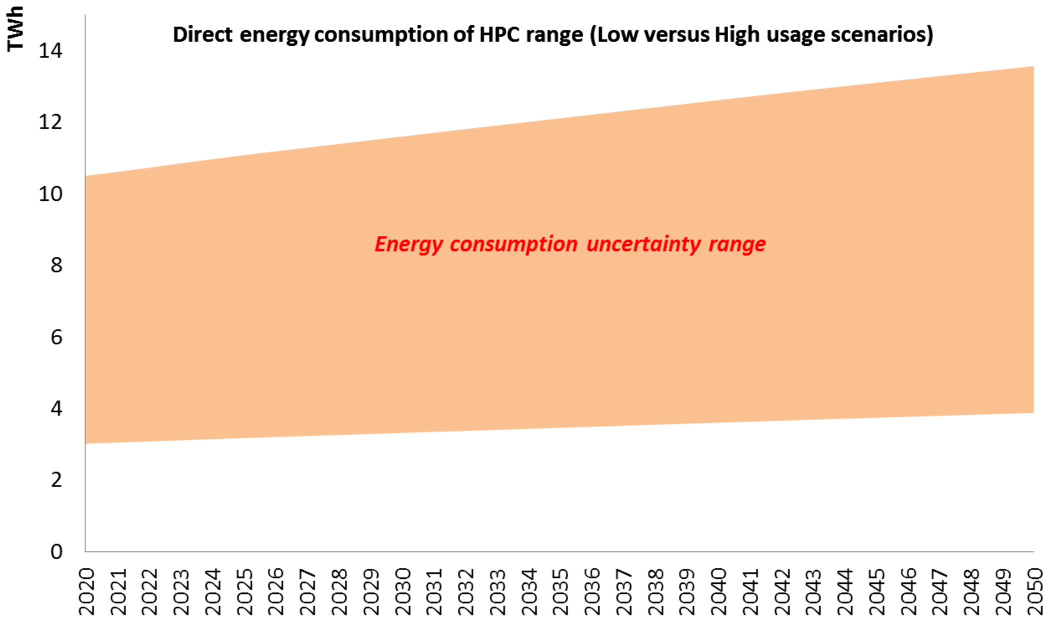


Figure 77. Total energy consumption (use phase) uncertainty range (low vs high usage scenario) for the 2020-2050 period at EU level

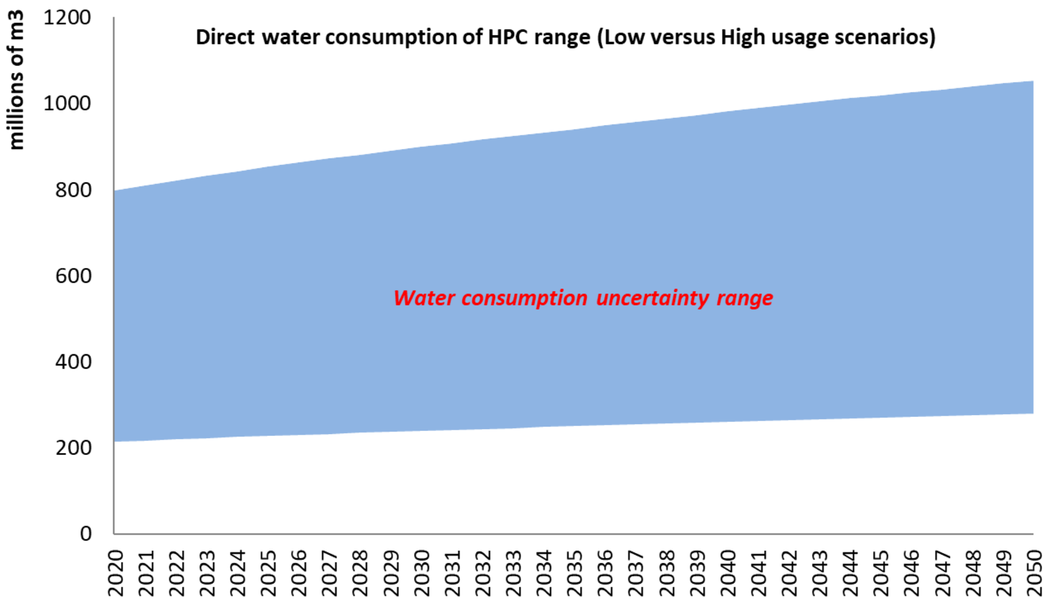


Figure 78. Total direct water consumption (use phase) uncertainty range (low vs high usage scenario) for the 2020-2050 period at EU level

As can be seen from Figure 77, the overall energy consumption of HPC for the year 2020 ranges from 3 TWh to 10.5 TWh (final energy at use phase); and water consumption from 215 million m^3 to 797 million m^3. The source of this significant range is the large variations of the usage pattern reported by stakeholders. High pressure cleaners, especially professional ones, are used in many different situations, so the definition of an average frequency and time of use is very difficult. This important source of uncertainty could be reduced with a better insight of the domestic and professional use of HPCs by means of a survey or interviews.

5.6 Conclusions

In domestic HPCs, the use phase is very significant in the consumption of energy and GHG emissions (40% at low usage pattern and 80% at high usage pattern), and water (100% process water). The use phase has a larger share in professional HPCs due to the higher frequency of use (85% and 95%). This suggests that measures aimed at reducing the energy and water consumption in the use phase will have a bigger impact in the professional units than in domestic units. In domestic units, in the low usage scenario, the production phase is equally important in terms of energy and GHG emissions, which indicates a potential improvement related to durability and reparability measures. In the high usage scenario, this potential improvement may be lower, due to a higher weight of the use phase.

In terms of LCC, water represents the largest share in all base cases, and it is more dominant in the professional base cases. LCC at unit and EU level increase along time, mainly due to the water price evolution. This results from the price series set by MEErP. These results may suggest that water- and energy-saving measures may be cost-effective; however, it depends on the additional cost and improvement potential of those measures and on the usage pattern of the machines. This is investigated in sections 6 and 7.

The usage patterns is the most important source of uncertainty, which is very difficult to reduce due to the large variations in uses and applications. Thereforeboth low and high usage scenarios are modelled in the following sections in this report to reflect and evaluate the impact of usage patterns.

6 Environment and economics of design options

6.1 Introduction

In accordance with the MEErP methodology, Task 6 identifies and presents the analysis of the design options, which are the options for improvement of the environmental performance taking into account the Least Life Cycle Costs (LLCC). The design options are based on the description and analyses in the Task 4 report. The assessments of impacts are based on the base cases (BC) as described in Task 5 and presented below.

The impacts of the design options are assessed quantitatively using the EcoReport Tool (LCA) and the stock model spreadsheet (LCC) for the identified base cases.

The base cases selected in Task 5 are:

- BC1: Domestic cold water electric motor HPC;
- BC2: Professional cold water electric motor single-phase HPC;
- BC3: Professional cold water electric motor three-phase HPC;
- BC4: Professional cold water combustion motor HPC;
- BC5: Professional hot water (fuel burner) electric motor single-phase HPC;
- BC6: Professional hot water (fuel burner) electric motor three-phase HPC.

The following section describes the identification and selection of design options followed by a brief description of each design option with the assumed direct impact and the associated costs, and afterwards an assessment of the LCA and LCC impact.

6.2 Design options

6.2.1 Identification of options

The design options are based on analyses of the previous tasks, mainly on Task 4 where opportunities for saving energy and water during the use phase through design improvements have been identified. Additionally, opportunities were identified for improving the durability of domestic HPCs and improving reparability for all HPCs. In total, four design options are described and assessed below:

- D1: Improvement of nozzle design (BC1-BC6);
- D2: Increase of electric motor-pump efficiency (BC1-BC3, BC5-BC6);
- D3: Increase of hot water fuel burner efficiency (BC5-BC6);
- D4: Improvement of durability and reparability (BC1).

6.2.2 D1: Improvement of nozzle design (BC1-BC6)

The nozzle creates the water spray jet and the shape and strength of the jet are determined by the type of nozzle, meaning that the nozzle design has a high impact on the cleaning performance.

Entry-level HPCs usually come with just one nozzle while higher-performing and more expensive HPCs often come with more types for different types of cleaning work and surfaces. Some top brands design their own improved-design nozzles, while the rest normally purchase generic types from suppliers. A conclusion from the Task 4 report was that there is significant variation in both water and energy consumption for a similar cleaning quality for different nozzles. This indicates that there is potential for energy and water savings through improvement of the nozzle design.

The nozzles can be divided into three main types:

- fixed jet: the shape and pressure of this jet cannot be adjusted;
- variable fan-jet: the nozzle has different positions that allow the user to vary the spray angle and pressure of the spray;
- rotating jet: a powerful, focused jet spins as it leaves the nozzle, providing very strong cleaning power.

The nozzle is connected to the main body of the HPC through a high-pressure hose.

The rationale behind this option is therefore that an improved nozzle design can save water and energy without reducing cleaning performance. Only some specific cleaning tasks need a high water flow to remove loosened dirt and low-water-flow attachments cannot be used for these tasks but also there the assumption is that improved nozzle design can reduce the water consumption.

A policy option to implement this design option would require a cleaning performance measurement method for water and energy consumption during a typical cleaning cycle established in the measurement method.

6.2.2.1 Impact

The assessment of the quantitative impact of improving the nozzle design is based on stakeholder data from cleaning performance tests carried out by an independent test laboratory (see Task 3, Section 3.5) of 43 domestic HPCs.

The test consisted of cleaning 1 m^2 of normal to very dirty pavement without making use of a cleaning agent. The cleaning cycle was repeated using a standard nozzle, a rotating nozzle and a floor scrubber accessor. Each cleaning cycle per accessory is carried out twice by two different experts: if results are within a reasonable range of deviation, the test is considered valid. Cleaning time, cleaning quality (a point score based on assessing the cleaning quality), total water consumption and input power during the test were measured and registered.

Using this dataset, we have identified HPCs with the same cleaning quality and approximately the same efficiency level. The efficiency is calculated as a proxy, meaning an indicator of the motor-pump performance: pressure delivered by the HPC multiplied by water flow divided by input power. The difference in water consumption between these HPCs is assumed to be due to the nozzle design. Table 65 shows the series of HPCs with the same cleaning quality and approximately the same efficiency proxy, indicating the water savings achieved by the best (BAT) in the series compared to the average water consumption for all HPCs in the series. The results of the two individual tests for each HPC were averaged.

Table 65. Assessment of water savings using BAT compared to average nozzle technology within a series of tested HPCs with the same cleaning quality

Water consumption, l	Cleaning quality	Efficiency proxy	Savings BAT to average, %
6.5	3	0.46	57
20.8	3	0.48	
18.5	3	0.51	
9	3	0.54	6
8	3	0.58	
10.9	3	0.73	21
7.1	3	0.86	
11.7	3.5	0.5	16
13.2	3.5	0.51	
12.1	3.5	0.52	
9.8	3.5	0.54	
14	4	0.47	10
11.4	4	0.49	
12.1	4	0.6	22
13.3	4	0.63	
9	4	0.64	
11.1	4	0.67	22
11.5	4	0.7	
7.8	4	0.7	
9.6	4	0.74	
10	4	0.78	18
6.9	4	0.78	
8.6	4.5	0.67	21
5.6	4.5	0.74	
7.6	4.5	0.78	16
5.5	4.5	0.83	
Average saving BAT compared to average			**21**

Note: Dotted lines in the table separate HPCs with approximately the same efficiency proxy. Each row represents a tested HPC. The bottom line shows an average of all savings.

The average saving in water consumption using a BAT nozzle compared to an average nozzle is thereby calculated to be 21% for this dataset. The result is rounded down to 15% to take into account the standard deviation of savings. The savings in water consumption are assumed to correlate directly with the savings in electricity consumption, as explained in Task 4.

This result can be compared to an impact analysis for an improved nozzle design carried out as part of an Environmental Design of Industrial Products project, which included a redesign of a high pressure cleaner by the company Alto Denmark (now part of Nilfisk)[92]. The achieved result was about 30% savings of water and energy without a reduction in cleaning performance.

These figures are for domestic HPCs, but no information disconfirms that the same pattern can be seen for professional HPCs. Stakeholder input during the study confirms that improvement of nozzle design is very relevant as an energy- and water-saving measure.

The assumption is that the improved nozzle design can reduce the energy, water and detergent consumption by 15% whilst maintaining cleaning quality for all the base cases.

[92] http://orbit.dtu.dk/files/4646274/Wenzel.pdf

6.2.2.2 Costs

Improvement of the nozzle design will typically require a one-time redesign including testing of the nozzles with the HPCs that they are designed for, followed by necessary changes in the production process. The type and amount of raw materials for the improved nozzles may be slightly different, but this is assumed to entail only marginal additional costs.

No data or estimations on the costs related to this design option were received from the stakeholders consulted. The study team therefore based the cost estimates on other sources. In the Task 4 report, retail prices in Spain of domestic nozzles as spare parts were stated to range from EUR 7/unit to EUR 27/unit for normal nozzles (Task 4 report, Table 14). The interval may be seen as evidence of the price difference between entry-level basic nozzles and more advanced and supposedly more efficient nozzles and part or all of the difference, EUR 20, is assumed to be the price premium for an efficient nozzle. However, spare parts are typically more expensive than the part's share of a retail price of the complete product because there are additional costs for handling spare parts. This means that the price premium is lower than EUR 20, such as EUR 15-17.

Additionally, the study team has collected retail prices for the same HPC models in the tests reported in the previous section and subject of the saving assessment. Comparing the prices for the HPCs in each comparable series, the price difference between the ones with the lowest water consumption and the ones with the highest consumption was around EUR 20-40. Some of the price difference is due to it being a premium product, brand name, better quality material etc. and some a better nozzle design.

Based on these two sources, the assumption is that an improved nozzle design has a retail cost impact of an additional EUR 16.

A similar pattern for professional products is assumed though with a higher price premium due to better quality materials, assumed to be 50% higher than for the domestic sector, i.e. in total EUR 24.

6.2.3 D2: Improvement of electric motor-pump efficiency (BC1-BC3, BC5-BC6)

A large proportion of the electric motors in domestic HPCs use universal motors, which are inexpensive, and usually operate at low efficiencies (30-50%) and with a short lifetime (500-600 hours) which however is not a limitation for domestic HPCs as the hours of use during lifetime are less than 500. Professional HPCs use induction motors with higher efficiency levels (around 60-75%) and a longer lifetime. The most efficient type of motors are brushless DC motors (BLDC) with efficiencies around 85-95%. Lifetimes for induction and BLDC motors are around 3 000-4 000 hours.

There are HPC models, both domestic and professional, where the electric motors are completely integrated with the high pressure pump, and in these cases the energy performance of the motor cannot be tested independently. Therefore, a potential Ecodesign requirement for HPCs should target the energy performance of the motor-pump combination.

6.2.3.1 Impact

The study team has assessed the possible impact of increasing the electric motor-pump efficiencies from average levels to a BAT level without changing the motor technology using the dataset of data collected on HPCs on the market as described in the Task 4 report.

The motor efficiencies were not available so instead we calculated the following index to use as a proxy for the efficiency:

$$Efficiency_{proxy} = \frac{Maximum\ working\ pressure\ \times Rated\ flow}{Connection\ load}$$

The results are presented in Figure 79 and Figure 80.Figure 79. Proxy efficiency levels vs connection load (kW) for domestic HPCs (BC1)

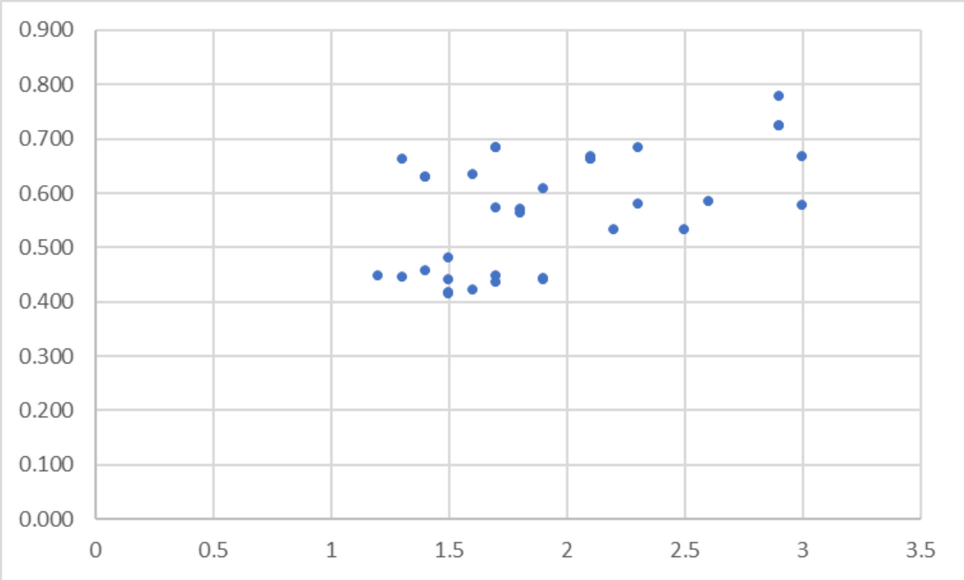


Figure 79. Proxy efficiency levels vs connection load (kW) for domestic HPCs (BC1)

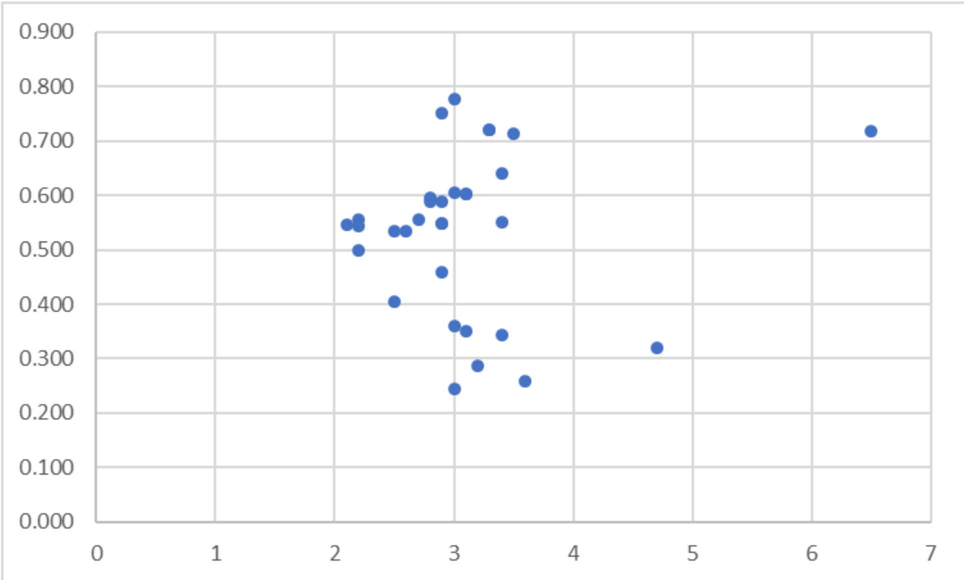


Figure 80. Proxy efficiency levels vs connection load (kW) for professional single-phase HPCs (BC2, BC5)

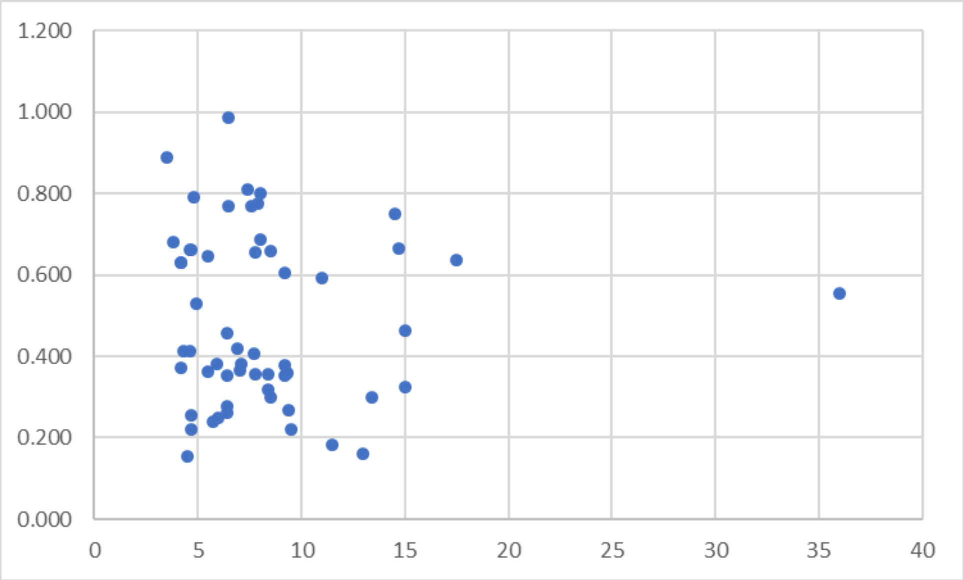


Figure 81. Proxy efficiency levels vs connection load (kW) for professional three-phase HPCs (BC3, BC6)

As can be observed from the graphs, and also described in Task 4, there is no correlation between the efficiency of the motor-pump and the connection load.

The increase in efficiency of the design option for improving the electric motor-pump, based on these datapoints, and the averaged associated savings are presented in Table 66. The thresholds proposed below discriminate 30% of the models of the datasets for domestic and professional categories.

Table 66. Proxy efficiency of electric motor-pump (threshold and average efficiency increase) and the associated savings

HPC type	Proxy efficiency of design option	Savings
Domestic (BC1)	Threshold: 0.50 Average eff. increase from 0.57 to 0.64	10%
Professional single-phase (BC2, BC5)	Threshold: 0.50 Average eff. increase from 0.53 to 0.61	13%
Professional three-phase (BC3, BC6)	Threshold: 0.35 Average eff. increase from 0.49 to 0.57	15%

6.2.3.2 Costs

For domestic HPCs (BC1) the manufacturing cost of universal motors is from around EUR 4 based on an assessment of vacuum cleaner motors[93]. With an assumed mark-up of 2.6%, the retail price is around EUR 10. The estimated additional cost for a more efficient universal motor (e.g. going from 35% to 44% electric efficiency to achieve 20% savings) is estimated at 25%, i.e. EUR 2.5.

For professional HPCs, the improvement of induction motors will lead to an increase of 25% of the manufacturing cost of the unit, according to stakeholder input.

[93] "Review study on vacuum cleaners. Draft final report." Viegand Maagøe A/S, Van Holsteijn en Kemna B.V. November 2018.

6.2.4 D3: Improvement of hot water fuel burner efficiency (BC5-BC6)

Most of the professional hot water HPCs use a fuel burner to heat the water. Electric heaters are only used for special HPCs used in areas where fuel burners are not suitable. The pressurised water is pumped through a heating coil placed in the burner chamber where the water is heated. The efficiency depends on the burner efficiency, the length and form of the heating coil and how the hot air is circulated around the heating coil.

The option consists of setting requirements on maximum thermal losses for the hot water fuel burner as defined by EN IEC 62885-5:2018, and presented in Table 67.

Table 67. Thermal requirements for increasing fuel burner efficiency

Net power of heater P (kW)	Max. thermal loss *q*A (%)
4 ≤ P ≤ 25	11
25 > P ≤ 50	10
P > 50	9

Estimations from stakeholders are that about 75% of products on the market comply with the requirements set above. Most just comply with the above thresholds and some are above these energy efficiency thresholds.

Most of the models in the dataset of professional heaters with a fuel burner and with data on fuel consumption are above 50 kW and only a few are below 25 kW.

6.2.4.1 Impact

It is assumed that an average non-complying model will have a net power of above 50 kW and a thermal efficiency of 80%. The impact on the fuel consumption of this design option will be calculated as the increase in thermal efficiency from 80% to 91%. The fuel savings are thereby 12%.

6.2.4.2 Costs

Professional hot water HPCs are expensive machines with prices around EUR 2 000 to EUR 5 000 for common types. The HPCs with low thermal efficiency are assumed to be at the lower price end of the market. Comparing these with similar cold water machines, the price difference is about EUR 1 000 and above.

When a non-complying HPC should be adapted to comply, the additional costs will consist of three elements:

- Redesign: It is necessary to redesign the burner itself and accommodate a larger burner in the HPC. This is a one-time investment, which is often high. If a company is redesigning for other purpose in addition to redesigning for a more efficient burner, the added cost related to the burner would naturally be smaller.
- Machine tool sets: This is a one-time investment for the production of the HPCs in redesigned versions.
- Extra material: The coil needs to be longer and perhaps of better quality and the burner chamber may need double walls. This is an added cost for each product.

According to stakeholder input, the additional manufacturing cost of this design option would be EUR 190.

6.2.5 D4: Improvement of durability and reparability (BC1)

This design option primarily aims at improving the durability of the domestic HPCs where large variation in the technical lifetime has been observed (see Section 3.5.2., Figure 21).

The design option consists of setting a minimum lifetime requirement, where the lifetime is according to a defined test method based on a certain number and duration of usage cycles. An example of such a test method has been provided by a stakeholder, who has tested a number of HPCs on the market (see Section 3.5.2).

The minimum lifetime required in this design option has been assumed to be 6 years compared to the current average of 2 years. The impact and costs have been assessed for domestic HPCs exclusively, but the policy measure should cover all HPCs, as all professional HPC units should already fulfil this minimum performance requirement.

Additionally, improvement of reparability is included in the same design option without specifically quantifying their impact. These are detailed below.

Improvement of reparability

This part of the design option consists of increasing the lifetime of HPCs by improving the reparability potential of the ones that are difficult to repair through:

- non-destructive access (disassembly) to critical components such as the motor-pump;
- assuring the availability of spare parts;
- repair and maintenance information and/or manuals provided by the manufacturer for each model.

Non-destructive access to the main components means that the main components of the HPC should be easily accessible; the HPC unit should be disassembled (non-destructive) with the use of common tools allowing professionals or end users to replace the failed parts according to the list of spare parts that is presented in Task 7.

Availability of spare parts means that professional repairers and for some of the spare parts also end users should be able to obtain spare parts for a minimum period of 10 years after the last unit of the model is placed on the market.

Repair and maintenance information means that the manufacturer, importer or authorised representative should provide access and all repair and maintenance information to professional repairers and to end users.

6.2.5.1 Impact

The stock spreadsheet has been used to calculate an average lifetime using the Weibull distribution based on the 6 years of minimum lifetime; the result of the average lifetime is 11 years.

6.2.5.2 Costs

The study team estimated the cost by comparing retail prices of domestic single-phase HPCs with prices of professional cold water single-phase HPCs within the same range of rated flow and working pressure. These two types of HPCs mainly differ in component quality and durability and the price difference can thereby be estimated as the added cost for durability.

We used the data set of data collected on HPCs on the market as described in the Task 4 report and isolated data for HPCs with maximum flow rates of 500-620 l/h and a maximum working pressure of 10-15 MPa. The average retail price in this range for domestic HPCs was EUR 494 and for professional HPCs EUR 589, resulting in a price difference of about EUR 100. However, it is assumed that a main part of this price difference is other improvements for a professional product compared to a domestic product.

The assumption is an additional cost of EUR 25 per unit at the retail price level for increasing the minimum lifetime performance from 2 to 6 years.

6.3 LCA and LCC impacts

The LCA impact is calculated using the EcoReport Tool for each base case, each design option and each usage scenario (low and high) as was done for BAU in Task 5. The results are presented in the following subsections in the form of total primary energy consumption and total water consumption over the full life cycle, i.e. production, distribution, use and end-of-life (disposal and recycling) for all the relevant design options and for BAU for each base case.

No other impact parameters are presented. GHG and other emission types correlate mostly with the energy consumption. Eutrophication (PO_4) correlates with the detergent consumption, which is proportional to water consumption.

The LCC per unit is calculated summing the purchase cost, the annual repair and maintenance costs and the annual electricity, fuel and water costs (consumption multiplied by the unit price for electricity, fuel and water, respectively) over the full lifetime. The data presented are for products purchased in the year 2018.

For D4, improvement of durability, the average lifetime is longer than for the other design options, 11 years compared to 9.5 years. In order to be able to compare with BAU and the other design options, energy and water consumption and LCC are converted to 9.5 years average lifetime.

6.3.1 LCA and LCC for BC1: Domestic cold water electric motor HPC

Figure 82 and Figure 83 show the results of the calculations for BC1, a domestic cold water HPC with an electric motor, for low and high usage scenarios.

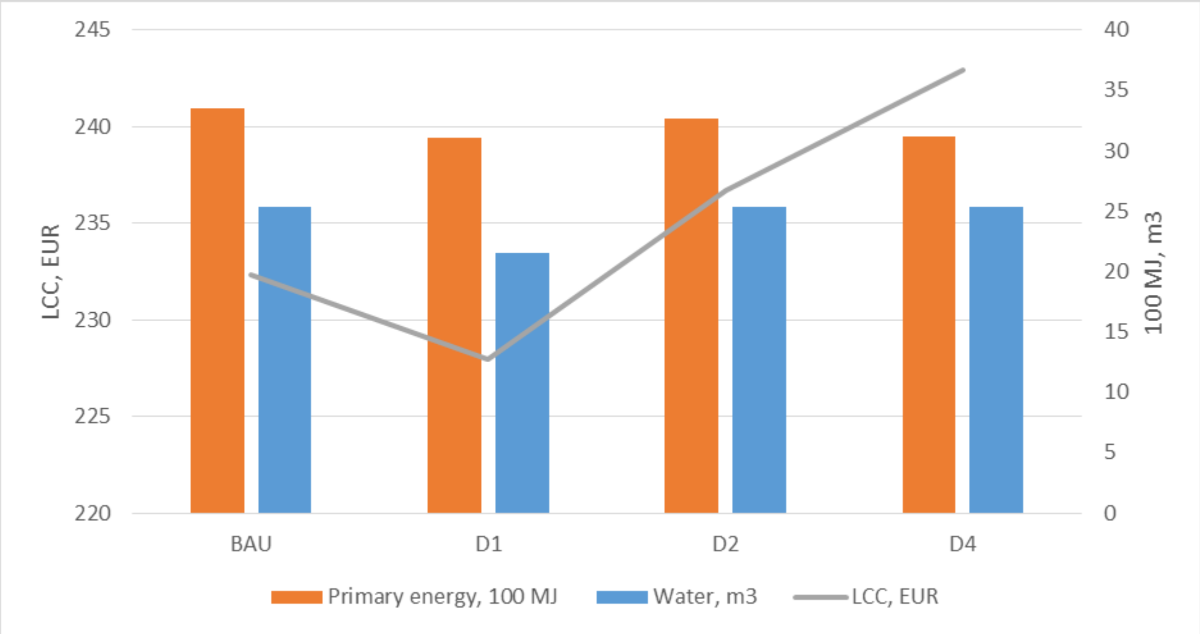


Figure 82. BC1 in BAU and with design options 1, 2 and 4 - Impact on primary energy and water consumption and LCC in the low usage scenario (constant 2015 EUR)

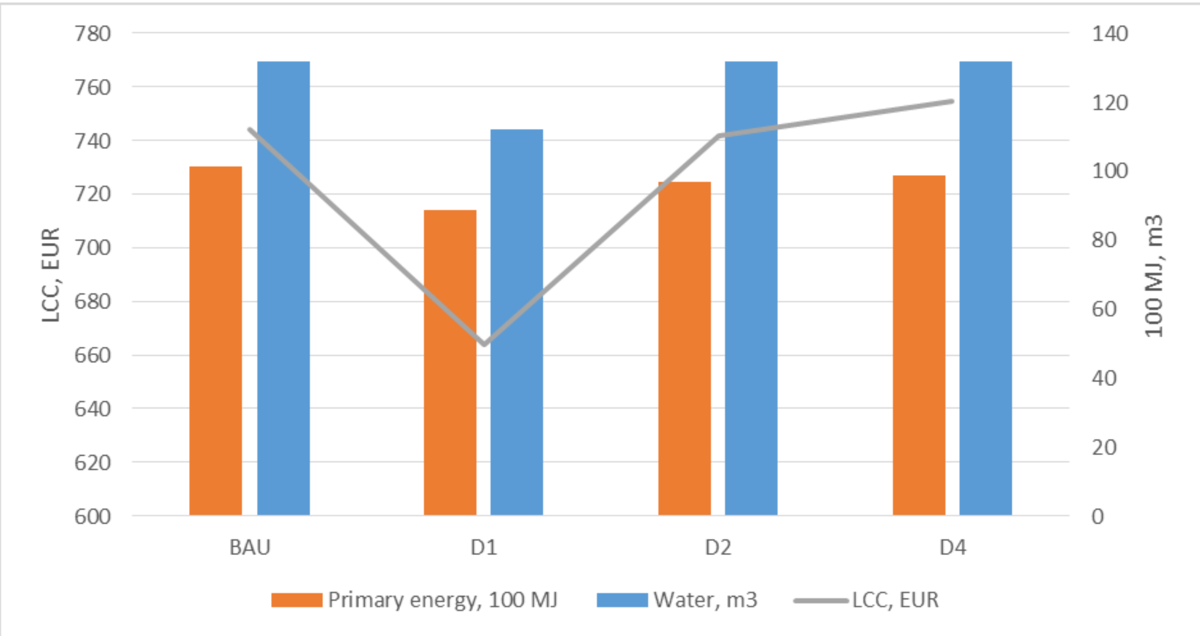


Figure 83. BC1 in BAU and with design options 1, 2 and 4 - Impact on primary energy and water consumption and LCC in the high usage scenario (constant 2015 EUR)

The figure shows that the LLCC is achieved for D1 (improvement of nozzle design) for both usage scenarios, resulting in 2% (low usage) and 11% (high usage) less LCC compared to BAU.

The main reason is that the impact of the manufacturing cost is not high, while the impact on the electricity, water and detergent lifetime costs is significant in the high usage scenario and small in the low usage scenario.

D1 results in the lowest energy and water consumption savings: 7% (low usage) and 12% (high usage) energy and 15% water. However, this design option would require a harmonised test method to measure the water and energy consumed per cleaning cycle which is not available. According to manufacturers, the development of a representative test method would be very complex due to the wide range of uses of HPCs.

The LCC for D2 (increase of electric motor-pump efficiency) are also lower than the LCC for BAU, while the LCC for D4 (improvement of durability and reparability) are higher than the LCC for BAU.

D2 and D4 also result in lower energy consumption than BAU.

6.3.2 LCA and LCC for BC2: Professional cold water electric motor single-phase HPC

Figure 84 and Figure 85 show the results of the calculations for BC2, a professional cold water HPC with a single-phase electric motor, for low and high usage scenarios.

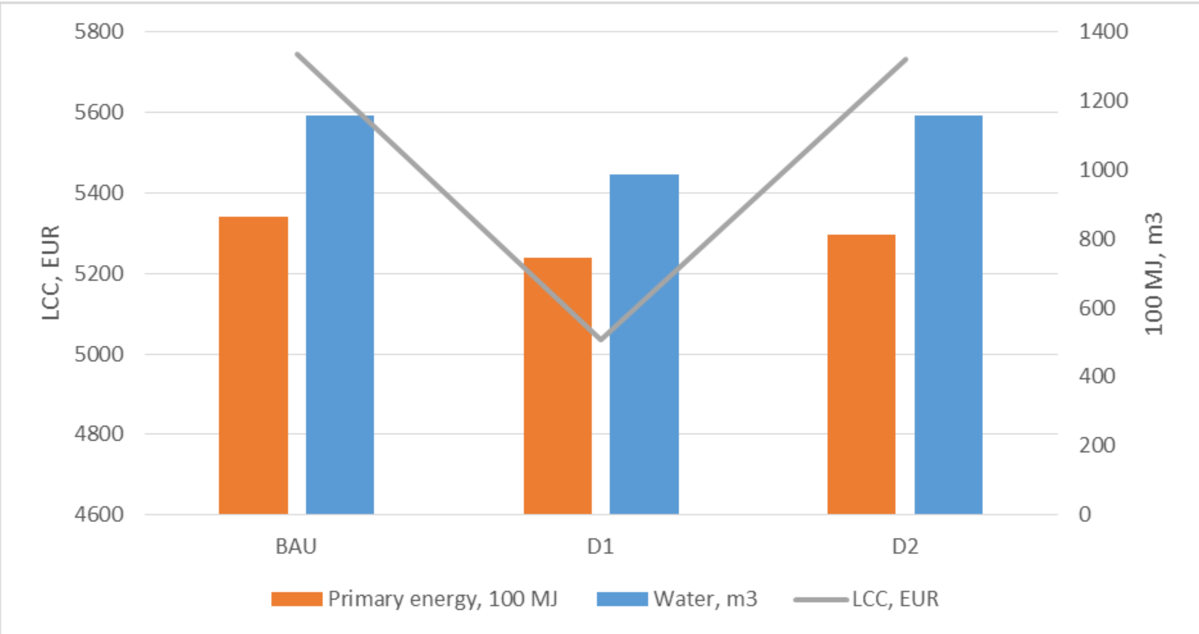


Figure 84. BC2 in BAU and with design options 1 and 2 - Impact on primary energy and water consumption and LCC in the low usage scenario (constant 2015 EUR)

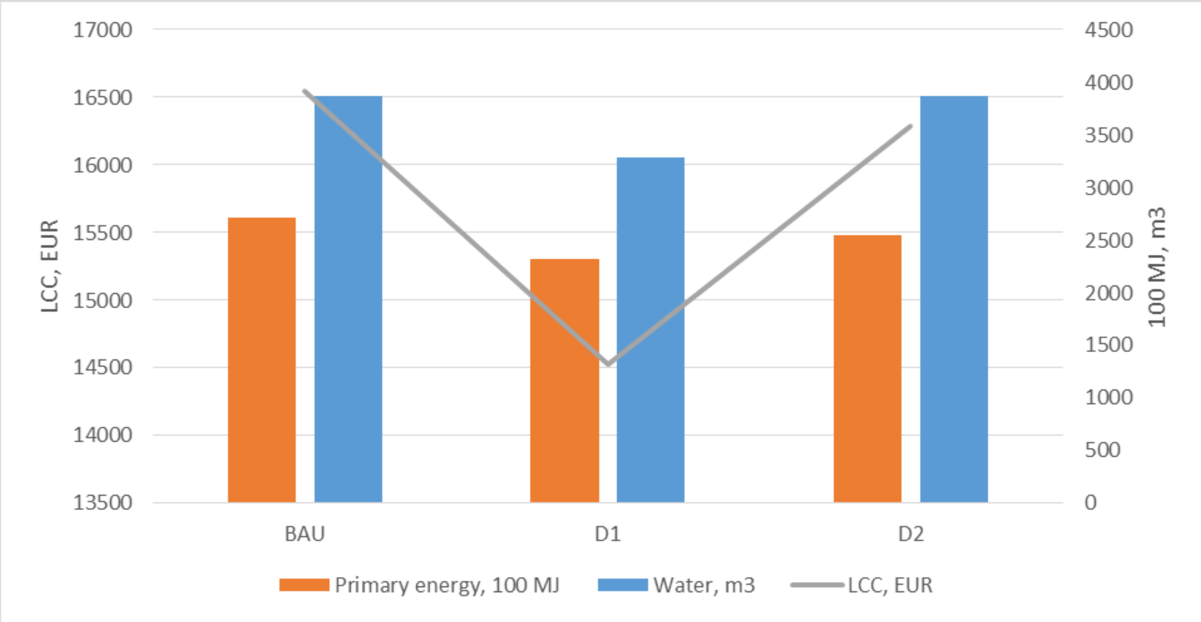


Figure 85. BC2 in BAU and with design options 1 and 2 - Impact on primary energy and water consumption and LCC in the high usage scenario (constant 2015 EUR)

The figures show that the LLCC are achieved for D1 (improvement of nozzle design), resulting in 12% less LCC compared to BAU. It also has the lowest energy and water consumption (about 15% reduction for both usage scenarios). The improvement is more significant compared to the same option for domestic high pressure cleaners due to the higher share of the use phase in the life cycle of professional products. However, the lack of a harmonised test method is also an obstacle in this case.

D2 (increase of electric motor-pump efficiency) results in a small reduction of the LCC (0-2%) and a 6% reduction of primary energy consumption.

6.3.3 LCA and LCC for BC3: Professional cold water electric motor three-phase HPC

Figure 86 and Figure 87 show the results of the calculations for BC3, a professional cold water HPC with a three-phase electric motor, for low and high usage scenarios.

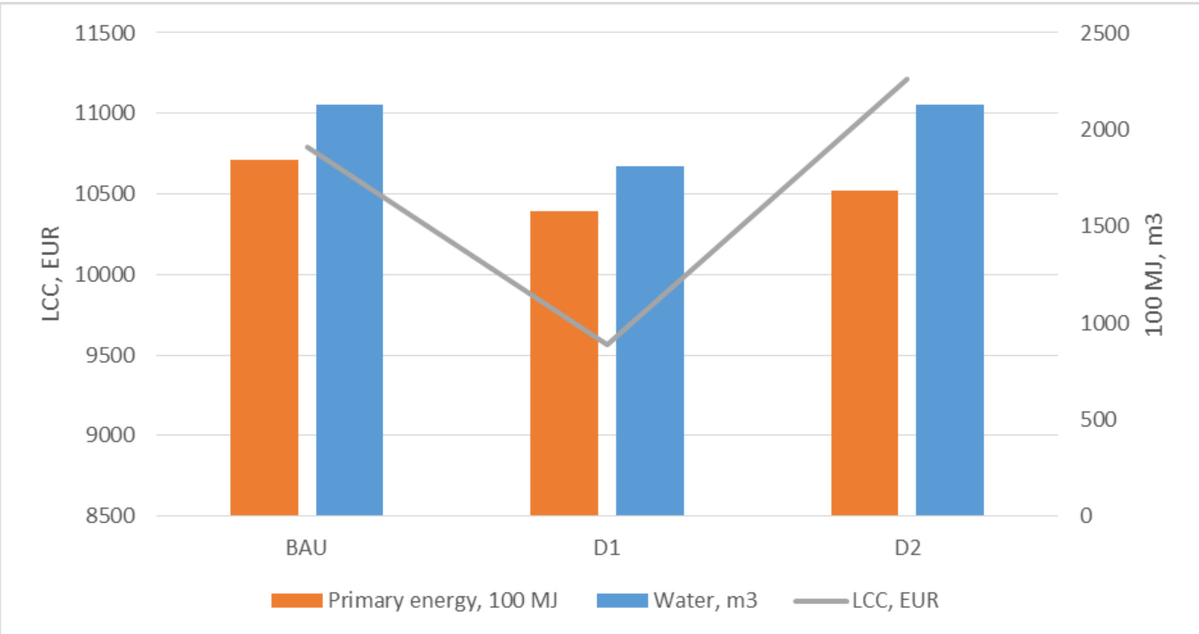


Figure 86. BC3 in BAU and with design options 1 and 2 - Impact on primary energy and water consumption and LCC in the low usage scenario (constant 2015 EUR)

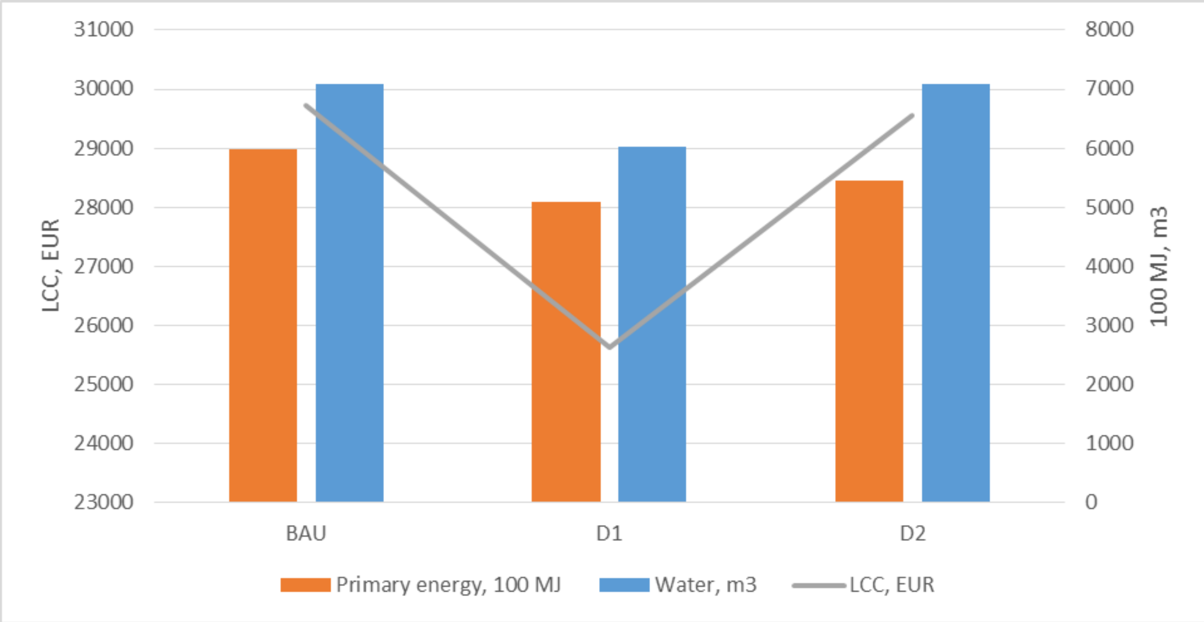


Figure 87. BC3 in BAU and with design options 1 and 2 - Impact on primary energy and water consumption and LCC in the high usage scenario (constant 2015 EUR)

The results show a similar pattern and savings to BC2; LLCC is also achieved for D1, saving 11% and 14% compared to BAU for the low and high usage scenarios, respectively. Energy and water consumptions are reduced by 15%. The LCC for D2 is slightly higher than for BAU for the low usage scenario and slightly lower for the high usage scenario. The energy consumption for D2 is about 9% lower than for BAU for both usage scenarios.

6.3.4 LCA and LCC for BC4: Professional cold water combustion motor HPC

Figure 88 and Figure 89 show the results of the calculations for BC4, a professional cold water HPC with a combustion motor, for low and high usage scenarios.

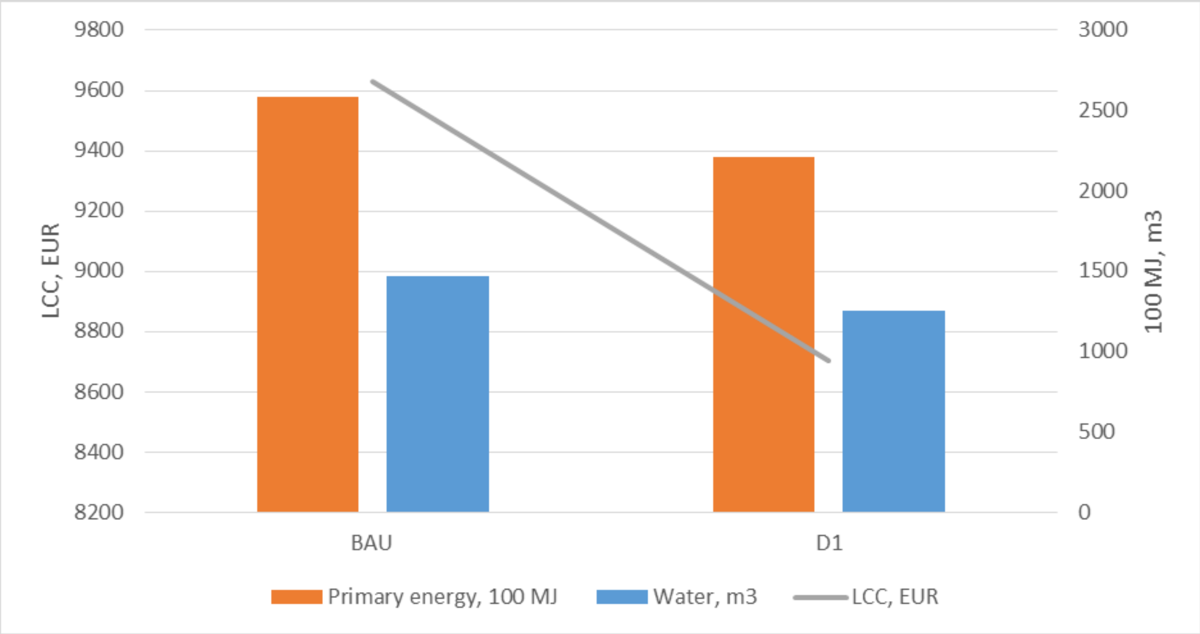


Figure 88. BC4 in BAU and with design option 1. Impact on primary energy and water consumption and LCC are shown. Low usage scenario. Constant 2015-EUR.

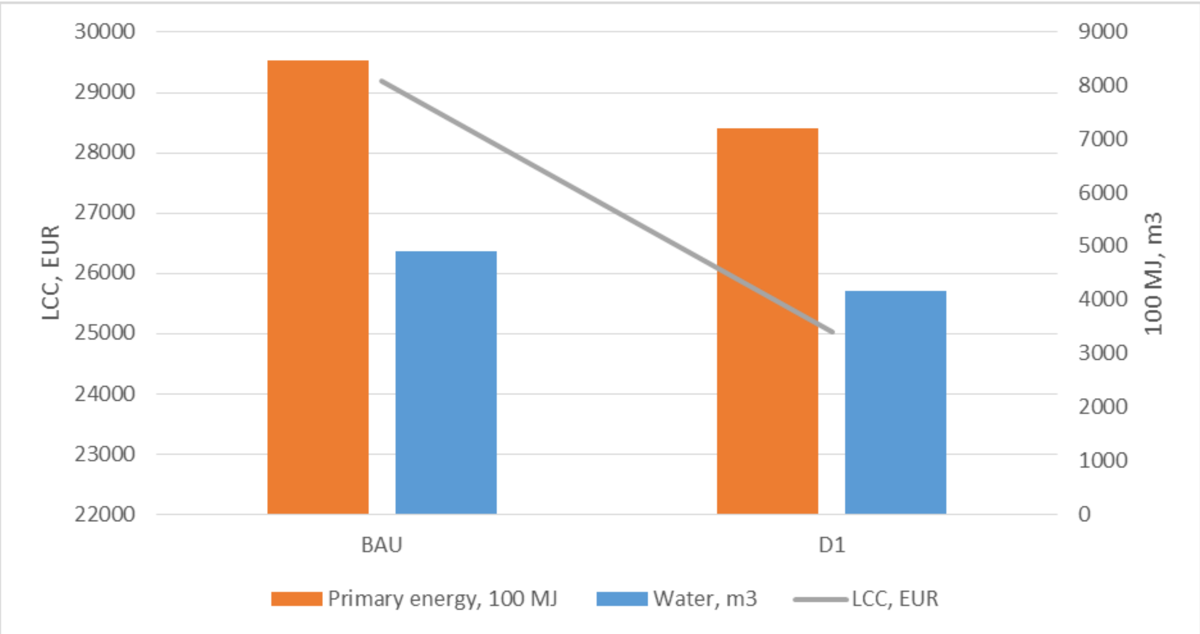


Figure 89. BC4 in BAU and with design option 1. Impact on primary energy and water consumption and LCC are shown. High usage scenario. Constant 2015-EUR.

LLCC is achieved for D1 saving from 10% (low usage) to 15% (high usage) compared to BAU. Energy and water consumption is reduced by 15%.

6.3.5 LCA and LCC for BC5: Professional hot water (fuel burner) electric motor single-phase HPC

In Figure 90 and Figure 91 are shown the results of the calculations for BC5, a professional hot water HPC (fuel burner) with a single-phase electric motor, for low and high usage scenarios.

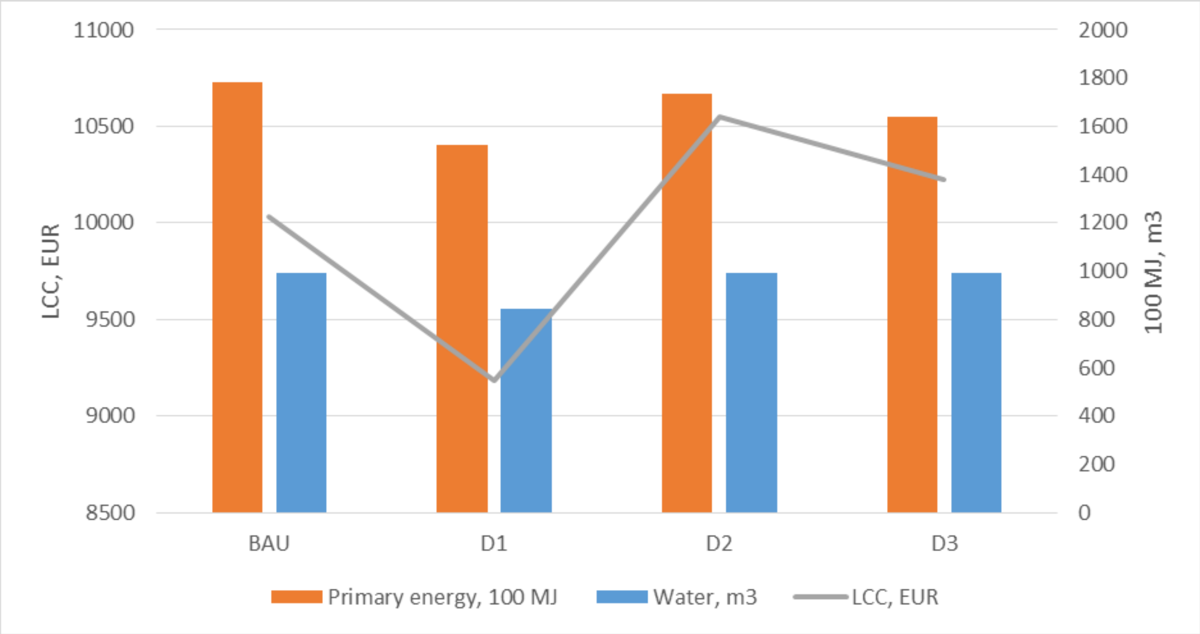


Figure 90. BC5 in BAU and with design options 1, 2 and 3 - Impact on primary energy and water consumption and LCC in the low usage scenario (constant 2015 EUR)

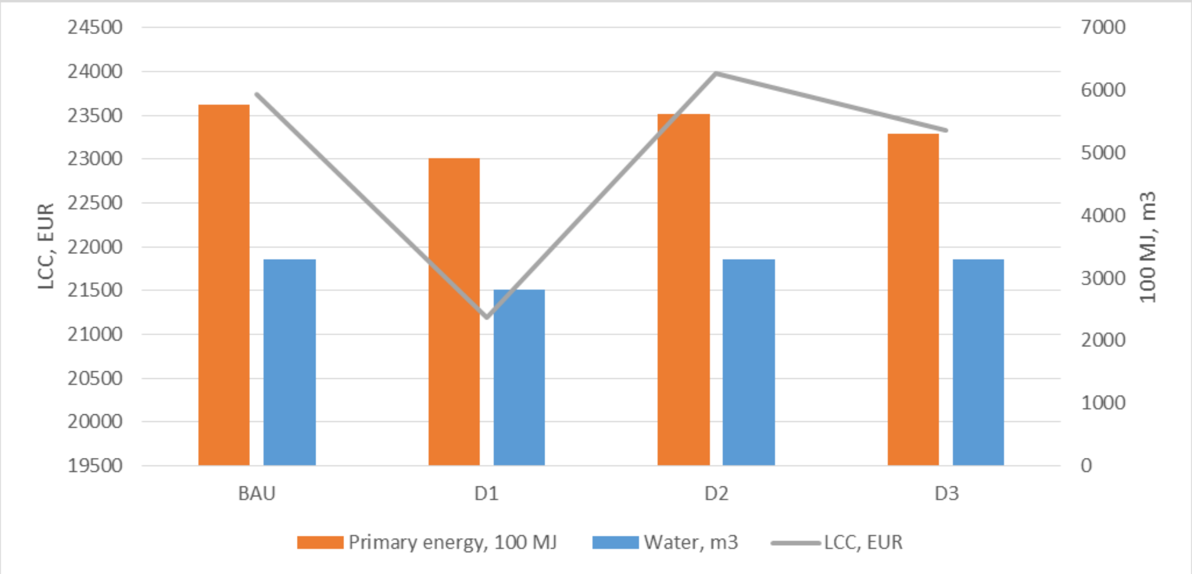


Figure 91. BC5 in BAU and with design options 1, 2 and 3 - Impact on primary energy and water consumption and LCC in the high usage scenario (constant 2015 EUR)

The figure shows that the LLCC are achieved for D1 (improvement of nozzle design), which also results in the lowest energy and water consumption for both the low and high usage scenarios. The LCC are 8% (low usage) to 11% (high usage) lower compared with BAU, while the energy and water consumption is about 15% lower.

For the low usage scenario, the LCC for D2 (increase of electric motor-pump efficiency) and for D3 (increase of hot water fuel burner efficiency) are slightly higher than for BAU, while for the high usage scenario, D2 is almost the same and D3 is lower.

D2 results in 3% energy savings and D3 in 8%, both figures for both usage scenarios. Water consumption is the same for D2, D3 and BAU.

6.3.6 LCA and LCC for BC6: Professional hot water (fuel burner) electric motor three-phase HPC

Figure 92 and Figure 93 show the results of the calculations for BC6, a professional hot water HPC (fuel burner) with a three-phase electric motor, for low and high usage scenarios.

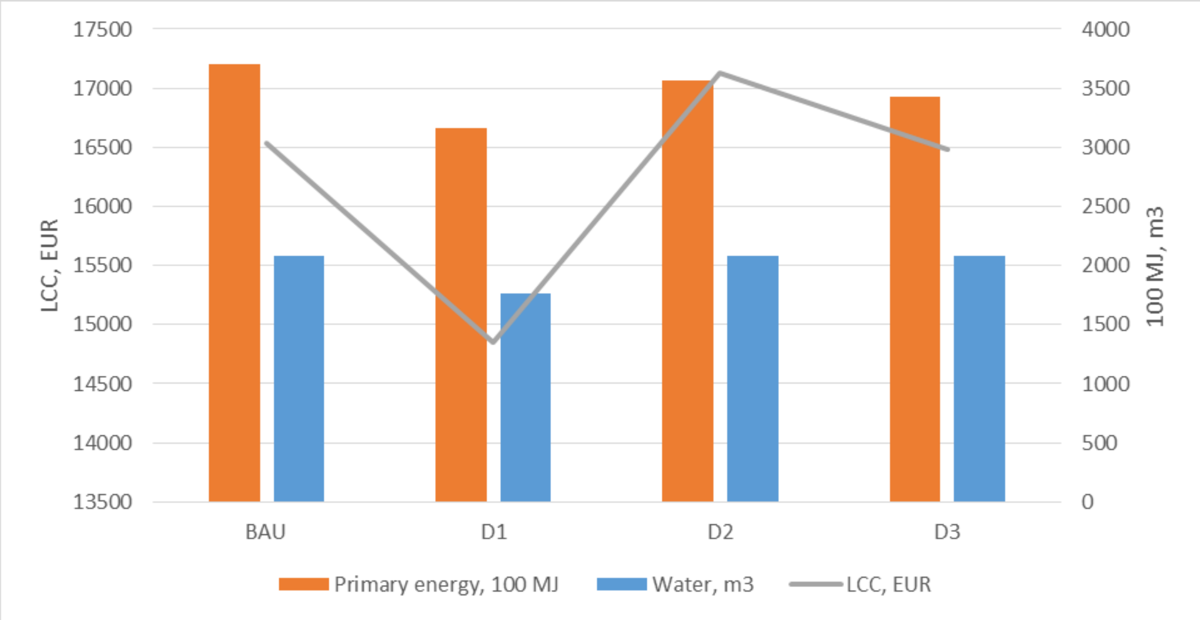


Figure 92. BC6 in BAU and with design options 1, 2 and 3 Impact on primary energy and water consumption and LCC in the low usage scenario (constant 2015 EUR)

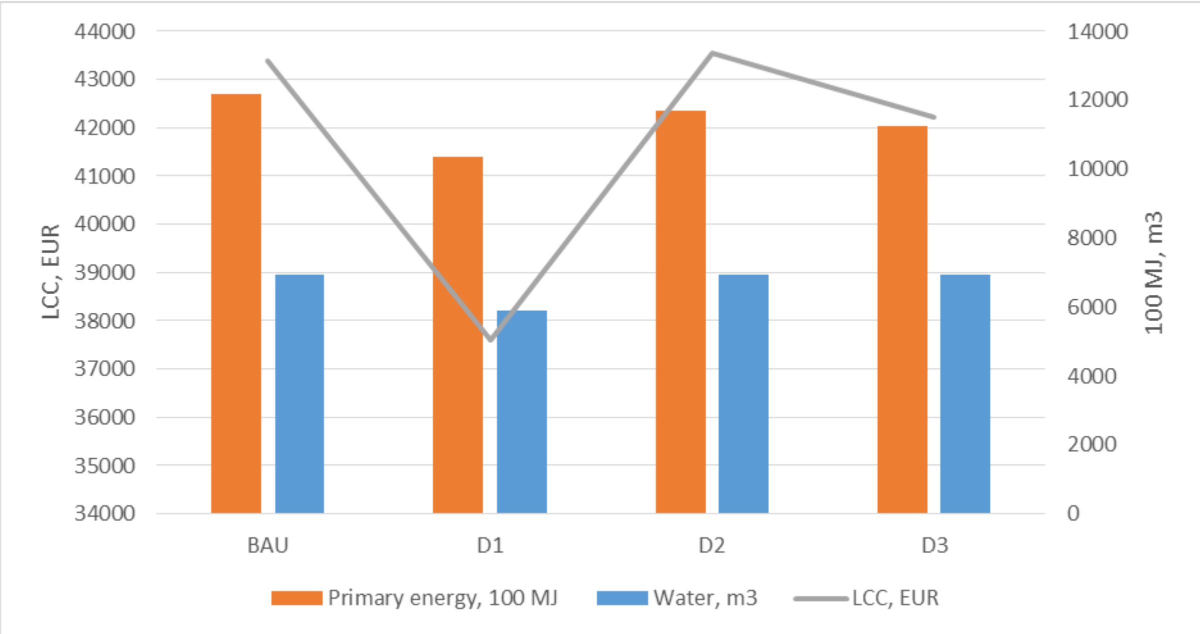


Figure 93. BC6 in BAU and with design options 1, 2 and 3 Impact on primary energy and water consumption and LCC is shown in the high usage scenario (constant 2015 EUR)

The figure shows that the LLCC is achieved for D1 (improvement of nozzle design), which also results in the lowest energy and water consumption for both the low and high usage scenarios. The LCC are 10% (low usage) to 13% (high usage) lower compared with BAU, while the energy and water consumption is about 15% lower.

For the low usage scenario, the LCC for D2 (increase of electric motor-pump efficiency) and for D3 (increase of hot water fuel burner efficiency) are slightly higher than for BAU, while for the high usage scenario, D2 is almost the same and D3 is lower.

D2 results in 4% energy savings and D3 in 7-8%, both figures for both usage scenarios. Water consumption is the same for D2, D3 and BAU.

6.4 Conclusions

All design options for both usage scenarios reduce the primary energy consumption and reduce the water consumption or keep it unchanged compared to BAU. All design options reduce the LCC by maximum 14% or increase the LCC by a maximum of 5% compared to BAU.

For all base cases, design option D1 (improvement of nozzle design) achieves the LLCC and has the largest primary energy- and water-savings potential. LCC savings are 2-14% and energy savings 2-15% depending on the base case and usage scenario. Water savings are 15%.

The high usage scenario generally provides the highest savings in LCC and in energy and water consumption. The LCC for design options in the high usage scenario are mostly below the LCC for BAU, apart from two cases, where they are 1% higher.

7 Policy analysis and scenarios

7.1 Introduction

In accordance with the MEErP methodology, this Task 7 report collects the information of all previous tasks and looks at suitable policy instruments and measures to achieve the potential, e.g. implementing LLCC as a minimum and BAT as a promotional target, using legislation or voluntary agreements, labelling, benchmarks and possible incentives. It draws up scenarios until 2050, quantifying the improvements that can be achieved versus a Business-as-Usual scenario.

This report estimates the impact on the industry and the consumers. Finally, in a sensitivity analysis of the main parameters, it studies the robustness of the outcome.

7.2 Policy analysis

7.2.1 Stakeholder consultation

Stakeholder consultation and stakeholder input are necessary for the technical study and the subsequent policy process. The JRC has established a dedicated website[94] as a communication hub (information, registration, documents, etc.) combined with e-mail submissions to the registered persons and organisations.

Stakeholders include the industry (OEMs and component manufacturers), industry associations, Member States, consumer and environmental organisations.

Formal stakeholder consultations carried out were a 1st Technical Working Group (TWG) meeting held on 3 May 2018 in Brussels and a 2nd stakeholder meeting held as a webinar over 2 days (23 and 24 January 2019). A 3rd stakeholder meeting was held on 17 June 2019.

Additionally, separate meetings and telephone conferences were held with industry associations and manufacturers throughout the study.

7.2.2 Barriers and opportunities for improvements

The basis for identifying the policy measures is the assessment of barriers and opportunities for improvements identified in the previous tasks (4, 5 and 6). Data from all the previous tasks have been used for the analyses in this report.

Based on the above assessments, five design options were selected for analysis in Task 6:

- D1: Improvement of nozzle design (BC1-BC6);
- D2: Increase of electric motor-pump efficiency (BC1-BC3, BC5-BC6);
- D3: Increase of hot water fuel burner efficiency (BC5-BC6);
- D4: Improvement of durability (BC1);
- D5: Improvement of reparability (BC1).

The base cases defined in Task 5 and used in Task 6 are:

- BC1: Domestic cold water electric motor HPC;
- BC2: Professional cold water electric motor single-phase HPC;
- BC3: Professional cold water electric motor three-phase HPC;
- BC4: Professional cold water combustion motor HPC;
- BC5: Professional hot water (fuel burner) electric motor single-phase HPC;
- BC6: Professional hot water (fuel burner) electric motor three-phase HPC.

94 http://susproc.jrc.ec.europa.eu/HighPressureCleaners

7.2.3 Policy instruments

There are several policy instruments available, which could be used to regulate high pressure cleaners (HPCs) aiming at a better environmental performance. The main types of policy instruments are presented below.

7.2.3.1 Ecodesign requirements

Ecodesign requirements (under the Ecodesign Directive (2009/125/EC)[95]) means that mandatory minimum requirements would be introduced for a set of parameters; the manufacturers would bear the responsibility for their products to be compliant when placed on the market and the Member States would verify compliance via market surveillance activities. This acts as a "push" instrument for products to achieve better performance because all appliances will have a minimum level of energy efficiency performance regulated by the implementing measures,in order to access the EU market.

7.2.3.2 Energy labelling

Energy labelling (under the Energy Labelling Regulation (2017/1369/EU)[96]) implies mandatory labelling of the product for a set of parameters and with an A to G scale (A indicates the best level). Manufacturers are responsible for labelling their products and the labelling is enforced by Member State market surveillance regarding both the actual labelling and the correct energy class. This acts as a "pull" instrument because the consumers will compare and choose the products they want to purchase, which pulls the market towards higher energy performance.

The energy label can contain further information besides the energy class, e.g. via icons and numbers indicating the content of specific substances, noise, water consumption, etc.

A combination of Ecodesign requirements and energy labelling is possible, where Ecodesign removes the least environmentally friendly products from the market and energy labelling promotes the more environmentally friendly products.

7.2.3.3 Self-regulation

The Ecodesign Directive (2009/125/EC) recognises self-regulation by industry as an alternative to implementing measures under this directive. Self-regulation is not initiated by the Commission, but by the manufacturers proposing a self-regulative mechanism to the Commission which is in charge of checking regularly if it fulfils its purpose. The Directive sets out requirements for self-regulation in its annex VIII, such as sufficiently high market coverage..

7.2.3.4 Voluntary labelling

Voluntary labelling implies that manufacturers can choose whether to label their products or not. In the case of the EU Ecolabel[97], the requirements to be met by products to be allowed to bear the Ecolabel are established through implementing regulations, ensuring that the labelled product belongs to the 'best in class' in terms of environmental aspects. Member States are responsible for market surveillance.

7.2.3.5 Considered policy instruments

Energy Labelling and/or Ecodesign implementing measures for high-pressure cleaners would need to take into consideration the water and energy consumption per cleaned surface area. This could be facilitated by the development of a standard to measure the cleaning performance of HPCs and to establish the thresholds and the label classes (for Energy Label). An Ecodesign measure could also be based on a transitional test method, and be revised to refer to a standard once one has been developed. The revision could also be an appropriate moment to assess the need for energy labelling requirements.

Self-regulation in the form of a voluntary agreement has been not been considered as an option because this was not proposed by the manufacturers.

A voluntary industry labelling scheme already exists: the "EUnited Cleaning Burner Efficiency" is a labelling scheme which is based on the EN IEC 62885-5:2018 standard that applies to burners of oil-heated HPCs, which

95 https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0125

96 Regulation (EU) 2017/1369 of the European Parliament and of the Council of 4 July 2017 setting a framework for energy labelling and repealing Directive 2010/30/EU

97 Regulation (EC) No 66/2010 of the European Parliament and of the Council of 25 November 2009 on the EU Ecolabel

have to meet requirements on thermal exhaust loss, CO emissions, and dust emissions. This is however not a label which fulfils the requirement for a self-regulative initiative or voluntary labelling. Voluntary labelling furthermore has the disadvantage that the market coverage may not be high and thereby the impact low.

7.2.4 Policy measures

7.2.4.1 No action – Business as Usual (BaU)

The business as usual option is based on no further interventions from the regulator beyond those applicable today as presented in this study. The BaU option is used as a reference for comparison with other policy scenarios. The development in environmental impact over the scenario period is based on the development of the sales and stock of HPC products.

7.2.4.2 D1: Requirements based on cleaning performance

The Task 6 assessments showed that D1: Improvement of nozzle design (BC1-BC6) can reduce the energy, water and detergent consumption by an estimated[98] 15% as compared to all the base cases, while maintaining the cleaning quality, with a limited retail price increase of EUR 16 and EUR 24 per unit for domestic and professional HPCs, respectively.

Defining quantitative requirements and measures more accurately than the abovementioned estimation would require a harmonised cleaning performance test method . Such a test method should reflect an average use and at the same time be sufficiently simple for the test laboratories to run and repeatable in order that different test laboratories would get the same result.

For instance, for vacuum cleaners a test standard is under development after a standardisation request by the Commission. The test consists of an amount of test dust spread over a specific type of carpet and hard floor and a special machine simulates a user vacuum cleaning the carpet and the floor. The energy consumption and the amount of dust pick-up and of dust re-emission are measured.

A test standard for HPCs could follow the same principle as used for vacuum cleaners and define a number of different surfaces with different kinds of soiling and define a certain cleaning pattern. Cleaning efficiency could be determined, for example based on the resource consumption for removing a defined amount of dirt within a given time or on the time needed to remove all the dirt from a defined surface type and size.

The surfaces would need to be thoroughly defined, selecting artificial test surfaces so that the tests can be reproduced in different test laboratories. Artificial test materials are widely used for the performance assessment of a wide range of household appliances including washing machines and dishwashers. The test materials are defined within the test standards.

Additionally, the test method should describe the potential variables in HPC usage that could affect the result, e.g. type of nozzle (or other attachment), height and angle of nozzle relative to the surface, speed of the water jet passed over the surface, water pressure, temperature, detergent. Furthermore, potential damage to the surface due to excessively high jet impact should be measured or assessed. For hot-water HPCs, the test methods may also include measurement of the temperature of the water as it leaves the HPC.

Some of the manufacturers consulted questioned the ability of any test method to reflect the real cleaning performance of HPCs. They indicate that the variety of surfaces, soils, and usage parameters (angle, distance, etc.) is too wide to come up with a representative, robust and reliable test method. If a method were to be developed nonetheless, in their view such a test method should be developed by the European Committee for Standardization, in response to a standardisation request that would encompass all the relevant test methods for this product group. This would deliver a representative dataset for the development of Ecodesign minimum requirements and/or Energy Labelling.

For the purpose of this report, a policy measure to achieve the estimated potential increase of 15% in cleaning efficiency is modelled in order to evaluate its potential impacts on water, energy and life cycle costs. The proposed date of effect would be January 2030, assuming the period of time that would be necessary for the European Committee for Standardization to develop a test method. The date is set for modelling purposes and the real standardisation process may have a different duration.

[98] based on the tests carried out by a consumer organisation

7.2.4.3 D2: Increase of electric motor-pump efficiency (BC1-BC3, BC5-BC6)

The policy measure addressing this design option set a minimum efficiency requirement for the electric motor-pump assembly used for HPCs.

An Ecodesign implementing measure is already in place for certain types of electric motors defined [99,100]. Motors within the scope include squirrel cage induction motors (i.e. not universal motors), which are rated on the basis of continuous duty operation. Motors that are completely integrated into a product (for example gear, pump, fan or compressor), of which the energy performance cannot be tested independently from the product, are not within the scope of the measure. This is the case for the majority of the motors in HPCs on the market. Where motors in HPCs fall within the scope the efficiency of the pump is still not covered. This existing measure will therefore not sufficiently ensure the high efficiency of the motor-pump.

The minimum efficiency requirement proposed in this measure will be based on a proxy for the efficiency calculated as follows:

$$Efficiency_{proxy} = \frac{Rated\ pressure\ pressure\ \times Rated\ flow}{Connection\ load}$$

Where rated pressure (MPa), rated flow (litres/second) and connection load (kW) are those defined according to to IEC 60335-2-79:

- rated pressure: maximum working pressure at the pressure generator during normal operation;
- rated flow: maximum flow at the rated pressure at the nozzle during normal operation;
- normal conditions: conditions under which the machine is operated in normal use (more details are defined in the standard).

The first term in the equation (pressure multiplied by flow) is the output power from the motor-pump and the second term (connection load) is the input power.

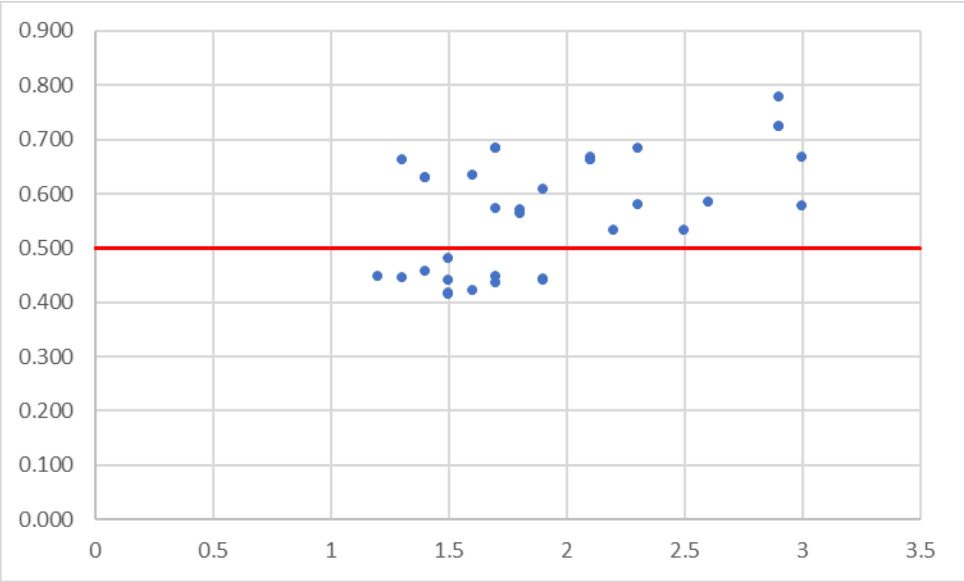
Based on the input from manufacturers, the measurement should be as follows:

- rated pressure: at the outlet of the pressure generator (high pressure pump);
- rated flow: at the appliance outlet, in any case upstream of any "Venturi" systems for suction of the detergent solution.

Threshold levels have been set aiming at removal of the least efficient products; see Figure 94, Figure 95 and Figure 96 for domestic, professional single-phase and professional three-phase HPCs.

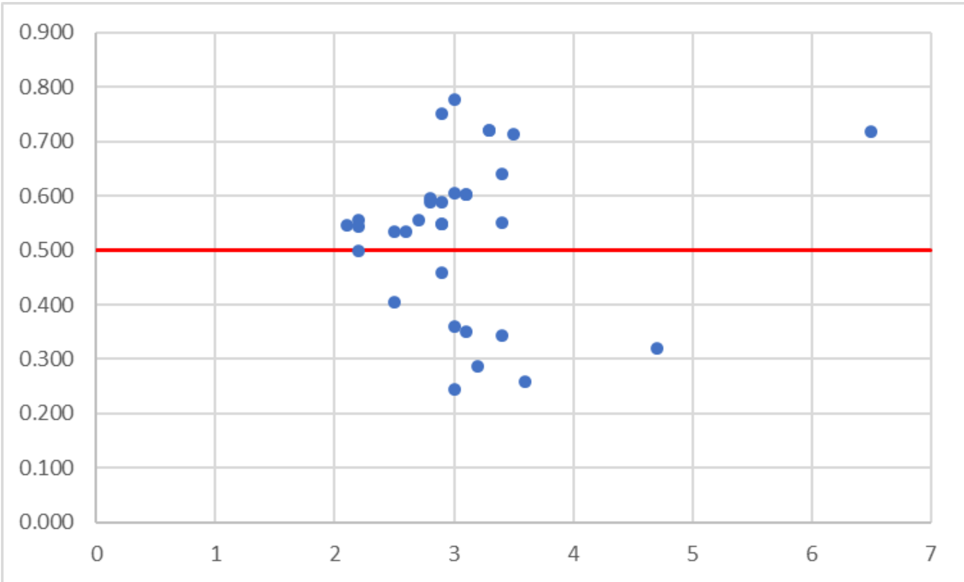
[99] Commission Regulation (EC) No 640/2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for electric motors OJ L 191, 23.07.2009

[100] Commission Regulation (EU) No 4/2014 of 6 January 2014 amending Regulation (EC) No 640/2009 implementing Directive 2005/32/EC of the European Parliament and of the Council with regard to ecodesign requirements for electric motors OJ L 2, 7.1.2014



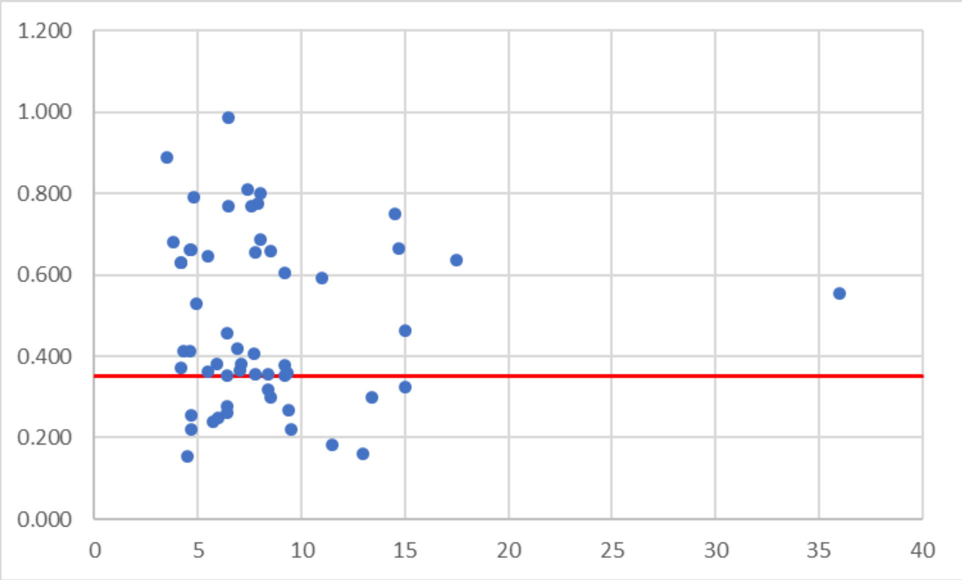
NB: Total number of datapoints is 35

Figure 94. Threshold proxy efficiency levels vs connection load (kW) for domestic HPCs



NB: Total number of datapoints is 32.

Figure 95. Threshold proxy efficiency level vs connection load (kW) for professional single-phase HPCs.



NB: Total number of datapoints is 56.

Figure 96. Threshold proxy efficiency level vs connection load for professional three-phase HPCs

The proposed requirements for the proxy efficiency of the electric motor-pump, based on the limited amount of datapoints and the associated savings from this threshold, are presented in Table 68.

Table 68. Proposed requirements for the proxy efficiency of the electric motor-pump and the associated threshold savings

HPC type	Threshold proxy efficiency	Threshold savings
Domestic	0.50	10%
Professional 1-phase	0.50	12%
Professional 3-phase	0.35	15%

The proposed date of effect is January 2025, assuming publication of the measure at the beginning of 2022 and the addition of a transitional period for compliance.

A transitional test method needs to be developed and published around the same time as the publication date.

7.2.4.4 D3: Increase of hot water fuel burner efficiency (BC5-BC6)

This policy measure sets a minimum efficiency requirement of the hot water fuel burner used for HPCs. The requirement is proposed to be in line with EN IEC 62885-5:2018[101], which is based on exhaust thermal losses. The threshold values for the fuel burner efficiency are presented in Table 69.

[101] https://webstore.iec.ch/publication/27171

Table 69. Thermal requirements for increasing fuel burner efficiency

Net power of heater P (kW)	Max. thermal loss *q*A (%)
4 ≤ P ≤ 25	11
25 > P ≤ 50	10
P > 50	9

As presented in the Task 6 report, about 70% of products on the market are assumed to comply with the requirements. An average non-complying model with a net power of above 50 kW (which most of the professional heaters with a fuel burner are) is assumed to have a thermal efficiency of 80% based on stakeholder input. The fuel savings of increasing the thermal efficiency from 80% to 91% (equal to 9% thermal losses) are 12%. The proposed date of entry into effect is January 2025, assuming publication at the beginning of 2022 and a transition period for compliance. The test method is the one of EN IEC 62885-5:2018[7].

A manufacturers' association proposed different thresholds to those set by EN IEC 62885-5:2018. These are the following:

- net power of heater from 4 to 30 kW: max. thermal loss (qA %) 15-13 (85/87%) until 550 l/h;
- net power of heater from 30 to 50 kW: max. thermal loss (qA %) 13-11 (87/89%) from 550 to 800 l/h;
- net power of heater from 50 to 70 kW – max. thermal loss (qA %) 11-10 (89/90%) from 800 to 1 000 l/h;
- net power of heater. 70 kW - max thermal loss (qA %) 10-9 (90/91%) over 1 000 l/h.

According to the association, a thermal loss below 9% is impossible to achieve for small boilers. They further indicated that the costs of research and development to reach an efficiency of 91% in boilers of 30 kW to 70 kW would not be feasible for the manufacturers of this type of product. Using the thresholds proposed by this association would lead to a slightly smaller saving potential for hot water HPCs.

7.2.4.5 D4: Improvement of durability

The policy measure sets a minimum lifetime performance requirement for domestic HPCs. This would particularly have an impact on domestic units, because professional units are typically already designed to cope with intensive use.

Two durability thresholds and test methods are proposed which are considered equivalent in terms of minimum durability requirements for domestic units. For professional units, the JRC proposal would need to be further developed to come up with appropriate thresholds. The first test method has been proposed by the JRC, based on the StiWa test cycle and the test results provided by a consumer organisation. In response to this proposal, the main association of manufacturers has put forward another test method for durability described below.

The proposed date of entry into effect is January 2025, assuming publication at the beginning of 2021 and a transition period for compliance.

Test method 1 (JRC proposal based on Stiftung Warentest – StiWa - test cycle)

The threshold level is 90 hours for domestic products, corresponding to 8 years of use assuming around 1 hour of use per month.

A test method should be developed, where the test is based on a certain number and duration of usage cycles. An example of such a test method has been provided by a stakeholder, who has tested a number of HPCs on the market. The test consists of running a number of cycles, with each cycle lasting 40 minutes as described below:

- 15 minutes with highest pressure and maximum water flow;
- 3 minutes with closed nozzle jet and the machine on;

- 12 minutes with highest pressure and maximum water flow;
- 10 minutes with the machine switched off.

Each cycle has thus 27 minutes of active use at maximum load and with a requirement at the level of 90 hours. This would mean that the HPC should operate for at least 200 cycles with pressurised water flowing, without motor or pump or nozzle breakage and without water leakages. In this case a similar test method needs to be standardised.

According to the industry, this test is too long and does not incorporate any switching activity. Besides, some parameters must be defined: water temperature, operating conditions, acceptance criteria, etc.

Test method 2 (EUnited Cleaning proposal; 25/5-s cycle)

EUnited has proposed an alternative durability test method which is presented below:

- Initial leakage of water during run-in time shall be ignored.
- Setup of high pressure cleaner under test conditions; it needs to be at room temperature.
- Measurement of p_{start} at pump outlet under conditions of normal operation according to IEC 60335-2-79.
- Performance of endurance test with cycles of 25 seconds followed by 5 seconds switched off via the trigger of the trigger gun. The water temperature should be 20 (±5) °C. The test should be at normal operating conditions according to IEC 60335-2-79. The following requirements are proposed for both domestic and commercial HPCs:
    - running time 150 h for commercial HPC, i.e. 18 000 cycles;
    - running time 40 h for household HPC, i.e. 4 800 cycles.
- After the test, let the high pressure cleaner cool down to room temperature again.
- Measurement of p_{end} at pump outlet under conditions of normal operation according to IEC 60335-2-79.
- Acceptance criteria $p_{end} \geq 0,9 * p_{start}$;

where p_{start} is the pressure at the start of the test (0 cycle) and p_{end} is the pressure at the end of the durability test (either at 4 800 cycles for domestic HPCs or 18 000 cycles for professional HPCs).

According to the manufacturers' association, the 25/5s-cycle is well known and it is a standardised cycle closely representing the average use behaviour of customers. As cycle is more intense in term of start and stop, than the one proposed in the first test method above, and thus the proposed number of cycles needed are less.

Other advantages mentioned by the industry are the following:

- Important increase of switching activities and integrating the elements pressure switch.
- Acceptance criteria are defined in terms of final pressure which is deemed more helpful to the customer than water leakage.
- Availability of test labs: it is a simple test setup which all manufacturers and most of the typical test houses will be able to apply without significant investments.
- Costs: Most of the tests will run automatically. Engineering activities are only needed during the preparation of the test and the initial measurement, as well as after the test to perform the final measurement. Costs will be relatively low, on a comparable level to the ErP motor endurance tests for vacuum cleaners in Europe.

However, another association of professional manufacturers has stated that many commercial HPCs have significant power installed with systems that create a delay in the shutdown of up to 30 seconds. For this reason, the 25/5s-cycle is not representative of the real use of commercial HPCs. They propose another cycle for professional units: 60s on / 30s off.

7.2.4.6 D5: Improvement of reparability

The measure sets requirements on easy access to the main components, availability of spare parts, and mandatory repair and maintenance information resulting in improved reparability potential, affecting mainly domestic HPCs as explained above, and thereby increased lifetime of domestic HPCs. This measure can be either an alternative or a supplement to the previous policy measure D4: Improvement of durability (BC1). The impact is naturally different for these two cases. More specifically, it includes the following:

- Disassembly requirements which means that the main components of a HPC should be easily accessible in a non-destructive way, allowing professionals and/or end users to replace them according to instructions described in the repair/maintenance manual provided by the manufacturer and the spare parts available.

- Availability of spare parts means that professional repairers and for some of the spare parts also end users should be able to obtain spare parts for a minimum period of 10 years for both domestic and professional HPCs after the last unit of the model is placed on the market.

- Repair and maintenance information means that the HPC manufacturer or importer or authorised representative shall provide access to manuals for repair and maintenance to professional personnel; as well as all relevant information to end users for repair and maintenance operations by themselves for the failures that do not entail potential health and safety issues.

- Maximum delivery time of spare parts: the manufacturer, importer or authorised representative shall ensure the delivery of spare parts within 15 working days of receiving the order.

The proposed date of effect is January 2025, assuming publication at the beginning of 2021. The specific requirements are included in Annex 5, and cover:

- non-destructive access (disassembly) to critical components;
- spare parts availability;
- repair and maintenance manuals.

7.2.5 Summary of policy scenarios

Table 70 presents a summary of the policy scenarios with all possible combinations of design options that are considered as feasible and meaningful to be combined.

Table 70. Summary of policy options*

	Scenario 1	Scenario 2	Scenario 3
Domestic and Professional HPCs	Energy Labelling and/or Ecodesign criteria based on cleaning performance (to be considered for the revision) [1, 2]	Energy Labelling and/or Ecodesign criteria based on cleaning performance, (to be considered for the revision) [1, 2]	
	Motor-Pump efficiency Ecodesign criteria [3]		
Hot water HPCs	Fuel burner efficiency Ecodesign requirement [4]	Fuel burner efficiency Ecodesign requirement [4]	Fuel burner efficiency Ecodesign requirement [4]
Domestic HPCs	Durability requirements ED One of the two durability test methods proposed in 7.2.4.4	Durability requirements ED One of the two durability test methods proposed in 7.2.4.4	Durability requirements ED One of the two durability test methods proposed in 7.2.4.4
Domestic and Professional HPCs	Reparability requirements [5]	Reparability requirements [5]	Reparability requirements [5]

* ***Options indicated in green can be adopted in the Regulation directly; those in orange can be considered in its revision.***

1 Based on a cleaning performance efficiency standard, which would be developed in response to a standardisation request covering all parameters relevant for this product group.

2 Energy Labelling and/or Ecodesign requirements will be considered in the revision of the Regulation.

3 A transitional method to measure maximum working flow and pressure and input power would be developed.

4 In line with EN IEC 62885-5.

5 Reparability requirements (see Annex 5 for details): i) non-destructive access (disassembly) to critical components; ii) spare part availability; iii) repair manuals.

7.3 Scenario analysis

7.3.1 Methodology for scenario modelling on environmental impacts

The Joint Research Centre has developed a spreadsheet product stock model which has been used for the scenario modelling. It is based on a bottom-up approach to calculate sales and stock combined with an LCC (life cycle costs) and LCA (Life Cycle Assessment) model, importing data from the Ecoreport tool based on BOM (bills Of materials) and consumption of energy, water and detergent calculated in Task 3. The scenario modelling gives the impact on energy, environment, economy and employment.

7.3.1.1 Policy options modelling

Each policy option has been modelled as follows:

- Energy Labelling and/or Ecodesign criteria based on cleaning performance efficiency: the lack of a harmonised test method to measure cleaning performance hinders the availability of data needed to model this policy option for professional units. The analysis carried out in Task 6 suggested that the variation in energy consumption in domestic units is allocated in similar shares between the effect of the motor-pump efficiency and the effect of the nozzle design. Therefore, for professional units, it is assumed that this option would add the same effect as motor-pump efficiency criteria when they are combined in Scenario 1, and that it would entail double savings of motor-pump efficiency criteria in Scenario 2. However, it is important to highlight that this assumption is very uncertain and the results of the modelling must be taken into account with caution.
- Non-compliant market shares:
    - For motor-pump efficiency and cleaning performance efficiency in domestic and professional HPCs, it is assumed that non-compliant units represent 50% of the market. The savings potential described in Section 7.2.4.3 would affect 50% of new sales.
    - For fuel burner efficiency requirements, it is assumed that the average fuel burner efficiency of non-compliant burners is 80% and that non-compliant burners represent 30% of the market. The savings potential described in section 7.2.4.4 would affect 30% of new sales.
- Durability requirements: see Section 7.3.1.2.
- Reparability requirements: see Section 7.3.1.2.

7.3.1.2 Modelling the effect of durability and reparability requirements

Both 'durability' and 'reparability' requirements that are proposed should be applied to all HPC categories as defined by the scope in Task 1, for domestic and professional HPCs. However, professional HPCs are typically more durable than domestic HPCs as they are manufactured with higher quality materials and components. Therefore, the proposed Ecodesign requirements are expected to mainly affect the domestic HPC category, and thus the modelling of reparability-durability requirements was performed only on BC1.

As mentioned above, the durability requirements will assure a minimum lifetime performance of 90 hours of use, which are defined by 200 prescribed cycles (see Section 7.2.4.4). To capture the effect of the extended durability, the so-called 'delay' factor in the Weibull lifetime distribution (see Section 2.2.1.2 for the domestic HPC lifetime calculations) has been increased accordingly. In the BAU scenario the delay factor is 2 years, representing the legal guarantee, and for the extended durability, this value has been increased to 8 years. The reason for this is that a minimum 90 hours of lifetime performance for domestic HPCs would ensure the consumers at least 8 years of normal use without any failure.

Reparability requirements will further aid in extending the average lifetime of domestic HPCs. To quantify this effect, a reparability scenario was constructed. This scenario, presented in Figure 97, assumes that, of the failed HPC domestic units, 60% will be repaired. Of these 60%:

- 30% regard major repair issues (referred to as 'Refurbished') which could result in a 60% lifetime extension;
- 50% regard minor repair issues which could result in a 40% lifetime extension;

- 20% will not be repairable at all (assuming they fail in their 8th year of use as an average), thus will not have any lifetime extension.

Based on this lifetime pathway scenario, the new average lifetime is calculated to be 11 years instead of the 9.5 years of the BAU scenario.

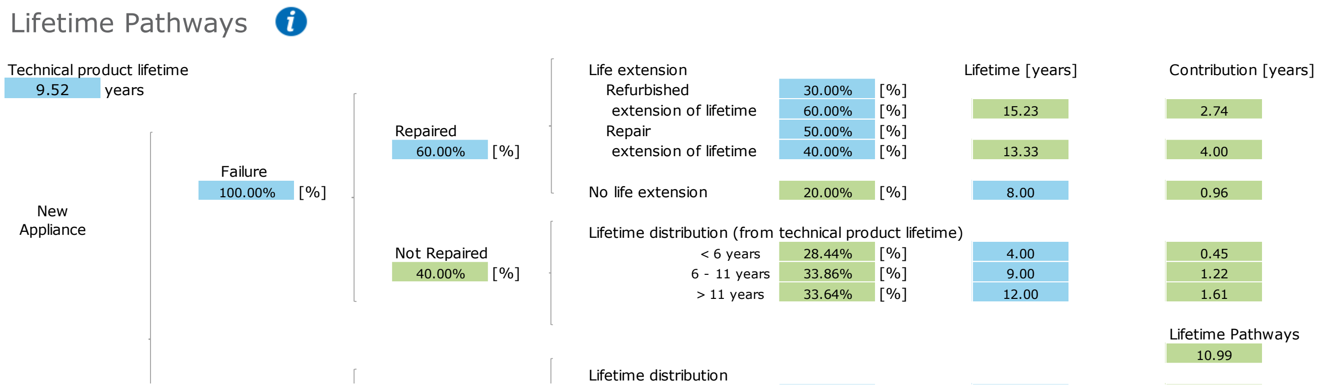


Figure 97. The reparability lifetime pathway scenario and the increase of the average lifetime for the domestic HPC (BC1)

The combination of the reparability and the durability requirements is then modelled by applying 8 years of 'delay' for the durability and 11 years of average lifetime in the spreadsheet model. Figure 98 presents the new Weibull lifetime distribution for the 'reparability-durability' combined scenario. Figure 98 presents the percentage of retiring domestic HPCs for the BAU scenario versus the combination of the reparability and durability requirements, divided into 5-year periods.

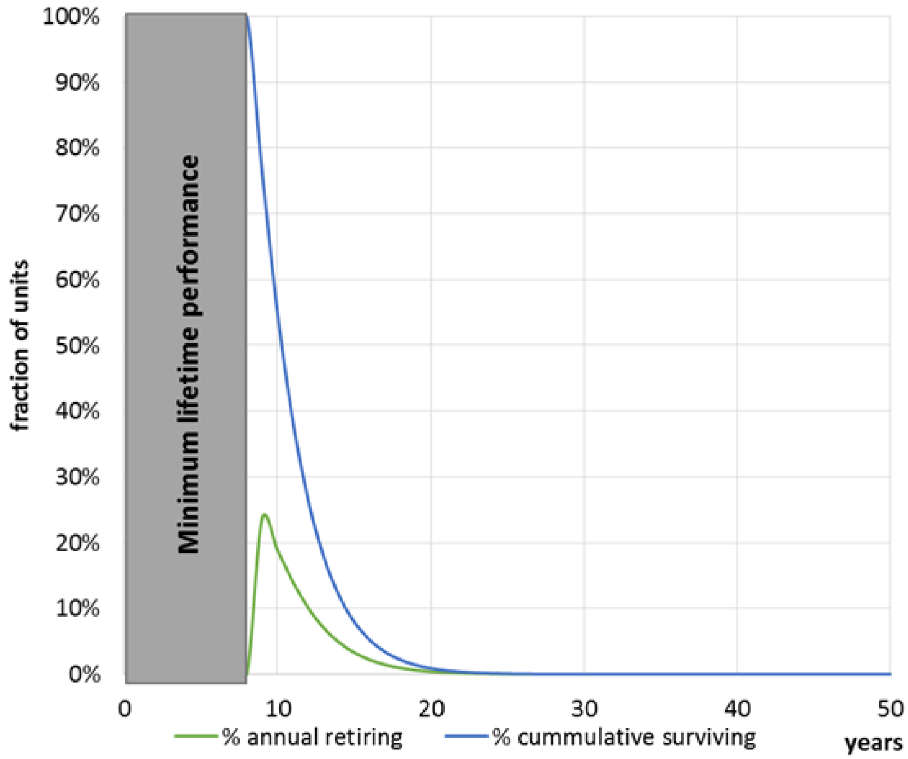


Figure 98. The new Weibull lifetime distribution for domestic HPCs due to the reparability and durability requirements

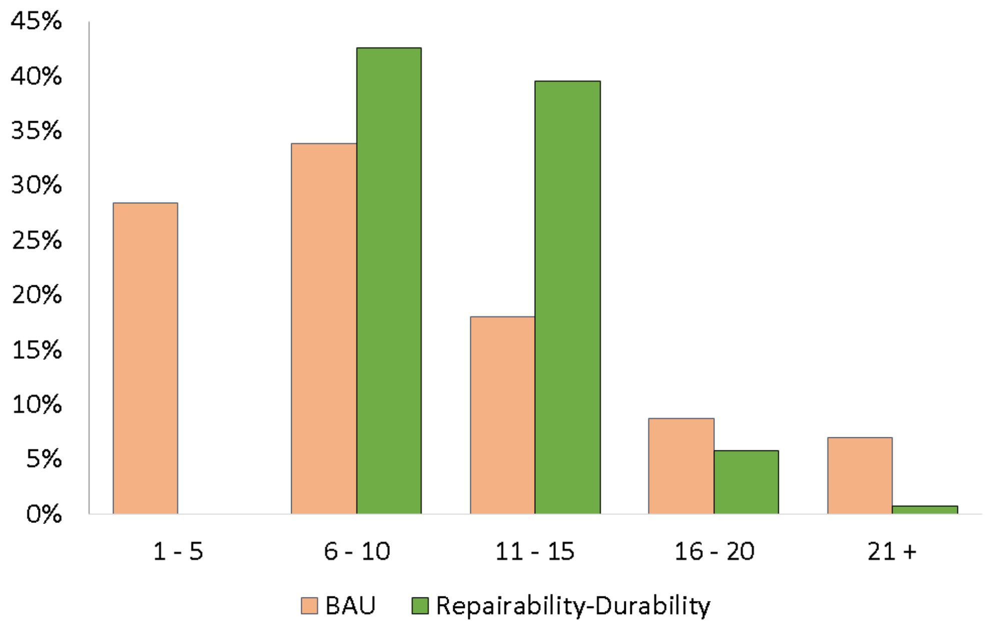


Figure 99. Percentage of retiring domestic HPCs divided into 5-year periods for BAU and for a combination of reparability and durability measures

Figure 98 presents the 'reparability-durability' scenario which can redistribute the lifetime distribution of domestic HPCs to higher values compared to BaU. The first 8 years no units are expected to be retired due to the durability requirements, in contrast with the BAU scenario; however, for the following years a higher percentage of units are expected to fail in the 'reparability-durability' scenario compared with the BAU scenario. In total, the average lifetime of the 'reparability-durability' scenario will be increased from the 9.5 years of the BAU scenario to 11 years with a different distribution as presented in Figure 98.

Based on the above analysis of the new lifetime distribution, the new sales and stocks from 2025 to 2050 were calculated, assuming that the estimated overall units (sales and stocks) in the market will be the same as in the BAU scenario (see Task 2). This would mean that the share of new sales and stocks will change as a result of the new lifetime distribution of the reparability-durability requirements without increasing the overall units, the summation of the new sales and stocks. As the average lifetime increases from 9.5 to 11 years in combination with the change of the lifetime distribution with the increased delay factor, the % of retiring units over time also change (see Figure 98), there will be a decrease in the new sales as the units will generally last longer as stock. A fraction of the new sales of the BAU scenario will be become stocks in the 'reparability-durability' scenario.

Figure 100 graphically presents this potential change in the share of new sales and stocks of the BAU versus the 'reparability-durability' scenario. The environmental impact savings were therefore calculated based on the avoided sales of domestic HPC units. Note that the sales in BAU that become stock in the 'reparability-durability' scenario are presented as normalised avoided sales per year.

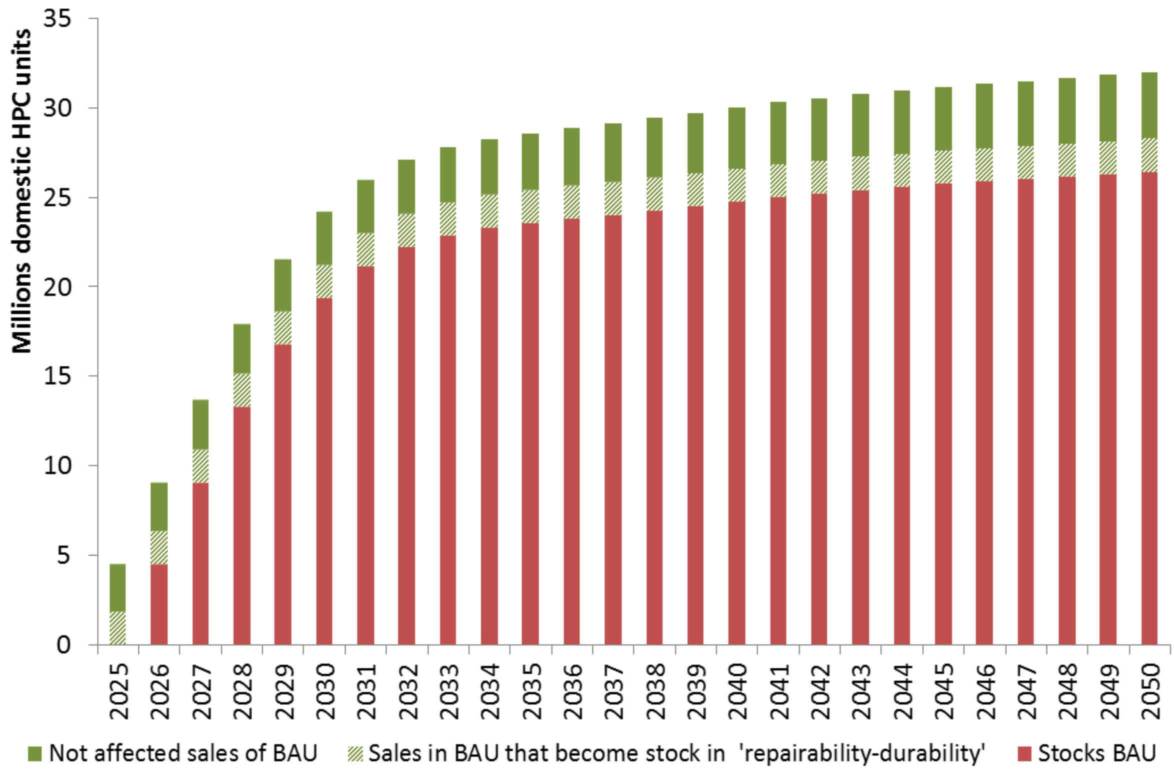


Figure 100. Stock and new sales of the BAU and of the reparability and durability measures[102]

The impact of the combination of durability and reparability requirements has been analysed for domestic HPCs only, because the main impact will be seen with these HPCs. The requirements are however proposed to cover all HPCs within the scope of the Regulation to ensure that no HPCs will fall within a grey area and that all comply with the minimum Ecodesign requirements.

7.3.2 Description of environmental impacts of scenarios

7.3.2.1 Scenario 1

This scenario consists of the following:

[102] The 'Sales in BAU that become stock in the reparability-durability' are normalised per year.

- Domestic and professional HPCs: Energy Labelling and/or Ecodesign criteria based on cleaning performance efficiency - to be further developed and defined in a future revision.
- Domestic and professional HPCs: Motor-Pump efficiency Ecodesign requirements.
- Hot water professional HPCs: Fuel burner efficiency Ecodesign requirements.
- Domestic HPCs: Durability and reparability Ecodesign requirements.

  Reparability requirements are expected to have limited impact on the professional sector, whose products are already very reparable.

The results of scenario 1 will be presented distinguishing between domestic and professional sectors, as follows:

- Scenario DOM 1: Energy Labelling and/or Ecodesign criteria based on cleaning performance efficiency + Motor-Pump efficiency Ecodesign criteria + Durability and reparability requirements.
- Scenario PROF 1: Motor-Pump efficiency Ecodesign criteria + Fuel burner efficiency Ecodesign requirements.

7.3.2.2 Scenario 2

This scenario consists of the following:

- Domestic and professional HPC: Energy Labelling and/or Ecodesign criteria based on cleaning performance efficiency - to be further developed and defined in a future revision.
- Hot water professional HPCs: Fuel burner efficiency Ecodesign requirements.
- Domestic HPCs: Durability and reparability Ecodesign requirements.

The results of scenario 2 will be presented distinguishing between domestic and professional sectors, as follows:

- Scenario DOM 2: Energy Labelling and/or Ecodesign criteria based on cleaning performance efficiency + Durability and reparability requirements.
- Scenario PROF 2: Energy Labelling and/or Ecodesign criteria based on cleaning performance efficiency + Fuel burner efficiency Ecodesign requirements.

7.3.2.3 Scenario 3

This scenario consists of the following:

- Hot water professional HPCs: Fuel burner efficiency Ecodesign requirements.
- Domestic HPCs: Durability and reparability Ecodesign requirements.

The results of scenario 3 will be presented distinguishing between domestic and professional sectors, as follows:

- Scenario DOM 3: Durability and reparability requirements.
- Scenario PROF 3: Fuel burner efficiency Ecodesign requirements.

7.3.2.4 Low usage and high usage scenario

One of the main parameters that affect the results is the usage pattern, i.e. the frequency and time of use of high pressure cleaners. Figure 101 and Figure 102 provide the range of low versus high usage scenarios (see Task 3), of the direct energy and water consumption of HPC at EU level, and for the 2020-2050 period.

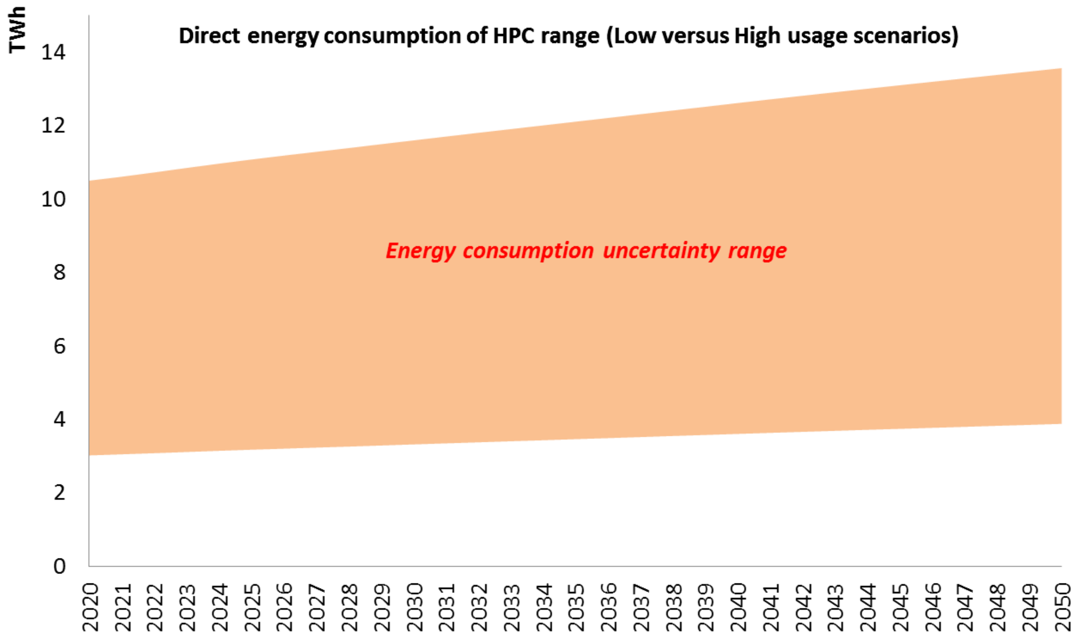


Figure 101. Total energy consumption (use phase) uncertainty range (average low vs average high usage scenario) for the 2020-2050 period at EU level.

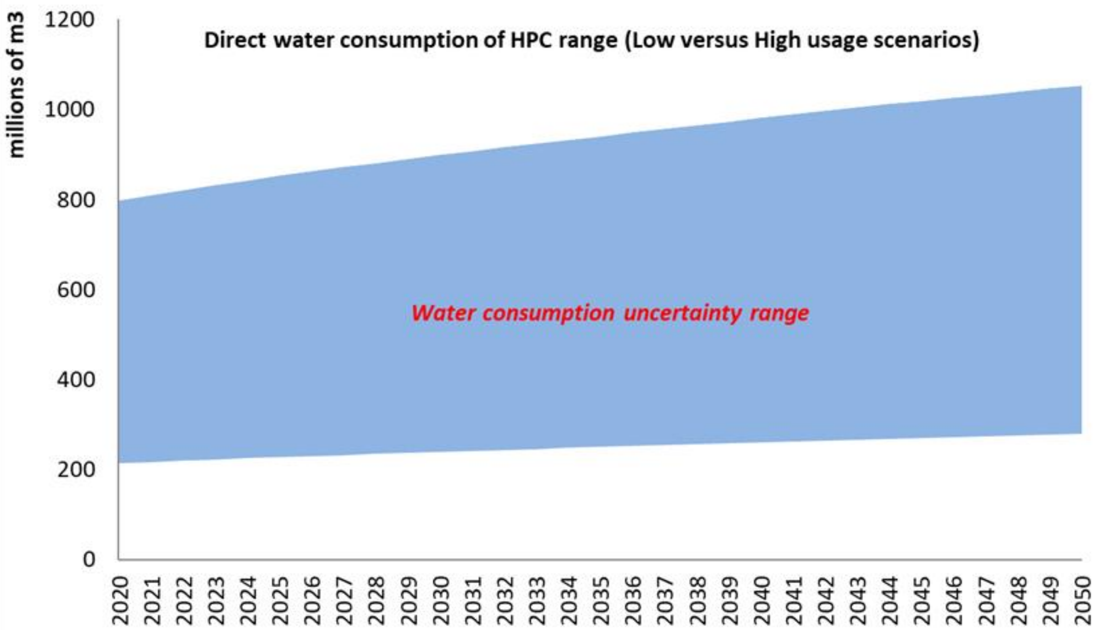


Figure 102. Total direct water consumption (use phase) uncertainty range (average low versus average high usage scenario) for the 2020-2050 period at EU level.

As can be seen from Figure 101, the overall energy consumption of HPCs for the year 2020 ranges from 3 TWh to 10.5 TWh (final energy at use phase); and water consumption from 215 million m^3 to 797 million m^3. The frequency and time of use cannot be precisely estimated in this product group due to the many different applications. This variation affects the results of the scenarios significantly. For this reason, the scenarios are modelled and presented according to both low and high usage patterns.

7.3.3 Analysis and comparison of environmental impacts of low usage scenarios

7.3.3.1 Domestic scenarios

The total life cycle primary energy demand for the scenarios DOM 1, DOM 2 and DOM 3 compared to BAU at low usage patterns is shown in Figure 103.

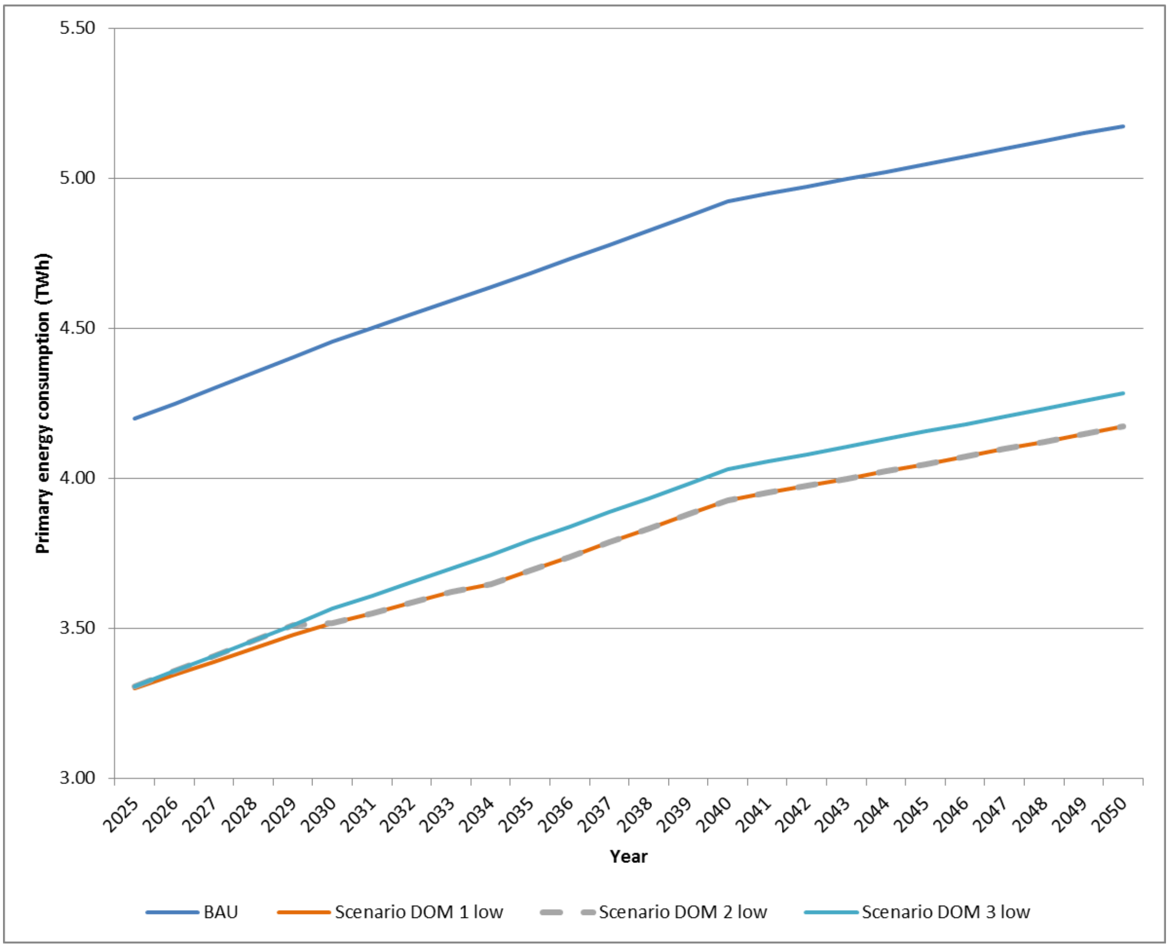


Figure 103. Total primary energy demand for production, use and end-of-life of the domestic HPCs for BAU and the scenarios at low usage patterns

The primary energy savings are gathered in Table 71.

Table 71. Primary energy yearly and cumulative savings for scenarios DOM 1, DOM 2 and DOM 3 from the BAU scenario at a low usage patterns (TWh)

	2030 (TWh/year)	2040 (TWh/year)	2050 (TWh/year)	Cumulative (TWh) (2025-2050)
Scenario DOM 1 low	0.94	0.99	1.00	25.3
Scenario DOM 2 low	0.94	0.99	1.00	25.2
Scenario DOM 3 low	0.9	0.9	0.9	23.2

The difference in cumulative primary energy savings between scenario DOM 3 and the two other scenarios is around 2.1 TWh, meaning that the durability and reparability policy options would entail the largest shares of savings linked to the manufacture of HPCs. Scenario DOM 2 would add 0.1 TWh savings. Scenario DOM 1 would benefit from earlier implementation that would increase the cumulative savings up to 25.3 TWh.

The total life cycle GHG emissions for the scenarios DOM 1, DOM 2 and DOM 3 compared to BAU at low usage patterns are shown in Figure 104.

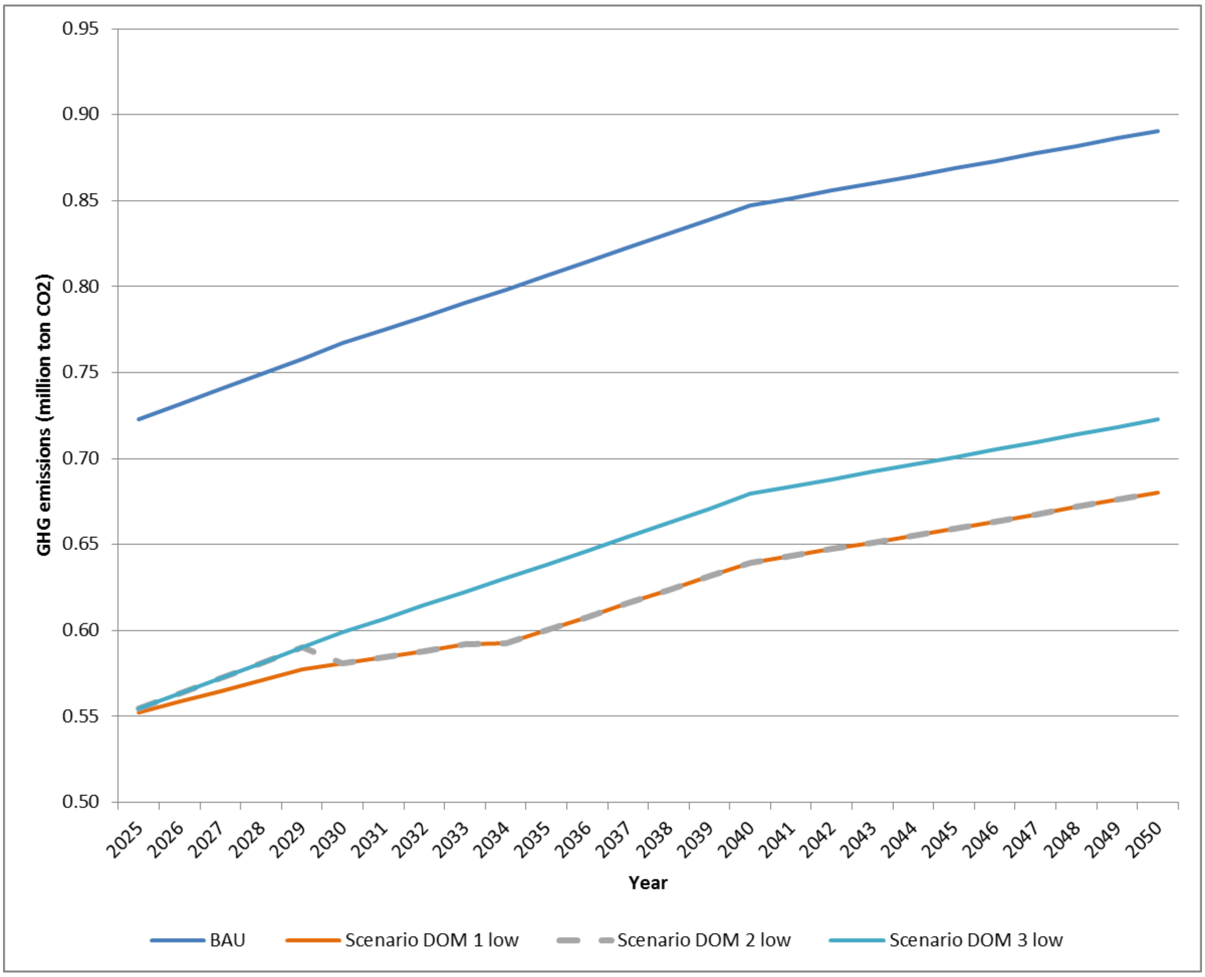


Figure 104 GHG emissions for production, use and end-of-life of the domestic HPCs for BAU and the scenarios at low usage patterns

The GHG savings are gathered in Table 72. Similar to the primary energy savings, the durability and reparability policy options would entail the largest shares of savings linked to the manufacture of HPCs. Scenario DOM 2 would add 0.7 Mtonnes CO_2 eq. savings to scenario DOM 3. Scenario DOM 1 would to some extent benefit from earlier implementation that would increase the cumulative savings up to 5.2 Mtonnes CO_2 eq.

Table 72. CO_2 eq. yearly and cumulative savings for scenarios DOM 1, DOM 2 and DOM 3 from the BAU scenario at a low usage patterns (Mtonnes)

	2030 (Mt CO_{2eq}/year)	2040 (Mt CO_{2eq}/year)	2050 (Mt CO_{2eq}/year)	Cumulative (Mt $CO_{2eq.}$) (2025-2050)
Scenario DOM 1 low	0.19	0.20	0.21	5.2
Scenario DOM 2 low	0.19	0.20	0.21	5.1

Scenario DOM 3 low	0.17	0.17	0.17	4.4

The water consumption in the use phase for the scenarios DOM 1 and DOM 2 compared to BAU at low usage patterns is shown in Figure 105.

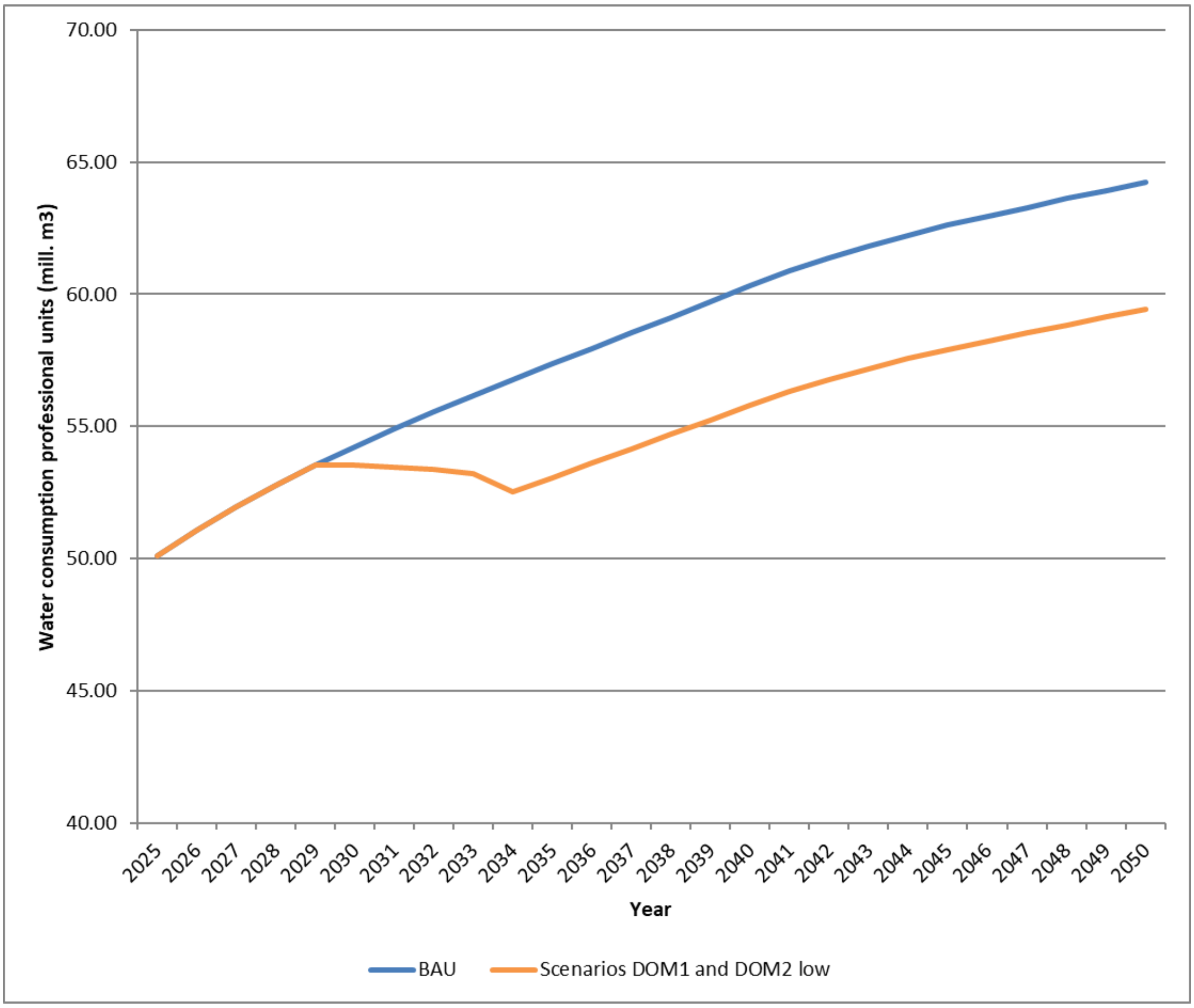


Figure 105. Water consumption in the use phase of the professional HPCs for BAU vs the scenarios at low usage patterns

The water savings are gathered in Table 73.

Table 73. Water savings scenarios DOM 1 and DOM 2 from the BAU scenario at a low usage patterns (million m^3)

	2030 (million m^3/year)	2040 (million m^3/year)	2050 (million m^3/year)	Cumulative (million m^3)
Scenario DOM 1 and 2 low	0.7	4.5	4.8	85.1

Scenarios DOM 1 and DOM 2 would result in savings at the use phase of 85.1 million m^3 (cumulative savings) due to the improvements in nozzle design.

7.3.3.2 Professional HPC scenarios

The total life cycle primary energy demand for the scenarios PROF 1, PROF 2 and PROF 3 compared to BAU at low usage patterns is shown in Figure 106. The effect of the motor-pump and burner efficiency is plotted in order to quantify its magnitude.

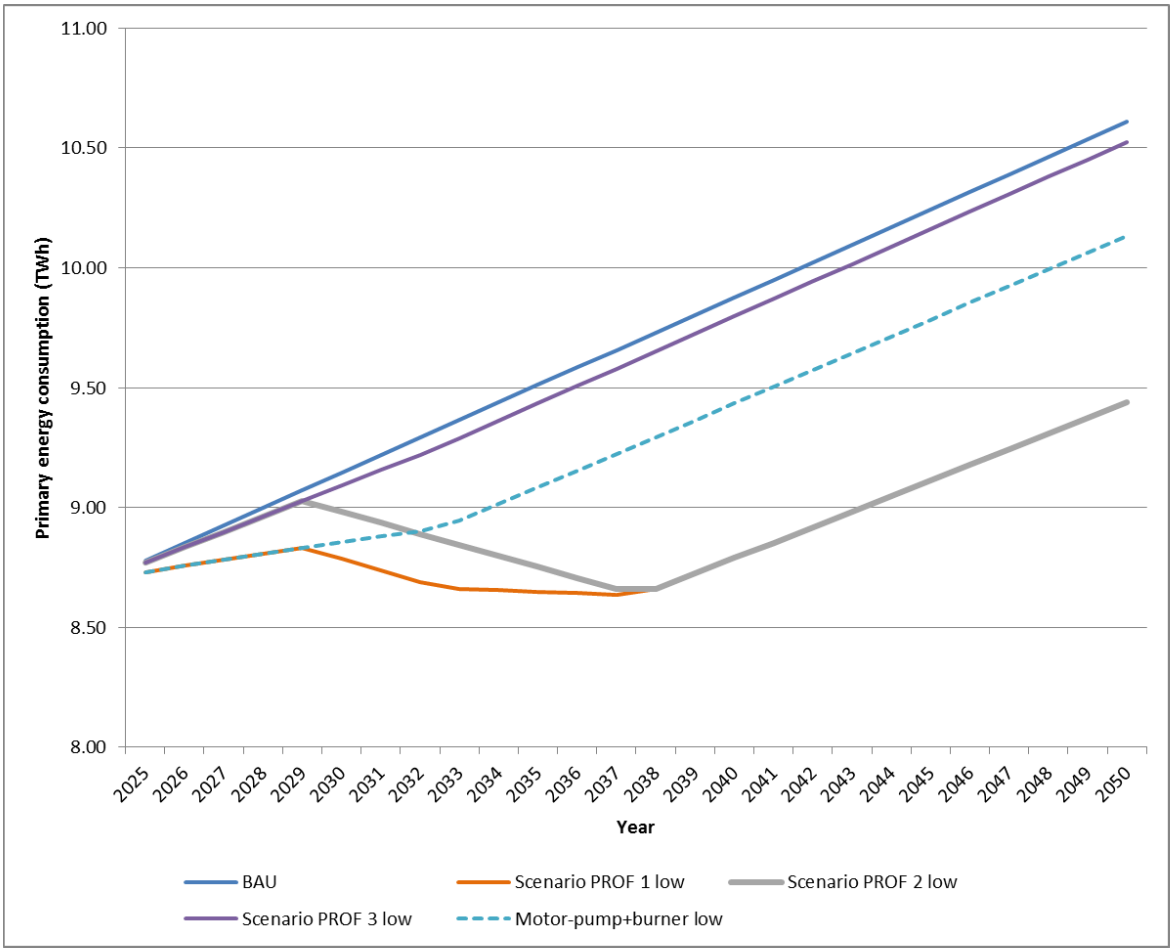


Figure 106. Total primary energy demand for production, use and end-of-life of the professional HPCs for BAU versus the scenarios at low usage patterns

The primary energy savings are gathered in Table 74.

Table 74. Primary energy yearly and cummulative savings for scenarios PROF 1, PROF 2 and PROF 3 from the BAU scenario at a low usage patterns (TWh)

	2030 (TWh/year)	2040 (TWh/year)	2050 (TWh/year)	Cumulative (TWh)
Scenario PROF 1 low	0.26	0.75	0.8	14.6
Scenario PROF 2 low	0.12	0.75	0.8	13.5
Scenario PROF 3 low	0.05	0.08	0.09	1.8

As can be observed, Scenario PROF 1 would entail the largest savings potential due to its earlier implementation that would increase the savings by 1.1 TWh. compared to PROF 2. Scenario PROF 3 would result in the lowest savings potential, reaching cumulative savings of 1.8 TWh.

The total life cycle CO_2 eq. for the scenarios PROF 1, PROF 2 and PROF 3 compared to BAU is shown in Figure 107.

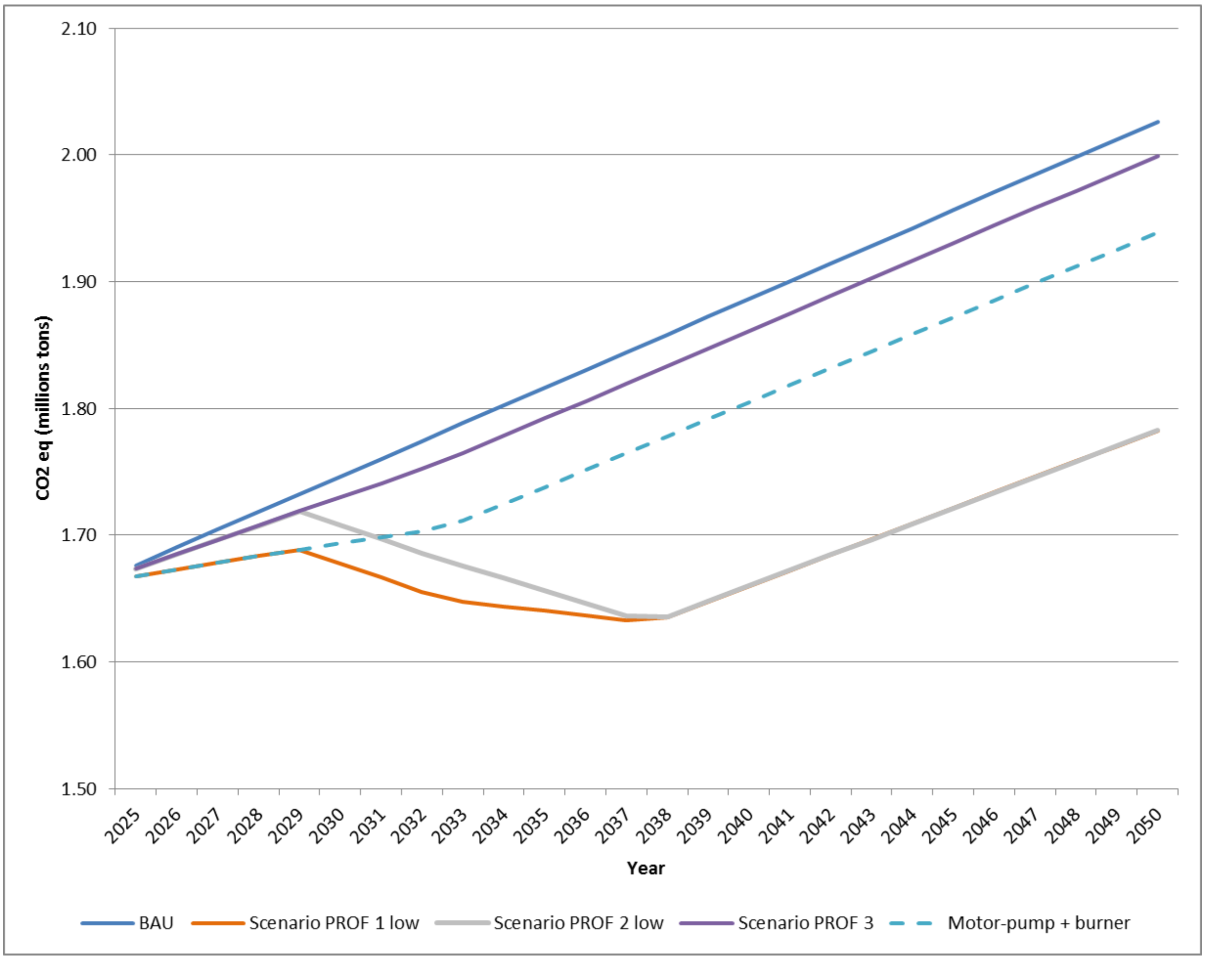


Figure 107. Total GHG emissions expressed in CO_2 eq. for the production, use and end-of-life of the professional HPCs for BAU vs the scenarios at low usage patterns

The CO_2 eq. savings are gathered in Table 75.

Table 75. CO_2 eq. yearly and cumulative savings for scenarios PROF 1, PROF 2 and PROF 3 compared to BAU scenario at average low usage patterns (Mtonnes CO_2 eq.)

	2030 (Mt CO_{2eq}/year)	2040 (Mt CO_{2eq}/year)	2050 (Mt CO_{2eq}/year)	Cumulative (Mt CO_{2eq})
Scenario PROF 1 low	0.05	0.16	0.17	3.07
Scenario PROF 2 low	0.03	0.16	0.17	2.89
Scenario PROF 3 low	0.02	0.025	0.03	0.57

Similar to primary energy savings, Scenario PROF 1 would result in the largest savings potential, due to its earlier implementation compared to PROF 2. Scenario PROF 3 would bring the lowest savings in GHG emissions, resulting in 0.57 Mtonnes CO_2 eq. in cumulative savings.

The water consumption in the use phase for the scenarios PROF 1 and PROF 2 compared to BAU at low usage patterns is shown in Figure 108.

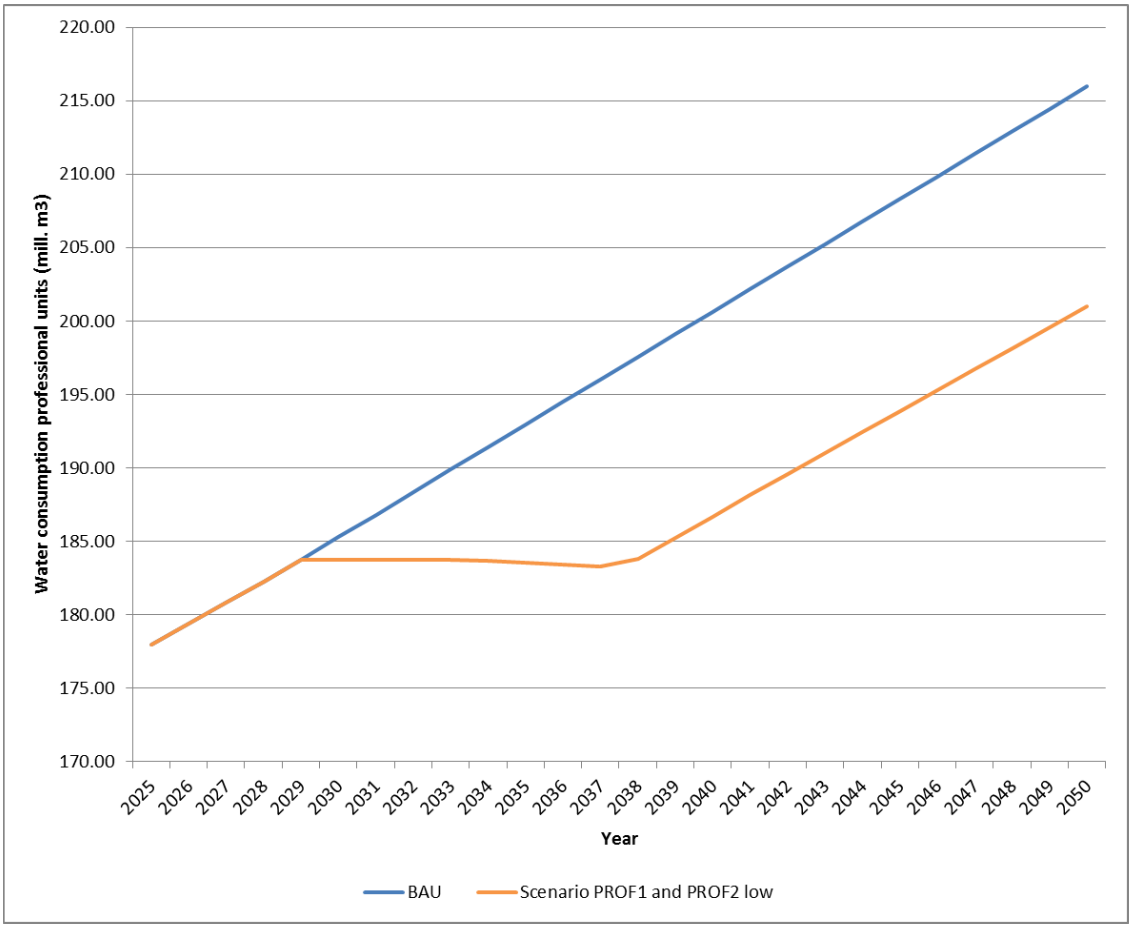


Figure 108. Water consumption in the use phase of the professional HPCs for BAU vs the scenarios at low usage patterns

The water savings are gathered in Table 76.

Table 76. Water savings scenarios PROF 1 and PROF 2 vs BAU scenario at a low usage patterns (million m^3)

	2030 (million m^3/year)	2040 (million m^3/year)	2050 (million m^3/year)	Cumulative (million m^3)
Scenario PROF 1 and 2 low	1.5	13.9	15.0	243

Scenarios PROF 1 and PROF 2 would result in savings at the use phase of 243 million m^3 (cumulative savings) due to the improvements in nozzle design.

7.3.4 Analysis and comparison of environmental impacts of high usage scenarios

7.3.4.1 Domestic HPC scenarios

The total life cycle primary energy demand for the scenarios DOM 1, DOM 2 and DOM3 compared to BAU in high usage scenarios is shown in Figure 109.

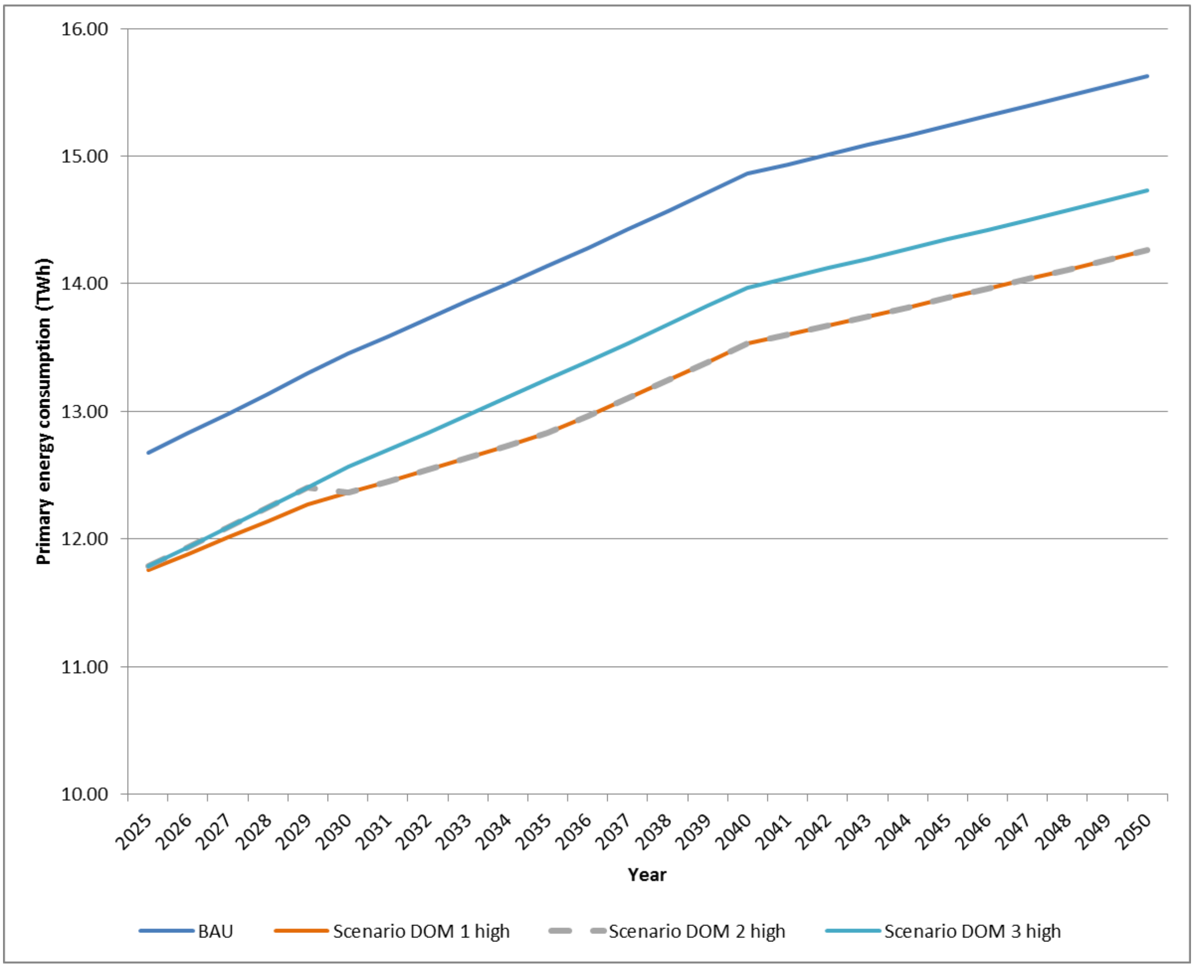


Figure 109. Total primary energy demand for production, use and end-of-life of the domestic HPCs for BAU and the policy scenarios

The primary energy savings are gathered in Table 77.

Table 77. Primary energy yearly and cumulative savings for scenarios DOM 1, DOM 2 and DOM 3 compared to BAU scenario at a high usage patterns (TWh)

	2030 (TWh/year)	2040 (TWh/year)	2050 (TWh/year)	Cumulative (TWh/year) (2025 - 2050)
Scenario DOM 1 high	1.1	1.3	1.4	32.2
Scenario DOM 2 high	1.1	1.3	1.4	31.8
Scenario DOM 3 high	0.9	0.9	0.9	23.2

The difference in cumulative primary energy savings between scenario DOM 3 and the other scenarios (DOM 1 and 2) is around 9 TWh, meaning that the durability and reparability policy options would lead to the largest shares of savings linked to the manufacture of HPCs, though its share is lower in the high usage than the low usage scenario. Scenario DOM 2 would add 0.4 TWh savings. Scenario DOM 1 would benefit from earlier implementation that would increase the cumulative savings up to 32.2 TWh.

The total life cycle GHG emissions for the scenarios DOM 1, DOM 2 and DOM 3 compared to BAU at high usage patterns are shown in Figure 110.

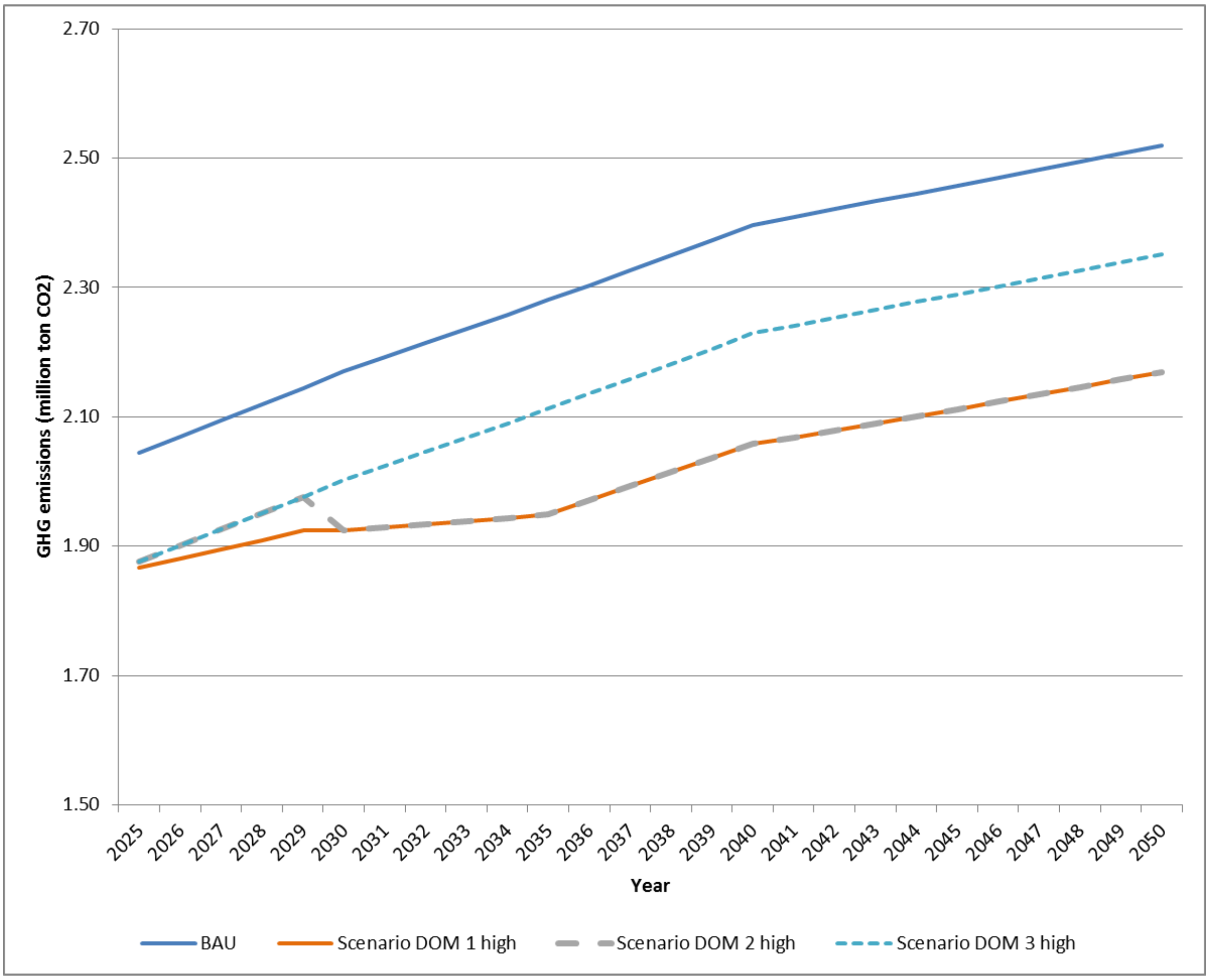


Figure 110 GHG emissions for production, use and end-of-life of the domestic HPCs for BAU and scenarios at high usage patterns

The GHG savings are gathered in Table 78.

Table 78. CO_2 eq. yearly and cumulative savings for scenarios DOM 1, DOM 2 and DOM 3 vs the BAU scenario at a high usage patterns (Mtonnes)

	2030 (Mt CO_2 eq. /year)	2040 (Mt CO_2 eq. /year)	2050 (Mt CO_2 eq. /year)	Cumulative (Mt CO_2 eq.) (2025-2050)
Scenario DOM 1 high	0.26	0.34	0.35	7.9
Scenario DOM 2 high	0.26	0.34	0.35	7.7
Scenario DOM 3 high	0.17	0.17	0.17	4.4

Similar to the primary energy savings, durability and reparability policy options would entail the largest shares of savings linked to the manufacture of HPCs. Scenario DOM 2 would add 3.3 Mtonnes CO_2 eq. savings to DOM 3. Scenario DOM 1 would benefit from earlier implementation which would increase the cumulative savings up to 7.9 Mtonnes CO_2 eq.

The water consumption in the use phase for the scenarios DOM 1 and DOM 2 compared to BAU at high usage patterns is shown in Figure 108.

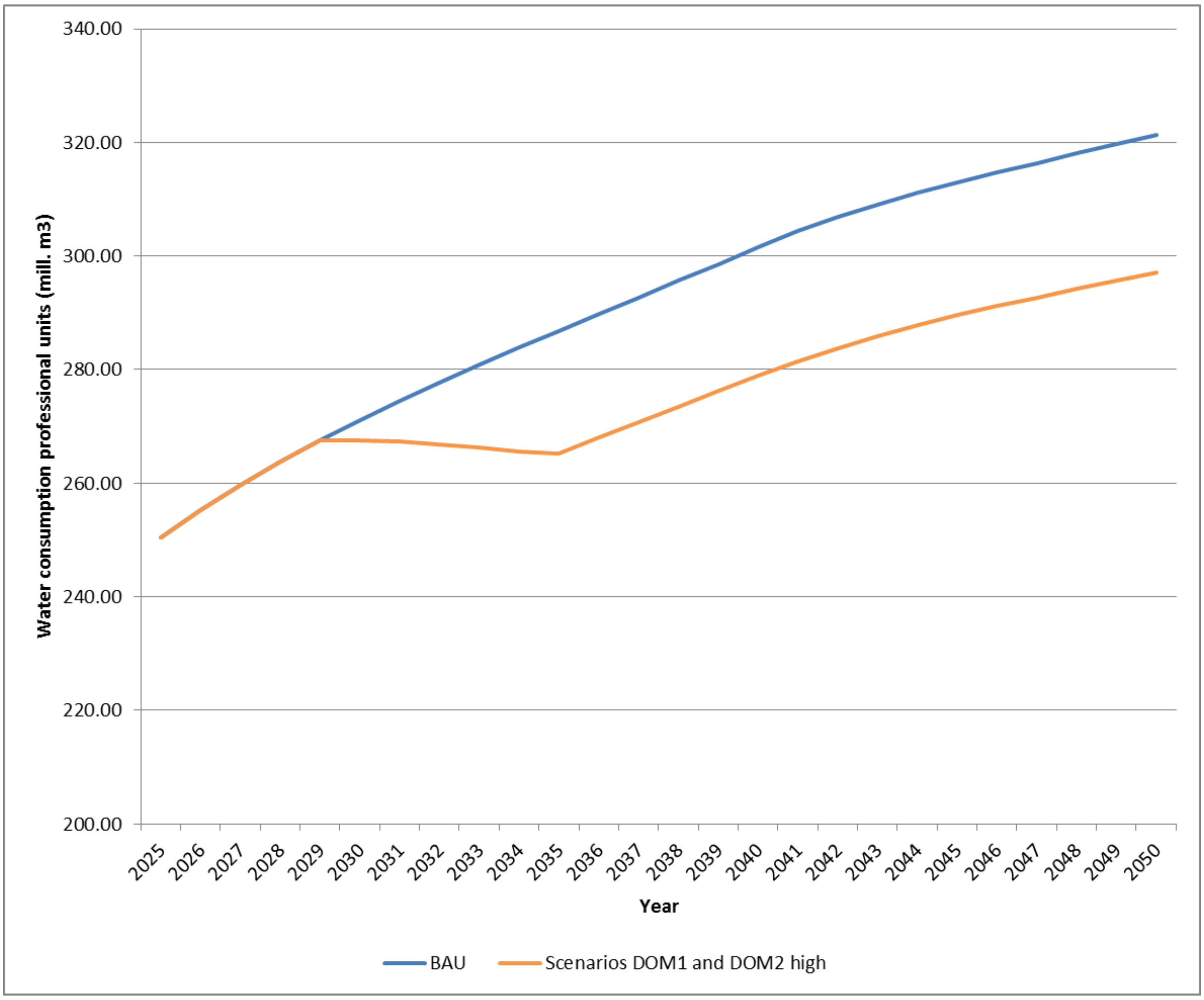


Figure 111. Water consumption in the use phase of the professional HPCs for BAU vs the scenarios at high usage patterns

The water savings are gathered in Table 79.

Table 79. Water yearly and cumulative savings for scenarios PROF 1 and PROF 2 from the BAU scenario at a high usage patterns (million m^3)

	2030 (million m^3/year)	2040 (million m^3/year)	2050 (million m^3/year)	Cumulative (million m^3)
Scenario DOM 1 and 2 high	3.6	22.6	24.1	422.0

Scenarios DOM 1 and DOM 2 would result in savings at the use phase of 0.422 million m^3 (cumulative savings) due to the improvements in nozzle design.

7.3.4.2 Professional HPC scenarios

The total life cycle primary energy demand for the scenarios PROF 1, PROF 2 and PROF 3 compared to BAU at high usage patterns is shown in Figure 112. The effect of the motor-pump and burner efficiency is plotted in order to quantify its magnitude.

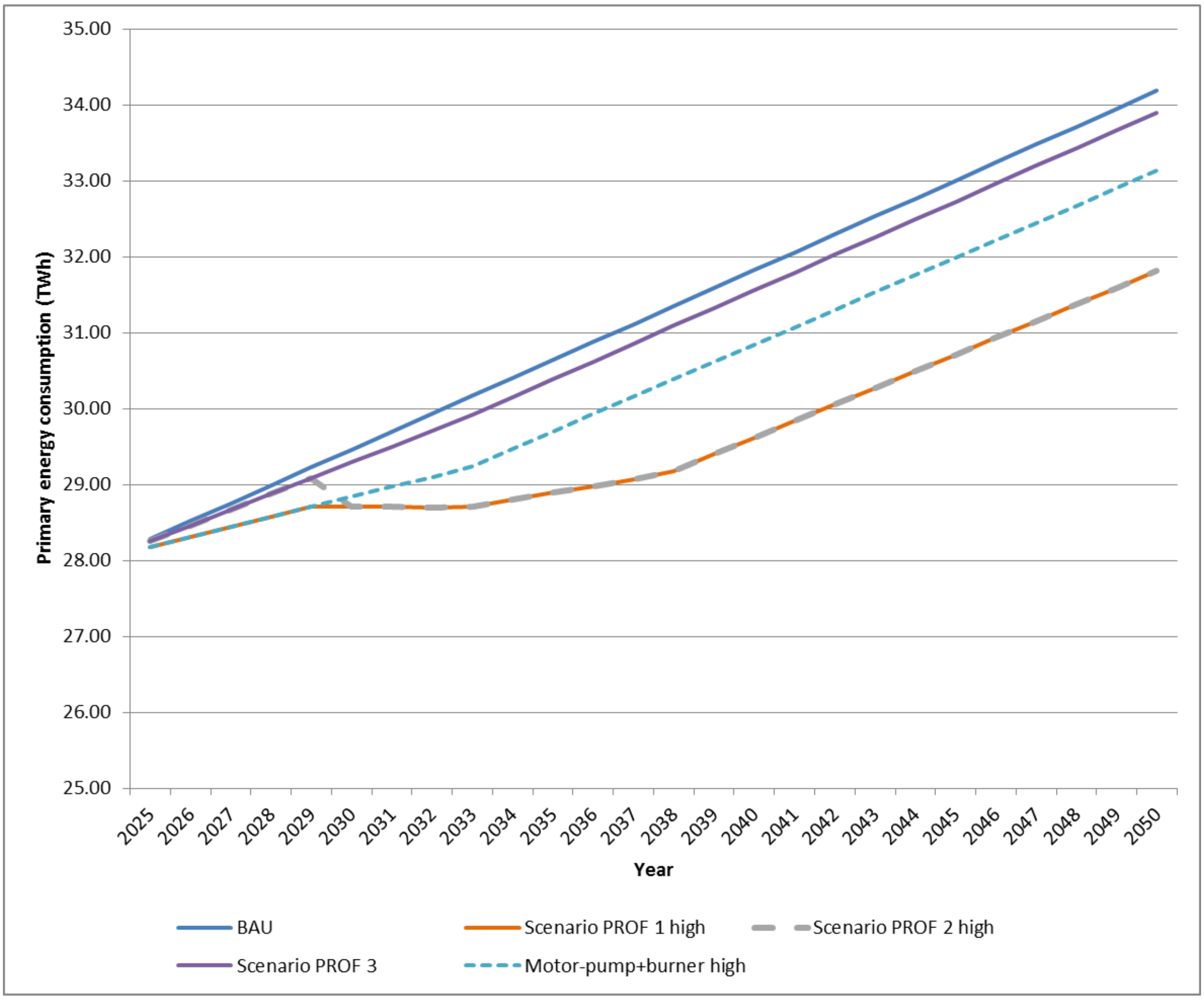


Figure 112. Total primary energy demand for production, use and end-of-life of the professional HPCs for BAU vs the scenarios at high usage patterns

The primary energy savings are gathered in Table 80.

Table 80. Primary yearly and cumulative energy savings scenarios PROF 1 and PROF 2 from BAU scenario at a high usage patterns (TWh)

	2030 (TWh/year)	2040 (TWh/year)	2050 (TWh/year)	Cumulative (TWh)
Scenario PROF 1 high	0.75	2.20	2.38	42.8
Scenario PROF 2 high	0.75	2.20	2.38	41.7
Scenario PROF 3 high	0.17	0.26	0.29	5.8

As can be observed, Scenario PROF 1 would entail the largest savings potentials, due to its earlier implementation that would increase the cumulative savings for 2025-2050 by 1.1 TWh compared to PROF 2. Scenario PROF 3 would result in the lowest savings potential, reaching cumulative savings of 5.8 TWh.

The total life cycle CO_2 eq. for the scenarios PROF 1, PROF 2 and PROF 3 compared to BAU at high usage patterns is shown in Figure 113.

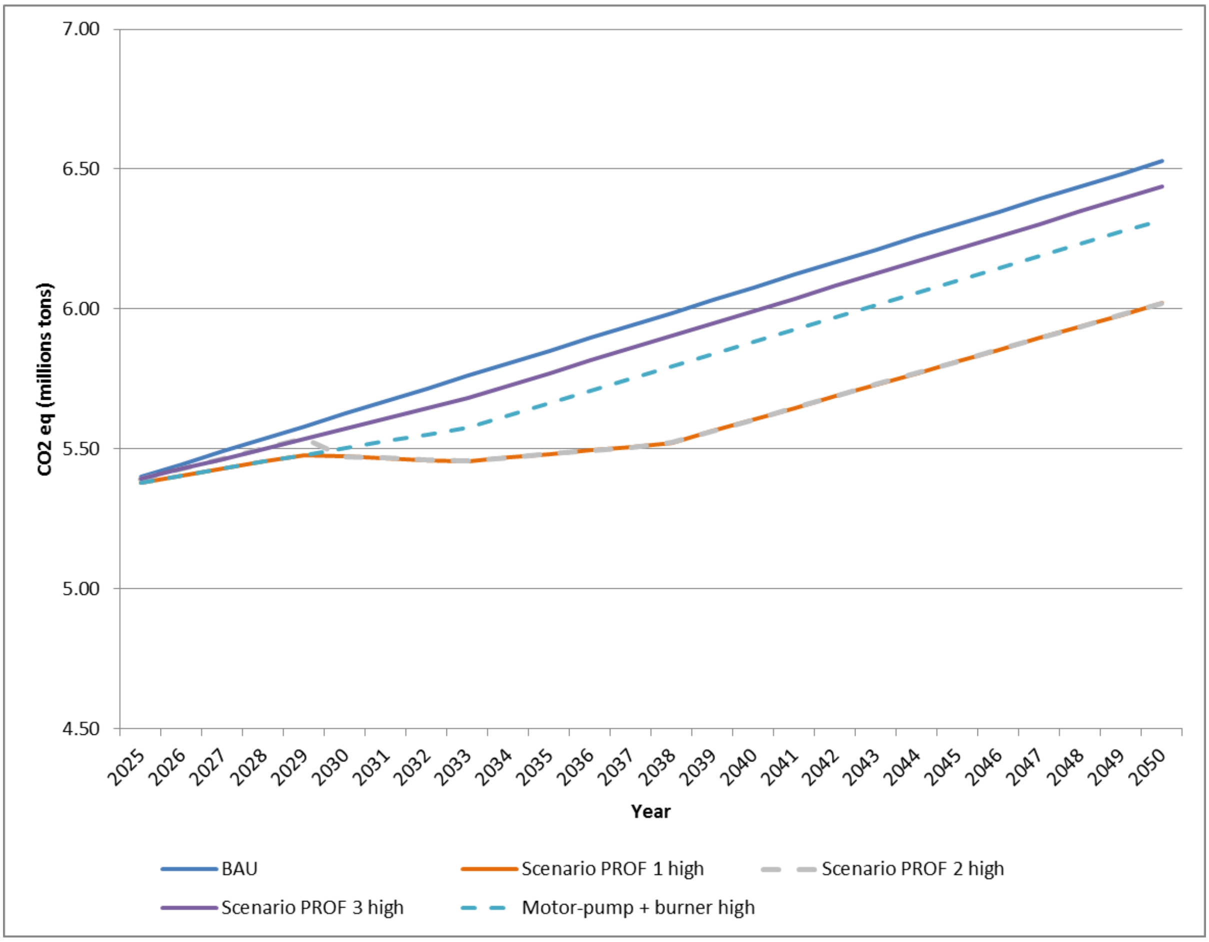


Figure 113. Total GHG emissions expressed in CO_2 eq. for the production, use and end-of-life of the professional HPCs for BAU vs the different policy scenarios

The CO_2 eq. savings are gathered in Table 81.

Table 81. CO_2 eq. yearly and cumulative savings for scenarios PROF 1, PROF 2 and PROF 3 from the BAU scenario at a high usage patterns (Mtonnes CO_2 eq.)

	2030 (Mtonnes CO_2 eq. / year)	2040 (Mtonnes CO_2 eq. / year)	2050 (Mtonnes CO_2 eq. / year)	Cumulative (Mtonnes CO_2 eq.)
Scenario PROF 1 high	0.15	0.47	0.50	9.1
Scenario PROF 2 high	0.15	0.47	0.50	8.9
Scenario PROF 3 high	0.05	0.08	0.09	1.9

Similar to primary energy savings, scenario PROF 1 high would result in the largest savings potential, due to a slight additional benefit of earlier implementation compared to PROF 2. Scenario PROF 3 would bring the lowest savings in GHG emissions, resulting in 1.9 Mtonnes CO_2 eq. in cumulative savings.

The water consumption in the use phase for the scenarios PROF 1 and PROF 2 compared to BAU at high usage patterns is shown in Figure 114.

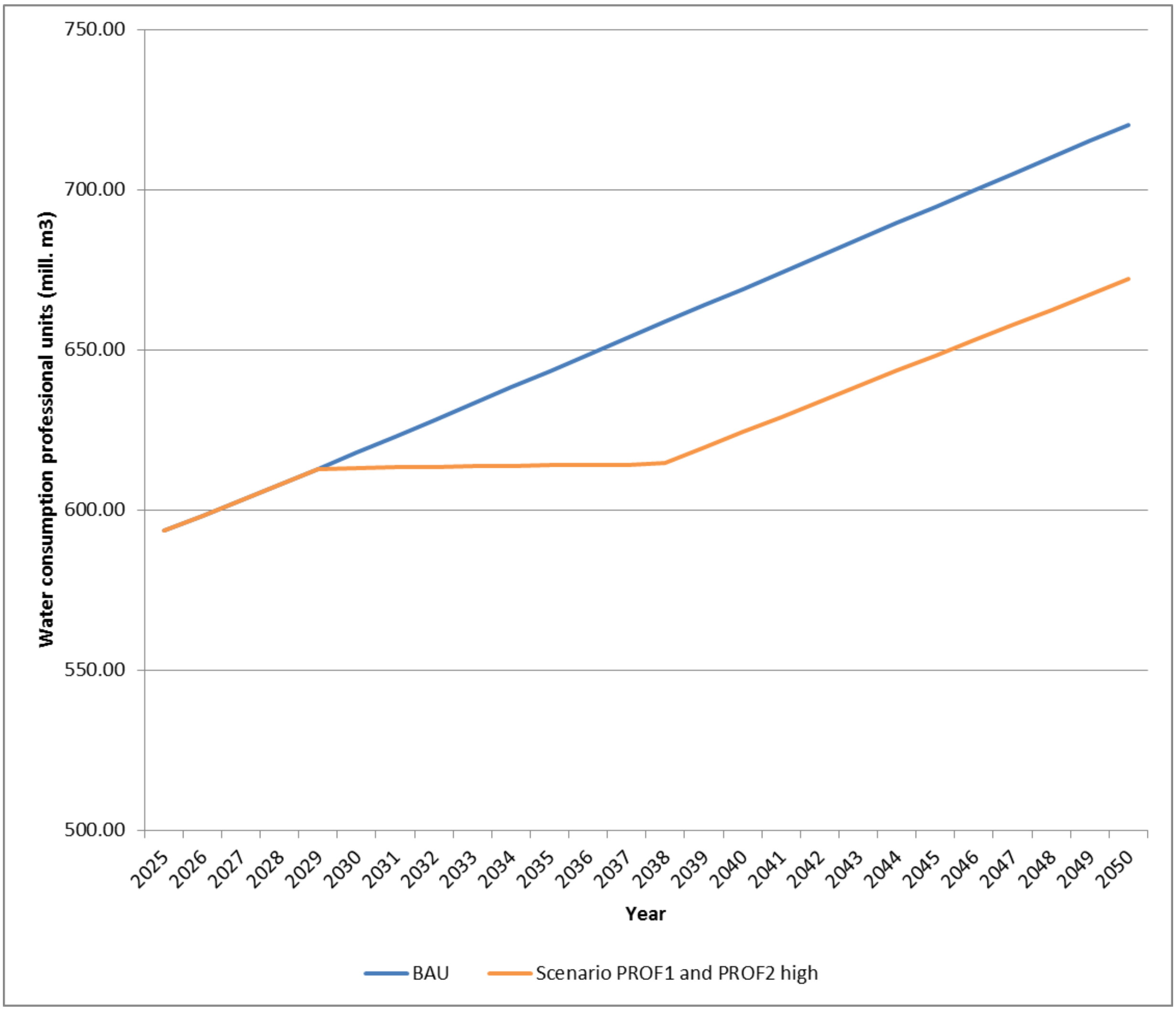


Figure 114. Water consumption in the use phase of the professional HPCs for BAU vs the scenarios at high usage patterns

The water savings are gathered in Table 82.

Table 82. Water yearly and cumulative savings for scenarios PROF 1 and PROF 2 vs the BAU scenario at a high usage patterns (million m^3)

	2030 (million m^3/year)	2040 (million m^3/year)	2050 (million m^3/year)	Cumulative (million m^3)
Scenario PROF 1 and 2 low	4.8	44.7	48.1	775

Scenarios PROF 1 and PROF 2 would result in savings at the use phase of 775 million m^3 (cumulative savings) due to the improvements in nozzle design.

7.4 Impacts on industry and end users

7.4.1 Low usage scenario

The different policy options described in this report have an impact on industry and the end user. In the case of end users, this impact can be quantified in terms of LCC. The evolution of the LCC at EU level for domestic units is shown in Figure 115.

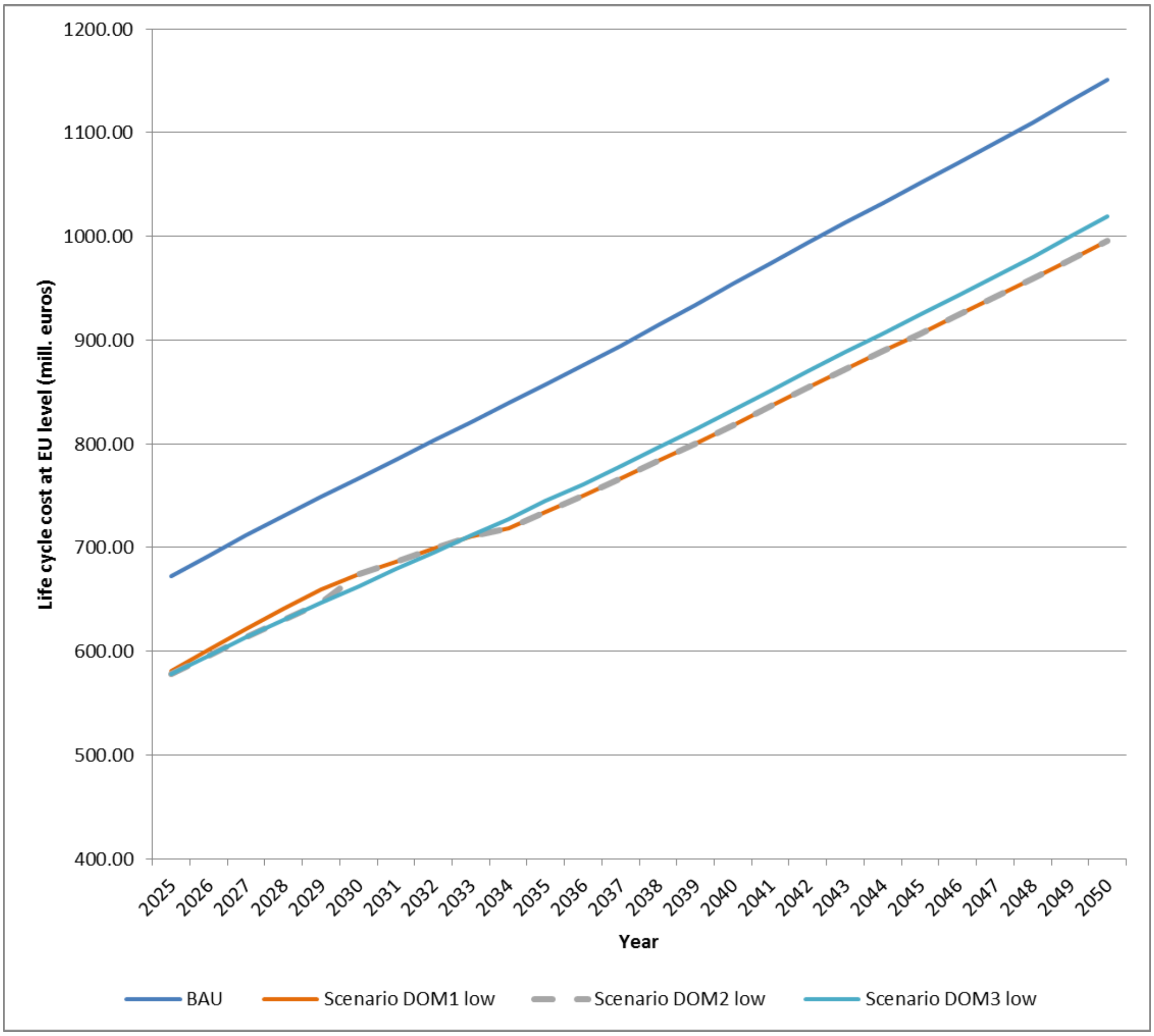


Figure 115. Evolution of BC1 LCC at EU level of the domestic HPCs for BAU and the policy scenarios at low usage patterns

As can be observed, motor-pump efficiency requirements that are part of scenario DOM 1 could slightly increase the LCC in the first years of implementation, meaning that the additional energy savings would not compensate the additional cost of improving the motor-pump.

Durability and reparability requirements (scenario DOM 3) would entail the largest share of LCC savings. This policy option would probably impact the sales of domestic units by decreasing them, due to a lower replacement rate. This is displayed in Figure 100.

Due to this potential reduction of sales, employment may be also affected by the durability and reparability policy options would likely reduce in production and increase in the repair sector. The share of employment in the manufacture, retail and repair subsectors would vary, though no sufficient data have been found to develop scenarios.

In the professional sector, motor-pump efficiency requirements would have a significant impact for industry. According to stakeholders, the additional manufacturing cost of improving the efficiency of induction motors can be estimated as 20% to 30% of the unit cost. The LCC at unit level for the different professional cases is plotted in Figure 116.

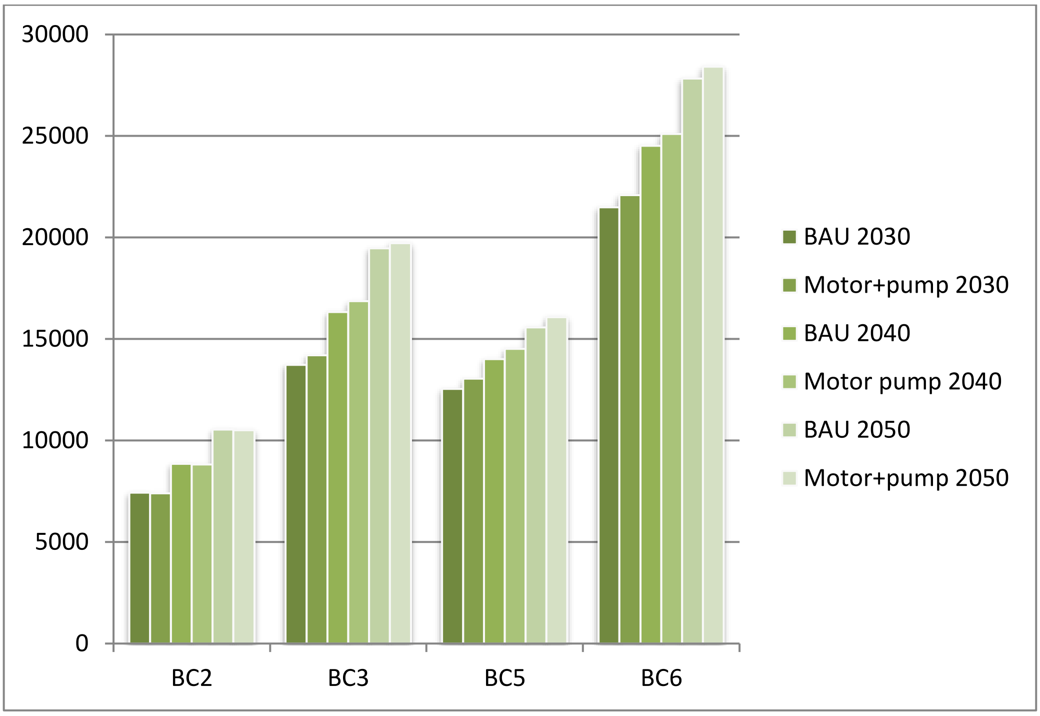


Figure 116. Evolution of LCC at unit level of professional cases for BAU and the motor-pump efficiency policy option at average low usage patterns

The figure shows that only BC2 would result in a slight decrease of LCC (0.26%), while the rest would increase their LCC, ranging from 1.25% for BC3 to 3.2% for BC5.

The impact of LCC at EU level is presented in Figure 117.

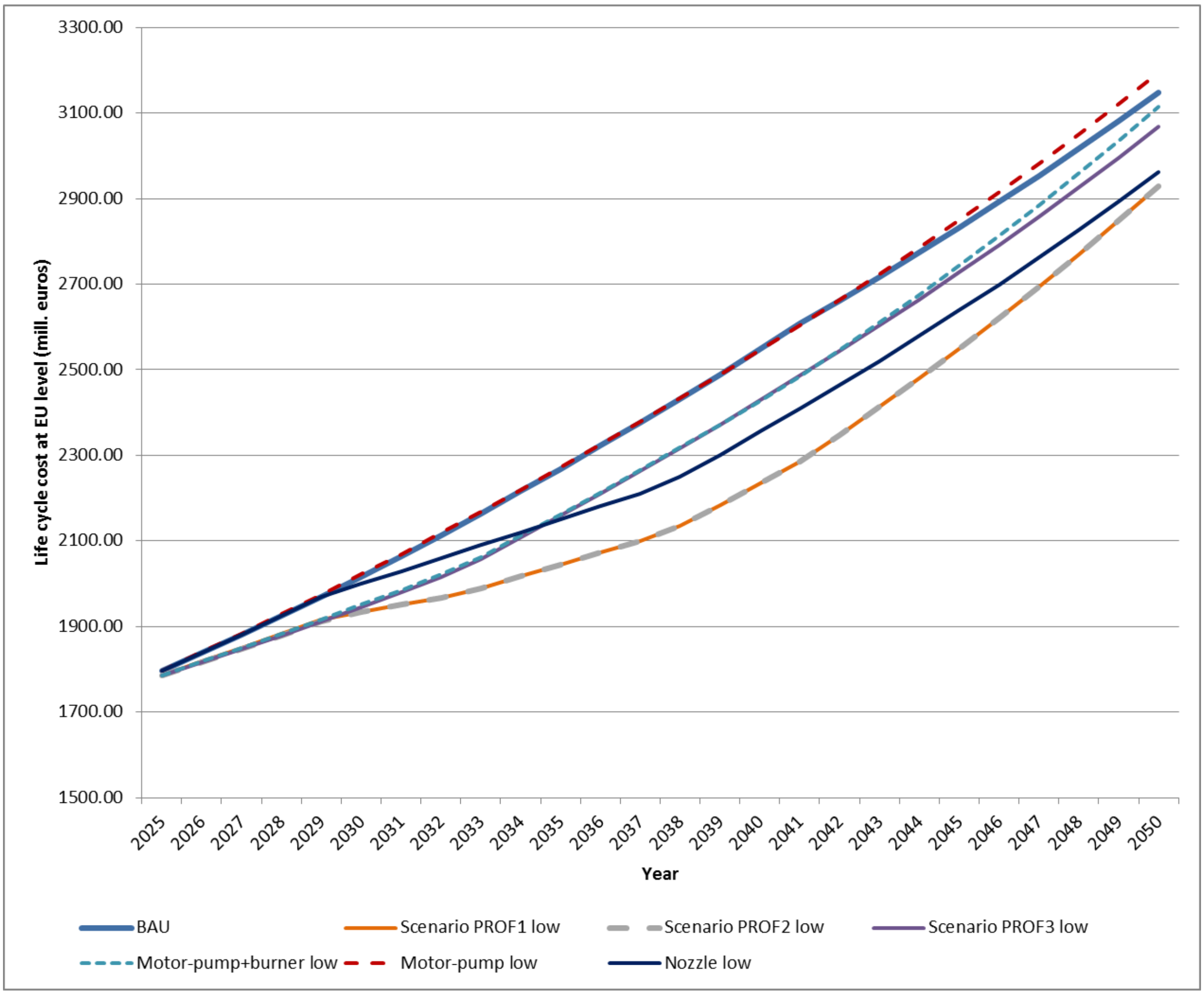


Figure 117. Evolution of LCC at EU level of the professional HPCs for BAU and the policy scenarios at low usage patterns

This figure shows the effect of the additional cost of the motor-pump in the aggregated life cycle costs of the professional sector compared to the most optimised cost-benefit ratio of improving the cleaning performance by means of nozzle design.

7.4.2 High usage scenario

Similar to the low usage scenario, the LCC at unit level for the different professional cases is plotted in Figure 118.

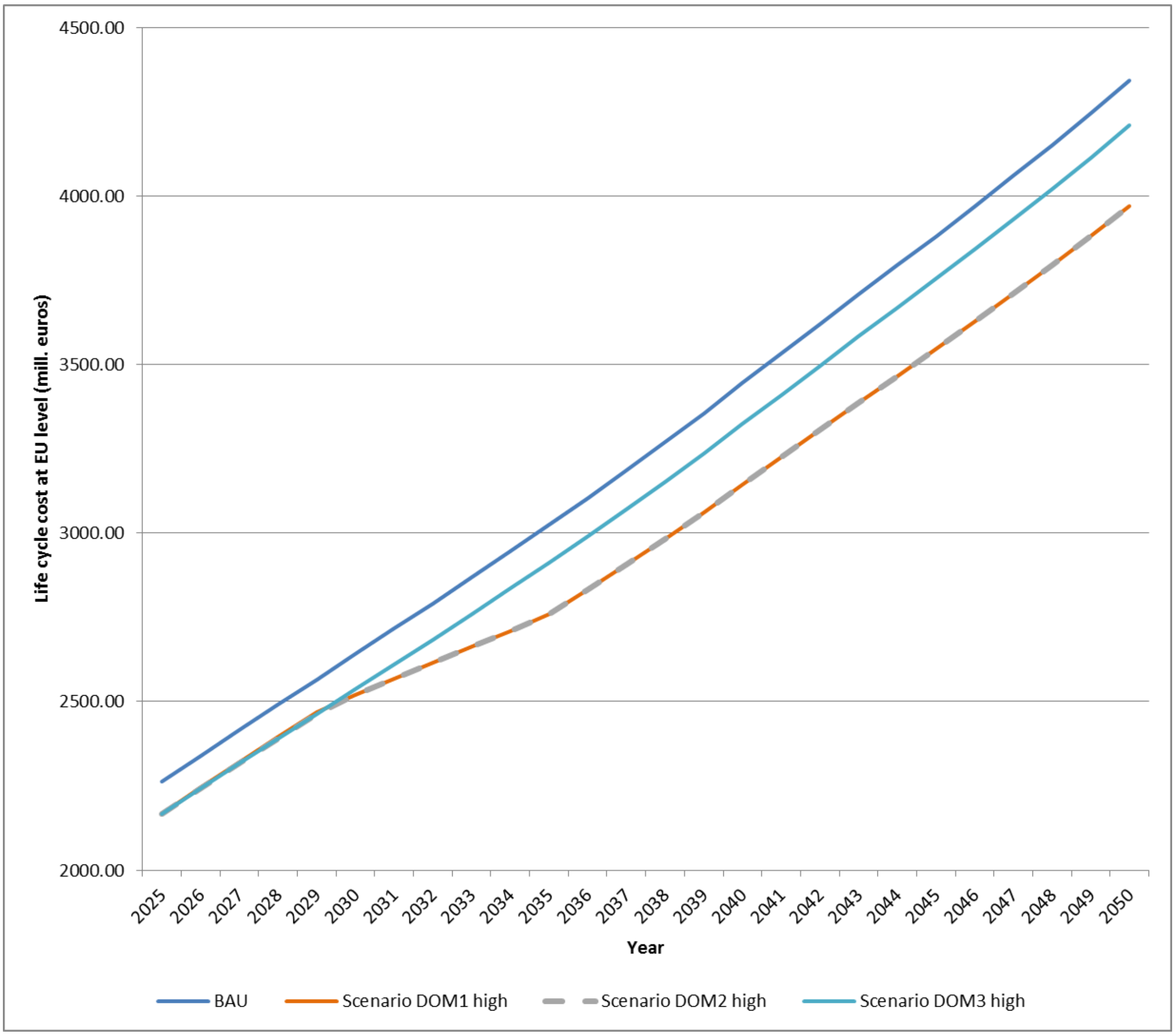


Figure 118. Evolution of BC1 LCC at EU level of the domestic HPCs for BAU and the policy scenarios at high usage patterns

As can be observed, the motor-pump efficiency requirements that are part of scenario DOM 1 does not significantly affect the LCC compared to DOM 2 and DOM 3 scenarios, meaning that the additional energy savings would not compensate the additional cost of improving the motor-pump.

Durability and reparability requirements (scenario DOM 3) would entail around half of the LCC savings, a lower share than in the low usage scenario due to a more intensive use of the machine.

Similar to the low usage scenario, the LCC at unit level for the different professional cases is plotted in Figure 119.

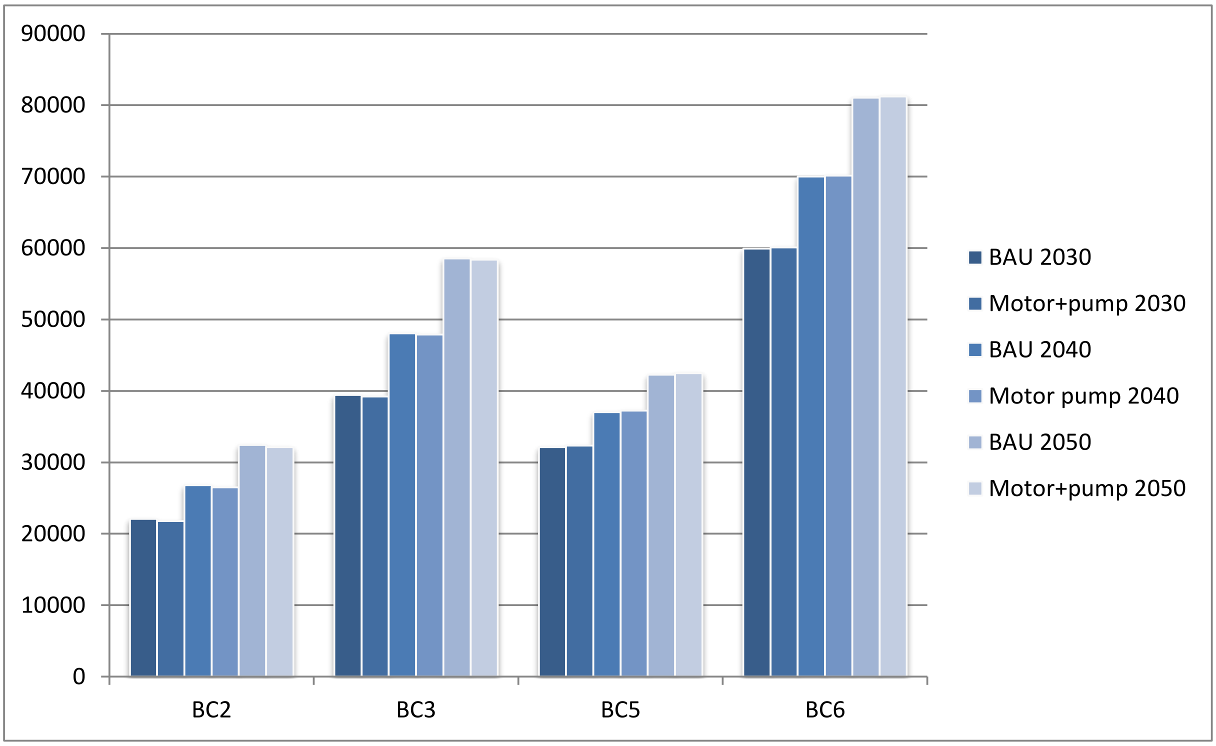


Figure 119. Evolution of LCC at unit level of professional cases for BAU and the motor-pump efficiency policy option at high usage patterns

The figure shows that BC2 and BC3 would result in decreases of 0.9% and 0.3% respectively, while BC5 and BC6 would slightly increase their LCC by 0.5% and 0.2% respectively.

The impact of LCC at EU level is presented in Figure 120.

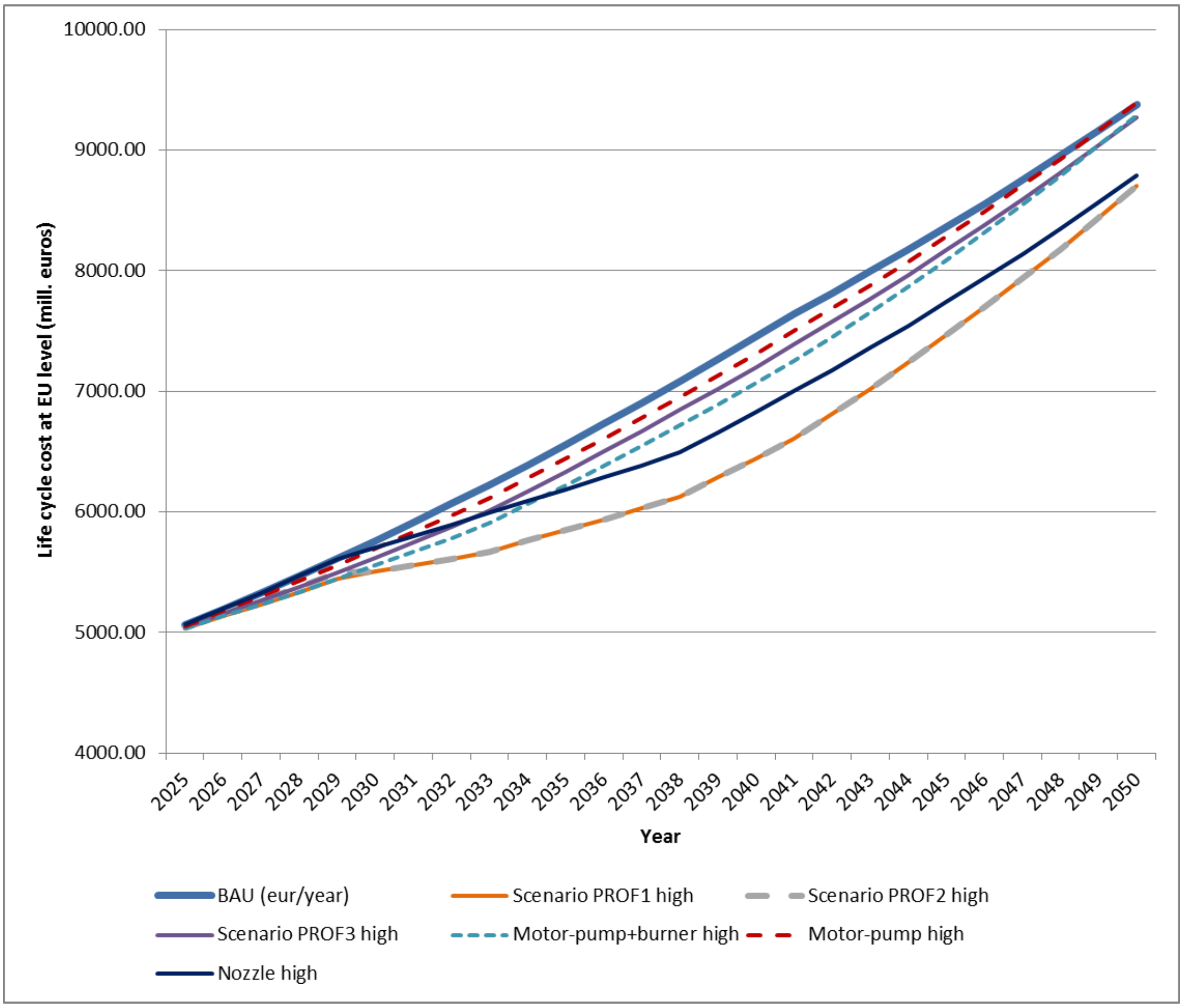


Figure 120. Evolution of LCC at EU level of the professional HPCs for BAU and the policy scenarios at high usage patterns

This figure shows the effect of the additional cost of the motor-pump in the aggregated life cycle costs of the professional sector compared to the most optimised cost-benefit ratio of improving the cleaning performance by means of nozzle design. In contrast to the low usage scenario, motor-pump improvement would slightly decrease the LCC at EU level, due to a more intensive use of the machine which would offset the additional cost of the motor-pump.

7.5 Sensitivity analysis

Average low and average high usage scenarios

As explained in previous sections, the variety of applications leads to a range of usage patterns that are differentiated in this report as average low and average high usage scenarios. This variation of frequency and time of use is the main source of uncertainty of the modelling results. Table 83 gathers the results of primary energy savings at low and high usage scenarios for comparison.

Table 83. Primary energy yearly and cumulative savings of professional scenarios at average low and average high usage patterns

	2030 (TWh/year)	2040 (TWh/year)	2050 (TWh/year)	Cumulative (TWh)
Scenario PROF 1 low	0.26	0.75	0.8	14.6
Scenario PROF 1 high	0.75	2.2	2.38	42.8
Scenario PROF 2 low	0.12	0.75	0.8	13.5
Scenario PROF 2 high	0.75	2.2	2.38	41.7
Scenario PROF 3 low	0.05	0.08	0.09	1.8
Scenario PROF 3 high	0.17	0.26	0.29	5.8

The savings are proportional to the total energy consumption and thus the savings in the high usage scenario are around three times the savings of low usage scenario. Figure 121 shows the annual savings of the scenario PROF 1 plotted as an area chart. The most probable real savings figure will be located in the blue area, while it is unlikely that the real savings are below the minimum set by the low usage scenario, i.e. the green area.

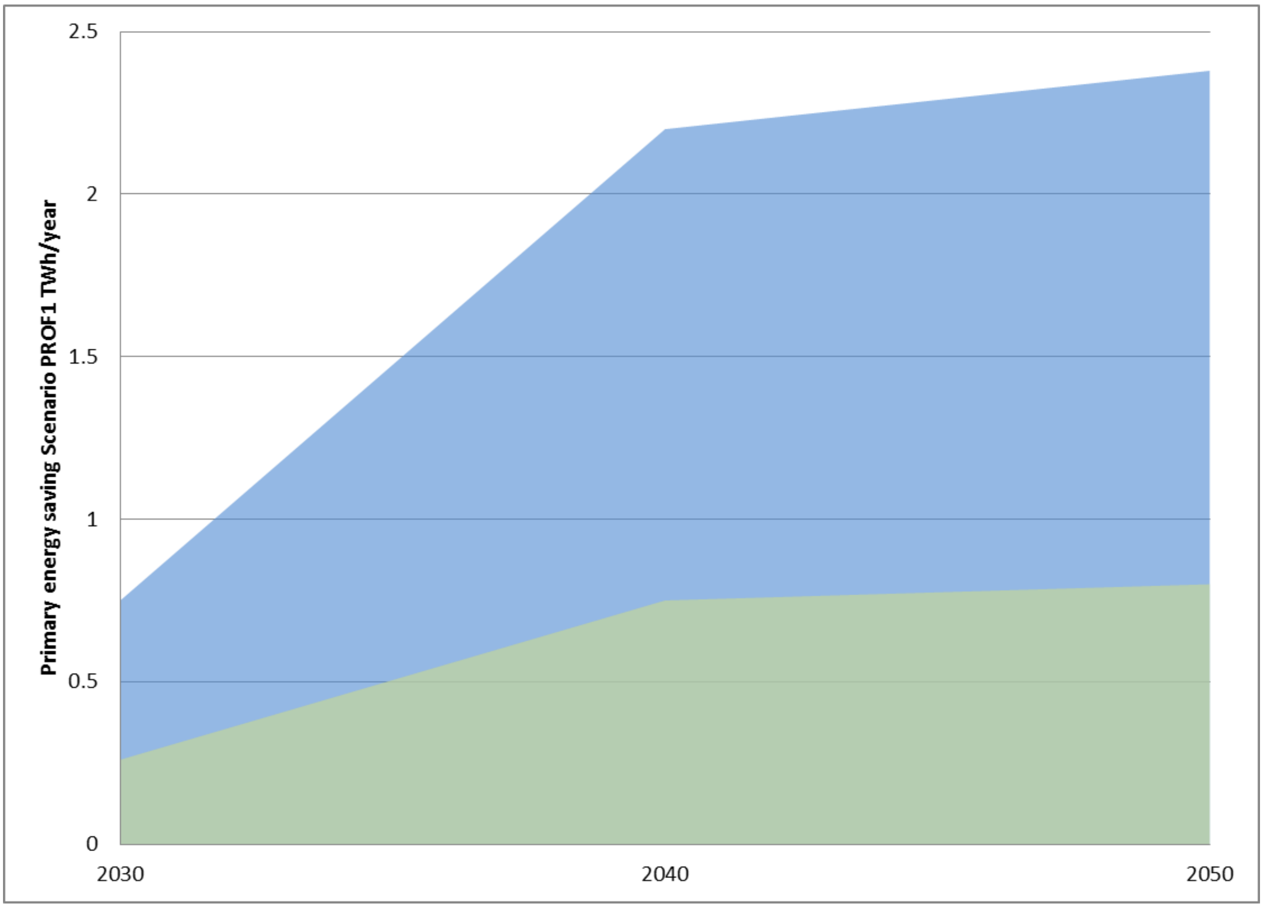


Figure 121. Annual savings of PROF 1 both in low (green area) and high (blue area) usage scenarios

Non-compliant market share

Another important parameter that can affect the results is the market share of products (new sales) that are not compliant with the proposed requirements on motor-pump efficiency and the energy and water cleaning performance.

Table 84 shows the results of primary energy savings increasing and reducing that parameter.

Table 84. Results of primary energy cumulative savings varying the market share of non-compliant products for the low usage scenario (TWh / % variation compared to 50% market share)

	Primary energy cumulative savings low usage scenario (2025-2050)		
	25% market share	50% market share (assumption in modelling)	75% market share
PROF 1	8.2 (-44%)	14.6	21.0 (+44%)
PROF 2	7.6 (-44%)	13.5	19.3 (+43%)

These results indicate that there is a significant uncertainty of +/-44%, which needs to be considered. The development of a test method to measure the cleaning performance of the HPCs would allow more insight into the impact of the proposed requirements on the market.

Figure 122 shows the annual savings of the scenario PROF 1 plotted as an area chart, including the effect of the non-compliant market share in the low usage scenario. There is an overlap of the low usage and the high usage scenario if the non-compliant market share is 75% (dark green area). It is unlikely that the real savings are below the minimum set by the low usage scenario with a non-compliant market share of 25%, i.e. the light green area.

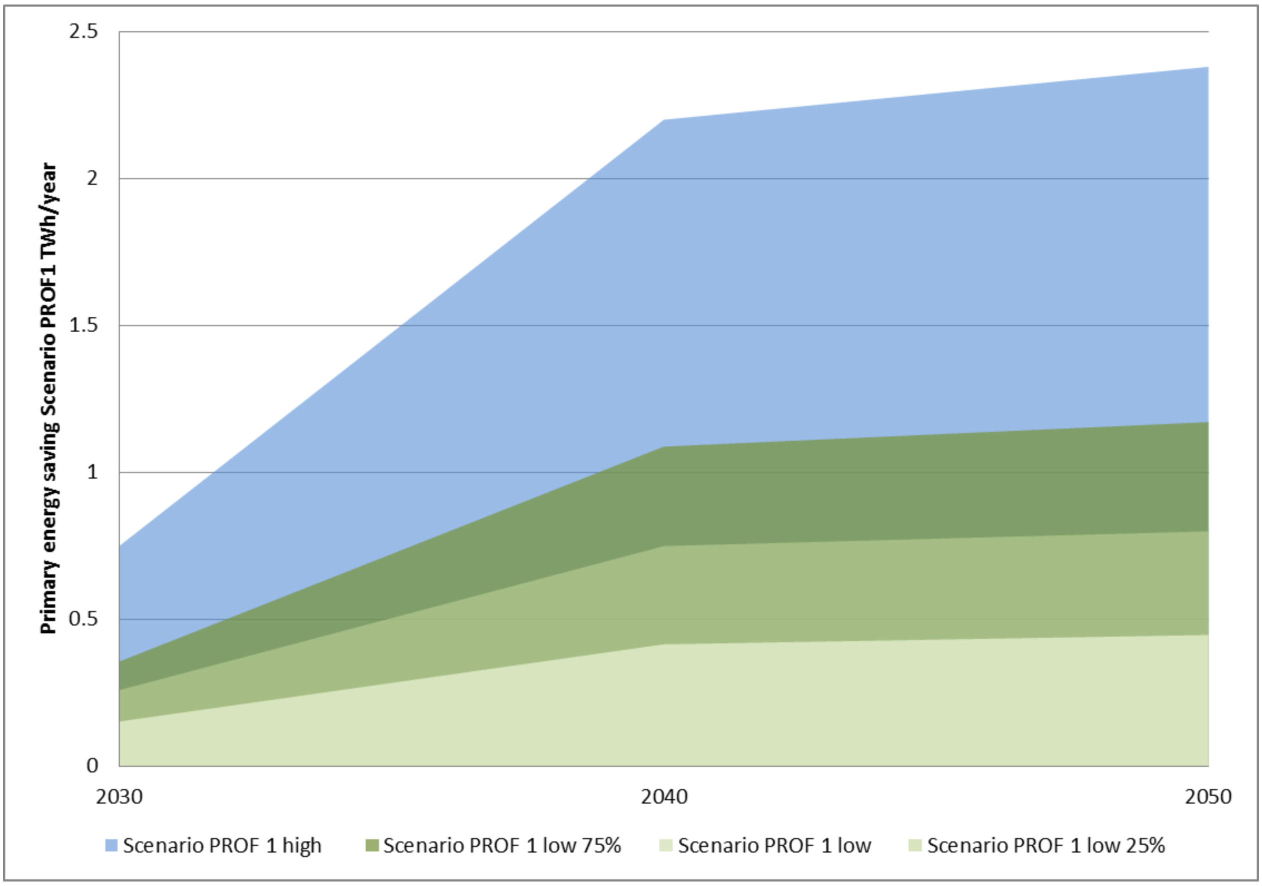


Figure 122. Annual savings of PROF 1 in high and low usage scenarios and different non-compliant professional market shares

7.6 Conclusions

Domestic sector

The saving potential of each domestic scenario is shown in Table 85:

Table 85. Primary energy yearly and cumulative savings of domestic scenarios at average low and average high usage patterns

	2030 (TWh/year)	2040 (TWh/year)	2050 (TWh/year)	Cumulative (TWh/year) (2025 - 2050)
Scenario DOM 1 low	0.94	0.99	1.00	25.3
Scenario DOM 1 high	1.1	1.3	1.4	32.2
Scenario DOM 2 low	0.94	0.99	1.00	25.2
Scenario DOM 2 high	1.1	1.3	1.4	31.8
Scenario DOM 3 low	0.9	0.9	0.9	23.2
Scenario DOM 3 high	0.9	0.9	0.9	23.2

NB:

Scenario DOM 1: Energy Labelling and/or Ecodesign criteria based on cleaning performance efficiency + Motor-Pump efficiency Ecodesign criteria + Durability and reparability requirements.

Scenario DOM 2: Energy Labelling and/or Ecodesign criteria based on cleaning performance efficiency + Durability and reparability requirements.

Scenario DOM 3: Durability and reparability requirements.

In the domestic sector, the policy option with the greatest savings potential is durability and reparability (0.9 TWh/year primary energy). Durability requirements would need the development of a test method or the adaptation of the endurance test within the safety standards. A longer lifetime of HPCs would likely cause a reduction in the sales of new units, which in turn could affect the employment in the manufacture and retail subsectors. However, it may also justify a higher purchase price for products, compensating for the reduced revenues of manufacturers. Also, the reparability requirements could increase employment in the repair or service subsectors.

The policy options motor-pump efficiency and Ecodesign or Energy Labelling based on cleaning performance could deliver 0.1 – 0.14 TWh/year in 2050. Motor-pump efficiency could be based on IEC 60335-2-79, though some manufacturers argued that it would require another test method focused on performance and not on safety. According to manufacturers' input, a cleaning performance standard would require a more elaborated test method that needs to be developed.

Scenario DOM 1 will potentially provide the largest energy and GHG cumulative savings due to its earlier implementation, while the life cycle cost would also be reduced. However, the additional improvement compared to scenario DOM 2 is marginal (< 1 TWh in cumulative results), and efforts may be more efficient if focused on development of new nozzle designs, which is the option with the greatest potential to reduce both water and energy.

Professional sector

The saving potential of each professional scenario is shown in Table 86:

Table 86. Primary energy yearly and cumulative savings of professional scenarios at average low and average high usage patterns

	2030 (TWh/year)	2040 (TWh/year)	2050 (TWh/year)	Cumulative (TWh)
Scenario PROF 1 low	0.26	0.75	0.8	14.6
Scenario PROF 1 high	0.75	2.2	2.38	42.8
Scenario PROF 2 low	0.12	0.75	0.8	13.5
Scenario PROF 2 high	0.75	2.2	2.38	41.7
Scenario PROF 3 low	0.05	0.08	0.09	1.8
Scenario PROF 3 high	0.17	0.26	0.29	5.8
NB: *Scenario PROF 1: Motor-Pump efficiency Ecodesign criteria + Fuel burner efficiency Ecodesign requirements.* *Scenario PROF 2: Energy Labelling and/or Ecodesign criteria based on cleaning performance efficiency + Fuel burner efficiency Ecodesign requirements.* *Scenario PROF 3: Fuel burner efficiency Ecodesign requirements.*				

In the professional sector, the largest savings could be achieved by the combination of Ecodesign or energy labelling based on cleaning performance and motor-pump requirements (0.8 – 2.38 TWh/year in 2050). As mentioned above, the motor-pump efficiency requirements would be easier to implement, while a cleaning performance test method would be developed, possibly in response to a standardisation request. The scenario PROF 1 would represent an interim solution that would bring energy savings while the cleaning performance test method was under development. This policy option would entail an additional manufacturing cost for improving the motor-pump efficiency, which would affect manufacturers and end users, but on the other hand provide savings by means of reduced energy use for the end users. The additional environmental benefits of this policy option represent around 1 TWh in the cumulative results. This option may shift the focus from innovative nozzle designs that are much more capable of saving water and energy at reasonable costs. The temporary requirements on motor-pumps would mean an increase in the manufacturing cost of 25%, which does not seem to be justified by the additional energy savings.

Annex 1. Definitions of key parameters and of other parameters

Parameter	**Definition**	**Source** (Standard (Clause))
Supply voltage (V)	Also known as **rated voltage** - voltage assigned to the appliance by the manufacturer.	EN 60335-1 (3.1.1)
Supply frequency (Hz)	Also known as **rated frequency** - frequency assigned to the appliance by the manufacturer.	EN 60335-1 (3.1.7)
Power source	Source of energy powering the water pump of the appliance: • Electrical – Mains • Electrical – Battery • Combustion – Petrol • Combustion – Diesel • Hydraulic or Pneumatic Source of energy heating the water, in hot water high pressure cleaners: • Electrical • Combustion – gas • Combustion – oil	Intertek
Rated pressure (MPa)	Maximum working pressure at the pressure generator during normal operation.	EN 60335-2-79 (3.103)
Power rating (kW or HP)	Also known as **rated power input –** power input assigned to the appliance by the manufacturer.	EN 60335-1 (3.1.4)
Flow rate (l/m)	Also known as **rated flow -** maximum flow at rated pressure at the nozzle during normal operation.	EN 60335-2-79 (3.105)
Maximum flow rate (l/m)	The highest possible flow rate at the nozzle. Typically, the maximum flow rate occurs at working pressures lower than the rated pressure and with a nozzle designed for spraying of cleaning agents.	EN 60335-2-79 (3.106)
Area performance (m^2/h)	No formal definition. A relative term for describing the cleaning performance of a high pressure cleaner. A more formal definition should form part of the development work for test methods establishing the performance of high pressure cleaners.	Intertek – Manufacturers' data

Parameter	Definition	Source (Standard (Clause))
Weight	Several weight labelling requirements are covered: • Packaged weight of product complete with all accessories • The weight of the high pressure cleaner complete with its primary tools is a handling requirement and forms part of the product instructions.	Intertek
Dimensions	Dimensions to include: • Packaged dimensions of product complete with all accessories • Nominal size of product complete with its primary tools in use.	Intertek
Application	No formal definition. A relative term for describing how the HPC is used and to provide a relative indication of the cleaning capability of a high pressure cleaner, e.g. 'Light domestic use'. A more formal definition should form part of the development work for test methods establishing the performance of high pressure cleaners.	Intertek
Water feed and temperature	No formal definition. Source – e.g. mains fed or water butt. Generally, taken as ambient temperature of source water.	Intertek
Self-priming (Y/N)	Manufacturer-declared – will allow use of water butt or other reservoir for feed.	-
Rated temperature	Maximum temperature of the cleaning agent during normal operation.	EN 60335-2-79 (3.107)
Sound Pressure Level (dBA)	Noise emission.	EN 60335-2-79 - Annex CC
Cable length (m)	Length of cable as supplied by the manufacturer.	EN 60335-2-79 (25)
Protection Class (Electric Shock)	Machines shall be one of the following classes with respect to protection against electric shock: • class I, • class II, or • class III.	EN 60335-2-79 (6)
IP rating	Degree of protection against harmful ingress of water.	EN 60335-2-79 (6.2)

Parameter	Definition	Source (Standard (Clause))
Maximum supply feed length	No formal definition – only applicable if pressure drop via long hose causes performance degradation.	-
Maximum power (Water heater/if fitted) – (kW)	Maximum power of the water heater in kW, if applicable (for electric heaters, the input Power; for gas-fired or oil-fired heaters, the output power).	EN 60335-2-79 (7.1)
Cleaning agent, volume	Water with or without the addition of gaseous, soluble or miscible detergent or solid abrasive. Volume to be declared by manufacturer (not a standard requirement).	EN 60335-2-79 (3.113)
Accessory types/supplied	No formal list or definition types – standard lance, turbo lance, patio cleaner, car wash brush. Will need to be defined as part of any meaningful performance evaluation.	Manufacturers' data

Other parameters

Parameter	Definition	Source
Commercial use	Intended use of machines. These machines are not intended for normal housekeeping purposes by private persons and may be a source of danger to the public.	EN 60335-2-79 (3Z.101)
Operator	Person installing, operating, adjusting, cleaning, moving or performing user maintenance on the machine.	EN 60335-2-79 (3.122)

Annex 2. Value of exports of steam or sand blasting machines and similar jet-projecting machines in euros – time series

Country	2009	2010	2011	2012	2013	2014	2015	2016
Austria	23 493 260	28 397 410	24 709 880	21 465 830	32 186 430	30 490 920	33 889 710	36 032 630
Belgium	22 785 380	29 908 650	39 673 880	42 814 500	63 082 910	67 980 670	66 473 650	84 897 300
Bulgaria	247 090	442 960	913 290	792 640	1 160 710	1 755 960	2 252 560	2 149 270
Croatia	1 181 660	1 779 810	2 556 930	3 259 070	1 790 310	2 742 360	3 290 390	741 410
Cyprus	12 070	0	300	65 260	34 240	232 510	496 920	570 090
Czech Republic	27 912 160	20 176 530	32 570 470	33 395 570	34 910 100	32 451 150	38 776 650	39 621 160
Denmark	46 324 980	50 812 370	45 695 560	51 770 490	59 263 250	73 087 480	79 723 700	49 174 120
Estonia	1 151 310	1 219 610	1 243 650	1 609 610	1 198 260	1 064 000	968 720	1 485 840
Finland	3 958 700	2 248 000	5 149 960	4 196 240	6 112 090	6 148 730	3 578 330	2 723 500
France	35 011 990	32 869 260	29 840 300	31 467 810	38 063 830	38 963 990	41 131 540	31 875 470
Germany	449 651 250	482 563 020	591 666 330	646 543 610	675 039 130	644 332 080	608 496 710	629 105 080
Greece	723 330	376 780	697 750	445 020	650 640	625 430	1 973 460	2 134 730
Hungary	25 238 470	30 135 790	30 773 210	30 918 190	29 429 160	31 871 290	27 961 680	27 493 620
Iceland	NA	NA	NA	NA	NA	NA	NA	NA
Ireland	734 380	752 370	266 260	163 630	438 700	1 235 490	1 516 810	895 140
Italy	283 255 220	294 026 750	307 258 430	335 524 130	331 466 850	328 348 510	330 804 430	324 295 370
Latvia	923 460	623 140	1 507 280	1 078 020	1 877 100	3 156 490	2 962 260	2 122 860
Lithuania	1 230 120	2 745 180	3 102 670	5 594 560	6 522 640	6 470 140	4 991 700	5 697 530
Luxemburg	150 110	318 850	244 540	373 540	6 149 910	573 970	356 940	509 050
Malta	16 660	0	18 530	43 800	55 670	0	45 800	500
Netherlands	48 642 130	43 969 790	50 530 900	48 267 140	50 078 040	41 130 950	52 510 540	68 929 810
Norway	NA	NA	NA	NA	NA	NA	NA	NA
Poland	15 281 010	14 209 860	22 683 840	25 220 980	35 515 720	34 344 880	48 853 360	57 700 770
Portugal	1 746 100	1 970 330	2 736 230	3 731 100	3 994 020	4 274 750	2 088 320	1 578 410
Romania	1 107 620	893 720	584 070	830 770	795 040	1 811 380	1 959 560	1 707 810

Slovakia	1 048 000	1 449 520	884 940	1 046 010	1 215 420	607 510	244 050	1 204 110
Slovenia	11 049 950	15 047 540	11 218 910	13 509 080	12 242 460	16 860 880	22 844 520	17 592 790
Spain	20 269 480	24 305 020	25 145 880	23 626 760	20 607 070	20 809 320	23 933 290	32 954 560
Sweden	8 030 870	6 356 080	22 294 740	11 529 380	8 952 670	7 451 210	8 473 410	9 006 500
United Kingdom	18 504 960	21 698 670	36 133 230	40 906 130	40 245 050	46 759 680	44 797 340	41 713 390

Annex 3. Value of imports of steam or sand blasting machines and similar jet-projecting machines in euros– time series

Country	2009	2010	2011	2012	2013	2014	2015	2016
Austria	38 102 590	44 705 970	47 060 930	45 479 770	45 036 700	49 435 220	56 207 120	55 249 540
Belgium	36 016 840	37 807 650	40 839 580	45 257 080	57 716 090	53 845 470	57 338 280	65 302 780
Bulgaria	4 798 290	3 781 490	4 236 700	3 738 220	7 288 630	4 936 960	6 502 380	6 283 540
Croatia	9 794 460	5 432 500	4 667 530	5 901 660	5 395 870	4 760 050	6 972 470	7 418 000
Cyprus	1 006 930	1 608 360	625 660	585 280	646 100	415 800	490 290	507 150
Czech Republic	18 145 210	13 173 800	16 345 750	13 243 270	18 034 820	16 659 690	21 388 210	24 425 450
Denmark	31 073 040	35 620 460	31 355 360	33 909 570	38 831 800	45 028 170	52 121 540	39 613 700
Estonia	2 696 690	1 777 550	2 123 730	3 084 450	2 484 890	2 193 000	2 699 710	2 952 750
Finland	12 638 790	13 634 210	16 758 720	16 021 080	14 539 130	13 255 610	14 460 670	14 651 410
France	131 834 470	139 738 150	143 293 050	163 951 890	161 740 790	163 764 310	172 534 150	178 653 730
Germany	137 115 010	138 947 300	150 995 070	161 244 850	160 644 950	188 134 660	193 053 280	190 281 430
Greece	12 329 460	10 527 160	6 596 360	4 214 800	4 675 380	5 676 740	8 056 900	6 170 520
Hungary	6 390 970	6 784 000	15 065 900	7 172 180	8 007 920	9 507 790	10 868 340	17 083 980
Iceland	NA	NA	NA	NA	NA	NA	NA	NA
Ireland	5 714 790	5 725 040	4 456 880	4 651 980	5 837 650	8 077 830	7 428 600	6 368 730
Italy	34 365 370	51 546 920	44 450 760	41 899 340	42 675 340	54 134 150	61 984 560	62 891 360
Latvia	1 351 750	1 504 770	2 769 020	2 338 360	2 841 150	3 221 060	3 963 810	3 218 010
Lithuania	1 852 280	2 361 770	2 706 840	3 623 270	4 846 720	5 405 380	5 862 750	6 387 950
Luxemburg	2 602 230	2 423 020	2 611 600	3 402 670	3 550 330	3 453 500	3 145 910	4 355 060
Malta	199 590	190 990	332 350	261 230	372 660	340 350	303 410	199 970
Netherlands	24 110 580	24 142 700	28 965 120	29 492 410	25 331 870	28 300 550	32 984 740	37 647 160
Norway	NA	NA	NA	NA	NA	NA	NA	NA
Poland	34 187 350	35 034 630	38 402 390	33 903 400	34 576 480	48 526 910	57 136 880	66 297 320
Portugal	12 340 590	11 079 460	10 738 980	6 830 860	8 085 160	10 721 740	16 017 280	14 689 300
Romania	11 347 080	8 481 760	11 969 570	18 523 920	10 953 680	11 833 040	17 557 280	15 128 680
Slovakia	6 337 830	7 338 110	4 980 870	5 800 730	10 823 470	14 856 240	9 766 580	9 980 920
Slovenia	6 199 230	6 351 350	6 773 640	5 921 480	5 411 450	11 242 280	13 057 570	16 820 290

Spain	38 362 850	35 739 770	35 321 880	28 626 340	28 944 200	36 207 070	47 031 000	55 693 060
Sweden	24 034 020	27 647 860	29 277 720	29 421 470	27 959 480	27 776 350	32 020 540	31 209 790
United Kingdom	87 491 660	83 267 360	86 325 890	80 203 960	121 907 760	127 104 740	137 035 160	144 806 240

Annex 4. Inflation rates

HICP - inflation rate											
Annual average rate of change (%)											
Year	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
European Union (changing composition)	2.2	2.3	3.7	1	2.1	3.1	2.6	1.5	0.5	0	0.3	1.7
EU (28 countries)	2.3	2.4	3.7	1	2.1	3.1	2.6	1.5	0.5	0	0.3	1.7
Euro area (changing composition)	2.2	2.1	3.3	0.3	1.6	2.7	2.5	1.4	0.4	0	0.2	1.5
Euro area (19 countries)	2.2	2.2	3.3	0.3	1.6	2.7	2.5	1.3	0.4	0	0.2	1.5
Euro area (18 countries)	2.2	2.2	3.3	0.3	1.6	2.7	2.5	1.3	0.4	0	0.2	1.5
Belgium	2.3	1.8	4.5	0	2.3	3.4	2.6	1.2	0.5	0.6	1.8	2.2
Bulgaria	7.4	7.6	12	2.5	3	3.4	2.4	0.4	-1.6	-1.1	-1.3	1.2
Czech Republic	2.1	2.9	6.3	0.6	1.2	2.2	3.5	1.4	0.4	0.3	0.6	2.4
Denmark	1.8	1.7	3.6	1	2.2	2.7	2.4	0.5	0.4	0.2	0	1.1
Germany	1.8	2.3	2.8	0.2	1.1	2.5	2.1	1.6	0.8	0.1	0.4	1.7
Estonia	4.4	6.7	10.6	0.2	2.7	5.1	4.2	3.2	0.5	0.1	0.8	3.7
Ireland	2.7	2.9	3.1	-1.7	-1.6	1.2	1.9	0.5	0.3	0	-0.2	0.3
Greece	3.3	3	4.2	1.3	4.7	3.1	1	-0.9	-1.4	-1.1	0	1.1
Spain	3.6	2.8	4.1	-0.2	2	3	2.4	1.5	-0.2	-0.6	-0.3	2
France	1.9	1.6	3.2	0.1	1.7	2.3	2.2	1	0.6	0.1	0.3	1.2
Croatia	3.3	2.7	5.8	2.2	1.1	2.2	3.4	2.3	0.2	-0.3	-0.6	1.3
Italy	2.2	2	3.5	0.8	1.6	2.9	3.3	1.2	0.2	0.1	-0.1	1.3
Cyprus	2.2	2.2	4.4	0.2	2.6	3.5	3.1	0.4	-0.3	-1.5	-1.2	0.7
Latvia	6.6	10.1	15.3	3.3	-1.2	4.2	2.3	0	0.7	0.2	0.1	2.9
Lithuania	3.8	5.8	11.1	4.2	1.2	4.1	3.2	1.2	0.2	-0.7	0.7	3.7
Luxembourg	3	2.7	4.1	0	2.8	3.7	2.9	1.7	0.7	0.1	0	2.1

Hungary	4	7.9	6	4	4.7	3.9	5.7	1.7	0	0.1	0.4	2.4
Malta	2.6	0.7	4.7	1.8	2	2.5	3.2	1	0.8	1.2	0.9	1.3
Netherlands	1.6	1.6	2.2	1	0.9	2.5	2.8	2.6	0.3	0.2	0.1	1.3
Austria	1.7	2.2	3.2	0.4	1.7	3.6	2.6	2.1	1.5	0.8	1	2.2
Poland	1.3	2.6	4.2	4	2.6	3.9	3.7	0.8	0.1	-0.7	-0.2	1.6
Portugal	3	2.4	2.7	-0.9	1.4	3.6	2.8	0.4	-0.2	0.5	0.6	1.6
Romania	6.6	4.9	7.9	5.6	6.1	5.8	3.4	3.2	1.4	-0.4	-1.1	1.1
Slovenia	2.5	3.8	5.5	0.8	2.1	2.1	2.8	1.9	0.4	-0.8	-0.2	1.6
Slovakia	4.3	1.9	3.9	0.9	0.7	4.1	3.7	1.5	-0.1	-0.3	-0.5	1.4
Finland	1.3	1.6	3.9	1.6	1.7	3.3	3.2	2.2	1.2	-0.2	0.4	0.8
Sweden	1.5	1.7	3.3	1.9	1.9	1.4	0.9	0.4	0.2	0.7	1.1	1.9
United Kingdom	2.3	2.3	3.6	2.2	3.3	4.5	2.8	2.6	1.5	0	0.7	2.7
Iceland	4.6	3.6	12.8	16.3	7.5	4.2	6	4.1	1	0.3	0.8	-1.7
Liechtenstein	:	:	:	:	:	:	:	:	:	:	:	:
Norway	2.4	0.8	3.4	2.3	2.3	1.3	0.4	2	1.9	2	3.9	1.9
Switzerland	1	0.8	2.4	-0.7	0.6	0.1	-0.7	0.1	0	-0.8	-0.5	0.6
Montenegro	:	:	:	:	:	:	:	:	:	:	:	:
North Macedonia	3.7	2.2	7.6	-0.1	1.1	3.2	1.8	2.7	0	0.1	0.2	2.1
Albania	:	:	:	:	:	:	:	:	:	:	:	:
Serbia	:	5.8	11.9	8.2	6.2	11.2	7.4	7.7	2.3	1.5	1.3	3.3
Turkey	9.3	8.8	10.4	6.3	8.6	6.5	9	7.5	8.9	7.7	7.7	11.1
United States	3.2	2.6	4.4	-0.8	2.6	3.9	2.2	1.3	1.3	-0.8	0.5	1.7

NB:

:=not available; d=definition differs (see metadata).

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Annex 5: Reparability requirements

Non-destructive access (disassembly) to critical components

The main components of the HPC should be easily accessible allowing professionals and/or end users to replace them according to the list of spare parts below.

Spare parts availability

Availability of spare parts to **professional repairers** for a minimum period of 10 years for household and professional products after placing the last unit of the model on the market:

- power supply cord;
- enclosure;
- motor, motor-pump system and motor brushes;
- pump.

Although they are not considered to be at the same level of priority by manufacturers, the following components could also be part of the list:

- combustion engine;
- transmission between motor and pump;
- heating coil;
- burner and burner chamber;
- electric heating elements;
- fuel tanks and hoses;
- internal hoses, pipes, valves and filters;
- printed circuit boards;
- electronic displays;
- pressure and flow switches;
- motor protection switches and fuses;
- pressure reliefs;
- thermostats, temperature sensors and pressure switches;
- on/off switches;
- operator presence controls;
- mains cable;
- software and firmware including reset software;
- cabinet.

Availability of spare parts to end users and professional repairers for a minimum period of 10 years for household and professional products after placing the last unit of the model on the market:

- high pressure hose;
- guns;
- nozzles and cleaning attachments.

Although they are not considered to be at the same level of priority by manufacturers, the following components could be part of the list:

- wheels;
- detergent tanks and hoses;
- other plastic peripherals;
- filters.

The list of spare parts and the procedure for ordering them shall be publicly available on the free-access website of the manufacturer, importer or authorised representative, at the latest 2 years after the placing on the market of the first unit of a model and until the end of the period of availability of these spare parts.

Maximum delivery time of spare parts: For spare parts mentioned above, the manufacturer, importer or authorised representative shall ensure their delivery within 15 working days of receiving the order.

Spare parts can be replaced with the use of commonly available tools and without permanent damage to the HPC. The list of spare parts and the procedure for ordering them and the repair instructions shall be publicly available on the free-access website of the manufacturer, importer or authorised representative, when placing the first unit of a model on the market and until the end of the period of availability of these spare parts.

Repair and maintenance manuals

After a period of 2 years after the placing on the market of the first unit of a model and until the end of the 10-year period (same as spare parts availability), the manufacturer, importer or authorised representative shall provide free access to the HPC repair and maintenance information to end-users and professional repairers in the following conditions:

The manufacturer's, importer's or authorised representative's website shall indicate the process for professional repairers to register for access to information; to accept such a request, the manufacturers, importers or authorised representatives may require the professional repairer to demonstrate that the following:

- The professional repairer has the technical competence to repair HPCs and complies with the applicable regulations for repairers of electrical equipment in the Member State(s) where it operates. Reference to an official registration system as professional repairer, where such a system exists in the Member State(s) concerned, shall be accepted as proof of compliance with this point.
- The professional repairer is covered by insurance covering liabilities resulting from its activity regardless of whether this is required by the Member State(s).
- The manufacturers, importers or authorised representatives shall accept or refuse the registration within 5 working days of the date of the request.
- Manufacturers, importers or authorised representatives may charge reasonable and proportionate fees for access to the repair and maintenance information or for receiving regular updates. A fee is reasonable if it does not discourage access by failing to take into account the extent to which the professional repairer uses the information.
- Once registered, a professional repairer shall have access, within 24 hours one working day after requesting it, to the requested repair and maintenance information for any product model of the manufacturer within the scope of this Regulation. The information may be provided for an equivalent model or model of the same family, if relevant.

Repair and maintenance information shall include:

- the unequivocal HPC identification;
- a disassembly map or exploded view;
- technical manual of instructions for repair;
- list of necessary repair and test equipment;

- component and diagnosis information (such as minimum and maximum theoretical values for measurements);
- wiring and connection diagrams;
- diagnostic fault and error codes (including manufacturer-specific codes, where applicable);
- instructions for installation of relevant software and firmware including reset software;
- information on how to access data records of reported failure incidents stored on the HPC (where applicable).

Manufacturers or importers may charge reasonable and proportionate fees for access to the repair and maintenance information or for receiving regular updates. A fee is reasonable if it does not discourage access by failing to take into account the extent to which the professional repairer uses it.

The user instructions shall also include instructions for the user to perform maintenance operations. Such instructions shall as a minimum include instructions for:

- correct connection to mains and connection to water inlets, cold and/or hot if appropriate;
- correct use and dosing of detergent and other additives, and main consequences of incorrect dosage;
- periodic cleaning, including optimal frequency, and limescale prevention and procedure;
- periodic checks of filters, including optimal frequency, and procedure;
- identification of errors, the meaning of the errors, and the action required, including identification of errors requiring professional assistance;
- correct storage when not in use;
- how to access professional repair (internet webpages, addresses, contact details).

Such instructions shall also include information on:

- any implications of self-repair or non-professional repair for the safety of the end user and for the guarantee;
- the minimum period during which the spare parts for the HPCs are available.

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